SEL-421-4, -5

Protection, Automation, and Control System

Instruction Manual

20171021

SEL SCHWEITZER ENGINEERING LABORATORIES

PM421-04

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Preface

This manual provides information and instructions for installing and operating the SEL-421 Relay. This manual is for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples. While this manual gives reasonable examples and illustrations of relay uses, you must exercise sound judgment at all times when applying the relay in a power system.

SEL-421 Versions and Supported Features on page 1.7 shows the relay features supported by versions SEL-421-4 and SEL-421-5. Throughout the manual, we provide margin notes next to the text explaining a feature to specify the availability of that feature in different versions of the relay. Note that, unless otherwise indicated, SEL-421 refers to the SEL-421-5.

Manual Overview

The SEL-421 Relay Manual set consists of two volumes:

- SEL-421 Instruction Manual
- SEL-400 Series Relays Instruction Manual

The SEL-421 Relay Manual set is a comprehensive work covering all aspects of relay application and use. Read the sections that pertain to your application to gain valuable information about using the SEL-421. For example, to learn about relay protection functions, read the protection sections of this manual and skim the automation sections, then concentrate on the operation sections or on the automation sections of this manual as your job needs and responsibilities dictate. An overview of each manual section and section topics follows.

SEL-421 Instruction Manual

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction and Specifications. Introduces SEL-421 Relay features, summarizes relay functions and applications, and lists relay specifications, type tests, and ratings.

Section 2: Installation. Discusses the ordering configurations and interface features (control inputs, control outputs, and analog inputs, for example). Provides information about how to design a new physical installation and secure the relay in a panel or rack. Details how to set relay board jumpers and make proper rear-panel connections (including wiring to CTs, PTs, and a GPS receiver). Explains basic connections for the relay communications ports and how to install optional communications cards (such as the Ethernet Card).

Section 3: Testing. Describes techniques for testing, troubleshooting, and maintaining the relay.

Section 4: Front-Panel Operations. Describes the LCD display messages and menu screens that are unique to the SEL-421.

Section 5: Protection Functions. Describes the function of various relay protection elements. Describes how the relay processes these elements. Gives detailed specifics on protection scheme logic for POTT, DCB, DCUB, and DTT. Provides trip logic diagrams, and current and voltage source selection details. Also describes basic 87L communications channel options and configuration parameters.

Section 6: Protection Applications Examples. Provides examples of configuring the SEL-421 for some common applications.

Section 7: Metering, Monitoring, and Reporting. Describes SEL-421-specific metering, monitoring, and reporting features.

Section 8: Settings. Provides a list of all relay settings and defaults. The settings list is organized in the same order as in the relay and in the ACSELERATOR QuickSet software.

Section 9: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 10: Communications Interfaces. Describes the SEL-421-specific communications characteristics.

Section 11: Relay Word Bits. Contains a summary of Relay Word bits.

Section 12: Analog Quantities. Contains a summary of analog quantities.

Appendix A: Firmware, ICD File, and Manual Versions. Lists the current firmware and manual versions and details differences between the current and previous versions.

Appendix B: Converting Settings From SEL-421-0, -1, -2, -3 to SEL-421-4, -5.
Describes differences in settings, Relay Word bits, analog quantities, and DNP3 mapping between these versions of the relay.

SEL-400 Series Relays Instruction Manual

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction. Introduces SEL-400 series relay common features.

Section 2: PC Software. Explains how to use ACSELERATOR QuickSet SEL-5030 Software.

Section 3: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and SER (Sequential Events Recorder) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 4: Front-Panel Operations. Describes the LCD display messages and menu screens. Shows you how to use front-panel pushbuttons and read targets. Provides information about local substation control and how to make relay settings via the front panel.

Section 5: Control. Describes various control features of the relay, including circuit breaker operation, disconnect operation, remote bits, and one-line diagrams.

Section 6: Autoreclosing. Explains how to operate the SEL-400 series relay two-circuit breaker multishot recloser. Describes how to set the relay for single-pole reclosing, three-pole reclosing, or both. Shows selection of the lead and follow circuit breakers.

Section 7: Metering. Provides information on viewing current, voltage, power, and energy quantities. Describes how to view other common internal operating quantities.

Section 8: Monitoring. Describes how to use the circuit breaker monitors and the substation dc battery monitors.

Section 9: Reporting. Explains how to obtain and interpret high-resolution raw data oscillograms, filtered event reports, event summaries, history reports, and SER reports. Discusses how to enter SER trigger settings.

Section 10: Testing, Troubleshooting, and Maintenance. Describes techniques for testing, troubleshooting, and maintaining the relay. Includes the list of status notification messages and a troubleshooting chart.

Section 11: Time and Date Management. Explains time keeping principles, synchronized phasor measurements, and estimation of power system states using the high-accuracy time-stamping capability. Presents real-time load flow/power flow application ideas.

Section 12: Settings. Provides a list of all common SEL-400 series relay settings and defaults.

Section 13: SELOGIC Control Equation Programming. Describes multiple setting groups and SELOGIC control equations and how to apply these equations. Discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers. Provides a tutorial for converting older format SELOGIC control equations to new freeform equations.

Section 14: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 15: Communications Interfaces. Explains the physical connection of the relay to various communications network topologies. Describes the various software protocols and how to apply these protocols to substation integration and automation. Includes details about Ethernet IP protocols, SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS communications.

Section 16: DNP3 Communication. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation. Provides a Job Done example for implementing DNP3 in a substation.

Section 17: IEC 61850 Communication. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 18: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the relay. Provides details on synchrophasor measurement and real-time control. Describes the IEEE C37.118 synchrophasor protocol settings. Describes the SEL Fast Message synchrophasor protocol settings.

Section 19: Remote Data Acquisition. Describes the basic concepts of remote data acquisition systems. This includes both the Time-Domain Link (TiDL) remote data acquisition system, which uses SEL-2440 Axion modules to provide remote data acquisition and I/O communication, and UCA 61850-9-2LE Sampled Values.

Appendix A: Manual Versions. Lists the current manual version and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: Cybersecurity Features. Describes the various features of the relay that impact cybersecurity.

Glossary. Definitions of various technical terms used in the SEL-400 series instruction manuals.

Safety Information

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols are often marked on SEL products.

	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Ray-O-Vac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks (Sheet 1 of 3)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers les ports ou connecteurs de fibres optiques.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes) et émetteurs-récepteurs ne peuvent pas être entretenus par l'usager. Retourner les unités à SEL pour réparation ou remplacement.

Other Safety Marks (Sheet 2 of 3)

⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION Equipment damage can result from connecting ac circuits to Hybrid (high-current interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	⚠ATTENTION Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kW) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	⚠ATTENTION Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kW) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.
⚠CAUTION If you are planning to install an INT4 I/O interface board in your relay, first check the firmware version of the relay. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O interface board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.	⚠ATTENTION Si vous avez l'intention d'installer une Carte d'Interface INT4 I/O dans votre relais, vérifiez en premier la version du logiciel du relais. Si la version est R111 ou antérieure, vous devez mettre à jour le logiciel du relais avec la version la plus récente et vérifier que la mise à jour a été correctement installée sur la nouvelle carte. Les instructions complètes de mise à jour sont fournies quand le nouveau logiciel est commandé.
⚠CAUTION Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.	⚠ATTENTION Le remplacement en chantier des cartes d'entrées/sorties INT1, INT2, INT5, INT6, INT7 ou INT8 par une carte INT4 peut causer la défaillance du contact d'entrée/sortie. La carte INT4 présente un intervalle d'ajustement pour les délais de montée et de retombée de 0 à 1 cycle. Pour toutes les autres cartes, l'intervalle de réglage du délai de montée et retombée (IN201PU–IN224PU, IN201DO– IN224DO, IN301PU–IN324PU, et IN301DO–IN324DO) est de 0 à 5 cycles. Quand une carte d'entrées/sorties est remplacée par une carte INT4, vérifier manuellement que les délais de montée et retombée sont dans l'intervalle de 0 à 1 cycle.
⚠CAUTION Do not install a jumper on positions A or D of the main board J21 header. Relay misoperation can result if you install jumpers on positions J21A and J21D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J21 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J21A et J21D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	⚠ATTENTION Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	⚠ATTENTION Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.

Other Safety Marks (Sheet 3 of 3)

⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.

General Information

The SEL-421 Instruction Manual uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways users typically communicate with SEL-400 series relays:

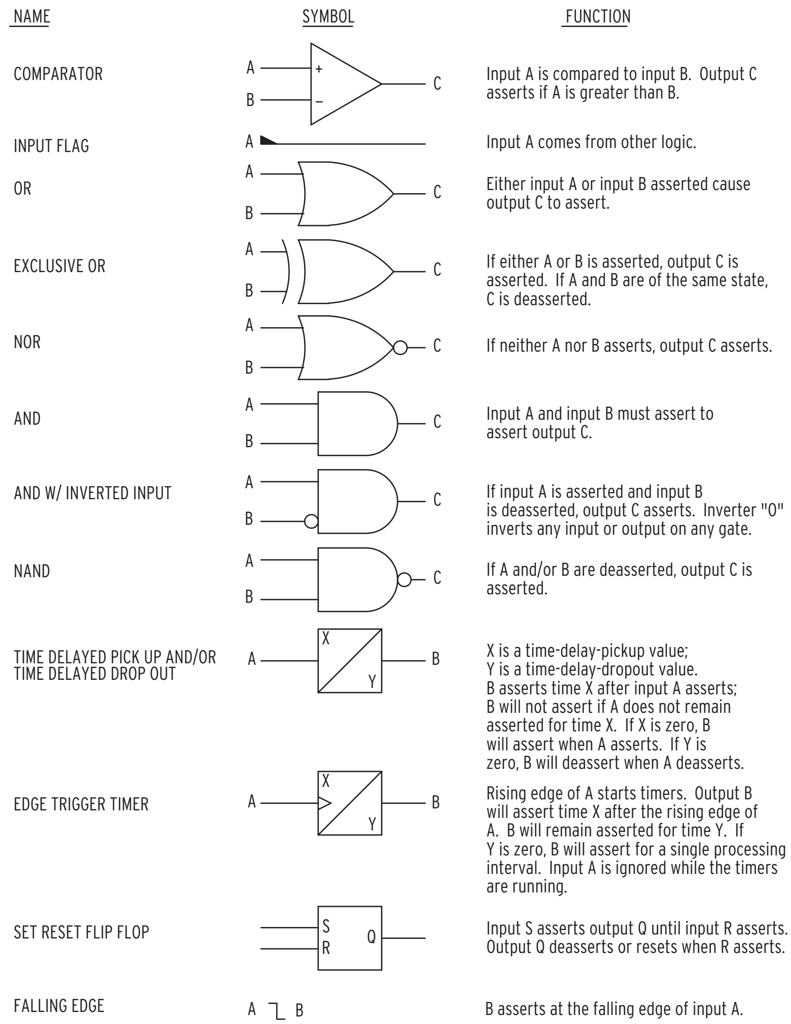
- ➤ Using a command line interface on a PC terminal emulation window, such as Microsoft HyperTerminal
- ➤ Using the front-panel menus and pushbuttons
- ➤ Using ACSELERATOR QuickSet SEL-5030 Software

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM** *n*	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
`MAIN > METER`	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.



Trademarks

Trademarks appearing in this manual are shown in the following table.

SEL Trademarks	
ACSELERATOR Architect®	Job Done®
ACSELERATOR QuickSet®	MIRRORED BITS®
Best Choice Ground Directional Element®	SELBOOT®
Connectorized®	SELOGIC®
Other Trademarks[a]	
EtherCAT®	Microsoft®
HyperTerminal®	Ray-O-Vac®
IEEE®	ST®

[a] All brand or product names appearing in this document are the trademark or registered trademark of their respective holders.

Technical Support

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SECTION 1

Introduction and Specifications

The SEL-421 Relay is a high-speed transmission line protective relay featuring single-pole and three-pole tripping and reclosing with synchronism check, circuit breaker monitoring, circuit breaker failure protection, and series-compensated line protection logic. The relay features extensive metering and data recording including high-resolution data capture and reporting.

NOTE: Not all features mentioned on this page are available in the SEL-421-4. See *SEL-421 Versions and Supported Features on page 1.7* for more details about the different versions of the relay and about differences among the SEL-421-4 and SEL-421-5.

The SEL-421 features expanded SELOGIC control equation programming for easy and flexible implementation of custom protection and control schemes. The relay has separate protection and automation SELOGIC control equation programming areas with extensive protection programming capability and 1000 lines of automation programming capability. You can organize automation of SELOGIC control equation programming into 10 blocks of 100 program lines each.

The SEL-421 provides extensive communications interfaces from standard SEL ASCII and enhanced MIRRORED BITS communications protocols to Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ the latest industry communications tools, including Telnet, FTP, IEC 61850, and DNP3 (serial and LAN/WAN) protocols.

Purchase of an SEL-421 includes the ACSELERATOR QuickSet SEL-5030 Software program. QuickSet assists you in setting, controlling, and acquiring data from the relays, both locally and remotely. ACSELERATOR Architect SEL-5032 Software is included with purchase of the optional Ethernet card with IEC 61850 protocol support. Architect enables you to view and configure IEC 61850 settings via a GUI interface.

The SEL-421 supports IEEE C37.118-2005, Standard for Synchrophasors for Power Systems.

The SEL-421 features bay control functionality. The SEL-421 provides a variety of user-selectable predefined mimic displays. The mimic display selected is displayed on the front-panel screen in one-line diagram format. The number of disconnects and breakers that can be controlled by the SEL-421 are a function of the selected mimic display screen. A maximum of ten disconnects and two breakers can be supported in a single mimic display. Control of the breakers and disconnects is available through front-panel pushbuttons, ASCII interface, Fast Message, or SELOGIC equations. See *Section 5: Control in the SEL-400 Series Relays Instruction Manual* for bay control logic and disconnect/circuit breaker operations.

A simple and robust hardware design features efficient digital signal processing. Combined with extensive self-testing, these features provide relay reliability and enhance relay availability.

This section introduces the SEL-421 and provides information on the following topics:

Features

The SEL-421 contains many protection, automation, and control features. *Figure 1.1* presents a simplified functional overview of the relay.

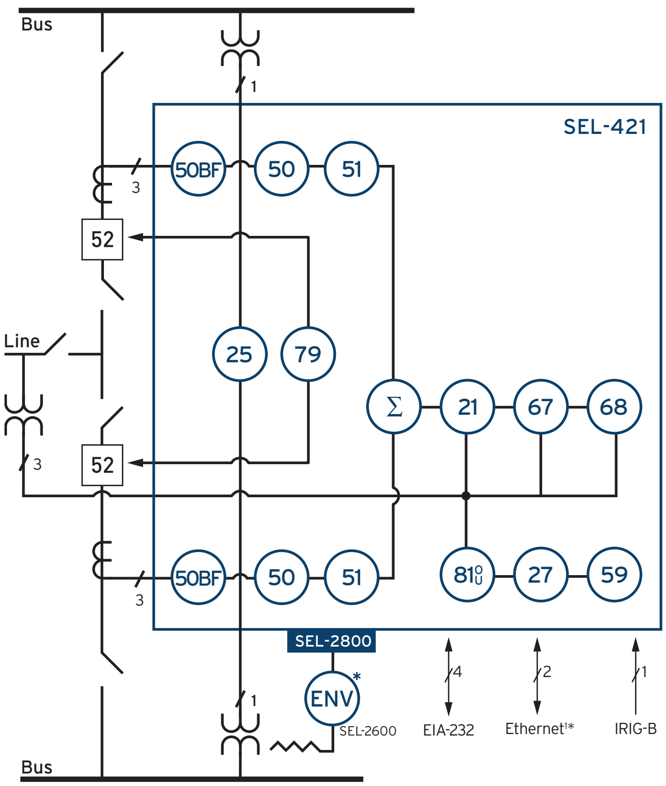


Figure 1.1 SEL-421 Functional Overview

- Password Separation of Protection and Automation
- Expanded SELOGIC Control Equations
- Event Reports and Oscillography
- Sequential Events Recorder
- Dual Breaker Condition Monitor
- Station Battery Monitor
- DNP3
- IEC 61850 (Optional Feature)
- High-Accuracy Metering
- MIRRORED BITS Communications
- Synchrophasors
- Fault Locator
- CCVT Transient Overreach and Load Encroachment Supervision
- Remote and Local Control Switches
- Advanced Local Display
- Time-Domain Link Remote Data Acquisition

SEL-421 features include the following:

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

Superior Protection. Combine five zones of phase-distance and ground-distance elements with directional overcurrent elements. Patented Coupling Capacitor Voltage Transformer (CCVT) transient overreach logic enhances Zone 1 distance element security. The Best Choice Ground Directional Element optimizes directional element performance and eliminates many settings. Additional logic prevents Zone 1 overreach on series-compensated lines.

NOTE: The SEL-421-4 does not provide high-speed directional elements and high-speed distance elements.

High-Speed Tripping. The SEL-421 uses the HSDPS (High-Speed Directional and Phase Selection) element and high-speed distance elements for subcycle detection of power system faults.

Reclosing. Incorporate programmable single-pole and three-pole tripping and reclosing of one and two circuit breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.

Breaker Failure. The SEL-421 incorporates CT subsidence detection to produce element dropout in 5/8 cycle. Apply the SEL-421 to supply three-pole breaker failure for one or two breakers. Included is the necessary logic for single-pole and three-pole breaker failure retrip and initiation of transfer tripping.

Out-of-Step Blocking and Tripping. Select out-of-step blocking of distance elements or out-of-step tripping during power swings. The SEL-421 includes multizone elements and logic for detection of an out-of-step condition.

Switch-Onto-Fault. Relay switch-onto-fault (SOTF) logic permits specific protection elements to quickly trip after the circuit breaker closes, protecting maintenance personnel and substation equipment.

Frequency Elements. Any of the six levels of frequency elements can operate as either an underfrequency element or as an overfrequency element. The frequency elements are suited for applications such as underfrequency load shedding and restoration control systems.

Voltage Elements. The relay offers as many as six undervoltage and six overvoltage elements. Each of these 12 elements has two levels, for a total of 24 over- and undervoltage elements.

Fault Locator. Efficiently dispatch line crews to quickly repair line problems.

Primary Potential Redundancy. Multiple voltage inputs to the SEL-421 provide primary input redundancy. At loss-of-potential (LOP) detection, configure the relay to use inputs from an electrically equivalent source. Protection remains in service without compromising security.

Dual CT Input. Apply with ring bus, breaker-and-a-half, or other two-breaker schemes. Combine currents within the relay from two sets of CTs for protection functions, but keep them separately available for monitoring and station integration applications.

NOTE: The SEL-421-4 has only one 100-line automation programming block.

Automation. Take advantage of enhanced automation features that include programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large format front-panel liquid crystal display (LCD) eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic to speed and improve control actions.

Monitoring. Schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole of two circuit breakers) indicates possible excess contact wear. Electrical and mechanical operating times are recorded for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (two independent battery monitors) even if voltage is low only during trip or close operations.

Comprehensive Metering. View metering information for Line, Circuit Breaker 1, and Circuit Breaker 2. SEL-421 metering includes fundamental and rms metering, as well as energy import/export, demand, and peak demand metering data. Synchrophasor data can be used for time-synchronized state measurements across the system.

Oscillography and Event Reporting. Record voltages, currents, and internal logic points at as high as 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.

Sequential Events Recorder (SER). Record the last 1000 entries, including setting changes, power-ups, and selectable logic elements.

High-Accuracy Time Stamping. Time-tag binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than 1/4 of an electrical degree.

Digital Relay-to-Relay Communication. Enhanced MIRRORED BITS communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

Parallel Redundancy Protocol (PRP). Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

Ethernet Access. Access all relay functions with the optional Ethernet card. Interconnect with automation systems using IEC 61850 or DNP3 LAN/WAN protocols directly or DNP3 through an SEL-2032 Communications Processor or SEL-3530 RTAC. Use file transfer protocol (FTP) for high-speed data collection.

Increased Security. The SEL-421 divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.

Rules-Based Settings Editor. Communicate with and set the relay using an ASCII terminal, or use the PC-based QuickSet Software to configure the SEL-421 and analyze fault records with relay element response. View real-time phasors.

Settings Reduction. Internal relay programming shows only the settings for the functions and elements you have enabled.

Thermal Overload Modeling. Use the SEL-421 with the SEL-2600 RTD Module for dynamic overload protection using SELOGIC control equations. For more information, see SEL Application Guide AG2003-06, *Implementation of the SEL-49 Relay Line Thermal Protection Using the SEL-421 Relay SELOGIC Equations*.

Bay Control. The SEL-421 provides bay control functionality with status indication and control of as many as ten disconnects. The relay features control for as many as two breakers and status indication of as many as three breakers. Numerous pre-defined user-selectable mimic displays are available; the selected mimic is displayed on the front-panel screen in one-line diagram format. The one-line diagram includes user-configurable labels for disconnect switches, breakers, bay name, and display for as many as six analog quantities. The SEL-421 features SELOGIC programmable local control supervision of breaker and disconnect switch operations. See *Section 5: Control in the SEL-400 Series Relays Instruction Manual* for more information.

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are now available for use in customized programming, making the initial programming and maintenance much easier.

Auxiliary TRIP/CLOSE Pushbuttons. The part number indicates whether the relay has auxiliary **TRIP** and **CLOSE** pushbuttons. These pushbuttons are shown in *Figure 4.2 on page 4.2 in the SEL-400 Instruction Manual*. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

Part numbers 0421*xxxxxxxxxx*3A*xxxxx*, 0421*xxxxxxxxxx*7A*xxxxx*, 0421*xxxxxxxxxx*3B*xxxxx*, and 0421*xxxxxxxxxx*7B*xxxxx* designate relays with the auxiliary **TRIP** and **CLOSE** pushbuttons.

The lowercase *x*s in the above part numbers represent fields that contain other values that are not important in determining the operator controls of the relay. Refer to the SEL-421 Model Option Table for complete part number details. These tables are available on the SEL website or from the factory.

Models and Options

NOTE: When used in TiDL applications, the relay is only available in the 4U chassis.

Consider the following options when ordering and configuring the SEL-421.

- Chassis size
  - 3U, 4U, and 5U

    (U is one rack unit—1.75 inches or 44.45 mm)
- Main board I/O
  - Main Board:

    Contact inputs: 5 independent and 2 common inputs (level sensitive and optoisolated);

    Contact outputs: 2 standard Form A, 3 standard Form C, and 3 high-current interrupting Form A outputs
- Additional I/O board (for 4U and 5U chassis)
  - INT1:

    Contact inputs: 8 independent inputs (programmable pickup threshold);

    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT2:

    Contact inputs: 8 independent inputs (level sensitive and optoisolated);

    Contact outputs: 13 standard Form A and 2 standard Form C outputs
  - INT3:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);

    Contact outputs: 4 high-current interrupting

    Form A outputs
  - INT4:

    Contact inputs: 18 common (2 groups of 9) and 6 independent inputs (level sensitive and optoisolated);

    Contact outputs: 6 high-speed, high-current interrupting Form A and 2 standard Form A outputs
  - INT5:

    Contact inputs: 8 independent inputs (programmable pickup threshold);

    Contact outputs: 8 high-speed, high-current interrupting Form A outputs

- INT6:

  Contact inputs: 8 independent inputs (programmable pickup threshold);

  Contact outputs: 13 high-current interrupting Form A and 2 standard Form C outputs
- INT7:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);

  Contact outputs: 13 high-current interrupting Form A and 2 standard Form C outputs
- INT8:

  Contact inputs: 8 independent inputs (level sensitive and optoisolated);

  Contact outputs: 8 high-speed, high-current interrupting Form A outputs

- Chassis orientation and type
  - Horizontal rack mount
  - Horizontal panel mount
  - Vertical rack mount
  - Vertical panel mount
- Power supply
  - 24–48 Vdc
  - 48–125 Vdc or 110–120 Vac
  - 125–250 Vdc or 110–240 Vac
- Secondary inputs
  - 1 A nominal or 5 A nominal CT inputs
  - 300 V phase-to-neutral wye configuration PT inputs
- Ethernet card options
  - Ethernet card with combinations of 10/100BASE-T and 100BASE-FX media connections on each of two ports
- Communications protocols
  - Complete group of SEL protocols

    (SEL ASCII, SEL Compressed ASCII, SEL Settings File Transfer, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, RTDs, Enhanced MIRRORED BITS Communications), and Synchrophasors (SEL Fast Message and IEEE C37.118 format), and DNP3
  - All of the standard protocols, plus IEC 61850
- Connector type
  - Screw-terminal block inputs
  - Connectorized

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support on page 3.23*). You can also view the latest part number and ordering information on the SEL website at selinc.com.

SEL-421 Versions and Supported Features

SEL-421 Features	-4	-5
Protection		
21MG Mho Ground-Distance and 21MP Mho Phase Distance	Standard	Standard
21XG Quadrilateral Ground-Distance and 21XP Quadrilateral Phase Distance	Standard	Standard
High-Speed Distance and High-Speed Directional		Standard
50N/G Ground, 50P Phase, and 50Q Negative-Sequence—O/C	Standard	Standard
51N/G Ground, 51P Phase, and 51Q Negative-Sequence Time—O/C	Standard	Standard
67N/G Ground, 67P Phase, and 67Q Neg.-Seq. Directional—O/C	Standard	Standard
Programmable Analog Math	Standard	Standard
Out-of-Step Trip and Block	Standard	Standard
Load-Encroachment Supervision	Standard	Standard
Switch-Onto-Fault	Standard	Standard
Single-Pole Trip	Standard	Standard
MIRRORED BITS Communications	Standard	Standard
Zone/Level Timers	Standard	Standard
Pilot Protection Logic	Standard	Standard
Series-Compensated Line Logic		Standard
Instrumentation and Control		
79 Automatic Reclosing, Voltage Check on Closing, 25 Synchronism Check	Standard	Standard
Fault Locating	Standard	Standard
SELOGIC Control Equations	Standard	Standard
Maximum Automation SELOGIC Control Equations	100	1000
Substation Battery Monitor	Standard	Standard
Breaker Wear Monitor	Standard	Standard
Event Report (Multicycle Data) and Sequential Events Recorder	Standard	Standard
Instantaneous, RMS, and Demand Meter	Standard	Standard
DNP3 Level 2 Outstation	Standard	Standard
Synchrophasors (IEEE C37.118 and SEL Fast Message)	Standard	Standard
Remote Synchrophasor Measurement		
Time-Domain Link (TiDL) Remote Data Acquisition	Optional	Optional
Contact Input Option		
Main Board—Optoisolated Level-Sensitive Contact Inputs	Standard	Standard
INT1 Interface Board—User-Settable Level-Sensitive Contact Inputs	Optional	Optional
INT2 Interface Board—Optoisolated Level-Sensitive Contact Inputs	Standard	Standard
INT3 Interface Board—Optoisolated Level-Sensitive Contact Inputs	Standard	Standard
INT4 Interface Board—Optoisolated Level-Sensitive Contact Inputs		
INT5 Interface Board—User-Settable Level-Sensitive Contact Inputs	Optional	Optional
INT6 Interface Board—User-Settable Level-Sensitive Contact Inputs	Optional	Optional
INT7 Interface Board—Optoisolated Level-Sensitive Contact Inputs	Standard	Standard
INT8 Interface Board—Optoisolated Level-Sensitive Contact Inputs	Standard	Standard

Applications

Use the SEL-421 in a variety of transmission line protection applications. For information on connecting the relay, see *Section 2: Installation*. See *Section 6: Protection Applications Examples* for a description of various protection applications using the SEL-421.

The figures in this subsection illustrate common relay application configurations. *Figure 1.2*, *Figure 1.3*, *Figure 1.4*, *Figure 1.5*, *Figure 1.6*, and *Figure 1.7* demonstrate relay versatility with Global setting ESS (Current and Voltage Source Selection). These figures show the power and simplicity of the four preprogrammed ESS options. For more information on setting ESS, see *Current and Voltage Source Selection on page 5.2*.

The SEL-421 has two sets of three-phase analog current inputs, IW and IX, and two sets of three-phase analog voltage inputs, VY and VZ. The drawings that follow use a two-letter acronym to represent all three phases of a relay analog input. For example, IW represents IAW, IBW, and ICW for A-, B-, and C-Phase current inputs on terminal W, respectively. The drawings list a separate phase designator if you need only one or two phases of the analog input set (VAZ for the A-Phase voltage of the VZ input set, for example).

The SEL-421 supports remote data acquisition through use of the SEL-2240 Axion. The SEL Axion provides remote analog and digital data over an IEC 61158 EtherCAT TiDL network. This technology provides low and deterministic latency over a point-to-point architecture. The SEL-421 can receive as many as eight fiber-optic links from as many as eight Axion remote data acquisition nodes. See *Section 2: Installation* for more details about TiDL applications.

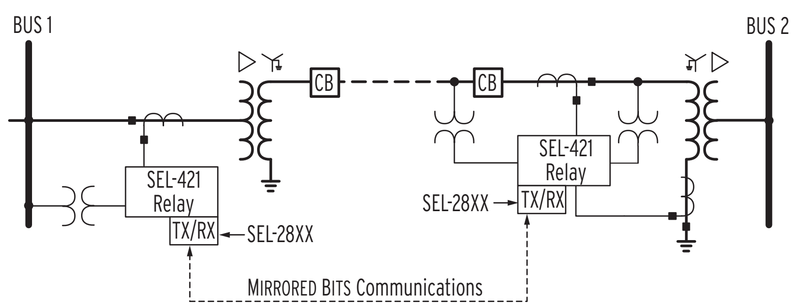
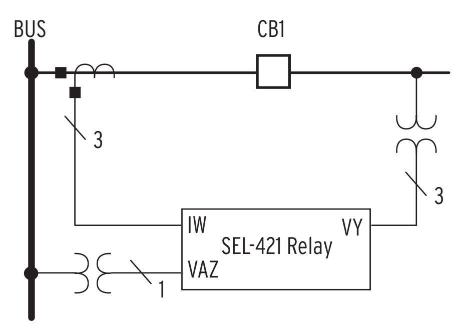
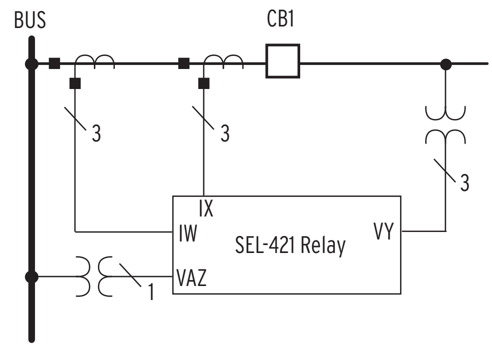


Figure 1.2 Protecting a Line Segment With MIRRORED BITS Communications on a Fiber Channel



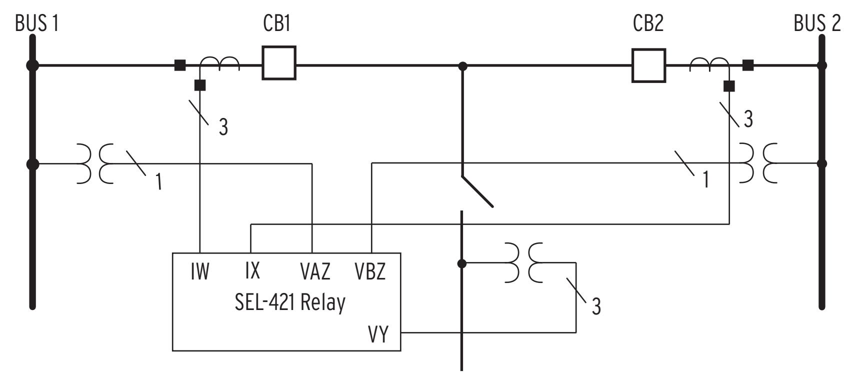
Analog Input	Function
IW	CB1 protection, line protection
VY	Line protection
VAZ	Synchronism check

Figure 1.3 Single Circuit Breaker Configuration (ESS := 1)



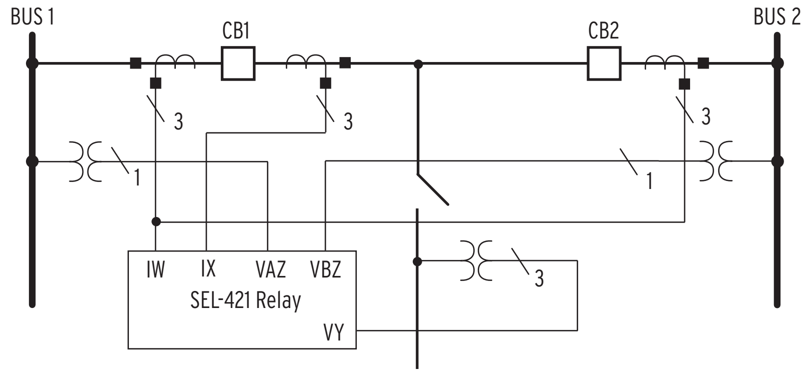
Analog Input	Function
IW	CB1 protection, line protection
IX	CB1 breaker failure
VY	Line protection
VAZ	Synchronism check

Figure 1.4 Single Circuit Breaker Configuration With Line Breaker CTs (ESS := 2)



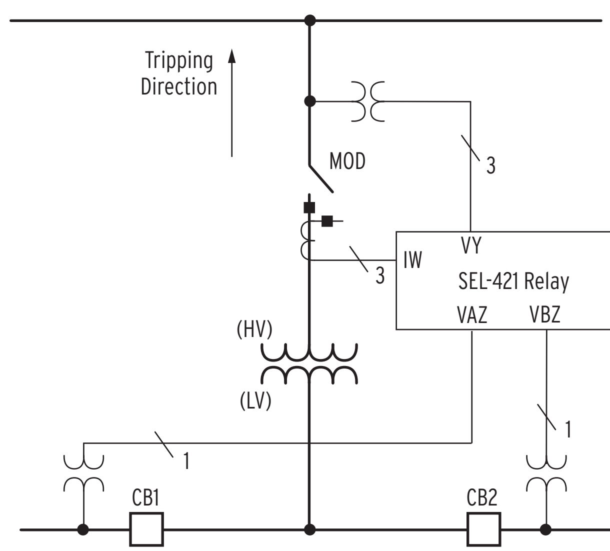
Analog Input	Function
IW+IX	Line Protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.5 Double Circuit Breaker Configuration (ESS := 3)



Analog Input	Function
IW+IX	CB2 protection
IW	Line protection
IX	CB1 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.6 Double Circuit Breaker Configuration With Bus Protection (ESS := 4)



Analog Input	Function
IW	Line protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 1.7 Tapped Line (ESS := Y)

Application Highlights

Apply the SEL-421 in power system protection and control situations. *Table 1.1* lists applications and key features of the relay.

NOTE: The SEL-421-4 does not provide high-speed directional elements and high-speed distance elements.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

Table 1.1 Application Highlights (Sheet 1 of 2)

Application	Key Features
Single-pole and three-pole tripping	High-speed distance elements Best Choice Ground Directional Element Secure protection during open-pole interval Pole-discordance logic trips three-pole for excessive single-pole-open conditions
Remote data acquisition	Time-domain link (TiDL)
Multiple-breaker tripping	SPT one; 3PT other SPT both; 3PT both Breaker failure protection
Reclosing and synchronism check	2 shots SPT; 4 shots 3PT Leader/follower breaker arrangements Two-circuit-breaker universal synchronism check
Coupling-Capacitor Voltage Transformer (CCVT) transient detection logic	Detect CCVT transients to provide correct operation of the direct tripping (Zone 1) distance elements
Long lines	Load-encroachment elements prevent unwanted trips on load Voltage elements detect local bus overvoltages Sensitive negative-sequence and residual overcurrent elements provide sensitive backup protection
Tapped and three-terminal lines	Five zones Three zero-sequence compensation factors for more accurate ground-distance reach on either side of tap Independent reach settings for phase, ground mho and phase, ground quadrilateral elements Multiple settings groups cover any switching configurations
Bus-tie or transfer circuit breakers	Multiple setting groups Match relay settings group to each line substitution Eliminate current reversing switches Local or remote operator switches the setting groups
Subtransmission lines	Time-step distance protection Ground directional overcurrent protection Torque-controlled time-overcurrent elements
Lines with capacitors	Series-compensated line logic
Lines with transformers	Negative-sequence overcurrent protection
Short transmission lines	Directional overcurrent elements and communications-assisted tripping schemes, quadrilateral phase distance
Permissive Overreaching Transfer Tripping (POTT) schemes	Current reversal guard logic Open breaker echo keying logic Weak-infeed and zero-infeed logic Time-step distance backup protection
Directional Comparison Unblocking Tripping (DCUB) schemes	Includes all POTT logic All loss-of-channel logic is inside the relay Time-step distance backup protection

Table 1.1 Application Highlights (Sheet 2 of 2)

Application	Key Features
Permissive Underreaching Transfer Tripping (PUTT) schemes	Supported by POTT logic Time-step distance backup protection
Directional Comparison Blocking Trip (DCB) schemes	Current reversal guard logic Carrier coordinating timers Carrier send and receive extend logic Zone 3 latch eliminates the need for offset three-phase distance elements Time-step distance backup protection
Direct Transfer Tripping (DTT) schemes	SELOGIC control equations program the elements that key direct tripping
SCADA applications	Analog and digital data acquisition for station wide functions
Communications capability	SEL ASCII Enhanced MIRRORED BITS communications SEL Fast Meter, SEL Fast Operate, SEL Fast SER SEL Compressed ASCII Phasor Measurement Unit (PMU) protocols RTD Serial DNP3 Optional protocols: Ethernet, IEC 61850, DNP3 (Ethernet), FTP, Telnet
Customized protection and automation schemes	Separate protection and automation SELOGIC control equation programming areas Use timers and counters in expanded SELOGIC control equations for complete flexibility
Synchrophasors	The SEL-421 can function as a phasor measurement unit (PMU) at the same time as it provides best-in-class protective relay functions. C37.118 message format allows as many as 12 current and 8 voltage synchronized measurements, as many as 60 messages per second (on a 60 Hz nominal power system). Five unique data streams, three choices of filter response, settable angle correction, and a choice of numeric representation makes the data usable for a variety of synchrophasor applications. SEL Fast Operate commands are available on the synchrophasor communications ports, allowing control actions initiated by the synchrophasor processor. Records as much as 120 seconds of C37.118 synchrophasor data based on a trigger. Recorded files follow the C37.232 file naming convention. SEL Fast Message Synchrophasor format is also available as legacy, with as many as four current and four voltage synchronized measurements.

Product Characteristics

Each SEL-400 series relay shares common features, but has unique characteristics. The following table summarizes the unique characteristics of the SEL-421.

Table 1.2 SEL-421 Relay Characteristics

Characteristic	Value
Standard processing rate	8 times per cycle
Battery monitor	Two
Autorecloser	Single-pole
MBG protocol	Supported
SELOGIC	
Protection freeform	250 lines
Automation freeform	421-4: 1 block of 100 lines 421-5: 10 blocks of 100 lines each
SELOGIC variables	64 protection 256 automation
SELOGIC math variables	64 protection 256 automation
Conditioning timers	32 protection
Sequencing timers	32 protection 32 automation
Counters	32 protection 32 automation
Latch bits	32 automation 32 protection
Control	
Remote bits	32
Breakers	Two for control and three for status: 1, 2, 3 Three-Pole or Single-Pole
Disconnects	10
Bay control	Supported
Metering	
Maximum/minimum metering	Supported
Energy metering	Supported

Specifications

Note: If the relay uses a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay. Element operate times will also have this small added delay.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B Class A

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference in which case the user will be required to correct the interference at his own expense.

UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)

CE Mark

General

AC Analog Inputs

Sampling Rate: 8 kHz

AC Current Inputs (Secondary Circuits)

Current Rating (With DC Offset at X/R = 10, 1.5 Cycles)

1 A Nominal:	18.2 A
5 A Nominal:	91 A

Continuous Thermal Rating

1 A Nominal:	3 A 4 A (+55°C)
5 A Nominal:	15 A 20 A (+55°C)

Saturation Current (Linear) Rating

1 A Nominal:	20 A
5 A Nominal:	100 A

A/D Current Limit

Note: Signal clipping may occur beyond this limit.

5 A Nominal:	247.5 A
1 A Nominal:	49.5 A

One-Second Thermal Rating

1 A Nominal:	100 A
5 A Nominal:	500 A

One-Cycle Thermal Rating

1 A Nominal:	250 A-peak
5 A Nominal:	1250 A-peak

Burden Rating

1 A Nominal:	≤0.1 VA at 1 A
5 A Nominal:	≤0.5 VA at 5 A

AC Voltage Inputs

Three-phase, four-wire (wye) connections are supported.

Rated Voltage Range:	0–300 V_{LN}
Ten-Second Thermal Rating:	600 Vac
Burden:	≤0.1 VA @ 125 V

Frequency and Rotation

Nominal Frequency Rating:	50 ±5 Hz 60 ±5 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking Range:	40.0–65.0 Hz <40 Hz = 40 Hz >65.0 Hz = 65 Hz
Maximum Slew Rate:	15 Hz/s

Power Supply

24–48 Vdc

Rated Voltage:	24–48 Vdc
Operational Voltage Range:	18–60 Vdc
Vdc Input Ripple:	15% per IEC 60255–26:2013
Interruption:	20 ms at 24 Vdc, 100 ms at 48 Vdc per IEC 60255-26:2013
Burden:	<35 W

48–125 Vdc or 110–120 Vac

Rated Voltage:	48–125 Vdc, 110–120 Vac
Operational Voltage Range:	38–140 Vdc 85–140 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255–26:2013
Interruption:	14 ms at 48 Vdc, 160 ms at 125 Vdc per IEC 60255-26:2013
Burden:	<35 W, <90 VA

125–250 Vdc or 110–240 Vac

Rated Voltage:	125–250 Vdc, 110–240 Vac
Operational Voltage Range:	85–300 Vdc 85–264 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255–26:2013
Interruption:	46 ms at 125 Vdc, 250 ms at 250 Vdc per IEC 60255–26:2013
Burden:	<35 W, <90 VA

Control Outputs

Standard

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	250 Vac, 330 Vdc
Pickup/Dropout Time:	≤6 ms, resistive load
Update Rate:	1/8 cycle

Break Capacity (10,000 Operations):

48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 Cycle/Second):

48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Hybrid (High-Current Interrupting)

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	330 Vdc
Pickup/Dropout Time:	≤ 6 ms, resistive load
Update Rate:	1/8 cycle

Breaking Capacity (10,000 Operations):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Note: Do not use hybrid control outputs to switch ac control signals. These outputs are polarity dependent.

High-Speed, High-Current Interrupting

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection (Maximum Voltage):	250 Vac/330 Vdc
Pickup Time:	≤10 µs, resistive load
Dropout Time:	≤8 ms, resistive load
Update Rate:	1/8 cycle

Breaking Capacity (10,000 Operations):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-2005.
Note: Per IEC 61810-2:2005.

Auxiliary Trip/Close Pushbuttons (Select Models Only)

Resistive DC or AC Outputs With Arc Suppression Disabled

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection:	250 Vac/330 Vdc/130 J

Breaking Capacity (1000 Operations):

48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

High Interrupt DC Outputs With Arc Suppression Enabled

Make:	30 A
Carry:	6 A continuous carry
1 s Rating:	50 A
MOV Protection:	330 Vdc/130 J

Breaking Capacity (10,000 Operations):

48 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Breaker Open/Closed LEDs:

250 Vdc:	on for 150–300 Vdc; 192–288 Vac
125 Vdc:	on for 80–150 Vdc; 96–144 Vac
48 Vdc:	on for 30–60 Vdc;
24 Vdc:	on for 15–30 Vdc

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.

Control Inputs

Direct Coupled (For Use With DC Signals)

INT1, INT5, and INT6 Interface Boards:	8 inputs with no shared terminals
Range:	15–265 Vdc, independently adjustable
Accuracy:	±5% ±3 Vdc
Maximum Voltage:	300 Vdc
Sampling Rate:	2 kHz
Typical Burden:	0.24 W @ 125 Vdc

Optoisolated (Use With AC or DC Signals)

Main Board:	5 inputs with no shared terminals 2 inputs with shared terminals
INT2, INT7, and INT8 Interface Boards:	8 inputs with no shared terminals
INT3 and INT4 Interface Boards:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs with each group sharing one terminal)
Voltage Options:	24 V standard 48, 110, 125, 220, 250 V level sensitive

DC Thresholds (Dropout Thresholds Indicate Level-Sensitive Option)

24 Vdc:	Pickup 19.2–30.0 Vdc
48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout <28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout <66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout <75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout <132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout <150 Vdc

AC Thresholds (Ratings Met Only When Recommended Control Input Settings Are Used—see *Table 2.1 on page 2.6*)

24 Vac:	Pickup 16.4–30.0 Vac rms
48 Vac:	Pickup 32.8–60.0 Vac rms; Dropout <20.3 Vac rms
110 Vac:	Pickup 75.1–132.0 Vac rms; Dropout <46.6 Vac rms
125 Vac:	Pickup 89.6–150.0 Vac rms; Dropout <53.0 Vac rms
220 Vac:	Pickup 150.3–264 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300 Vac rms; Dropout <106 Vac rms
Current Drawn:	<5 mA at nominal voltage <8 mA for 110 V option
Sampling Rate:	2 kHz

Communications Ports

EIA-232:	1 Front and 3 Rear
Serial Data Speed:	300–57600 bps

Communications Card Slot for Optional Ethernet Card

Ordering Options:	100BASE-FX fiber-optic Ethernet
Fiber Type:	Multimode
Wavelength:	1300 nm
Source:	LED
Connector Type:	LC fiber
Min. TX Power:	–19 dBm
Max. TX Power:	–14 dBm
RX Sensitivity:	–32 dBm
Sys. Gain:	13 dB

Communications Ports for Optional TiDL Interface

EtherCAT Fiber-Optic Ports:	8
Data Rate:	Automatic
Connector Type:	LC fiber
Protocols:	Dedicated EtherCAT
Class 1 LASER/LED	
Wavelength:	1300 nm
Fiber Type:	Multimode
Link Budget:	11 dB
Min. TX Power:	–20 dBm
Min. RX Sensitivity:	–31 dBm
Fiber Size:	50–200 µm
Approximate Range:	2 km
Data Rate:	100 Mbps
Typical Fiber Attenuation:	–2 dB/km

Time Inputs

IRIG Time Input-Serial Port 1

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≤2.8 Vdc
Logic Low Threshold:	≥0.8 Vdc
Input Impedance:	2.5 kΩ

IRIG-B Input—BNC Connector

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≤2.2 Vdc
Logic Low Threshold:	≥0.8 Vdc
Input Impedance:	50 Ω or > 1 kΩ
Dielectric Test Voltage:	0.5 kVac

PTP—Ethernet Port 5A, 5B

Input:	IEEE 1588 PTPv2
Profiles:	Default, C37.238-2011 (Power Profile)
Synchronization Accuracy:	±100 ns @ 1-second synchronization intervals when communicating directly with master clock

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

3U Rack Unit:	8.0 kg (17.7 lb)
4U Rack Unit:	9.4 kg (20.7 lb)
5U Rack Unit:	11.3 kg (25.0 lb)

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum:	1.0 Nm (9 in-lb)
Maximum:	2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device unless otherwise required by local or national regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (5.3 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)
Other Connection	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

These tests do not apply to contacts rated for 24 Vdc.

Electromagnetic Compatibility (EMC)

Emissions:	IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	IEC 60255-22-6:2001, 10 Vrms IEC 61000-4-6:2008, 10 Vrms
Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 Levels 2, 4, 6, and 8 kV contact; Levels 2, 4, 8, and 15 kV air IEEE C37.90.3-2001 Levels 2, 4, and 8 kV contact; Levels 4, 8, and 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:2008 4 kV at 5 kHz and 2 kV at 5 kHz (Comm Ports) IEC 61000-4-4:2011 4 kV at 5 kHz
Magnetic Field Immunity:	IEC 61000-4-8:2009 1000 A/m for 3 s 100 A/m for 1 min IEC 61000-4-9:2001 1000 A/m
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2001 Severity Level: 100 A/m

Power Supply Immunity:	IEC 60255-11:2008 IEC 61000-4-11:2004 IEC 61000-4-29:2000
Radiated Digital Radio Telephone RF Immunity:	ENV 50204:1995 10 V/m at 900 MHz and 1.89 GHz
Radiated Radio Frequency Immunity:	IEC 60255-22-3:2007, 10 V/m IEC 61000-4-3:2010, 10 V/m IEEE C37.90.2-2004, 35 V/m
Surge Immunity:	IEC 60255-22-5:2008 IEC 61000-4-5:2005 1.0 kV line-to-line 2.0 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 60255-22-1:2007 2.5 kV peak common mode 1.0 kV peak differential mode IEEE C37.90.1-2002 2.5 kV oscillatory 4.0 kV fast transient waveform

Environmental

Cold:	IEC 60068-2-1:2007 Severity Level: 16 hours at –40°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat:	IEC 60068-2-2:2007 Severity Level: 16 hours at +85°C
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 2 (endurance); Class 2 (response) IEC 60255-21-2:1988 Severity Level: Class 1 (shock withstand, bump); Class 2 (shock response) IEC 60255-21-3:1993 Severity Level: Class 2 (quake response)

Safety

Dielectric Strength:	IEC 60255-5:2000 IEEE C37.90-2005 2500 Vac on contact inputs, contact outputs, and analog inputs for 1 min 3100 Vdc on power supply for 1 min
Impulse:	IEC 60255-5:2000, 0.5 J, 5 kV IEEE C37.90-2005, 0.5 J, 5 kV
IP Code:	IEC 60529:2001 + CRGD:2003, IP3X

Reporting Functions

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE C37.111-1999, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.*

Event Reports

Length:	0.25–24 seconds (based on LER and SRATE settings)
Volatile Memory:	3 s of back-to-back event reports sampled at 8 kHz
Nonvolatile Memory:	At least 4 event reports of a 3 s duration sampled at 8 kHz
Resolution:	4 and 8 samples/cycle

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements
Resolution:	0.5 ms for contact inputs 1/8 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle
Reclosing logic runs once per power system cycle

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Mho Phase-Distance Elements

Zones 1–5 Impedance Reach

Setting Range	
5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps
Sensitivity	
5 A Model:	0.5 A_{P-P} secondary
1 A Model:	0.1 A_{P-P} secondary (Minimum sensitivity is controlled by the pickup of the supervising phase-to-phase overcurrent elements for each zone.)
Accuracy (Steady State):	± 3% of setting at line angle for SIR (source-to-line impedance ratio) < 30 ± 5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	< 5% of setting plus steady-state accuracy
SEL-421-5 Maximum Operating Time:	0.8 cycle at 70% of reach and SIR = 1
SEL-421-4 Maximum Operating Time:	1.5 cycle at 70% of reach and SIR = 1

Quadrilateral Phase-Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach	
5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps
Quadrilateral Resistance Reach	
Zones 1, 2, and 3	
5 A Model:	OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Zones 4 and 5

5 A Model:	OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting *plus* steady-state accuracy

Mho Ground-Distance Elements

Zones 1–5 Impedance Reach

Mho Element Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Zone 1 Transient Overreach:	<5% of setting *plus* steady-state accuracy
SEL-421-5 Maximum Operating Time:	0.8 cycle at 70% of reach and SIR = 1
SEL-421-4 Maximum Operating Time:	1.5 cycle at 70% of reach and SIR = 1

Quadrilateral Ground-Distance Elements

Zones 1–5 Impedance Reach

Quadrilateral Reactance Reach

5 A Model:	OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

Quadrilateral Resistance Reach

Zones 1, 2, and 3

5 A Model:	OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

Zones 4 and 5

5 A Model:	OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps
1 A Model:	OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

Sensitivity

5 A Model:	0.5 A secondary
1 A Model:	0.1 A secondary (Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)
Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Transient Overreach:	<5% of setting plus steady-state accuracy

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

Pickup Range

5 A Model:	OFF, 0.25–100.00 A secondary, 0.01 A steps
1 A Model:	OFF, 0.05–20.00 A secondary, 0.01 A steps

Accuracy (Steady State)

5 A Nominal:	±0.05 A plus ±3% of setting
1 A Nominal:	±0.01 A plus ±3% of setting
Transient Overreach:	<5% of pickup
Time-Delay:	0.00–16000.00 cycles, 0.125 cycle steps
Timer Accuracy:	±0.125 cycle plus ±0.1% of setting
Maximum Operating Time:	1.5 cycles

Time-Overcurrent Elements

Pickup Range

5 A Model:	0.25–16.00 A secondary, 0.01 A steps
1 A Model:	0.05–3.20 A secondary, 0.01 A steps

Accuracy (Steady State)

5 A Model:	±0.05 A plus ± 3% of setting
1 A Model:	±0.01 A plus ± 3% of setting

Time Dial Range

US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ± 4% of curve time (for current between 2 and 30 multiples of pickup)
Reset:	1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)

5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω

Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)

5 A Model:	–64 to 64 Ω
1 A Model:	–320 to 320 Ω

Supervisory Overcurrent Pickup 50FP, 50RP

5 A Model:	0.25 to 5.00 A 3I0 secondary 0.25 to 5.00 A 3I2 secondary
1 A Model:	0.05 to 1.00 A 3I0 secondary 0.05 to 1.00 A 3I2 secondary

Undervoltage and Overvoltage Elements

Pickup Ranges

Phase Elements:	2–300 V secondary, 0.01 V steps
Phase-to-Phase Elements:	4–520.0 V secondary, 0.01 V steps
Accuracy (Steady State):	±0.5 V plus ± 5% of setting
Transient Overreach:	<5% of pickup

Underfrequency and Overfrequency Elements

Pickup Range:	40.01–69.99 Hz, 0.01 Hz steps
Accuracy, Steady State Plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 Hz
Maximum Pickup/ Dropout Time:	3.0 cycles
Time-Delay Range:	0.04–400.0 s, 0.01 s increments

Time-Delay Accuracy: ±0.1% ±0.0042 s

Pickup Range, Undervoltage Blocking: 20–200 V_{LN} (Wye)

Pickup Accuracy, Undervoltage Blocking: ±2% ±0.5 V

Optional RTD Elements (Models Compatible With SEL-2600 RTD Module)

12 RTD Inputs Via SEL-2600 RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

As long as 500 m Fiber-Optic Cable to SEL-2600 RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range

- 5 A Model: 0.50–50.0 A, 0.01 A steps
- 1 A Model: 0.10–10.0 A, 0.01 A steps

Accuracy

- 5 A Model: ±0.05 A plus ± 3% of setting
- 1 A Model: ±0.01 A plus ± 3% of setting

Transient Overreach: <5% of setting

Maximum Pickup Time: 1.5 cycles

Maximum Reset Time: 1 cycle

Timers Setting Range: 0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*)
0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)

Time Delay Accuracy: 0.125 cycle plus ± 0.1% of setting

Synchronism-Check Elements

Slip Frequency Pickup Range: 0.005–0.500 Hz, 0.001 Hz steps

Slip Frequency Pickup Accuracy: ±0.0025 Hz plus ± 2% of setting

Close Angle Range: 3–80°, 1° steps

Close Angle Accuracy: ±3°

Load-Encroachment Detection

Setting Range

- 5 A Model: 0.05–64 Ω secondary, 0.01 Ω steps
- 1 A Model: 0.25–320 Ω secondary, 0.01 Ω steps
- Forward Load Angle: –90° to +90°
- Reverse Load Angle: +90° to +270°

Accuracy

- Impedance Measurement: ±3%
- Angle Measurement: ±2°

Out-of-Step Elements

Blinders (R1) Parallel to the Line Angle

- 5 A Model: 0.05 to 70 Ω secondary
–0.05 to –70 Ω secondary
- 1 A Model: 0.25 to 350 Ω secondary
–0.25 to –350 Ω secondary

Blinders (X1) Perpendicular to the Line Angle

- 5 A Model: 0.05 to 96 Ω secondary
–0.05 to –96 Ω secondary
- 1 A Model: 0.25 to 480 Ω secondary
–0.25 to –480 Ω secondary

Accuracy (Steady State)

- 5 A Model: ±5% of setting plus ±0.01 A for SIR (source to line impedance ratio) < 30
±10% of setting plus ±0.01 A for 30 ≤ SIR ≤ 60
- 1 A Model: ±5% of setting plus ±0.05 A for SIR (source to line impedance ratio) < 30
±10% of setting plus ±0.05 A for 30 ≤ SIR ≤ 60

Transient Overreach: < 5% of setting *plus* steady-state accuracy

Positive-Sequence Overcurrent Supervision

Setting Range

- 5 A Model: 1.0–100.0 A, 0.01 A steps
- 1 A Model: 0.2–20.0 A, 0.01 A steps

Accuracy (Steady State)

- 5 A Model: ±3% of setting plus ± 0.05 A
- 1 A Model: ±3% of setting plus ± 0.01 A

Transient Overreach: <5% of setting

Bay Control

Breakers: 2 (control), 3rd indication

Disconnects (Isolators): 10 (maximum)

Timers Setting Range: 1–99999 cycles, 1-cycle steps

Time-Delay Accuracy: ±0.1% of setting, ±0.125 cycle

Timer Specifications

Breaker Failure: 0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*)
0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)

Communications-Assisted Tripping Schemes: 0.000–16000 cycles, 0.125 cycle steps

Out-of-Step Timers

- OSBD, OSTD: 0.500–8000 cycles, 0.125 cycle steps
- UBD: 0.500–120 cycles, 0.125 cycle steps

Pole-Open Timer: 0.000–60 cycles, 0.125 cycle steps

Recloser: 1–99999 cycles, 1 cycle steps

Switch-Onto-Fault

- CLOEND, 52AEND: OFF, 0.000–16000 cycles, 0.125 cycle steps
- SOTFD: 0.50–16000 cycles, 0.125 cycle steps

Synchronism-Check Timers

- TCLSBK1, TCLSBK2: 1.00–30.00 cycles, 0.25 cycle steps

Zone Time Delay: 0.000–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Rated Voltage: 15–300 Vdc

Sampling Rate: DC1: 2 kHz
DC2: 1 kHz

Processing Rate: 1/8 cycle

Operating Time: Less than 1.5 cycles (all elements except ac ripple)
Less than 1.5 seconds (ac ripple element)

Setting Range

- 15–300 Vdc, 1 Vdc steps (all elements except ac ripple)
- 1–300 Vac, 1 Vac steps (ac ripple element)

Accuracy

- Pickup Accuracy: ±3% ±2 Vdc (all elements except ac ripple)
±10% ±2 Vac (ac ripple element)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

Currents

Phase Current Magnitude

5 A Model: ±0.2% plus ±4 mA (2.5–15 A sec)

1 A Model: ±0.2% plus ±0.8 mA (0.5–3.0 A sec)

Phase Current Angle

All Models: ±0.2° in the current range 0.5 • I_{NOM} to 3.0 • I_{NOM}

Sequence Current Magnitude

5 A Model: ±0.3% plus ± 4 mA (2.5–15 A sec)

1 A Model: ±0.3% plus ± 0.8 mA (0.5–3 A sec)

Sequence Current Angle

All Models: ±0.3° in the current range 0.5 • I_{NOM} to 3.0 • I_{NOM}

Voltages

Phase and Phase-to-Phase Voltage Magnitude: ±0.1% (33.5–300 $V_{L–N}$)

Phase and Phase-to-Phase Angle: ±0.5° (33.5–300 $V_{L–N}$)

Sequence Voltage Magnitude: ±0.1% (33.5–300 V_{L-N})

Sequence Voltage Angle: ±0.5° (33.5–300 V_{L-N})

Frequency (Input 40–65 Hz)

Accuracy: ± 0.01 Hz

Power

MW (P), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVAr (Q), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

MVA (S), Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

PF, Per Phase (Wye), 3ϕ (Wye or Delta) Per Terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

Energy

MWh (P), Per Phase (Wye), 3ϕ (Wye or Delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVARh (Q), Per Phase (Wye), 3ϕ (Wye or Delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

Synchrophasor

Number of Synchrophasor Data Streams: 5

Number of Synchrophasors for Each Stream:
15 Phase Synchrophasors (6 Voltage and 9 Currents)
5 Positive-Sequence Synchrophasors (2 Voltage and 3 Currents)

Number of User Analogs for Each Stream: 16 (any analog quantity)

Number of User Digitals for Each Stream: 64 (any analog quantity)

Synchrophasor Protocol: IEEE C37.118, SEL Fast Message (Legacy)

Synchrophasor Data Rate: as many as 60 messages per second

Synchrophasor Accuracy

Voltage Accuracy: ±1% Total Vector Error (TVE)
Range 30–150 V, f_{NOM} ±5 Hz

Current Accuracy: ±1% Total Vector Error (TVE)
Range (0.1–2.0) • I_{NOM} A, f_{NOM} ±5 Hz

Synchrophasor Data Recording: Records as much as 120 s
IEEE C37.232 File Naming Convention

SECTION 2

Installation

The first steps in applying the SEL-421 Relay are installing and connecting the relay. This section describes common installation features and particular installation requirements for the many physical configurations of the SEL-421. You can order the relay in horizontal and vertical orientations, and in panel-mount and rack-mount versions. SEL also provides various expansion I/O (input/output) interface boards to tailor the relay to your specific needs.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options and relay jumper configuration. You should carefully plan relay placement, cable connection, and relay communication. Consider the following when installing the SEL-421:

- ➤ *Shared Configuration Attributes on page 2.1*
- ➤ *Plug-In Boards on page 2.13*
- ➤ *Jumpers on page 2.15*
- ➤ *Relay Placement on page 2.24*
- ➤ *Connection on page 2.25*
- ➤ *AC/DC Connection Diagrams on page 2.50*

It is also very important to limit access to the SEL-421 settings and control functions by using passwords. For information on relay access levels and passwords, see *Changing the Default Passwords in the Terminal on page 3.10 in the SEL-400 Series Relays Instruction Manual*.

For more introductory information on using the relay, see *Section 2: PC Software* and *Section 3: Basic Relay Operations in the SEL-400 Series Relays Instruction Manual*.

Shared Configuration Attributes

There are common or shared attributes among the many possible configurations of SEL-421 Relays. This section discusses the main shared features of the relay.

Relay Sizes

NOTE: When used in TiDL applications, the relay is only available in the 4U chassis.

SEL produces the SEL-421 in horizontal and vertical rack-mount versions and horizontal and vertical panel-mount versions. Relay sizes correspond to height in rack units, U, where U is approximately 1.75 inches or 44.45 mm. The SEL-421 is available in 3U, 4U, and 5U sizes.

Front-Panel Templates

The horizontal front-panel template shown in *Figure 2.1* is the same for all 3U, 4U, and 5U horizontal versions of the relay. The vertical front-panel template (shown in *Figure 2.1*) is the same for all 3U, 4U, and 5U vertical versions of the relay.

The SEL-421 front panel has three pockets for slide-in labels: one pocket for the target LED label, and two pockets for the operator control labels. *Figure 2.1* shows the front-panel pocket areas and openings for typical horizontal and vertical relay orientations; dashed lines denote the pocket areas. Refer to the instructions included in the Configurable Label kit for information on reconfiguring front-panel LED and pushbutton labels.

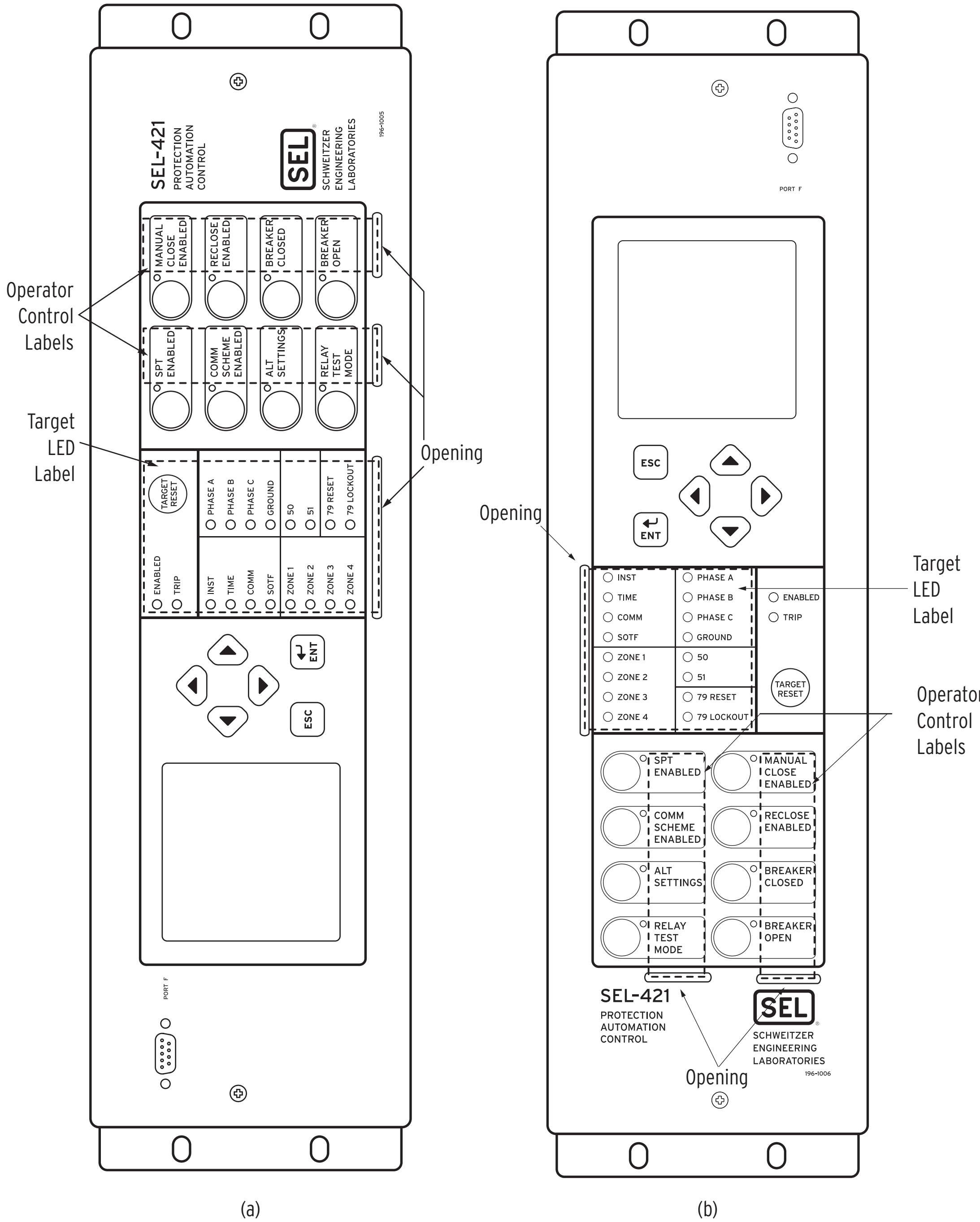


Figure 2.1 Horizontal Front-Panel Template (a); Vertical Front-Panel Template (b)

Rear Panels

Rear panels are identical for the horizontal and the vertical configurations of the relay. *Figure 2.2* is an example of a rear panel for a 3U relay with fixed terminal block analog inputs. *Figure 2.3* shows a rear panel for a 3U relay with Connectorized analog inputs. See *Rear-Panel Layout on page 2.26* for representative 3U, 4U, and 5U relay rear panels (large drawings are in *Figure 2.24–Figure 2.32*).

Connector Types

Screw-Terminal Connectors—I/O and Monitor/Power

Connect to the relay I/O and Monitor/Power terminals on the rear panel through screw-terminal connectors. You can remove the entire screw-terminal connector from the back of the relay to disconnect relay I/O, dc battery monitor, and power without removing each wire connection. The screw-terminal connectors are keyed (see *Figure 2.34*), so you can replace the screw-terminal connector on the rear panel only at the location from which you removed the screw-terminal connector. In addition, the receptacle key prevents you from inverting the screw-terminal connector, making removal and replacement easier.

Secondary Circuit Connectors

Fixed Terminal Blocks

Connect PT and CT inputs to the fixed terminal blocks in the bottom row of the relay rear panel.

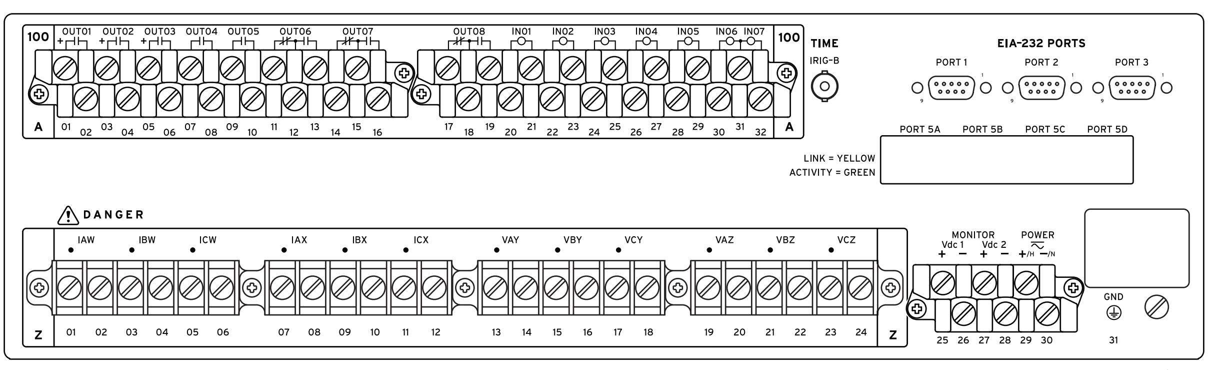
You cannot remove these terminal blocks from the relay rear panel. These terminals offer a secure high-reliability connection for PT and CT secondaries.

Connectorized

The Connectorized SEL-421 features receptacles that accept plug-in/plug-out connectors for terminating PT and CT inputs; this requires ordering a wiring harness (SEL-WA0421) with mating plugs and wire leads. *Figure 2.3* shows the relay 3U chassis with Connectorized CT and PT analog inputs (see *Connectorized on page 2.35* for more information).

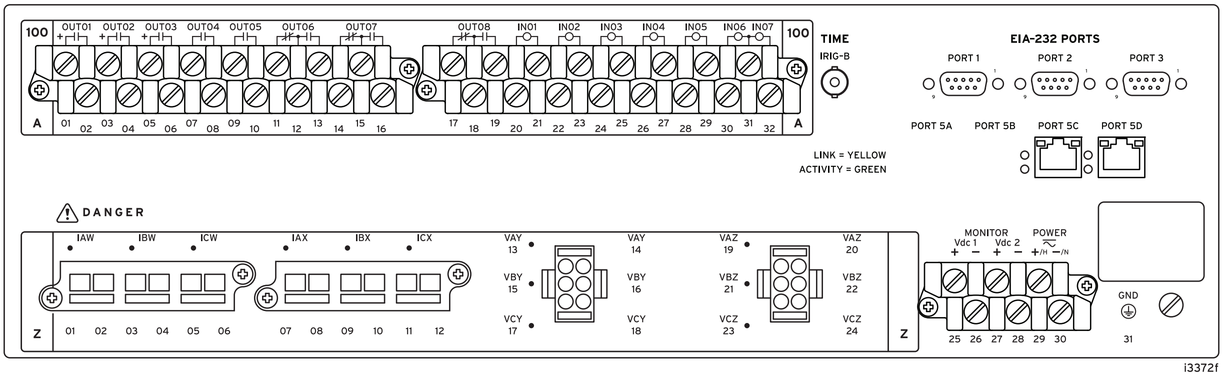
Time-Domain Link (TiDL)

The TiDL SEL-421 features eight fiber-optic EtherCAT connections instead of the standard CT and PT analog inputs (see *TiDL Connections on page 2.38* for more information).



(In a vertical-mount relay, the right rear side is at the top.)

Figure 2.2 Rear 3U Template, Fixed Terminal Block Analog Inputs



(In a vertical-mount relay, the right rear side is at the top.)

Figure 2.3 Rear 3U Template, Connectorized Analog Inputs

Secondary Circuits

⚠**WARNING**
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

The SEL-421 is a very low burden load on the CT secondaries and PT secondaries. For both the CT and PT inputs, the frequency range is 40–65 Hz.

The relay accepts two sets of three-phase currents from power system CT inputs:

➤ IAW, IBW, and ICW
➤ IAX, IBX, and ICX

For 5 A relays, the rated nominal input current, I_{NOM}, is 5 A. For 1 A relays, the rated nominal input current, I_{NOM}, is 1 A.

Input current for both relay types can range to $20 \bullet I_{NOM}$.

See *AC Current Inputs (Secondary Circuits) on page 1.14* for complete CT input specifications.

The relay also accepts two sets of three-phase, four-wire (wye) potentials from power system PT or CCVT (coupling-capacitor voltage transformer) secondaries:

➤ VAY, VBY, and VCY
➤ VAZ, VBZ, and VCZ

The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a range of 0–300 volts. The PT burden is less than 0.5 VA at 67 volts, L-N. See *AC Voltage Inputs on page 1.14* for complete PT input specifications.

Some applications do not use all three phases of a source; for example, voltage synchronization sources can be single phase. See *Section 6: Protection Applications Examples* for examples of connections to the potential inputs.

See *Secondary Circuit Connections on page 2.34* for information on connecting power system secondary circuits to these inputs.

Relays that use the TiDL system do not contain secondary circuits on the relay. The secondary circuit uses a remote SEL-2240 Axion to supply the voltages and currents through a direct fiber link; however, the nominal current must be selected to appropriately apply scaling through various protection functions. The relay, by default, assumes 5 A as the nominal current selection. For 1 A scaling, use the **CFG CTNOM** command (see *Table 14.28 on page 14.10 in the SEL-400 Series Relays Instruction Manual* for more information). The SEL-2245-42 AC

Analog Input Module also sets its internal calculations based on this command. The relay internally transmits these data to the Axion modules and adjusts the appropriate scaling in the Axion module when this command is used.

In addition to the CT nominal values, TiDL relays also require you to set the nominal frequency by issuing the **CFG NFREQ** command. At Access Level 2, issue a **CFG NFREQ 60** command to set the relay to 60 Hz nominal or issue a **CFG NFREQ 50** command to set the relay to 50 Hz nominal. This command changes the NFREQ setting and restarts the relay, and it is only available in TiDL relays. The relay defaults to 60 Hz, so only use this command if you want to switch to 50 Hz nominal. Issue this command after the **CFG CTNOM** command but before sending settings to the relay.

Control Inputs

Direct Coupled

NOTE: The SEL-421 INT1, INT5, and INT6 I/O interface boards have polarity-sensitive inputs, and the terminals are identified with a polarity mark.

The SEL-421 inputs on the optional I/O interface boards (INT1, INT5, or INT6 I/O boards—see *Models and Options on page 1.5*), are direct-coupled, high-impedance control inputs. Use these inputs for monitoring on/off and logical change-of-state conditions of power system equipment. These high-isolation control inputs are polarity-sensitive circuits. You cannot damage these inputs with a reverse polarity connection, although the relay will not detect input changes with a reverse-polarity input. For more information on control input specifications, see *Control Inputs on page 1.15*.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections to a high-isolation analog-to-digital converter (ADC). There are no internal connections among independent inputs. Common inputs share one input leg in common; all input legs of common inputs are ground-isolated. Each pair of common inputs is isolated from all other pairs.

Nominal current draw for these inputs is very low (4 mA or less) with an input voltage range of 15 Vdc to 265 Vdc. You can adjust the level at which these inputs assert (and deassert) and can also debounce the control inputs. See *Global Settings on page 8.2* for the default settings and more information.

To ensure secure performance of the control inputs, set the control input pickup level according to the battery voltage level. *Table 2.1* lists some of the common DC voltage levels and appropriate settings.

Table 2.1 Recommended Control Input Pickup Settings

Substation DC Voltage Level	Recommended Settings	
	Pickup: GINP[a]	Dropout: GINDF
24	18 Vdc	85%
48	36 Vdc	85%
110	88 Vdc	80%
125	100 Vdc	80%
220	176 Vdc	80%
250	200 Vdc	80%

[a] Applies to IN2*nn*P and IN3*nn*P when global setting EICIS := N.

The control input accuracy is ±5 percent of the applied signal plus ±3 Vdc. The maximum voltage input is 300 Vdc, and the relay samples the control inputs at 2 kHz. See *Data Processing on page 9.1 in the SEL-400 Series Relays Instruction Manual*.

Optoisolated

The SEL-421 main board inputs, and the inputs on the optional I/O interface boards (INT2, INT3, INT4, INT7, or INT8 I/O boards—see *Models and Options on page 1.5*), are fixed pickup threshold, optoisolated, control inputs. The pickup voltage level is determined for each board at ordering time.

NOTE: The SEL-421 main board and the INT2, INT3, INT4, INT7, and INT8 I/O interface boards have optoisolated contact inputs that can be used in either polarity.

Use these inputs for monitoring change-of-state conditions of power system equipment. These high-isolation control inputs are ground-isolated circuits and are not polarity sensitive. In other words, the relay will detect input changes with voltage applied at either polarity.

Inputs can be independent or common. Independent inputs have two separate ground-isolated connections, with no internal connections among inputs. Common inputs share one input leg in common; all input legs of common inputs are ground isolated. Each group of common inputs is isolated from all other groups.

Nominal current drawn by these inputs is 8 mA or less with 6 voltage options covering a wide range of voltages, as listed in *Control Inputs on page 1.15*. You can debounce the control input pickup delay and dropout delay separately for each input, or you can use a single debounce setting that applies to all the contact input pickup and dropout times (see *Global Settings on page 8.2*).

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Control Inputs on page 1.15*. Specific pickup and dropout time-delay settings are required to achieve the specified ac thresholds, as shown in *Table 2.2*.

NOTE: Only the optoisolated control inputs can be used to detect ac control signals. Direct-coupled control inputs can only be used with dc control signals.

It is possible to mix ac and dc control signal detection on the same interface board with optoisolated contact inputs, provided that the two signal types are not present on the same set of combined inputs. Use standard debounce time settings (usually the same value in both the pickup and dropout settings) for the inputs being used with dc control voltages.

Table 2.2 Required Settings for Use with AC Control Signals

Global Settings[a]	Prompt	Entry[b]	Relay Recognition Time for AC Control Signal state change
IN*nmm*PU[c]	Pickup Delay	0.1250 cycles	0.625 cycles maximum (assertion)
IN*nmm*DO[c]	Dropout Delay	1.0000 cycle	1.1875 cycles maximum (deassertion)

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings.
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.
[c] Where *n* is 1 for Main Board, 2 for Interface Board 1, and 3 for Interface Board 2; *mm* is the number of available contact inputs depending on the type of board.

The recognition times listed in *Table 2.2* are only valid when:

➤ The ac signal applied is at the same frequency as the power system.

➤ The signal is within the ac threshold pickup ranges defined in *Optoisolated (Use With AC or DC Signals) on page 1.15*.

➤ The signal contains no dc offset.

The SEL-421 samples the optoisolated inputs at 2 kHz (see *Data Processing on page 9.1 in the SEL-400 Series Relays Instruction Manual*).

Control Outputs

I/O control outputs from the relay include standard outputs, hybrid (high-current interrupting) outputs, and high-speed, high-current interrupting outputs. High-speed, high-current interrupting outputs are available only on the optional INT4, INT5, or INT8 I/O interface boards. A metal oxide varistor (MOV) protects against excess voltage transients for each contact. Each output is individually isolated, except Form C outputs, which share a common connection between the NC (normally closed) and NO (normally open) contacts.

The relay updates control outputs eight times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is reenabled, the control outputs assume the state that reflects the present protection processing.

Standard Control Outputs

NOTE: You can use ac or dc circuits with standard control outputs.

The standard control outputs are "dry" Form A contacts rated for tripping duty. Ratings for standard outputs are 30 A make, 6 A continuous, and 0.5 A or less break (depending on circuit voltage). Standard contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. Maximum break time is 6 µs with a resistive load. The maximum pickup time for the standard control outputs is 6 ms. *Figure 2.4* shows a representative connection for a Form A standard control output on the main board I/O terminals.

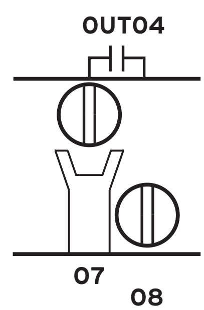


Figure 2.4 Standard Control Output Connection

See *Control Outputs on page 1.14* for complete standard control output specifications.

Hybrid (High-Current Interrupting) Control Outputs

⚠CAUTION
Equipment damage can result from connecting ac circuits to Hybrid (high-current interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.

The hybrid (high-current interrupting) control outputs are polarity-dependent and are capable of interrupting high-current, inductive loads. Hybrid control outputs use an Insulated Gate Bipolar Junction Transistor (IGBT) in parallel with a mechanical contact to interrupt (break) highly inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients.

With any hybrid output, break time varies according to the circuit inductive/resistive (L/R) ratio. As the L/R ratio increases, the time needed to interrupt the circuit fully increases also. The reason for this increased interruption delay is that circuit current continues to flow through the output MOV after the output deasserts, until all of the inductive energy dissipates. Maximum dropout (break) time is 6 ms with a resistive load, the same as for the standard control outputs. The other ratings of these control outputs are similar to the standard control outputs, except that the hybrid outputs can break current as great as 10 A. Hybrid contact outputs have a maximum voltage rating of 330 Vdc.

The maximum pickup time for the hybrid control outputs is 6 ms. *Figure 2.5* shows a representative connection for a Form A hybrid control output on the main board I/O terminals.

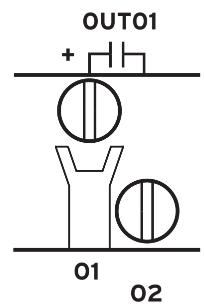


Figure 2.5 Hybrid Control Output Connection

See *Section 1: Introduction and Specifications*, for complete hybrid control output specifications.

High-Speed, High-Current Interrupting Control Outputs

NOTE: You can use ac or dc circuits with high-speed, high-current interrupting outputs.

In addition to the standard control outputs and the hybrid control outputs, the INT4, INT5, and INT8 I/O interface boards offer high-speed, high-current interrupting control outputs. These control outputs have a resistive load pickup time of 10 µs, which is much faster than the 6 ms pickup time of the standard and hybrid control outputs. The high-speed, high-current interrupting control outputs drop out at a maximum time of 8 ms. The maximum voltage rating is 250 Vac/330 Vdc. See *Control Outputs on page 1.14*, for complete high-speed, high-current interrupting control output specifications.

Figure 2.6 shows a representative connection for a Form A high-speed, high-current interrupting control output on the INT5 (INT8) I/O interface terminals.

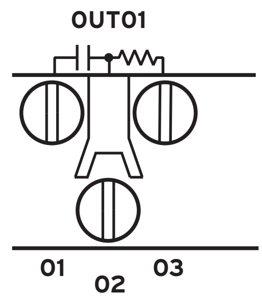


Figure 2.6 High-Speed, High-Current Interrupting Control Output Connection, INT5 (INT8)

Figure 2.7 shows a representative connection for a Form A high-speed, high-current interrupting control output on the INT4 I/O interface terminals. The HS marks are included to indicate that this is a high-speed control output.

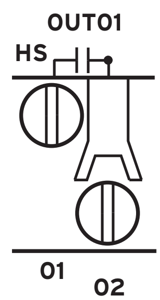


Figure 2.7 High-Speed, High-Current Interrupting Control Output Connection, INT4

The INT5 (INT8) high-speed, high-current interrupting control output uses three terminal positions, while the INT4 high-speed, high-current interrupting uses two. The third terminal of each INT5 (INT8) high-speed, high-current interrupting control output is connected to precharge resistors that can be used to mitigate transient inrush current conditions, as explained below. A similar technique can be used with INT4 board high-speed, high-current interrupting control outputs using external resistors.

Short transient inrush current can flow at the closing of an external switch in series with open high-speed, high-current interrupting contacts. This transient will not energize the circuits in typical relay-coil control applications (trip coils and close coils), and standard auxiliary relays will not pick up. However, an extremely sensitive digital input or light-duty, high-speed auxiliary relay can pick up for this condition. This false pickup transient occurs when the capacitance of the high-speed, high-current interrupting output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure). A third terminal (03 in *Figure 2.8*) provides an internal path for precharging the high-speed, high-current interrupting output circuit capacitance when the circuit is open.

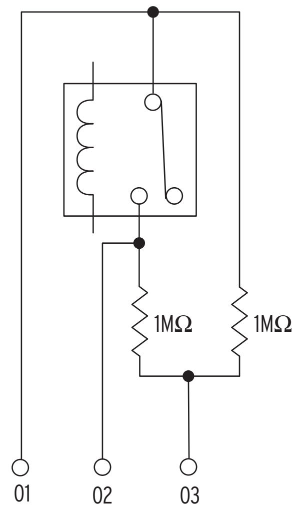


Figure 2.8 High-Speed, High-Current Interrupting Control Output Typical Terminals, INT5 (INT8)

Figure 2.9 shows some possible connections for this third terminal that will eliminate the false pick-up transients when closing an external switch. In general, you must connect the third terminal to the dc rail (positive or negative) that is on the same side as the open external switch condition. If an open switch exists on either side of the output contact, then you can accommodate only one condition because two open switches (one on each side of the contact) defeat the precharge circuit.

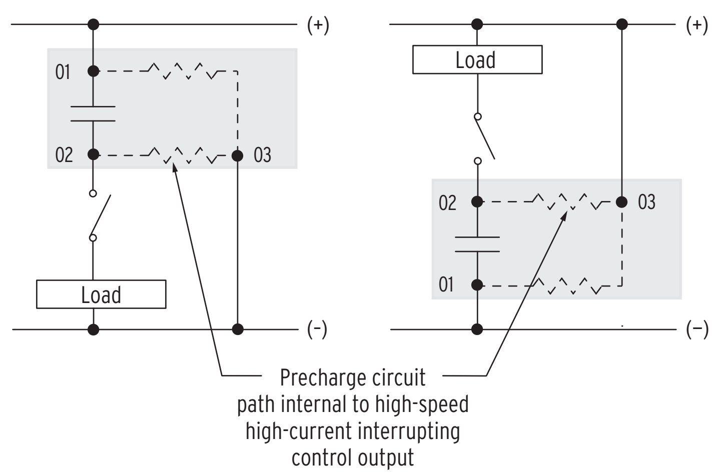


Figure 2.9 Precharging Internal Capacitance of High-Speed, High-Current Interrupting Output Contacts, INT5 (INT8)

For wiring convenience, on the INT5 (INT8) I/O interface board, the precharge resistors shown in *Figure 2.8* are built-in to the I/O board, and connected to a third terminal. On the INT4 I/O interface board, there are no built-in precharge resistors, and each high-speed, high-current interrupting control output has only two terminal connections.

Main Board I/O

The SEL-421 base model is a 3U chassis with I/O interface on the main board (the top board). See *Figure 2.2* and *Figure 2.3* for representative rear-panel views of the 3U chassis rear panel.

Every SEL-421 configuration includes the main board I/O and features these connections:

- Three hybrid (high-current interrupting) Form A outputs
- Two standard Form A outputs
- Three standard Form C outputs
- Seven high-isolation control inputs (five with no shared terminals and two with shared terminals)

IRIG-B Inputs

The SEL-421 has a regular IRIG-B timekeeping mode, and a high-accuracy IRIG-B (HIRIG) timekeeping mode. The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields, from which the relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data in the IRIG time mode. There is one IRIG-B input on the SEL-421 rear panel, capable of supporting the HIRIG mode.

IRIG-B Pins of Serial Port 1

This IRIG-B input is capable of regular IRIG mode timekeeping only. Timing accuracy for the IRIG time mode is 500 µs.

IRIG-B BNC Connector

This IRIG-B input is capable of both modes of timekeeping. If the connected timekeeping source is qualified as high-accuracy, the relay enters the HIRIG mode, which has a timing accuracy of 1 µs. If both inputs are connected, the SEL-421 uses the IRIG-B signal from the BNC connection (if a signal is available).

Battery-Backed Clock

If relay input power is lost or removed, a lithium battery powers the relay clock, providing date and time backup. The battery is a 3 V lithium coin cell, Ray-O-Vac No. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C), the battery will operate for approximately 10 years at rated load.

When the SEL-421 is operating with power from an external source, the self-discharge rate of the battery only is very small. Thus, battery life can extend well beyond the nominal 10-year period because the battery rarely discharges after the relay is installed. The battery cannot be recharged. *Figure 2.19* shows the clock battery location (at the front of the main board).

If the relay does not maintain the date and time after power loss, replace the battery (see *Replacing the Lithium Battery on page 10.22 in the SEL-400 Series Relays Instruction Manual*).

Communications Interfaces

The SEL-421 has several communications interfaces you can use to communicate with other intelligent electronic devices (IEDs) via EIA-232 ports: **PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**. See *Section 10: Communications Interfaces* for more information and options for connecting your relay to the communications interfaces.

An optional Ethernet card provides Ethernet capability for the SEL-421. An Ethernet card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, IEEE C37.118 Synchrophasors, and IEC 61850 over local area and wide area networks (the Ethernet card with IEC 61850 support is available at purchase as a factory-installed option). For information on DNP3 applications, see *Section 16: DNP3 Communication in the SEL-400 Series Relays Instruction Manual*. For more information on IEC 61850 applications, see *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Plug-In Boards

The SEL-421 is available in many input/output configuration options. The relay base model is a 3U chassis with main board I/O and screw-terminal connector connections (see *Figure 2.2*). Other ordering options include versions of the relay in larger enclosures (4U or 5U) with all, partial, or no extra I/O boards installed.

NOTE: Ordering the 4U and 5U relay with partial or no extra I/O allows for future system expansion and future use of additional relay features.

Plug-in communications cards are also available for the SEL-421. The optional Ethernet card allows you to use TCP/IP, FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is available at the time of purchase as a factory-installed option or as a factory-installed conversion to an existing relay.

I/O Interface Boards

You can choose among eight input/output interface boards for the I/O slots of the 4U and 5U chassis. These I/O interface boards are in addition to the main board I/O described in *Main Board I/O on page 2.11*. The I/O interface boards are INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8. *Figure 2.10*. *Figure 2.11*, *Figure 2.12*, *Figure 2.13*, *Figure 2.14*, *Figure 2.15*, *Figure 2.16*, and *Figure 2.17* show the rear screw-terminal connectors associated with these interface boards.

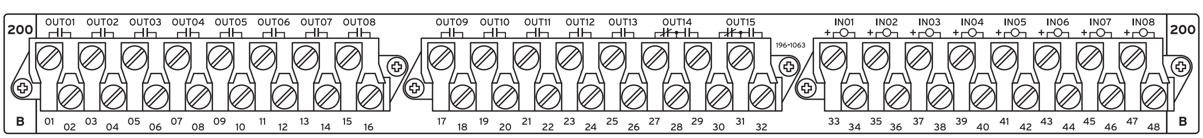


Figure 2.10 INT1 I/O Interface Board

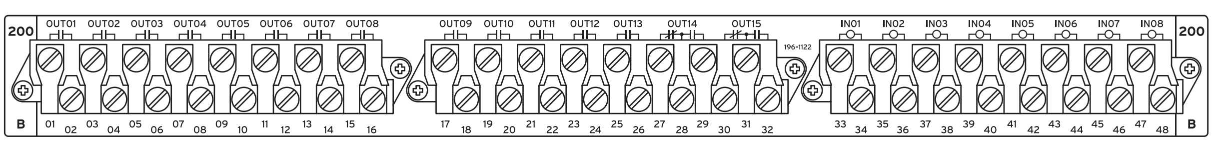


Figure 2.11 INT2 I/O Interface Board

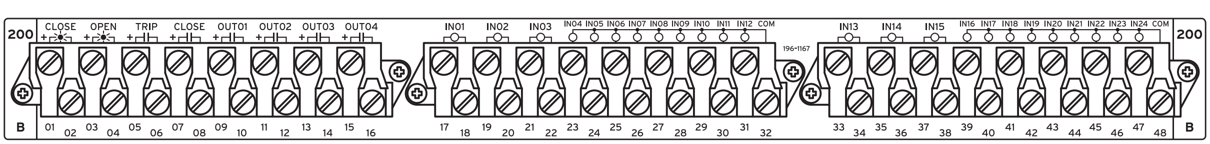


Figure 2.12 INT3 I/O Interface Board

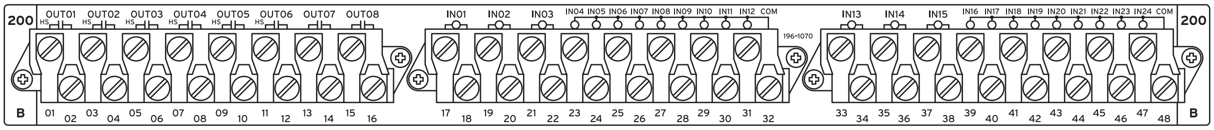


Figure 2.13 INT4 I/O Interface Board

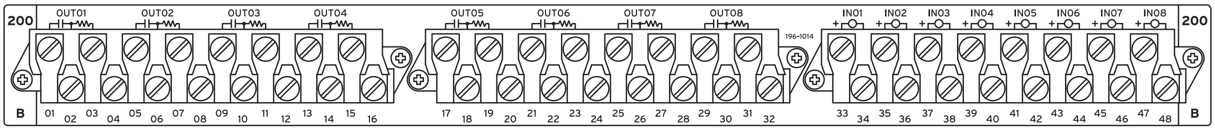


Figure 2.14 INT5 I/O Interface Board

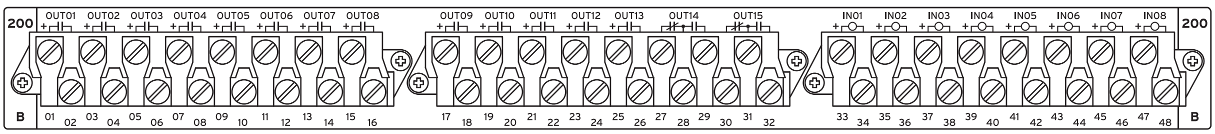


Figure 2.15 INT6 I/O Interface Board

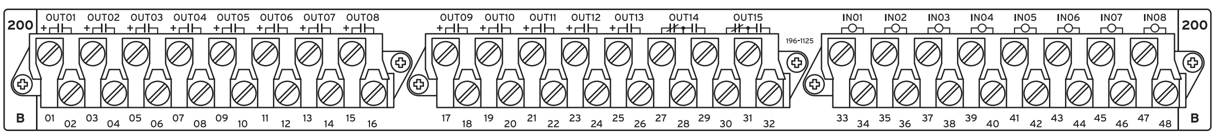


Figure 2.16 INT7 I/O Interface Board

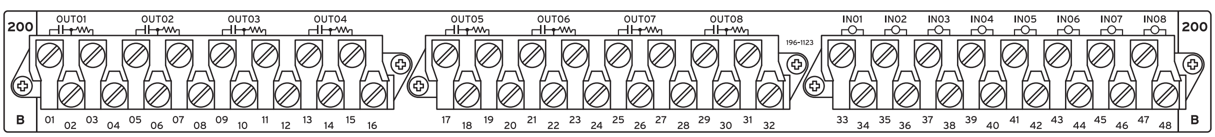


Figure 2.17 INT8 I/O Interface Board

The I/O interface boards carry jumpers that identify the board location (see *Jumpers on page 2.15*).

I/O Interface Board Inputs

⚠**CAUTION**
Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.

The INT1, INT5, and INT6 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These high-isolation control inputs are direct coupled and hence polarity-sensitive. You cannot damage these inputs with a reverse polarity connection; though, the relay will not detect input changes with a reverse-polarity input.

The INT3 and INT4 I/O interface board has two groups of nine (9) common contacts (18 total) and six (6) independent control inputs. The INT2, INT7, and INT8 I/O interface boards have eight independent control inputs. All independent inputs are isolated from other inputs. These control inputs are optoisolated and hence are not polarity sensitive, i.e., the relay will detect input changes with voltage applied at either polarity, or ac signals (when properly configured, see *Optoisolated on page 2.7*).

Table 2.3 is a comparison of the I/O board input capacities; the table also shows the I/O inputs on the main board. See *Control Inputs on page 1.15* for complete control input specifications.

Table 2.3 Control Inputs

Board	Independent Contact Pairs	Common Contacts
INT1[a], INT5[a], INT6[a]	8	
INT2[b], INT7[b], INT8[b]	8	
INT3[b], INT4[b]	6	Two sets of 9
Main Board	5	2

[a] INT1, INT5, and INT6 control inputs are direct coupled, and are polarity sensitive.
[b] Main Board, INT2, INT3, INT4, INT7, and INT8 control inputs are optoisolated, and are not polarity sensitive.

I/O Interface Board Outputs

NOTE: Form A control outputs cannot be jumpered to Form B.

The I/O interface boards vary by the type and amount of output capabilities. *Table 2.4* lists the outputs of the additional I/O interface boards; the table also shows the I/O outputs on the main board. Information about the standard and hybrid (high-current interrupting) control outputs is in *Control Outputs on page 2.8*.

NOTE: The SEL-421-1 does not support main board B I/O and INT2, INT3, INT7, and INT8 I/O interface boards.

Table 2.4 Control Outputs

Board	Standard		High-Speed, High-Current Interrupting	Hybrid[a]
	Form A	Form C	Form A	Form A
INT1, INT2	13	2		
INT3				4
INT4	2		6	
INT5, INT8			8	
INT6, INT7		2		13
Main Board	2	3		3

[a] High-Current Interrupting.

Ethernet Card

You can add communications protocols to the SEL-421 by purchasing the Ethernet card option. When installed in the rear relay **PORT 5**, the Ethernet card provides Ethernet ports for industrial applications that process data traffic between the SEL-421 and a local area network (LAN).

Jumpers

The SEL-421 contains jumpers that configure the relay for certain operating modes. The jumpers are located on the main board (the top board) and the I/O interface boards (one or two boards located immediately below the main board).

Main Board Jumpers

The jumpers on the main board of the SEL-421 perform these functions:

- ➤ Temporary/emergency password disable
- ➤ Circuit breaker and disconnect control enable
- ➤ Rear serial port +5 Vdc source enable

Figure 2.19 shows the positions of the main board jumpers. The main board jumpers are in two locations. The password disable jumper and circuit breaker control jumper are at the front of the main board. The serial port jumpers are near the rear-panel serial ports; each serial port jumper is directly in front of the serial port that it controls.

Password and Circuit Breaker Jumpers

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-421 front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers (position number J18 or J21) are located on the front of the main board, immediately left of the power connector (see *Figure 2.18*).

⚠CAUTION
Do not install a jumper on positions A or D of the main board J18 header. Relay misoperation can result if you install jumpers on positions J18A and J18D.

There are four jumpers, denoted D, BREAKER, PASSWORD, and A from left to right (position D is on the left). Position PASSWORD is the password disable jumper; position BREAKER is the circuit breaker control enable jumper. Positions D and A are for SEL use. *Figure 2.18* shows the jumper header with the circuit breaker/control jumper in the ON position and the password jumper in the OFF position; these are the normal jumper positions for an in-service relay. *Table 2.5* lists the jumper positions and functions.

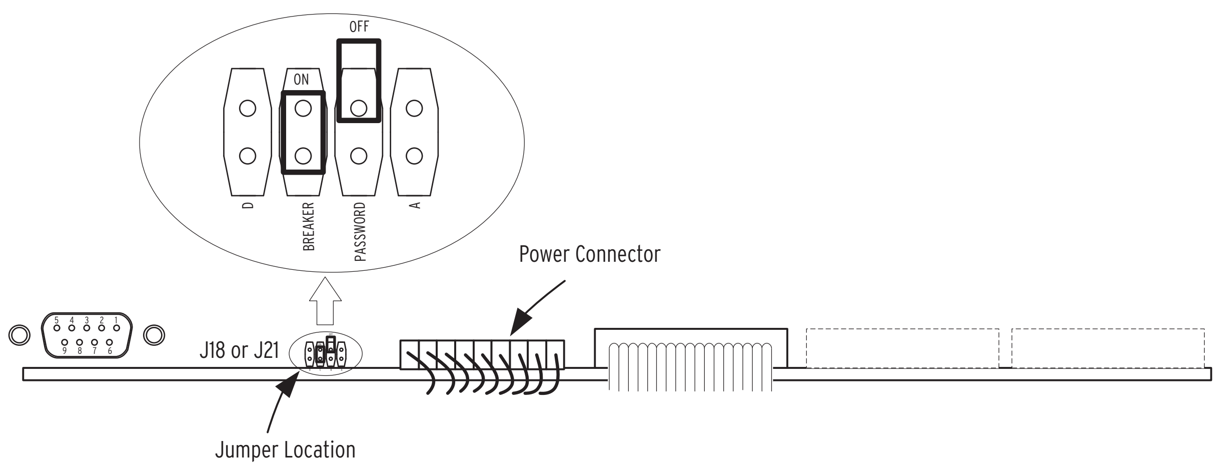


Figure 2.18 Jumper Location on the Main Board

Table 2.5 Main Board Jumpers (Sheet 1 of 2)

Jumper	Jumper Location	Jumper Position[a]	Function
A	Front	OFF	For SEL use only
PASSWORD	Front	OFF	Enable password protection (normal and shipped position)
		ON	Disable password protection (temporary or emergency only)

Table 2.5 Main Board Jumpers (Sheet 2 of 2)

Jumper	Jumper Location	Jumper Position[a]	Function
BREAKER	Front	OFF	Disable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b] (shipped position)
		ON	Enable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b]
D	Front	OFF	For SEL use only

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

[b] Also affects the availability of the Fast Operate Breaker Control Messages and the front-panel `LOCAL CONTROL > BREAKER CONTROL`, and front-panel `LOCAL CONTROL > OUTPUT TESTING` screens.

The password disable jumper, PASSWORD, is for temporary or emergency suspension of the relay password protection mechanisms. Under no circumstance should you install PASSWORD on a long-term basis. The SEL-421 ships with password disable jumper PASSWORD OFF (passwords enabled).

The circuit breaker control enable jumper, BREAKER, supervises the **CLOSE *n*** command, the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install Jumper BREAKER. The relay checks the status of the circuit breaker control jumper when you issue **CLOSE *n***, **OPEN *n***, **PULSE OUT*nnn***, and when you use the front panel to close or open circuit breakers, control a local bit, or pulse an output. The SEL-421 ships with circuit breaker Jumper BREAKER OFF. For commissioning and testing of the SEL-421 contact outputs, it may be convenient to set BREAKER ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. BREAKER must also be set ON if SCADA control of the circuit breaker via Fast Operate is required, or if the `LOCAL CONTROL > BREAKER CONTROL` screens are going to be used.

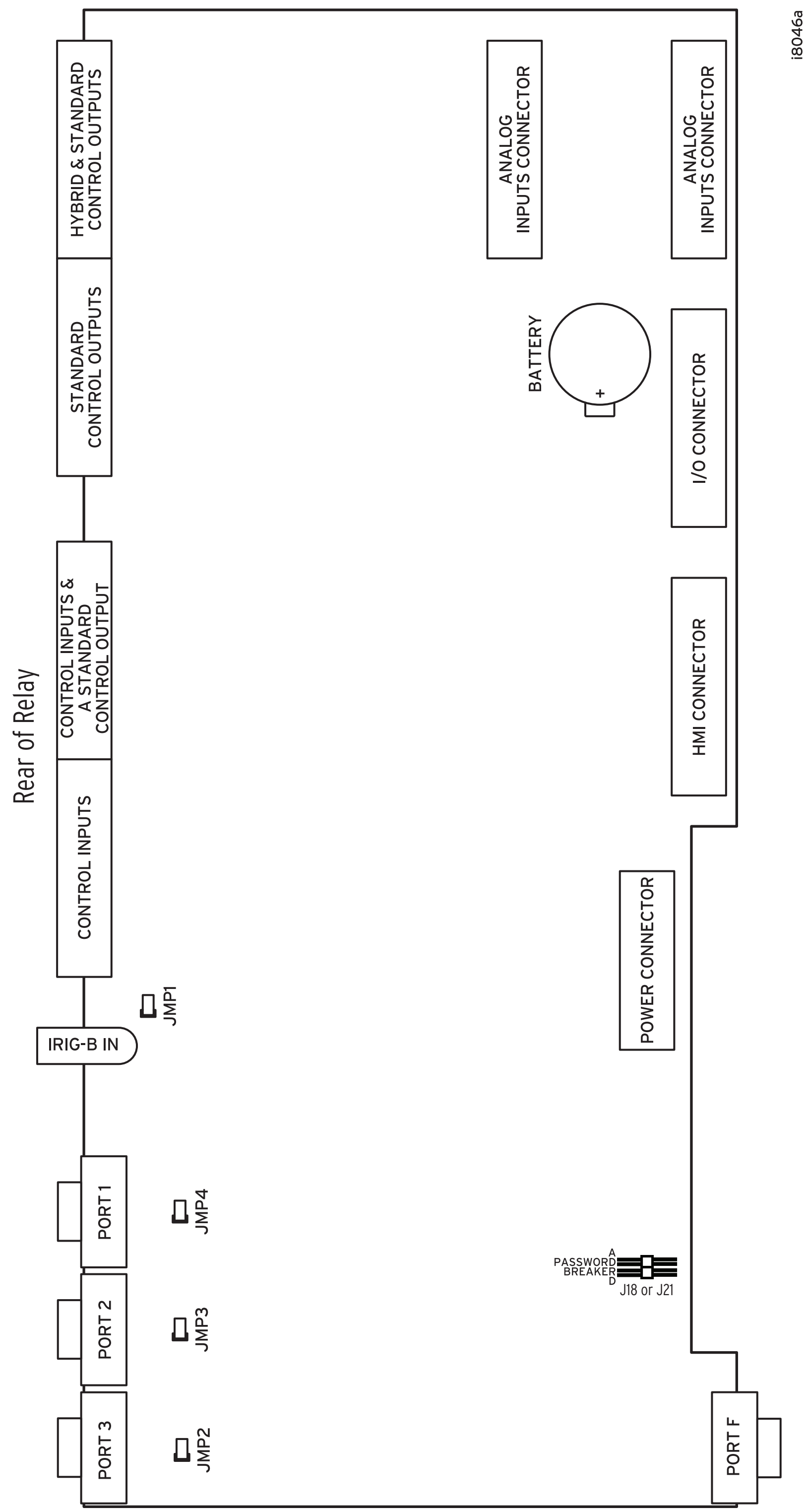


Figure 2.19 Major Component Locations on the SEL-421 Main Board

Serial Port Jumpers

Place jumpers on the main board to connect +5 Vdc to Pin 1 of each of the three rear-panel EIA-232 serial ports. The maximum current available from this Pin 1 source is 0.5 A. The Pin 1 source is useful for powering an external modem.

Table 2.6 describes the JMP2, JMP3, and JMP4 positions. Refer to *Figure 2.19* for the locations of these jumpers. The SEL-421 ships with JMP2, JMP3, and JMP4 OFF (no +5 Vdc on Pin 1).

Table 2.6 Main Board Jumpers—JMP2, JMP3, and JMP4

Jumper	Jumper Location	Jumper Position[a]	Function
JMP2	Rear	OFF	Serial **PORT 3**, Pin 1 = not connected
		ON	Serial **PORT 3**, Pin 1 = +5 Vdc
JMP3	Rear	OFF	Serial **PORT 2**, Pin 1 = not connected
		ON	Serial **PORT 2**, Pin 1 = +5 Vdc
JMP4	Rear	OFF	Serial **PORT 1**, Pin 1 = not connected
		ON	Serial **PORT 1**, Pin 1 = +5 Vdc

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.

Changing Serial Port Jumpers

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

⚠WARNING
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You must remove the main board to access the serial port jumpers. Perform the following steps to change the JMP2, JMP3, and JMP4 jumpers in an SEL-421:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-421.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-panel **EIA-232 PORT** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 6. Remove any Ethernet and IRIG-B connections.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 10. Carefully pull out the drawout assembly containing the main board.

Step 11. Locate the jumper you want to change.

Jumpers JMP2, JMP3, and JMP4 are located at the rear of the main board, directly in front of PORT 3, PORT 2, and PORT 1, respectively (see *Figure 2.19*).

Step 12. Install or remove the jumper as needed (see *Table 2.5* for jumper position descriptions).

Step 13. Reinstall the SEL-421 main board, and reconnect the power, the interface board, and the analog input board cables.

Step 14. Reconnect the cable removed in Step 7 and reinstall the relay front-panel cover.

Step 15. Reattach the rear-panel connections.

Step 16. Reconnect any external cables that you removed from the relay in the disassembly process.

Step 17. Follow your company standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the I/O interface boards identify the particular I/O board configuration and I/O board control address. Eight I/O interface boards are available: INT1, INT2, INT3, INT4, INT5, INT6, INT7, and INT8 (see *I/O Interface Boards on page 2.13* for more information on these boards). The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.20* and *Figure 2.21*.

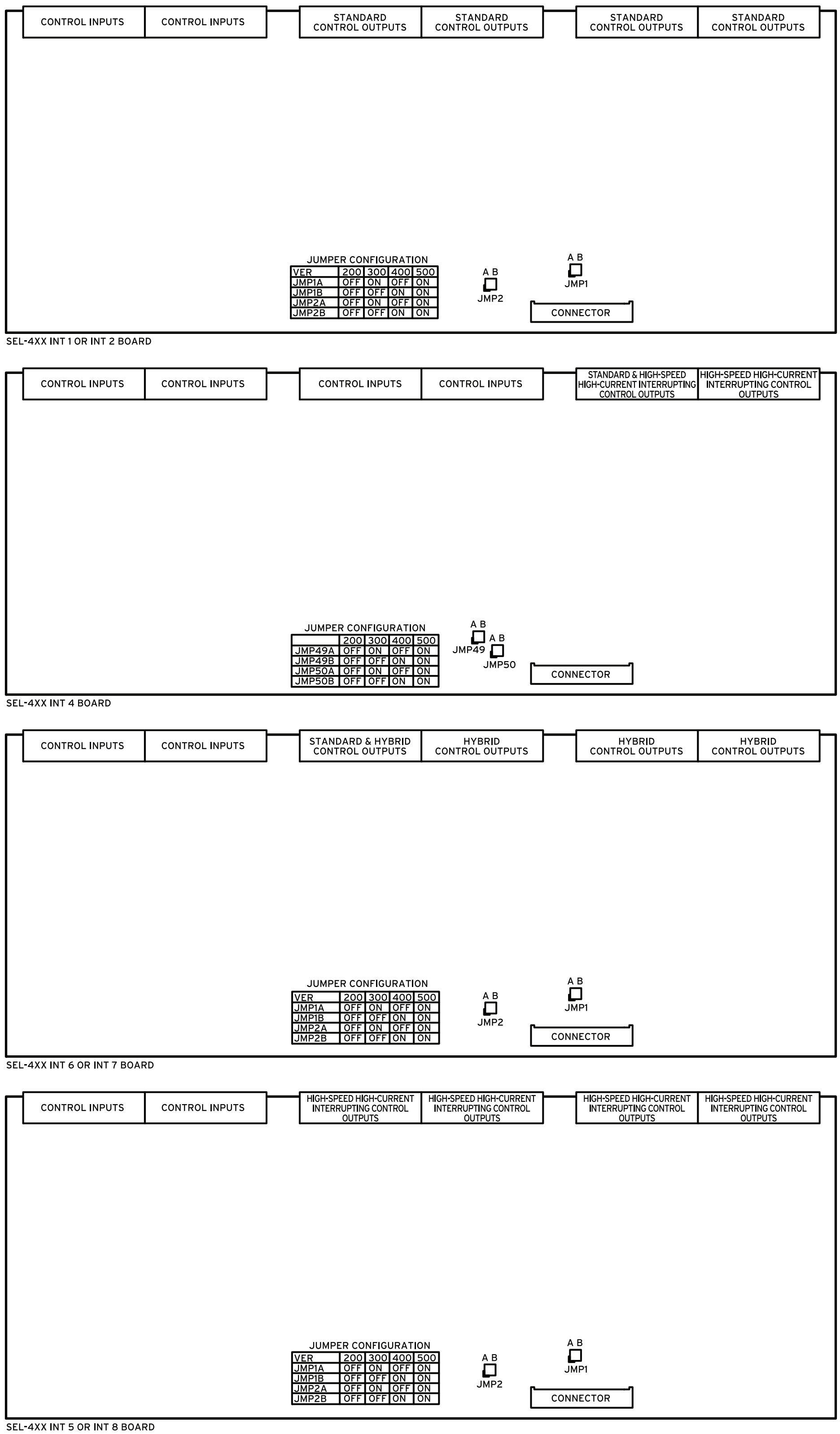


Figure 2.20 Major Component Locations on the SEL-421 INT1, INT2, INT4, INT5, INT6, INT7, and INT8 I/O Boards

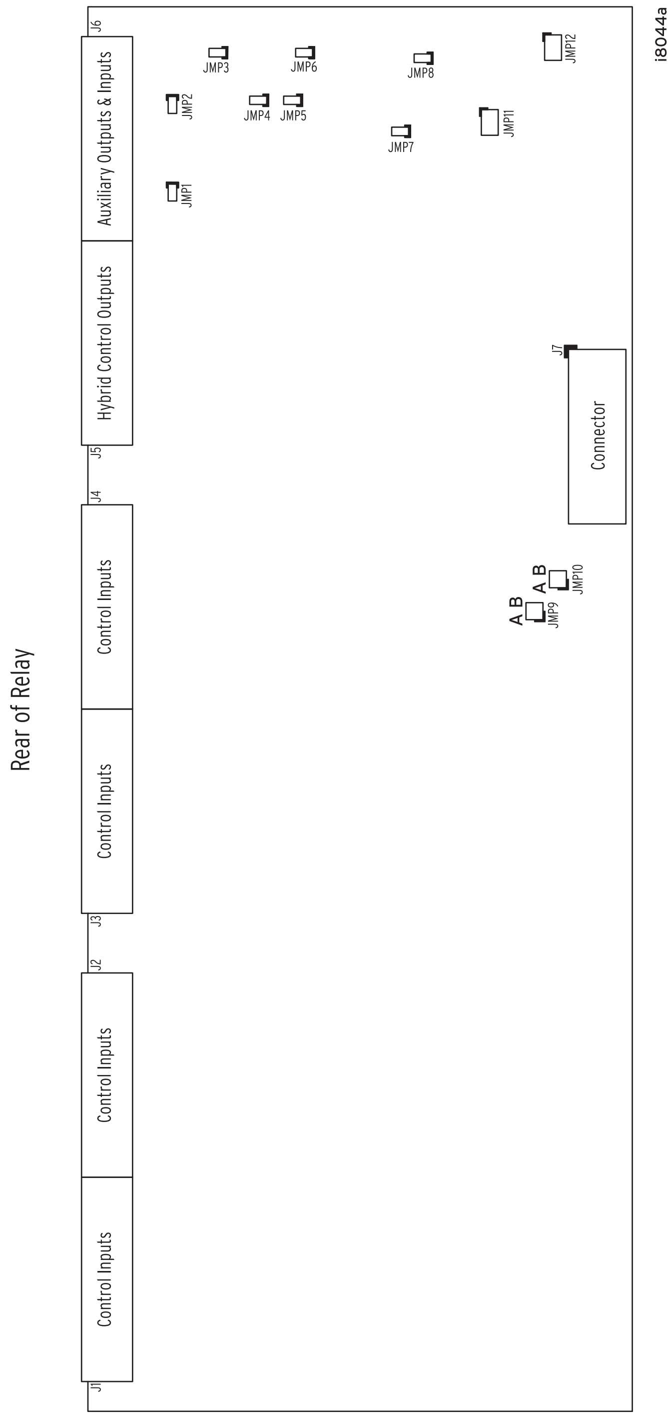


Figure 2.21 Major Component Locations on the SEL-421 INT3 I/O Board

To confirm the positions of your I/O board jumpers, remove the front panel and visually inspect the jumper placements. *Table 2.7* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.20* for the locations of these jumpers.

The I/O board control address has a hundreds-series prefix attached to the control inputs and control outputs for that particular I/O board chassis slot. A 4U chassis has a 200-addresses slot for inputs IN201, IN202, etc., and outputs OUT201, OUT202, etc. A 5U chassis has a 200-addresses slot and a 300-addresses slot.

The drawout tray on which each I/O board is mounted is keyed. See *Section 10: Testing, Troubleshooting, and Maintenance in the SEL-400 Series Relays Instruction Manual*.

Table 2.7 I/O Board Jumpers

I/O Board Control Address	JMP1A/ JMP49A[a]	JMP1B/ JMP49B[a]	JMP2A/ JMP50A[a]	JMP2B/ JMP50B[a]
2XX	OFF	OFF	OFF	OFF
3XX	ON	OFF	ON	OFF

[a] INT4 I/O interface board jumper numbering.

Auxiliary TRIP/CLOSE Pushbutton and Breaker Status LED Jumpers (Select Models Only)

The jumpers listed in *Table 2.8* are used to select the proper control voltage for breaker open/closed indicating LEDs on the front panel of the relay. *Figure 2.21* shows the jumper locations on the magnetics/auxiliary pushbutton board. The jumpers come preset from the factory with the voltage range set the same as the control input voltage, as determined by the part number at order time.

The voltage setting can be different for each LED. To access these jumpers, remove the relay front cover and any ribbon cables that impede accessing the interface board, and draw out the interface board. See the instructions and precautions in the subsection *Changing Serial Port Jumpers on page 2.19*.

Table 2.8 Jumper Positions for Breaker OPEN/CLOSE Indication

	BREAKER OPEN LED			BREAKER CLOSED LED		
	JMP4	JMP5	JMP5	JMP3	JMP6	JMP8
24 V	Installed	Installed	Installed	Installed	Installed	Installed
48 V	Installed	Installed	Not Installed	Installed	Installed	Not Installed
110/125 V	Installed	Not Installed	Not Installed	Installed	Not Installed	Not Installed
220/250 V	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed

Table 2.9 shows how to enable or disable the arc suppression feature of the TRIP and CLOSE pushbuttons. If ac control power is used to operate the breaker, then the corresponding arc suppression jumper must be removed. If dc control power is used to operate the breaker, then the arc suppression is strongly recommended to break inductive loads. The arc suppression comes enabled from the factory. *Figure 2.21* shows the jumper locations on the magnetics/auxiliary pushbutton board.

NOTE: With arc suppression enabled, the corresponding output polarity marks must be followed when wiring the control.

Table 2.9 Jumper Positions for Arc Suppression

Option	TRIP pushbutton	CLOSE pushbutton
	JMP2	JMP1
Arc Suppression Enabled	Installed	Installed
Arc Suppression Disabled	Not Installed	Not Installed

Table 2.10 Front-Panel LED Option

JMP11, JMP12[a]	LED Color
BRIDGE Pins 1 and 3 Pins 2 and 4	Red
BRIDGE Pins3 and 5 Pins 4 and 6	Green

[a] JMP11 Open; JMP12 Closed.

Relay Placement

Proper placement of the SEL-421 helps make certain that you receive years of trouble-free power system protection. Use the following guidelines for proper physical installation of the SEL-421.

Physical Location

You can mount the SEL-421 in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay.

The relay is rated at Installation/Overvoltage Category II and Pollution Degree 2. This rating allows mounting the relay indoors or in an outdoor (extended) enclosure where the relay is protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity are controlled.

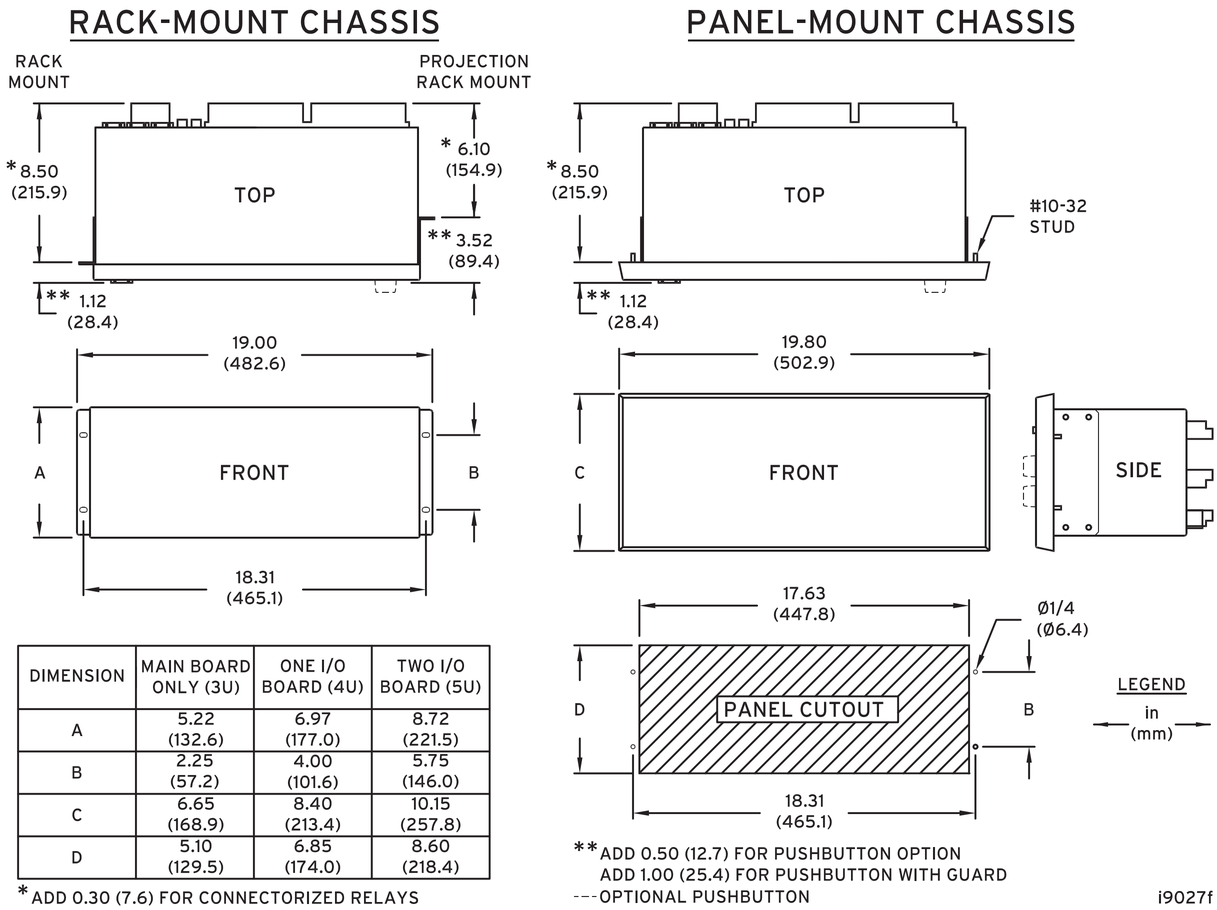
You can place the relay in extreme temperature and humidity locations. The temperature range over which the relay operates is –40° to +185°F (–40° to +85°C, see *Operating Temperature on page 1.16*). The relay operates in a humidity range from 5 to 95 percent, no condensation, and is rated for installation at a maximum altitude of 2000 m (6560 feet) above mean sea level.

Rack Mounting

When mounting the SEL-421 in a rack, use the reversible front flanges to either semiflush-mount or projection mount the relay.

The semiflush mount gives a small panel protrusion from the relay rack rails of approximately 1.1 in. or 27.9 mm. The projection mount places the front panel approximately 3.5 in. or 88.9 mm in front of the relay rack rails.

See *Figure 2.22* for exact mounting dimensions for both the horizontal and vertical rack-mount relays. Use four screws of the appropriate size for your rack.



DIMENSION	MAIN BOARD ONLY (3U)	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)
A	5.22 (132.6)	6.97 (177.0)	8.72 (221.5)
B	2.25 (57.2)	4.00 (101.6)	5.75 (146.0)
C	6.65 (168.9)	8.40 (213.4)	10.15 (257.8)
D	5.10 (129.5)	6.85 (174.0)	8.60 (218.4)

*ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS

Figure 2.22 SEL-421 Chassis Dimensions

Panel Mounting

Place the panel-mount versions of the SEL-421 in a switchboard panel. See the drawings in *Figure 2.22* for panel cut and drill dimensions (these dimensions apply to both the horizontal and vertical panel-mount relay versions). Use the supplied mounting hardware to attach the relay.

Connection

⚠CAUTION
Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.

The SEL-421 is available in many different configurations, depending on the number and type of control inputs, control outputs, and analog input termination you specified at ordering. This subsection presents a representative sample of relay rear-panel configurations and the connections to these rear panels. Only horizontal chassis are shown; rear panels of vertical chassis are identical to horizontal chassis rear panels for each of the 3U, 4U, and 5U sizes.

When connecting the SEL-421, refer to your company plan for wire routing and wire management. Be sure to use wire that is appropriate for your installation with an insulation rating of at least 90°C.

Rear-Panel Layout

Figure 2.23 through *Figure 2.32* show available SEL-421 rear panels.

All relay versions have screw-terminal connectors for I/O, power, and battery monitor. You can order the relay with fixed terminal blocks for the CT and PT connections, or you can order SEL Connectorized rear-panel configurations that feature plug-in/plug-out PT connectors and shorting CT connectors for relay analog inputs. *Figure 2.24* shows the Connectorized 3U horizontal configuration of the SEL-421.

The screw-terminal connections for the INT1 (or INT2) and the INT6 (or INT7) I/O interface boards are the same. The INT5 (or INT8) I/O interface board has control output terminals grouped in threes, with the fourth terminal as a blank additional separator (terminals 4, 8, 12, 16, 20, 24, 28, and 32). The INT3, INT4, and INT5 (or INT8) I/O interface boards both contain high-speed, high-current interrupting control outputs, but use a different terminal layout—see *Control Outputs on page 2.8* for details.

For more information on the main board control inputs and control outputs, see *Main Board I/O on page 2.11*. For more information on the I/O interface board control inputs and control outputs, see *I/O Interface Board Jumpers on page 2.20*.

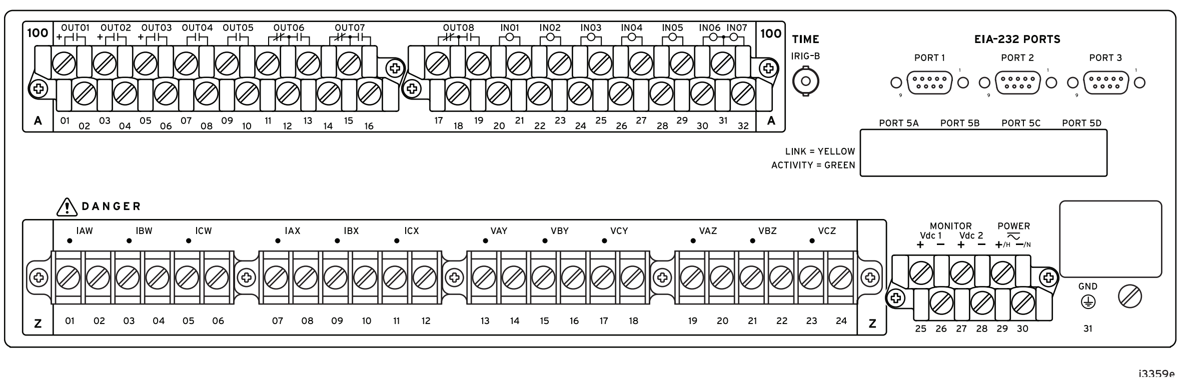


Figure 2.23 3U Rear Panel, Main Board

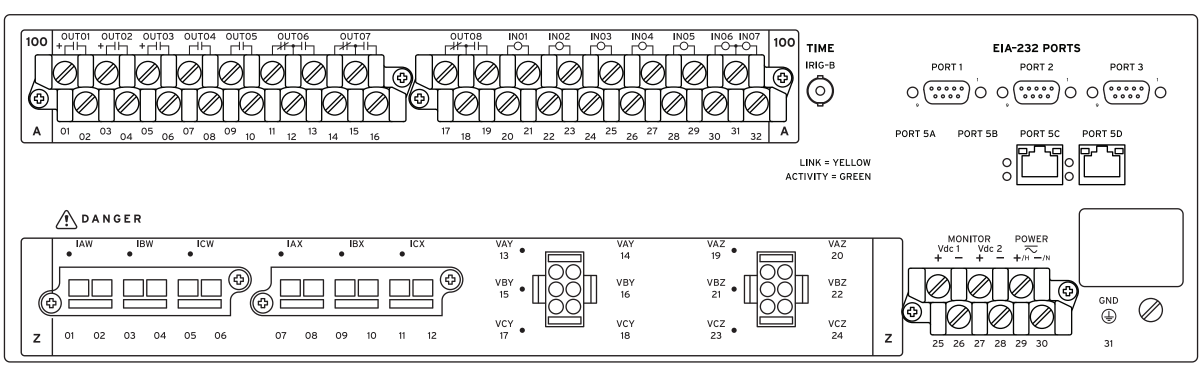
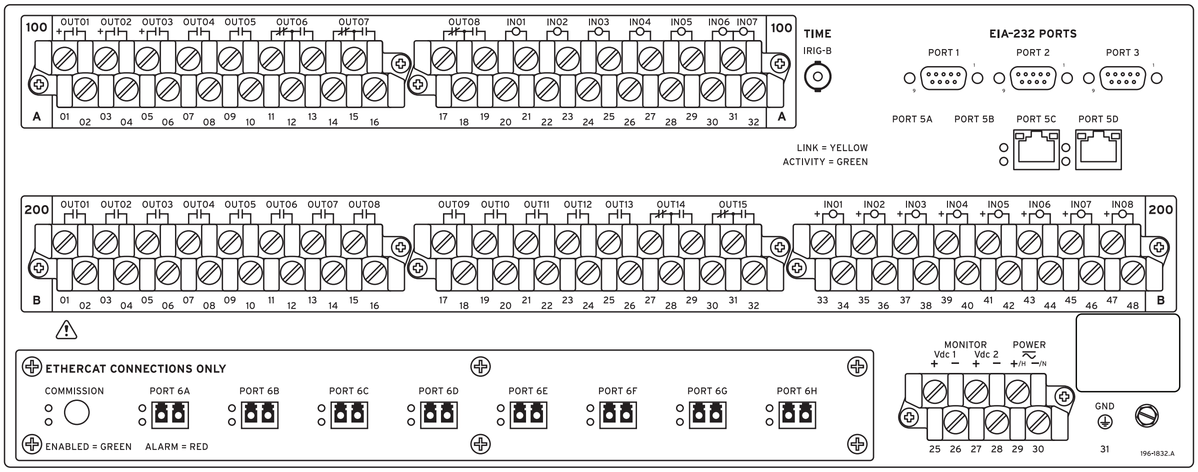
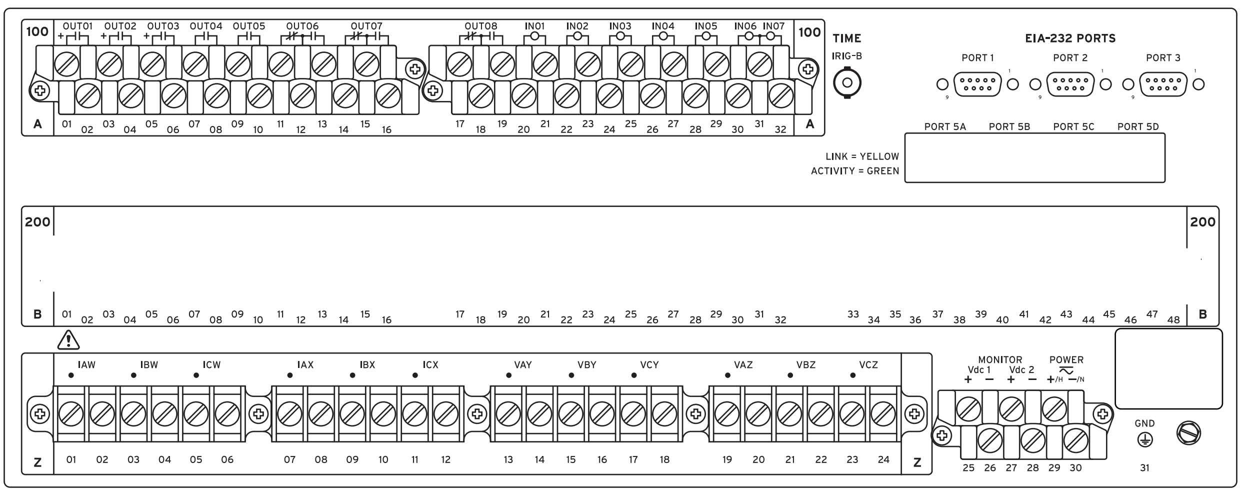


Figure 2.24 3U Rear Panel, Main Board, Connectorized



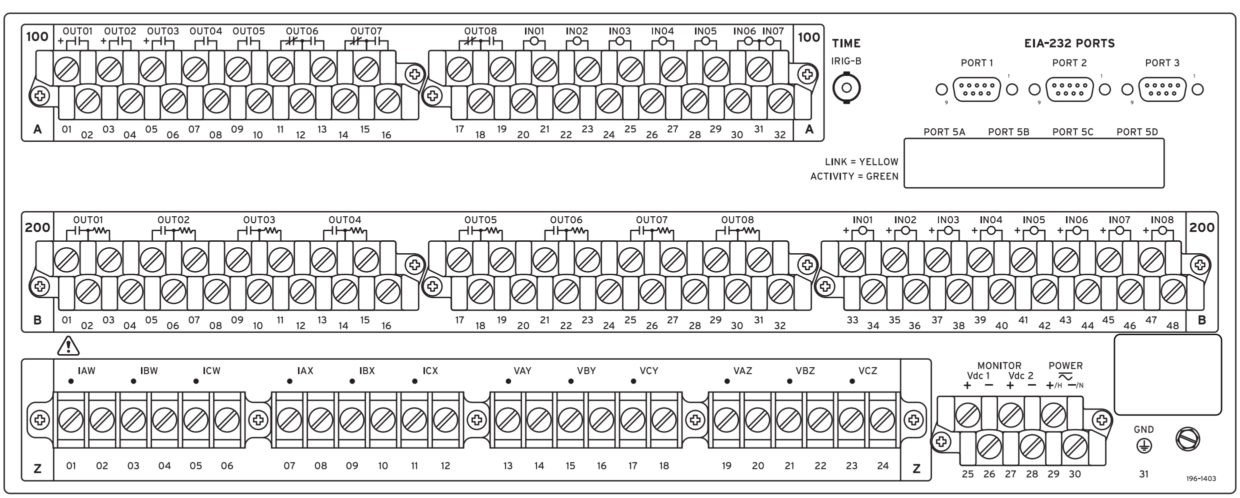
i7131a

Figure 2.25 EtherCAT Board for TiDL



i7001d

Figure 2.26 4U Rear Panel, Main Board, Without Optional I/O



i7001d

Figure 2.27 4U Rear Panel, Main Board, INT5 I/O Interface Board

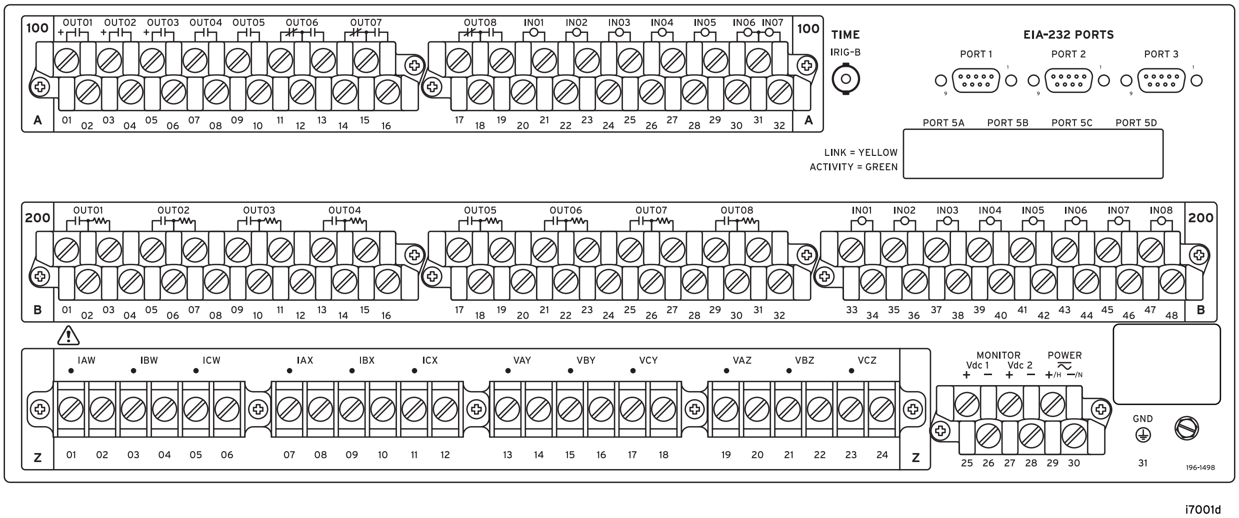
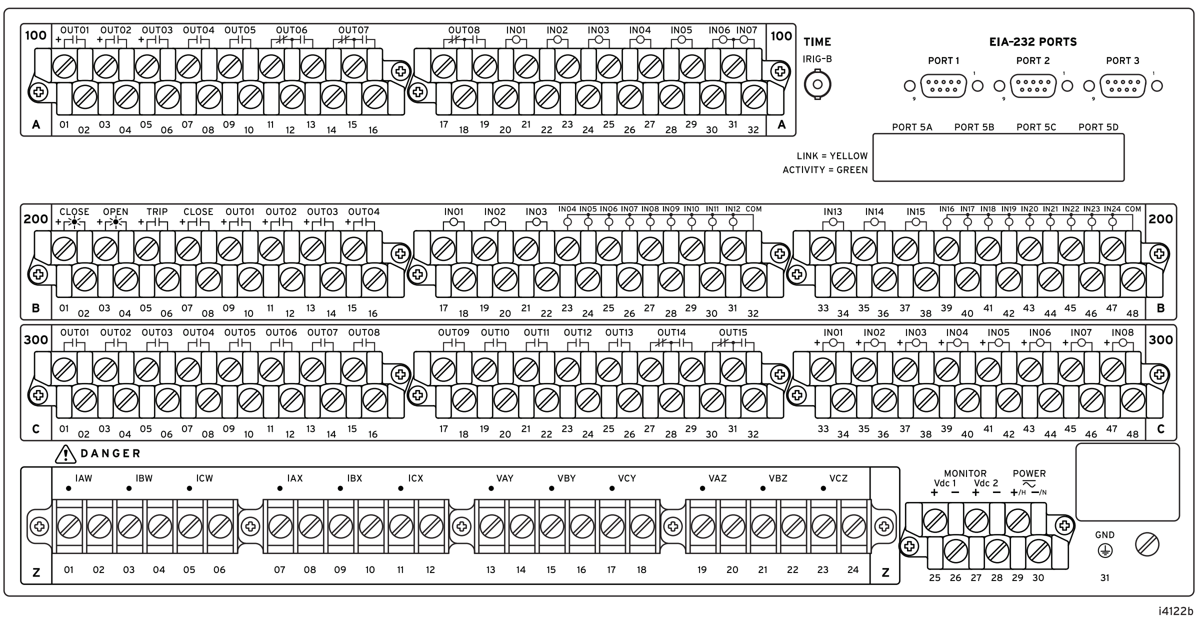
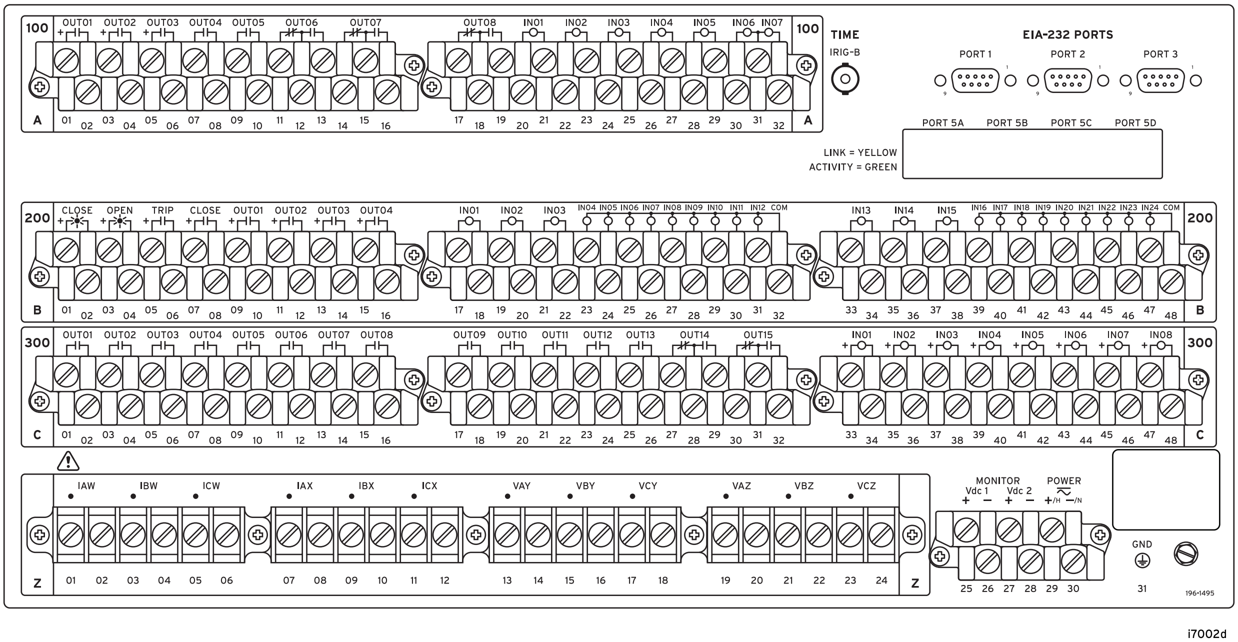


Figure 2.28 4U Rear Panel, Main Board, INT8 I/O Interface Board



(The INT3 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)

Figure 2.29 5U Rear Panel, Main Board, INT3 and INT1 I/O Interface Board



(The INT4 board is the 200-addresses slot; the INT1 board is the 300-addresses slot.)

Figure 2.30 5U Rear Panel, Main Board, INT4 and INT1 I/O Interface Board

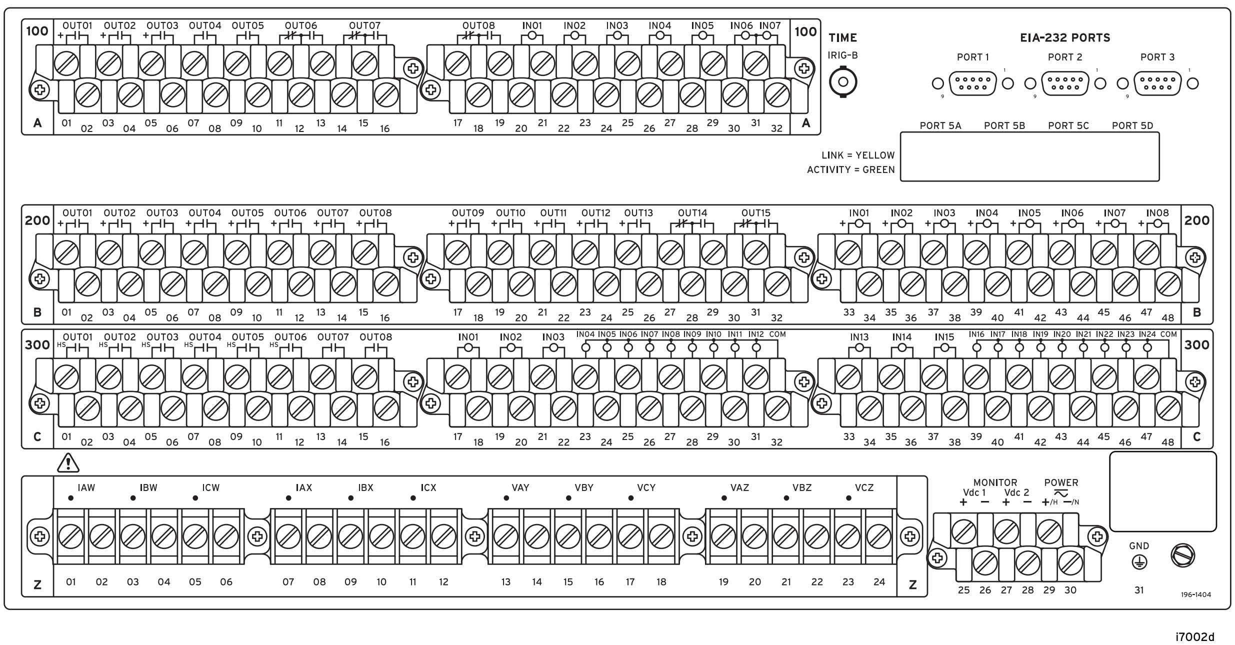


Figure 2.31 5U Rear Panel, Main Board, INT6 and INT4 I/O Interface Board

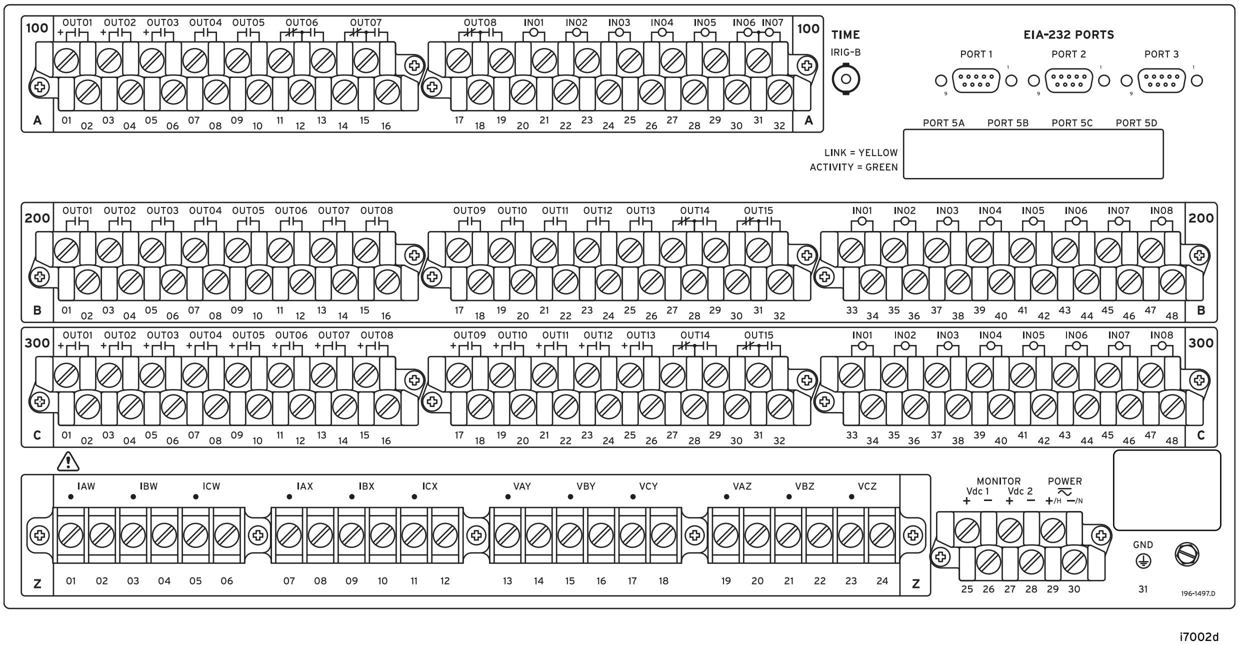


Figure 2.32 5U Rear Panel, Main Board, INT2 and INT7 I/O Interface Board

Rear-Panel Symbols

There are important safety symbols on the rear of the SEL-421 (see *Figure 2.33*). Observe proper safety precautions when you connect the relay at terminals marked by these symbols. In particular, the danger symbol located on the rear panel corresponds to the following: Contact with instrument terminals can cause electrical shock that can result in injury or death. Be careful to limit access to these terminals.

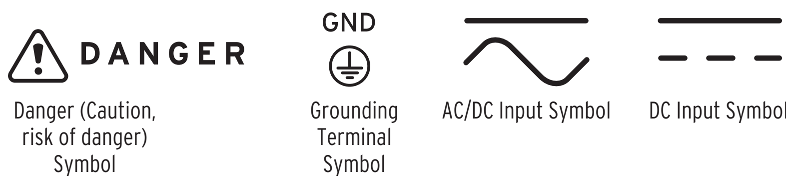


Figure 2.33 Rear-Panel Symbols

Screw-Terminal Connectors

Terminate connections to the SEL-421 screw-terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 9.1 mm (0.360 in.). The screws in the rear-panel screw-terminal connectors are #8-32 binding head, slotted, nickel-plated brass screws. Tightening torque for the terminal connector screws is 1.0 Nm to 2.0 Nm (9 in-lb. to 18 in-lb.).

You can remove the screw-terminal connectors from the rear of the SEL-421 by unscrewing the screws at each end of the connector block. Perform the following steps to remove a screw-terminal connector:

Step 1. Remove the connector by pulling the connector block straight out.

Note that the receptacle on the relay circuit board is keyed; you can insert each screw-terminal connector in only one location on the rear panel.

Step 2. To replace the screw-terminal connector, confirm that you have the correct connector and push the connector firmly onto the circuit board receptacle.

Step 3. Reattach the two screws at each end of the block.

Changing Screw-Terminal Connector Keying

You can rotate a screw-terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw-terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw-terminal connector keying.

Inserts in the circuit board receptacles key the receptacles for only one screw-terminal connector in one orientation. Each screw-terminal connector has a missing web into which the key fits (see *Figure 2.34*).

If you want to move a screw-terminal connector to another circuit board receptacle or reverse the connector orientation, you must rearrange the receptacle keys to match the screw-terminal connector block. Use long-nosed pliers to move the keys.

Figure 2.35 shows the factory-default key positions.

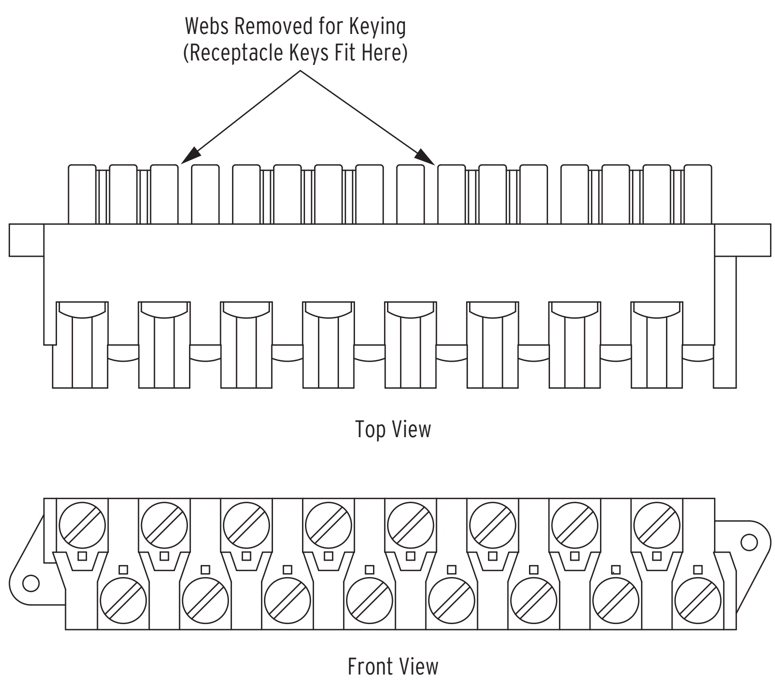


Figure 2.34 Screw-Terminal Connector Keying

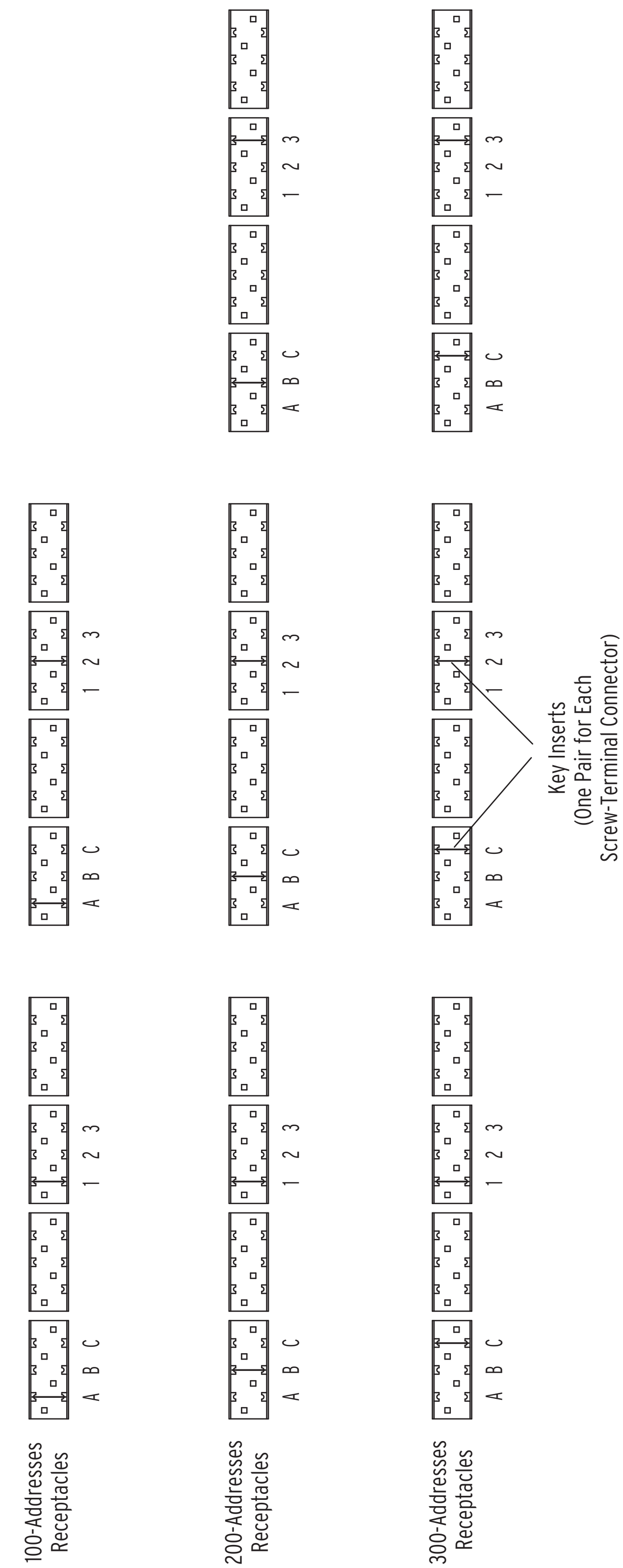


Figure 2.35 Rear-Panel Receptacle Keying

Grounding

Connect the grounding terminal (#Z31) labeled GND on the rear panel to a rack frame ground or main station ground for proper safety and performance.

This protective earthing terminal is in the lower right side of the relay panel (see *Figure 2.23* through *Figure 2.32*). The symbol that indicates the grounding terminal is shown in *Figure 2.33*.

Use 2.5 mm^2 (14 AWG) or larger wire less than 2 m (6.6 feet) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-421.

Power Connections

The terminals labeled POWER on the rear panel (#Z29 and #Z30) must connect to a power source that matches the power supply characteristics that your SEL-421 specifies on the rear-panel serial number label. (See *Power Supply on page 1.14*, for complete power input specifications.) For the relay models that accept dc input, the serial number label specifies dc with the symbol shown in *Figure 2.33*.

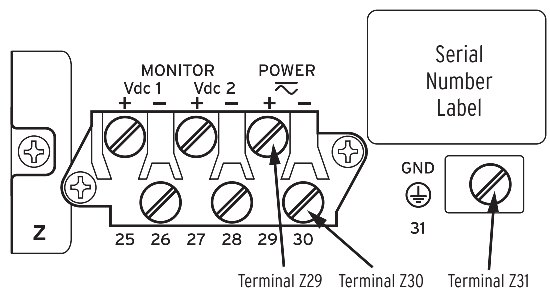


Figure 2.36 Power Connection Area of the Rear Panel

NOTE: The combined voltages applied to the POWER and MONITOR terminals must not exceed 600 V (rms or dc).

The POWER terminals are isolated from chassis ground. Use 0.8 mm^2 (18 AWG) or larger size wire to connect to the POWER terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3 and must be identified as the disconnect device for the equipment.

Place an external disconnect device, switch/fuse combination, or circuit breaker in the POWER leads for the SEL-421; this device must interrupt both the hot (H/+) and neutral (N/–) power leads. The current rating for the power disconnect circuit breaker or fuse must be 20 A maximum. Be sure to locate this device within 3.0 m (9.8 feet) of the relay.

Operational power is internally fused by power supply fuse F1. *Table 2.11* lists the SEL-421 power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-421 with one of three operational power input ranges listed in *Table 2.11*. Each of the three supply voltage ranges represents a power supply ordering option. As noted in *Table 2.11*, model numbers for the relay with these power supplies begin 04214*n* (or 04215*n*), where *n* is 2, 4, or 6, to indicate low, middle, and high voltage input power supplies, respectively. Note that each power supply range covers two widely used nominal input voltages. The SEL-421 power supply operates from 30 Hz to 120 Hz when ac power is used for the POWER input.

Table 2.11 Fuse Requirements for the Power Supply

Rated Voltage	Operational Voltage Range	Fuse F1	Fuse Description	Model Number
24–48 Vdc	18–60 Vdc	T5.0AH250V	5x20 mm, time-lag, 5.0 A, high break capacity, 250 V	042142 or 042152
48–125 Vdc, 110–120 Vac	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	042144 or 042154 or 042146 or 042156
125–250 Vdc, 110–240 Vac	85–300 Vdc or 85–264 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	

The SEL-421 accepts dc power input for all three power supply models. The 48–125 Vdc supply also accepts 110–120 Vac; the 125–250 Vdc supply also accepts 110–240 Vac. When connecting a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (Terminal #**Z29**) and **–** (Terminal #**Z30**) symbols on the power terminals. When connecting to an ac power source, the **+** Terminal #**Z29** is hot (**H**), and the **–** Terminal #**Z30** is neutral (**N**).

Each model of the SEL-421 internal power supply exhibits low power consumption and a wide input voltage tolerance. For more information on the power supplies, see *Power Supply on page 1.14*.

Monitor Connections (DC Battery)

The SEL-421 monitors two dc battery systems. For information on the battery monitoring function, see *Station DC Battery System Monitor Specifications on page 1.19*.

NOTE: The combined voltages applied to the **POWER** and **MONITOR** terminals must not exceed 600 V (rms or dc).

Connect the positive lead of Battery System 1 to Terminal #**Z25** and the negative lead of Battery System 1 to Terminal #**Z26**. (Usually Battery System 1 is also connected to the rear-panel **POWER** input terminals.) For Battery System 2, connect the positive lead to Terminal #**Z27**, and the negative lead to Terminal #**Z28**.

Secondary Circuit Connections

⚠**CAUTION**
Relay misoperation can result from applying anything other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.

⚠**DANGER**
Contact with instrument terminals can cause electrical shock that can result in injury or death.

The SEL-421 has two sets of three-phase current inputs and two sets of three-phase voltage inputs. *Secondary Circuits on page 2.5* describes these inputs in detail. The alert symbol and the word **DANGER** on the rear panel indicate that you should use all safety precautions when connecting secondary circuits to these terminals.

To verify these connections, use SEL-421 metering (see *Examining Metering Quantities on page 3.35 in the SEL-400 Series Relays Instruction Manual*). You can also review metering data in an event report that results when you issue the **TRIGGER** command (see *Triggering Data Captures and Event Reports on page 9.6 in the SEL-400 Series Relays Instruction Manual*).

Fixed Terminal Blocks

Connect the secondary circuits to the Z terminal blocks on the relay rear panel. Note the polarity dots above the odd-numbered terminals #**Z01**, #**Z03**, #**Z05**, #**Z07**, #**Z09**, and #**Z11** for CT inputs. Similar polarity dots are above the odd-numbered terminals #**Z13**, #**Z15**, #**Z17**, #**Z19**, #**Z21**, and #**Z23** for PT inputs.

Connectorized

For the Connectorized SEL-421, order the wiring harness kit, SEL-WA0421. The wiring harness contains four prewired connectors for the relay current and voltage inputs.

You can order the wiring harness with various wire sizes and lengths. Contact your local Technical Service Center or the SEL factory for ordering information.

Perform the following steps to install the wiring harness:

Step 1. Plug the CT shorting connectors into terminals #Z01 through #Z06 for the IW inputs, and #Z07 through #Z12 for the IX inputs, as appropriate.

Odd-numbered terminals are the polarity terminals.

Step 2. Secure the connector to the relay chassis with the two screws located on each end of the connector.

When you remove the CT shorting connector, pull straight away from the relay rear panel.

As you remove the connector, internal mechanisms within the connector separately short each power system current transformer.

You can install these connectors in only one orientation.

Step 3. Plug the PT voltage connectors into terminals #Z13 to #Z18 for the VY inputs, and #Z19 to #Z24 for the VZ inputs, as appropriate.

Odd numbered terminals are the polarity terminals. You can install these connectors in only one orientation.

Control Circuit Connections

You can configure the SEL-421 with many combinations of control inputs and control outputs. See *Main Board I/O on page 2.11* and *I/O Interface Boards on page 2.13* for information about I/O configurations. This subsection provides details about connecting these control inputs and outputs. Refer to *Figure 2.2*, *Figure 2.10*, and *Figure 2.14* for representative rear-panel screw-terminal connector locations.

Control Inputs

NOTE: The combined voltages applied to the IN*nnn* and OUT*nnn* terminals must not exceed 600 V (rms or dc).

Table 2.3 lists the control inputs available with the SEL-421, and notes that some are Direct-Coupled, and some are Optoisolated.

Direct-Coupled

Direct-coupled control inputs are polarity-sensitive. These inputs use direct-coupled circuitry, and have terminal markings to indicate polarity: a **+** mark appears for each input. Connect the positive sense of the control input to the **+** terminal. Although you cannot damage these inputs with a reverse polarity connection, a reverse polarity connection will cause the relay internal A/D converter to measure the input voltage incorrectly and the relay will no longer detect input changes (see *Control Inputs on page 2.6*).

Optoisolated

Optoisolated control inputs are not polarity sensitive. These inputs respond to voltage of either polarity, and can be used with ac control signals when properly configured.

Note that the main board I/O control inputs have one set of two inputs that share a common input leg and INT3 and INT4 I/O interface boards have two sets of nine inputs that share a common leg (see *Figure 2.13*).

Assigning

To assign the functions of the control inputs, see *Operating the Relay Inputs and Outputs on page 3.61 in the SEL-400 Series Relays Instruction Manual* for more details. You can also use ACSELERATOR QuickSet SEL-5030 Software to set and verify operation of the inputs.

Control Outputs

The SEL-421 has three types of outputs:

- Standard outputs
- Hybrid (high-current interrupting) outputs
- High-speed, high-current interrupting outputs

See *Control Outputs on page 2.8* for more information.

You can connect the standard outputs and the high-speed, high-current interrupting outputs in either ac or dc circuits. Connect the hybrid (high-current interrupting) outputs to dc circuits only. The screw-terminal connector legends alert you about this requirement by showing polarity marks on the hybrid (high-current interrupting) contacts.

Form A (SPST NO) contacts comprise the majority of the control outputs. Two pairs of Form C (SPDT CO) contacts are on the main board, the INT1 (INT2) I/O interface board, and the INT6 (INT7) I/O interface board.

Alarm Output

The SEL-421 monitors internal processes and hardware in continual self-tests. If the relay senses an out-of-tolerance condition, the relay declares a Status Warning or a Status Failure. The relay signals a Status Warning by pulsing the HALARM Relay Word bit (hardware alarm) to a logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1.

To provide remote alarm status indication, connect the b contact of OUT108 to your control system remote alarm input. *Figure 2.37* shows the configuration of the a and b contacts of control output OUT108.

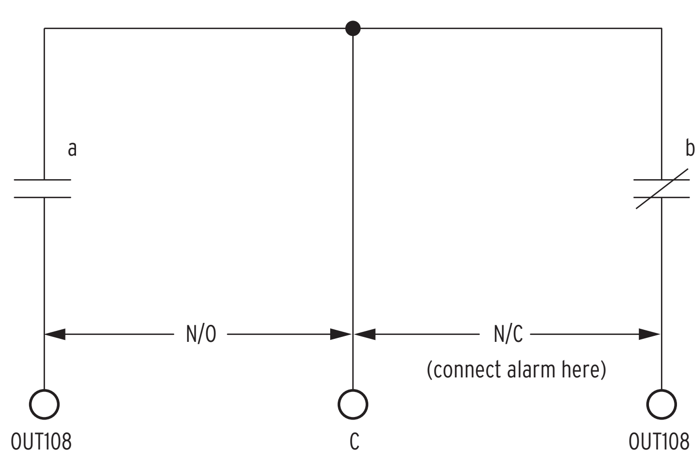


Figure 2.37 Control Output OUT108

Program OUT108 to respond to NOT HALARM by entering the following SELOGIC control equation with a communications terminal in QuickSet:

OUT108 := **NOT HALARM**

When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contacts of control output OUT108 are open.

When a status warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contacts of OUT108 close momentarily to indicate an alarm condition.

For a status failure, the relay disables all control outputs and the OUT108 b contacts close to trigger an alarm. Also, when relay power is off, the OUT108 b contacts close to generate a power-off alarm. See *Relay Self-Tests on page 10.15 in the SEL-400 Series Relays Instruction Manual* for information on relay self-tests.

The relay pulses the SALARM Relay Word bit for software programmed conditions; these conditions include settings changes, access-level changes, and alarming after three unsuccessful password entry attempts.

The SEL-421 also pulses the BADPASS Relay Word bit after three unsuccessful password entry attempts.

You can add the software alarm SALARM to the alarm output by entering the following SELOGIC control equation:

OUT108 := **NOT (HALARM OR SALARM)**

Tripping and Closing Outputs

To assign the control outputs for tripping and closing, see *Setting Outputs for Tripping and Closing on page 3.67 in the SEL-400 Series Relays Instruction Manual*. In addition, you can use the **SET O** command (see *Output Settings on page 8.35* for more details). You can also use the front panel to set and verify operation of the outputs (see *Set/Show on page 4.25 in the SEL-400 Series Relays Instruction Manual*).

Auxiliary TRIP/CLOSE Pushbuttons and OPEN/CLOSED LEDs (Select Models Only)

Select relay models feature auxiliary **TRIP** and **CLOSE** pushbuttons and **OPEN** and **CLOSED** LED indicators. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

The pushbuttons and LEDs can be hard-wired into a substation trip and close control circuit and operate the same as a separate installation of external trip/close switches and LED indicators. *Figure 2.57* shows example trip and close circuit connections for a control scheme configuration with a dc substation voltage source. The pushbutton switches come set from the factory for dc operation (arc suppression enabled). To use an ac trip or close potential, the arc suppression must be disabled for one or both pushbuttons (see *Table 2.9*). The voltage operating ranges of the LEDs are selected by jumpers (see *Table 2.8*).

⚠**WARNING**
SEL-421 features such as Hot Line Tag and Synchronism Check do not supervise the auxiliary close pushbutton.

Because the **TRIP** and **CLOSE** pushbuttons are functionally separate from the relay, a manual trip or close cannot be distinguished from an external protection or automation-initiated operation. Unless provisions are made in the control wiring, the action of the close pushbutton is unsupervised.

TiDL Connections

SEL-421 Relays that support TiDL have a 4U chassis. The SEL-421 supports I/O on the main board as well as one additional I/O board. The main board and additional I/O board map to the 100- and 200-level inputs and outputs. The Axion remote modules provide additional I/O for the 300, 400, and 500 levels and analog channels.

The protection functions remain unchanged from the standard SEL-421 Relay.

Axion Remote Modules

The SEL-2240 Axion is a fully integrated analog and digital I/O control solution that is suitable for remote data acquisition. An Axion node consists of a 10-slot, 4-slot, or dual 4-slot chassis that is configurable to contain a power module and combinations of CT/PT, digital input (DI), or digital output (DO) modules.

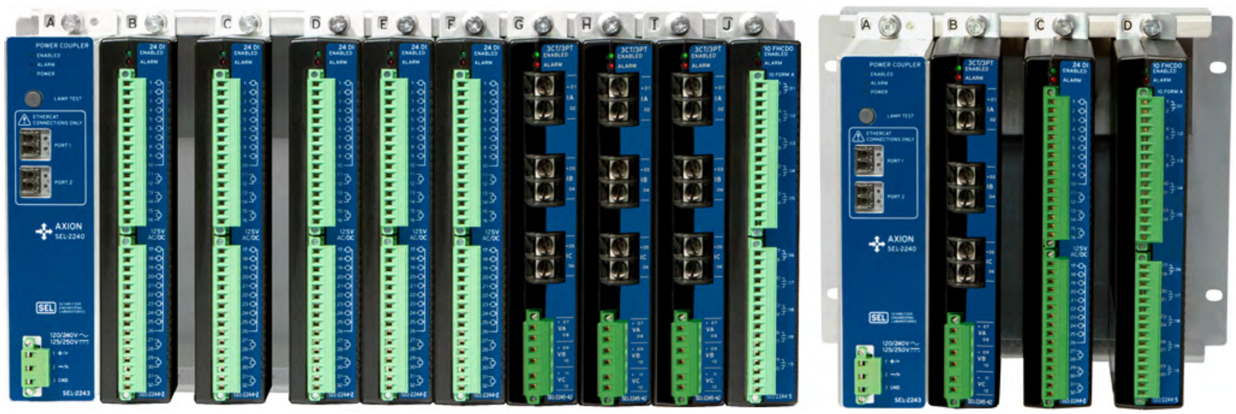


Figure 2.38 Axion Chassis

SEL-2243 Power Coupler

Each chassis requires a SEL-2243 Power Coupler (see *Figure 2.39*). This module supplies power to the rest of the node and transmits the data to the relay through fiber-optic communication. Although the power coupler has two fiber-optic ports, only PORT 1 is currently used for TiDL.

Figure 2.39 SEL-2243 Power Coupler

The SEL-2243 has sufficient power capacity to accommodate an entire Axion node. The terminal strip at the bottom of the unit (shown in *Figure 2.39*) is the connection point for incoming power. All Axion modules have a 55-position IEC C-style connector that provides a communications and power interface to the backplane. See the *SEL-2240 Axion Instruction Manual* for more information.

SEL-2244-2 Digital Input Module

The SEL-2244-2 Digital Input Module (see *Figure 2.40*) consists of 24 optoisolated inputs that are not polarity dependent. These inputs can be configured to respond to ac or dc control signals. The TiDL system maps as many as 72 DI points to the relay in the 300, 400, and 500 I/O board levels, based on the modules that occur in the network. Only the first 12 of 24 inputs are used in each module to help distribute the I/O around the network more efficiently. The inputs are mapped to the relay inputs based on the order in which the DI module occurs in the TiDL network.

There can be multiple DI modules in an Axion node, and the order of the DI modules will proceed from left to right in the node to determine the mapping of the inputs.

The first DI module that exists in the system, for example, on **PORT 6A**, will map to **IN301**–**IN312**, and if a second module is available on **PORT 6A**, it will map to **IN313**–**IN324**. If a second module does not exist on **PORT 6A**, **IN313**–**IN324** will be mapped from the next module appearing in the TiDL system. Mapping order determination starts with **PORT 6A** and ends with the last port, **PORT 6H**.

First SEL-2244-2 DI Module	**IN301–IN312**
Second SEL-2244-2 DI Module	**IN313–IN324**
Third SEL-2244-2 DI Module	**IN401–IN412**
Fourth SEL-2244-2 DI Module	**IN413–IN424**

Fifth SEL-2244-2 DI Module	IN501–IN512
Sixth SEL-2244-2 DI Module	IN513–IN524

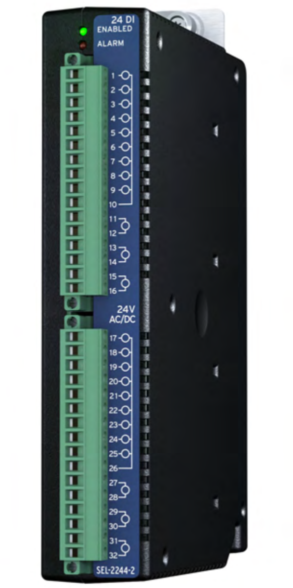


Figure 2.40 SEL-2244-2 Digital Input Module

SEL-2244-5 Fast High-Current Digital Output Module

The SEL-2244-5 Fast High-Current Digital Output Module consists of 10 fast, high-current output contacts. The outputs use the first 8 of the10 outputs and map as follows:

First SEL-2244-5 DO Module	OUT301–OUT308
Second SEL-2244-5 DO Module	OUT309–OUT316
Third SEL-2244-5 DO Module	OUT401–OUT408
Fourth SEL-2244-5 DO Module	OUT409–OUT416
Fifth SEL-2244-5 DO Module	OUT501–OUT508
Sixth SEL-2244-5 DO Module	OUT509–OUT516

Figure 2.41 SEL-2244-5 Fast High-Current Digital Output Module

For both the DI and DO modules, use 24–12 AWG (0.2–3.31 mm^2) wire of sufficient current capacity to connect to the digital input and output terminals for your application.

The order of mapping for DO modules is the same as that for DI modules.

SEL-2245-42 AC Analog Input Module

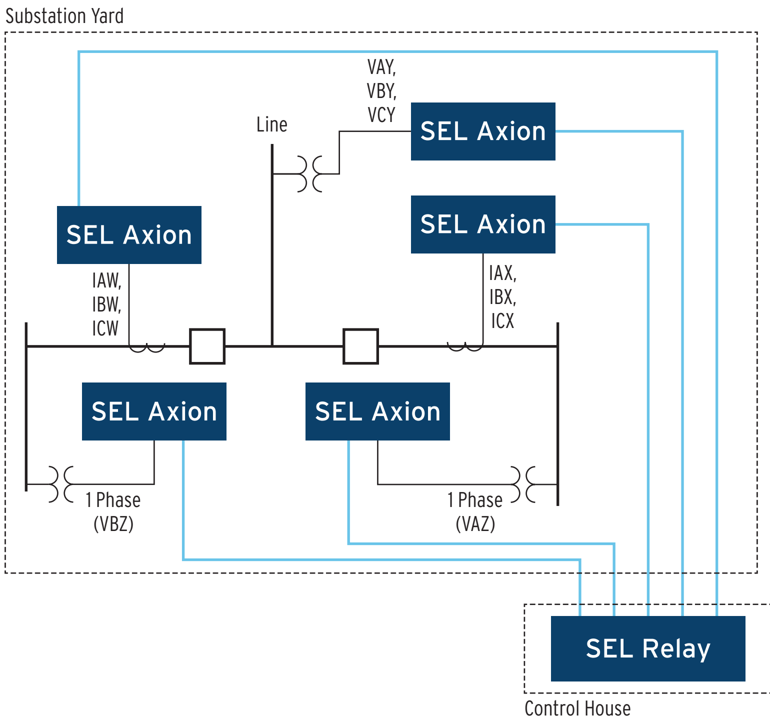
The SEL-2245-42 AC Analog Input Module (see *Figure 2.42*) provides protection-class ac analog input (CT/PT) and can accept three voltage and three current inputs. The module samples at 24 kHz and is 1 A or 5 A software-selectable. Depending on the supported fixed topology, multiple CT/PT input modules can function in each node. Some topologies only support one CT/PT module per node. See *Topologies on page 2.42* for more information on supported relay topologies and their connections.

Figure 2.42 SEL-2245-42 AC Analog Input Module

Topologies

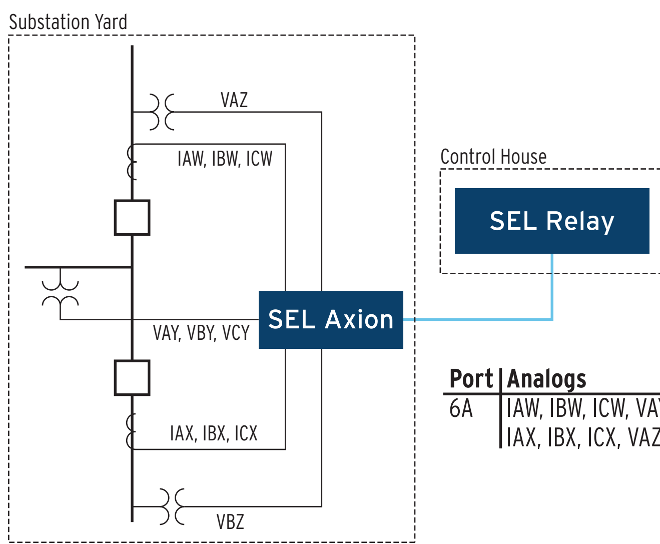
The SEL-421 Relay has a set of fixed topologies. These topologies map the voltages and currents internally in the relay to maintain existing settings and functionality. When the TiDL system is commissioned (see *Commissioning on page 2.44*), the firmware validates the connected Axion nodes and identifies if the installed CT/PT modules in the system match one of the supported topologies for the SEL-421.

Ports listed as optional in the following topology diagrams do not require a CT/PT module to be connected to them. All other ports require a CT/PT module to be connected for the relay to verify the topology.



Port	Analogs
6A	IAW, IBW, ICW
6B	IAX, IBX, ICX (optional)
6C	VAY, VBY, VCY
6D	VAZ (optional)
6E	VBZ (optional)
6F	VCZ (optional)

Figure 2.43 Topology 1



Port	Analogs
6A	IAW, IBW, ICW, VAY, VBY, VCY
	IAX, IBX, ICX, VAZ, VBZ, VCZ

This topology uses two CT/PT modules installed in one Axion node. The first module maps to the W currents and Y voltages, and the second module maps to the X currents and Z voltages.

Figure 2.44 Topology 2

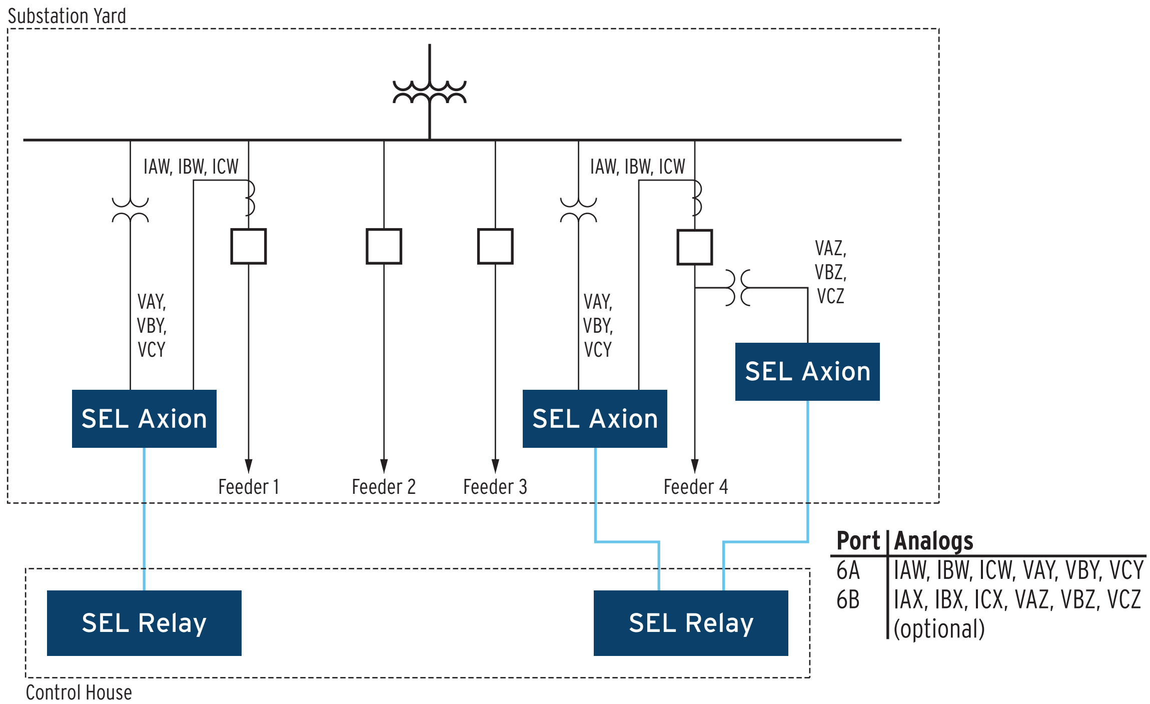


Figure 2.45 Topology 3

Commissioning

In TiDL applications, the relay receives currents from a remote module. You must set the nominal current input of the relay to either 1 A or 5 A. Many settings and ranges of settings depend on the nominal current. Use the **CFG CTNOM** command to set the nominal current value. At Access Level 2, issue a **CFG CTNOM 1** command to set the relay to 1 A values or use the **CFG CTNOM 5** command to set it to 5 A values. This command is only available in relays that support TiDL technology. Note that after issuing this command, the relay settings are forced to their default values and the relay turns off and back on again to reinitialize the settings. The relay defaults to 5 A nominal, so only use this command if you are switching to a 1 A setting (see *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual* for more information). The SEL-2245-42 AC Analog Input Module also sets its internal calculations based on this command. The relay internally transmits this data to the Axion modules and adjusts the scaling in the appropriate Axion module when this command is used.

In addition to the CT nominal values, TiDL relays also require that the nominal frequency be set by issuing the **CFG NFREQ** command. At Access Level 2, issue a **CFG NFREQ 60** command to set the relay to 60 Hz nominal or issue a **CFG NFREQ 50** command to set the relay to 50 Hz nominal. This command changes the NFREQ setting and restarts the relay, and it is only available in TiDL relays. The relay defaults to 60 Hz. This command should be issued after the **CFG CTNOM** command but before settings are sent to the relay.

The TiDL system uses a commissioning feature to identify that the connected remote Axion nodes meet the requirements of the supported topologies for the applied relay. These topologies are a balance between copper reduction and number of nodes. The nodes must be connected in one of the supported topologies so that the relay will map the voltages and currents accordingly.

The SEL-421 has a new interface on its back panel that replaces the original CT and PT input connections. These standard inputs are replaced with a remote module interface that supports eight fiber ports, labeled **PORT 6A–PORT 6H** (see *Figure 2.46*).

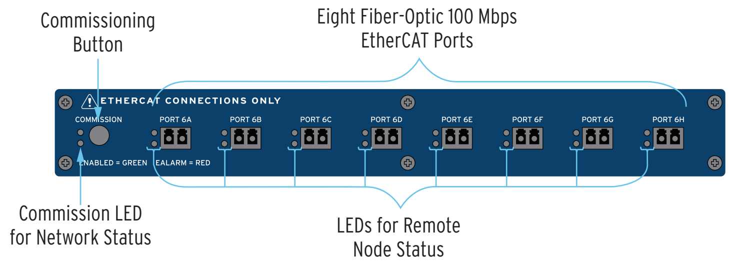


Figure 2.46 Remote Module Interface

Once all the remote Axion nodes are connected to the relay, press the **COMMISSION** pushbutton on the Remote Module Interface. This process verifies that the connected ports and Axion nodes are installed according to one of the supported topologies. Once the process is complete, the topology is stored in memory. At each additional startup of the relay, the firmware validates that the connected modules match those of the stored configuration. It recognizes whether any of the CT/PT modules within the node have changed. If the topology needs to be changed (e.g., modules are added or replaced), the system will need to be recommissioned by pressing the **COMMISSION** pushbutton.

When the commissioning and validation of the topology is complete, the voltages and currents map according to the topology assignments (see *Topologies on page 2.42*). Secondary injection testing takes place at each Axion node. Test sources must inject voltages and currents to the Axion node to verify correct installation and mapping. Monitoring of the voltages and currents remains in the control house with the relay.

LED Status

As shown in *Figure 2.46*, the TiDL relay provides LED status indication about the network and configuration. Once the system is connected, and the **COMMISSION** pushbutton is pressed, the LEDs will provide the status of the commissioning process. *Table 2.12* shows the status of the rear-panel LEDs for each commissioning state.

Table 2.12 TiDL LED Status (Sheet 1 of 2)

State	Description	LED Status	
Initial State	Determining if topology exists	Green **COMMISSION** LED	OFF
		Red **COMMISSION** LED	ON
		Green LED: **PORT 6A–PORT 6H**	OFF
		Red LED: **PORT 6A–PORT 6H**	ON
Verify Topology	Determining if topology is supported	Green **COMMISSION** LED	Blinking
		Red **COMMISSION** LED	ON
		Green LED: **PORT 6A–PORT 6H**	Blinking
		Red LED: **PORT 6A–PORT 6H**	ON

Table 2.12 TiDL LED Status (Sheet 2 of 2)

State	Description	LED Status	
Topology Mismatch	Connection does not match supported topology	Green COMMISSION LED	Blinking
		Red COMMISSION LED	ON
		Green LED: PORT 6A–PORT 6H	OFF—mismatched/unused
			ON—matched
		Red LED: PORT 6A–PORT 6H	Blinking—mismatched
			ON—matched
			OFF—ports unused
Topology Matched	Connection matches topology	Green COMMISSION LED	ON
		Red COMMISSION LED	OFF
		Green LED: PORT 6A–PORT 6H	ON
		Red LED: PORT 6A–PORT 6H	OFF
N/A	A commissioned port experiences an error	Green COMMISSION LED	ON
		Red COMMISSION LED	OFF
		Green LED: PORT 6A–PORT 6H	ON
		Red LED: PORT 6A–PORT 6H	Blinking—failed port

IRIG-B Input Connections

The SEL-421 accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These IRIG-B inputs are the BNC connector labeled **IRIG-B** and Pin 4 (**+**) and Pin 6 (**–**) of the DB-9 rear-panel serial port labeled **PORT 1**. When you use the **PORT 1** input, ensure that you connect Pins 4 and 6 with the proper polarity. See *Communications Ports Connections on page 2.47* for other DB-9 connector pinouts and additional details.

These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with positive edge on the time mark. For more information on IRIG-B and the SEL-421, see *IRIG-B Inputs on page 2.12*.

The **PORT 1** IRIG-B input connects to a 2.5 kΩ grounded resistor and goes through a single logic signal buffer. The **PORT 1** IRIG-B is equipped with robust ESD and overvoltage protection but is not optically isolated. When you are using the **PORT 1** input, ensure that you connect Pin 4 (**+**) and Pin 6 (**–**) with the proper polarity.

The IRIG network should be properly terminated with an external termination resistor (SEL 240-1802, BNC Tee, and SEL 240-1800, BNC terminator, 50 ohm) placed on the unit that is farthest from the source. This termination provides impedance matching of the cable for the best possible signal-to-noise ratio.-

Where distance between the SEL-421 and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use transceivers to provide isolation and to establish communication to remote locations.

Conventional fiber-optic and telephone modems do not support IRIG-B signal transmission. The SEL-2810 Fiber-Optic Transceiver/Modem includes a channel for the IRIG-B time code. These transceivers enable you to synchronize time precisely from IRIG-B time code generators (such as the SEL-2032 Communications Processor) over a fiber-optic communications link.

Communications Ports Connections

The SEL-421 has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F**. For information on serial communication, see *Establishing Communication on page 3.3*, *Serial Communication on page 15.2*, and *Serial Port Hardware Protocol on page 15.5 in the SEL-400 Series Relays Instruction Manual*.

In addition, the rear panel features a **PORT 5** for an optional Ethernet card. For additional information about communications topologies and standard protocols that are available in the SEL-421, see *Section 15: Communications Interfaces*, *Section 16: DNP3 Communication*, and *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual* and *Section 10: Communications Interfaces* in this manual.

Serial Ports

The SEL-421 serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin (DB-9) connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a DB-9 connector, use an SEL-C234A cable. Alternatively, you can use a SEL-C662 cable to connect to a USB port.

Figure 2.47 shows the configuration of SEL-C234A cable that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or QuickSet along with the SEL-C234A cable provide communication with the relay in most cases.

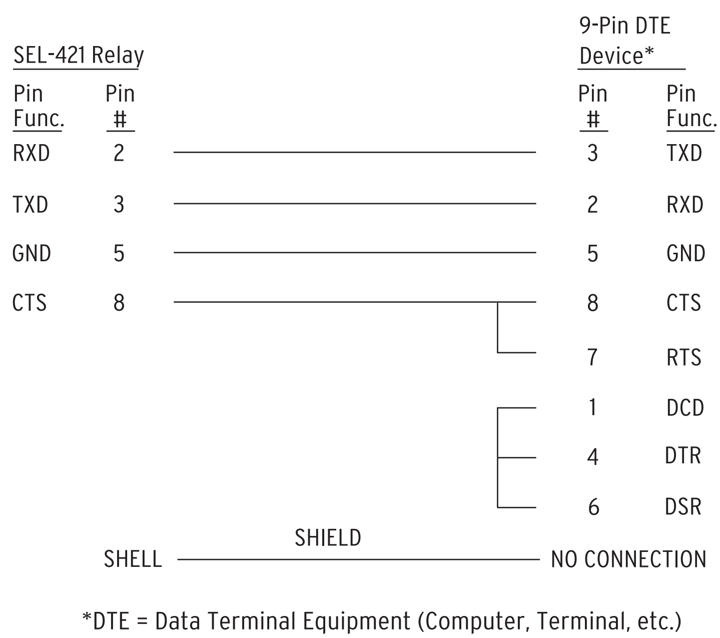


Figure 2.47 SEL-421 to Computer—D-Subminiature 9-Pin Connector

Serial Cables

⚠**CAUTION**
Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

Using an improper cable can cause numerous problems or failure to operate, so you must be sure to specify the proper cable for application of your SEL-421. Several standard SEL communications cables are available for use with the relay.

The following list provides additional rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables:

- Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.
- Keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.
- Ensure that EIA-232 communications cable lengths never exceed 50 feet, and always use shielded cables for communications circuit lengths greater than 10 feet.
- Modems provide communication over long distances and give isolation from ground potential differences that are present between device locations (examples are the SEL-28XX-series transceivers).
- Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. Use the lowest data speed that provides an adequate data transfer rate.

Ethernet Network Connections

The optional Ethernet card for the SEL-421 comes with two ports, either A and B or C and D. You can use either installed port. These ports can work together to provide a primary and backup interface. Other operating modes (FIXED and SWITCHED) are also available. The following list describes the Ethernet card port options.

- 10/100BASE-T. 10 Mbps or 100 Mbps communication using Cat 5 cable (category 5 twisted-pair) and an RJ45 connector
- 100BASE-FX. 100 Mbps communication over multimode fiber-optic cable using an LC connector

⚠CAUTION
Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

⚠WARNING
Do not look into the fiber ports/connectors.

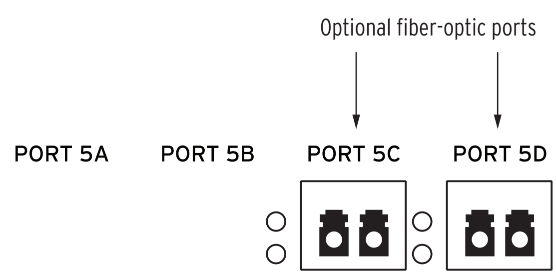


Figure 2.48 Example Ethernet Panel With Fiber-Optic Ports

Ethernet Card Rear-Panel Layout

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.49–Figure 2.54*.

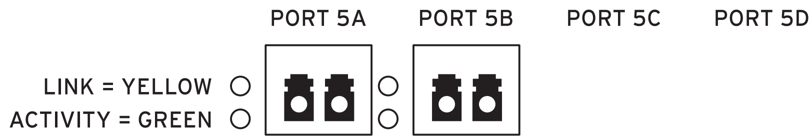


Figure 2.49 Two 100BASE-FX Port Configuration on Ports 5A and 5B

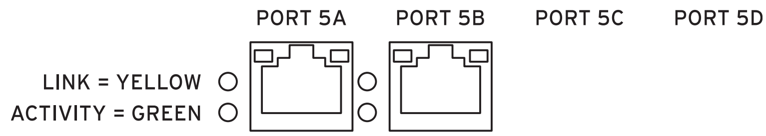


Figure 2.50 Two 10/100BASE-T Port Configuration on Ports 5A and 5B

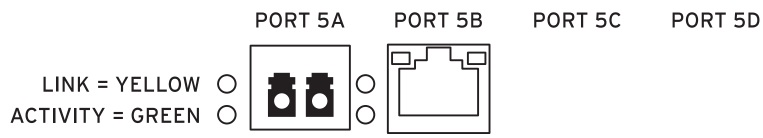


Figure 2.51 100BASE-FX and 10/100BASE-T Port Configuration on Ports 5A and 5B

⚠**WARNING**
Do not perform any procedures or adjustments that this instruction manual does not describe.

⚠**WARNING**
During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.

⚠**WARNING**
Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.

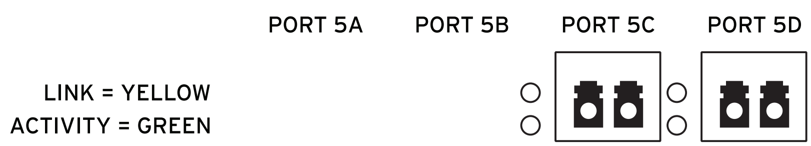


Figure 2.52 Two 100BASE-FX Port Configuration on Ports 5C and 5D

Figure 2.53 Two 10/100BASE-T Port Configuration on Ports 5C and 5D

Figure 2.54 100BASE-FX and 10/100BASE-T Port Configuration on Ports 5C and 5D

Twisted-Pair Networks

NOTE: Use caution with UTP cables as these cables do not provide adequate immunity to interference in electrically noisy environments unless additional shielding measures are employed.

While Unshielded Twisted Pair (UTP) cables dominate office Ethernet networks, Shielded Twisted Pair (STP) cables are often used in industrial applications. The SEL-421 Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

Typically UTP cables are installed in relatively low-noise environments including offices, homes, and schools. Where noise levels are high, you must either use STP cable or shield UTP using grounded ferrous raceways such as a steel conduit.

Several types of STP bulk cable and patch cables are available for use in Ethernet networks. If noise in your environment is severe, you should consider using fiber-optic cables. We strongly advise against using twisted-pair cables for segments that leave or enter the control house.

If you use twisted-pair cables, you should use care to isolate these cables from sources of noise to the maximum extent possible. Do not install twisted-pair cables in trenches, raceways, or wireways with unshielded power, instrumentation, or control cables. Do not install twisted-pair cables in parallel with power, instrumentation, or control wiring within panels, rather make them perpendicular to the other wiring.

You must use a cable and connector rated as Category 5 (Cat 5) to operate the twisted-pair interface (10/100BASE-T) at 100 Mbps. Because lower categories are becoming rare and because you may upgrade a 10 Mbps network to 100 Mbps, we recommend using all Cat 5 or better components.

Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ45 connectors are grounded so you can ground the shielded cable by using a standard, externally shielded jack with cables terminating at the Ethernet card.

AC/DC Connection Diagrams

You can apply the SEL-421 in many power system protection schemes. *Figure 2.55* shows one particular application scheme with connections that represent typical interfaces to the relay for a single circuit breaker connection. *Figure 2.56* depicts typical connections for a dual circuit breaker protection scheme.

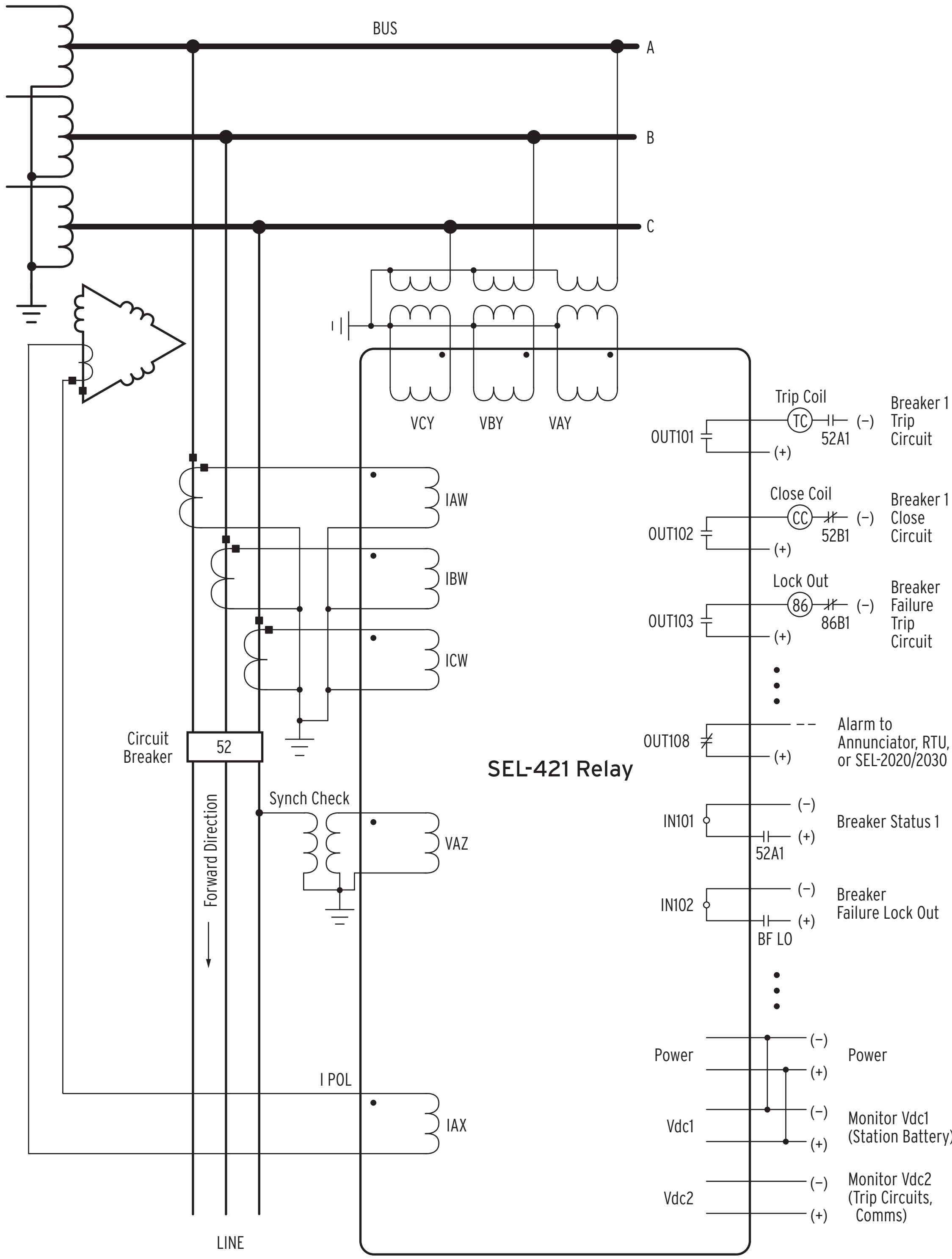


Figure 2.55 Typical External AC/DC Connections—Single Circuit Breaker

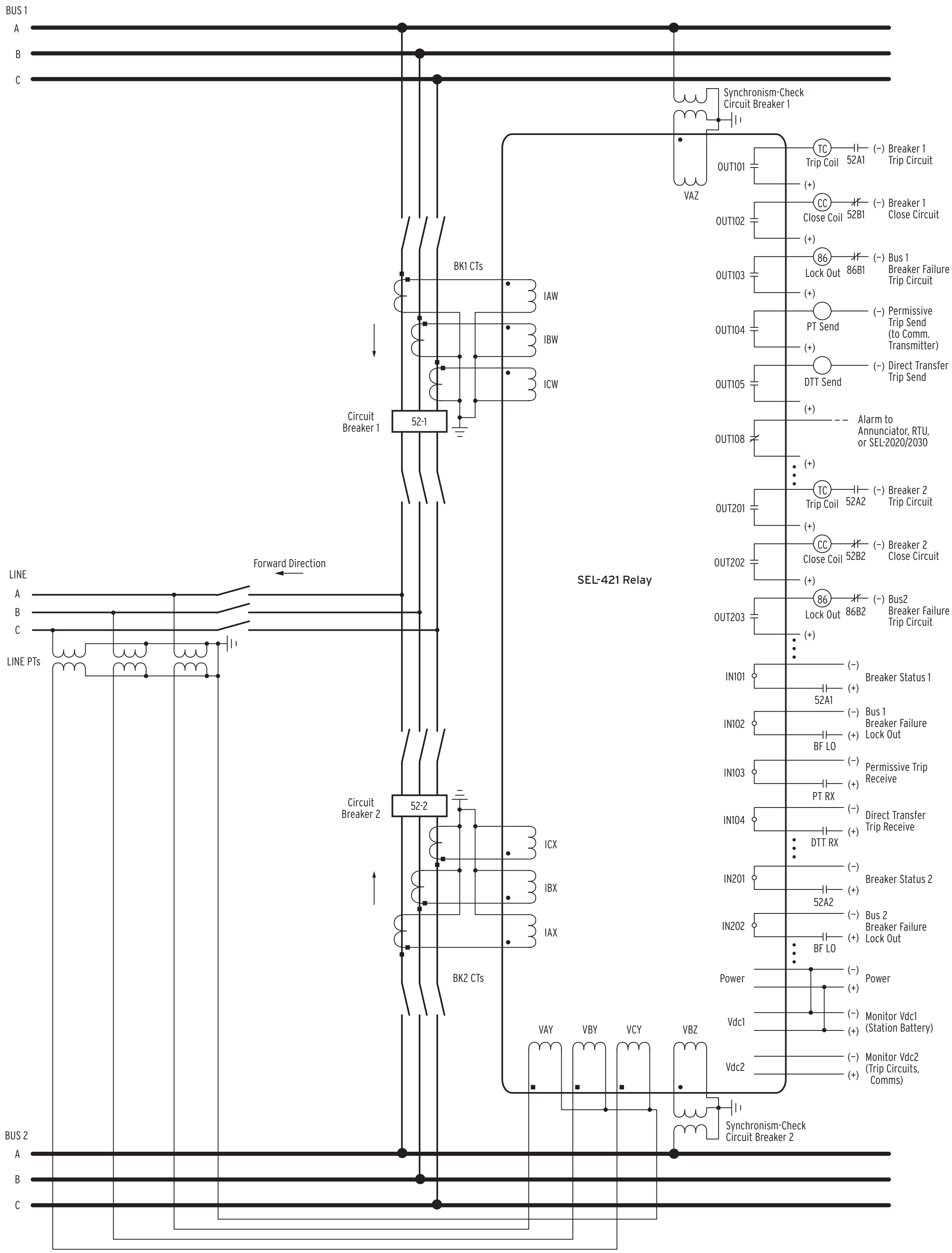


Figure 2.56 Typical External AC/DC Connections—Dual Circuit Breaker

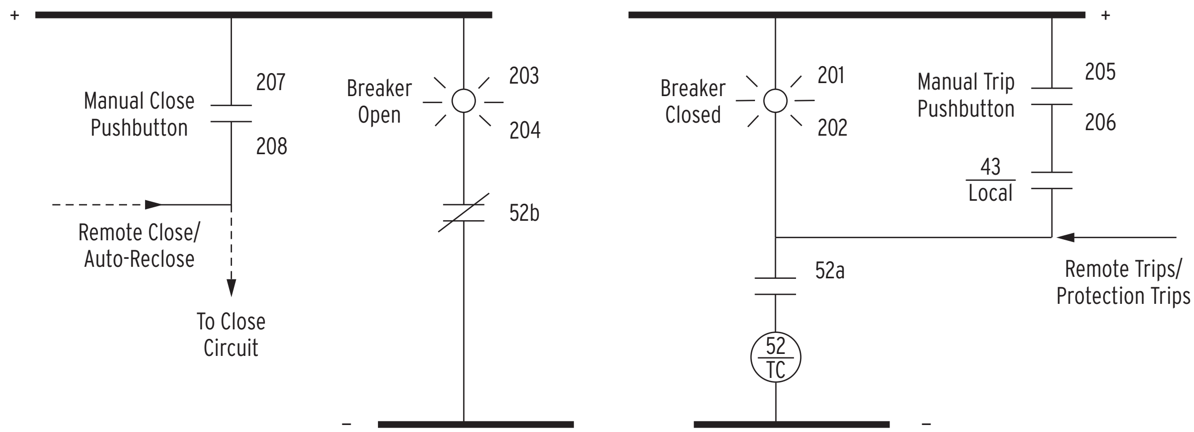


Figure 2.57 SEL-421 Example Wiring Diagram Using the Auxiliary TRIP/CLOSE Pushbuttons

SECTION 3

Testing

This section contains guidelines for determining and establishing test routines for the SEL-421 Relay. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. *Section 10: Testing, Troubleshooting, and Maintenance in the SEL-400 Series Relays Instruction Manual* addresses the concepts related to testing. This section provides supplemental information specific to testing the SEL-421.

Topics presented in this section include the following:

The SEL-421 is factory calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Low-Level Test Interface

You can test the relay in two ways: by using secondary injection testing, or by applying low-magnitude ac voltage signals to the low-level test interface. This subsection describes the low-level test interface between the calibrated input module and the processing module.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

The top circuit board is the relay main board and the bottom circuit board is the input module board. At the right side of the relay main board (the top board) is the processing module. The input to the processing module is multipin connector J24, the analog or low-level test interface connection. Receptacle J24 is on the right side of the main board; for a locating diagram, see *Figure 2.19 on page 2.18*.

Figure 3.1 shows the low-level interface connections. Note the nominal voltage levels, current levels, and scaling factors listed in *Figure 3.1* that you can apply to the relay. Never apply voltage signals greater than 6.6 Vp-p sinusoidal signal (2.33 Vrms) to the low-level test interface.

To use the low-level test interface, perform the following steps:

Step 1. Remove any cables connected to serial ports on the front panel.

Step 2. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

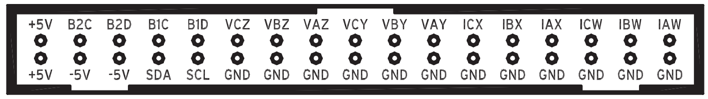
Step 3. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 4. Remove the ribbon cable from the main board J24 receptacle.

Step 5. Substitute a test cable with the signals specified in *Figure 3.1*.

Step 6. Reconnect the cables removed in *Step 4* and replace the relay front-panel cover.

Step 7. Reconnect any cables previously connected to serial ports on the front panel.



Input Module Output (J3): 66.6 mV At Nominal Current (1 A or 5 A)
446 mV at Nominal Voltage (67 V_{LN})

Processing Module Input (J24): 6.6 Vp-p Maximum

U.S. Patent 5,479,315

Figure 3.1 Low-Level Test Interface

Use signals from the SEL-4000 Low-Level Relay Test System to test the relay processing module. Apply appropriate signals to the low-level test interface J24 from the SEL-4000 Relay Test System (see *Figure 3.1*). These signals simulate power system conditions, taking into account PT ratio and CT ratio scaling. Use relay metering to determine whether the applied test voltages and currents produce correct relay operating quantities.

The UUT Database entries for the SEL-421 in the SEL-5401 Relay Test System Software are shown in *Table 3.1* and *Table 3.2*.

Table 3.1 UUT Database Entries for SEL-5401 Relay Test System Software—5 A Relay

	Label	Scale Factor	Unit
1	IAW	75	A
2	IBW	75	A
3	ICW	75	A
4	IAX	75	A
5	IBX	75	A
6	ICX	75	A
7	VAY	150	V
8	VBY	150	V
9	VCY	150	V
10	VAZ	150	V
11	VBZ	150	V
12	BCZ	150	V

Table 3.2 UUT Database Entries for SEL-5401 Relay Test System Software—1 A Relay (Sheet 1 of 2)

	Label	Scale Factor	Unit
1	IAW	15	A
2	IBW	15	A
3	ICW	15	A
4	IAX	15	A

Table 3.2 UUT Database Entries for SEL-5401 Relay Test System Software—1 A Relay (Sheet 2 of 2)

	Label	Scale Factor	Unit
5	IBX	15	A
6	ICX	15	A
7	VAY	150	V
8	VBY	150	V
9	VCY	150	V
10	VAZ	150	V
11	VBZ	150	V
12	BCZ	150	V

Relay Test Connections

NOTE: The procedures specified in this subsection are for initial relay testing only. Follow your company policy for connecting the relay to the power system.

⚠WARNING
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

The SEL-421 is a flexible tool that you can use to implement many protection and control schemes. Although you can connect the relay to the power system in many ways, connecting basic bench test sources helps you model and understand more complex relay field connection schemes.

For each relay element test, you must apply ac voltage and current signals to the relay. The text and figures in this subsection describe the test source connections you need for relay protection element checks. You can use these connections to test protective elements and simulate all fault types.

Connections for Three Voltage Sources and Three Current Sources

Figure 3.2 shows the connections to use when you have three voltage sources and three current sources available.

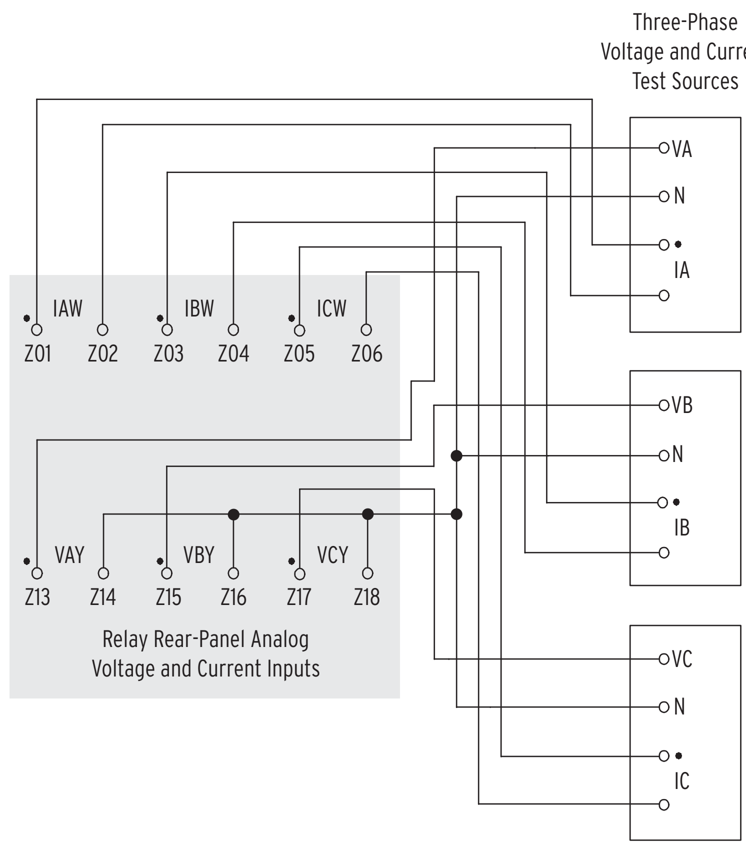


Figure 3.2 Test Connections Using Three Voltage and Three Current Sources

Connections for Three Voltage Sources and Two Current Sources

Figure 3.3 and *Figure 3.4* show connections to use when you have three voltage sources and two current sources. You can use the connections shown in *Figure 3.3* to simulate phase-to-phase, phase-to-ground, and two-phase-to-ground faults. Use the connections shown in *Figure 3.4* to simulate three-phase faults.

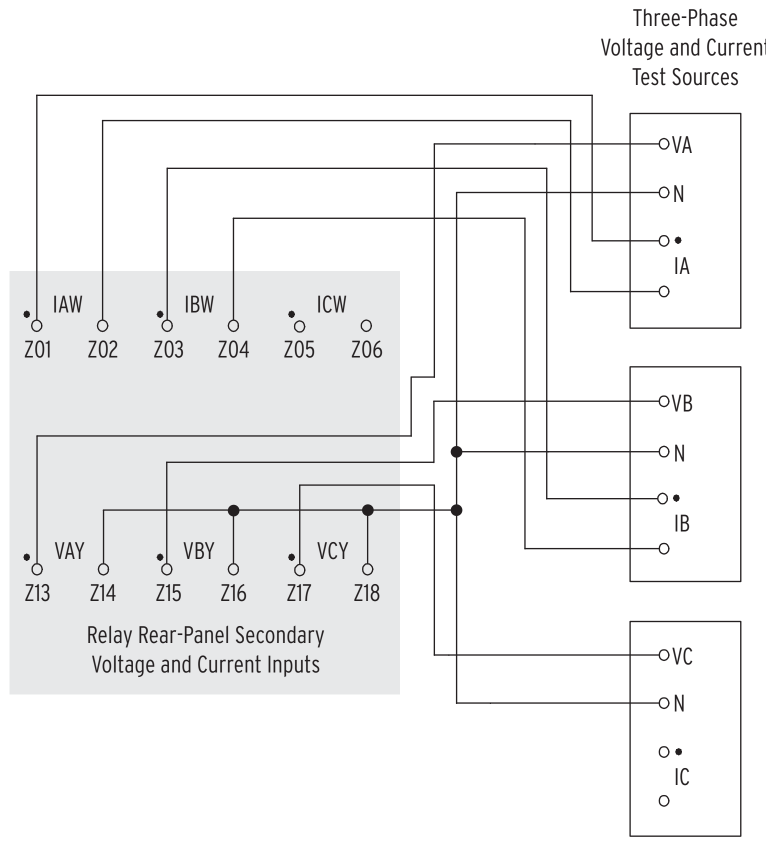


Figure 3.3 Test Connections Using Two Current Sources for Phase-to-Phase, Phase-to-Ground, and Two-Phase-to-Ground Faults

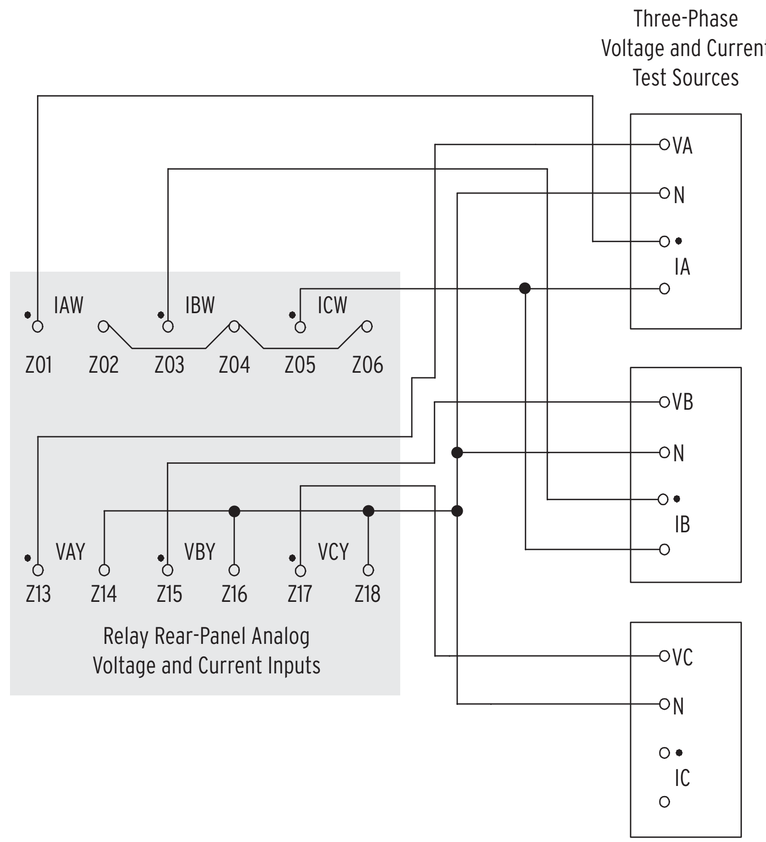


Figure 3.4 Test Connections Using Two Current Sources for Three-Phase Faults

Connections for Three Voltage Sources and One Current Source

Figure 3.5 and *Figure 3.6* show connections to use when you have three voltage sources and a single current source. You can use the connections shown in *Figure 3.5* to simulate phase-to-ground faults. Use the connections shown in *Figure 3.6* to simulate phase-to-phase faults.

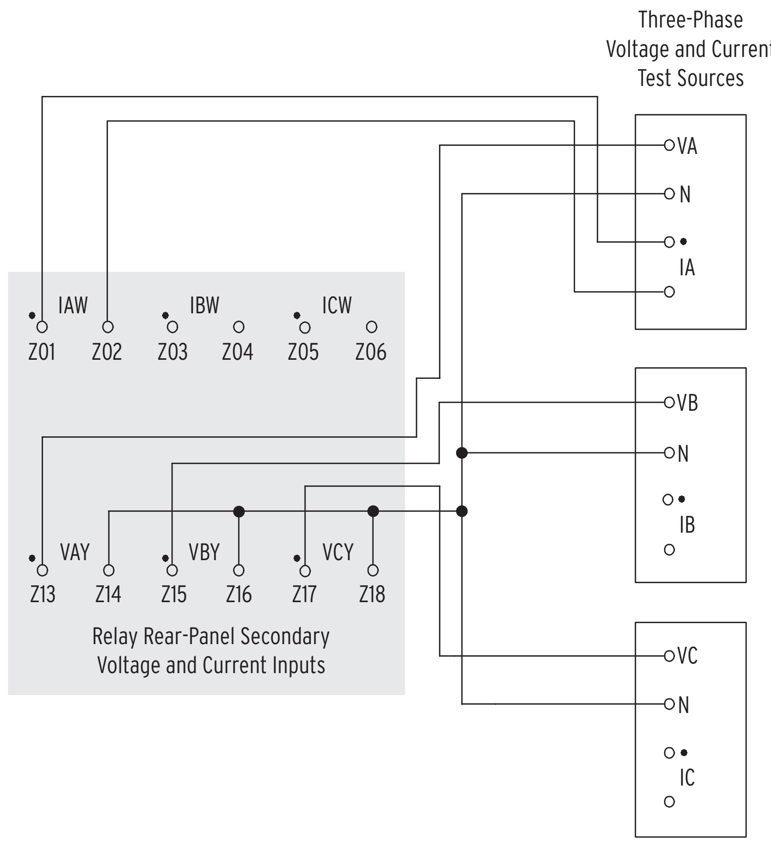


Figure 3.5 Test Connections Using a Single Current Source for a Phase-to-Ground Fault

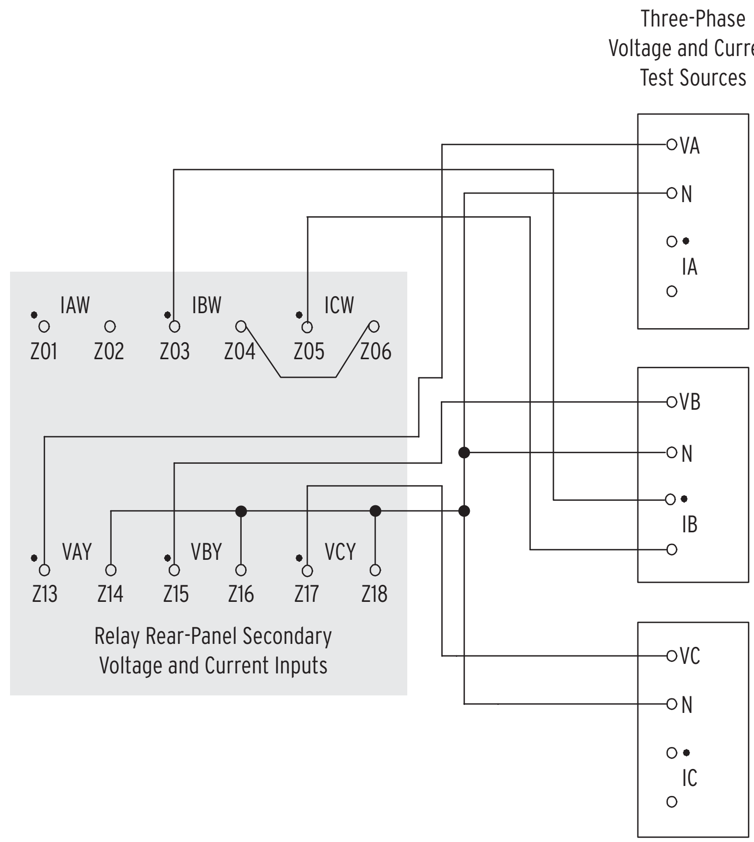


Figure 3.6 Test Connections Using a Single Current Source for a Phase-to-Phase Fault

Checking Relay Operation

The SEL-421 comes to you with all functions fully checked and calibrated so that the relay operates correctly and accurately. You can perform tests on the relay to verify proper relay operation, but you do not need to test every relay element, timer, and function in this evaluation. The following checks are valuable for confirming proper SEL-421 connections and operation:

- ➤ AC connection check (metering)
- ➤ Commissioning tests
- ➤ Functional tests
- ➤ Element verification

An ac connection check uses relay metering to verify that the relay current and voltage inputs are the proper magnitude and phase rotation (see *Examining Metering Quantities on page 3.35 in the SEL-400 Series Relays Instruction Manual*).

Commissioning tests help you verify that you have properly connected the relay to the power system and all auxiliary equipment. These tests confirm proper connection of control inputs and control outputs as well (see *Operating the Relay Inputs and Outputs on page 3.61 in the SEL-400 Series Relays Instruction Manual*).

Brief functional tests and element verification confirm correct internal relay processing.

This subsection discusses tests of the following relay elements:

- Overcurrent element: negative-sequence instantaneous, 50Q1
- Directional element: negative-sequence portion, F32Q/R32Q, of the phase directional element, F32P/R32P
- Distance element: phase-to-phase mho element, MBC2, of Zone 2 mho distance element Z2P

Testing Overcurrent Elements

Overcurrent elements operate by detecting power system sequence quantities and asserting when these quantities exceed a preset threshold.

Apply current to the analog current inputs and compare relay operation to the element pickup settings to test the instantaneous and definite-time overcurrent elements. Be sure to apply the test current to the proper input set (IW or IX), according to the Global Current and Voltage Source Selection settings (ESS and ALINEI, for example) to accept the input. See *Current and Voltage Source Selection on page 5.2* for more information.

Phase Overcurrent Elements

The SEL-421 phase overcurrent elements compare the phase current applied to the secondary current inputs with the phase overcurrent element pickup setting. The relay asserts the phase overcurrent elements when any of the three phase currents exceeds the corresponding element pickup setting.

Negative-Sequence Overcurrent Elements

The SEL-421 negative-sequence overcurrent elements compare a negative-sequence calculation of the three-phase secondary inputs with the corresponding negative-sequence overcurrent element pickup setting. The relay makes this negative-sequence calculation (assuming ABC rotation):

$3I_2$ = A-Phase + B-Phase (shifted by –120°) + C-Phase (shifted by 120°)

The relay asserts negative-sequence overcurrent elements when the 3I2 calculation exceeds the corresponding negative-sequence current pickup setting. If balanced currents are applied to the relay, the relay reads $3I_2 \approx 0$ (load conditions) and does not pick up the negative-sequence overcurrent elements.

For testing, apply current to a single phase of the relay, causing the negative-sequence overcurrent elements to operate. For example, assume 1 A of current on A-Phase and zero current input on the B-Phase and C-Phase:

$3I_2$ = 1 A + 0 (shifted –120°) + 0 (shifted 120°) = 1 A (a simulated ground fault condition)

Ground Overcurrent Elements

The SEL-421 ground overcurrent elements compare a residual ground calculation of the three-phase inputs with the residual overcurrent setting. The relay makes this residual current calculation:

$3I_0$ = A-Phase + B-Phase + C-Phase

The relay asserts ground overcurrent elements when the $3I_0$ calculation exceeds the ground current element pickup setting. If balanced currents are applied to the relay, the relay reads $3I_0 = 0$ (load conditions) because the currents cancel in the calculation; the relay does not pick up the ground overcurrent elements.

For testing, apply current to a single phase of the relay, causing the residual overcurrent elements to operate. For example, assume 1 A of current on A-Phase and zero current input on B-Phase and C-Phase:

$3I_0 = 1 \text{ A} + 0 + 0 = 1 \text{ A}$ (a simulated ground fault condition)

Checking the Negative-Sequence Instantaneous Overcurrent Element, 50Q1

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The procedure in the following steps tests the 50Q1 negative-sequence overcurrent element. Use a similar procedure to test other overcurrent elements.

Step 1. Configure the relay.

a. Start ACSELERATOR QuickSet SEL-5030 Software, and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to QuickSet.

c. Expand the **Group 1** settings and click the **Negative-Seq Inst O/C** button of the **Settings** tree view as shown in *Figure 3.7*.

You will see the **Negative Sequence Instantaneous Overcurrent** dialog box similar to *Figure 3.7*.

d. Click the arrow in the **Instantaneous and Definite Time Overcurrent Element Levels E50Q** dialog box and select **1**.

e. For this test, set the **50Q1P** level to **1.00** and **67Q1TC** to **1**.

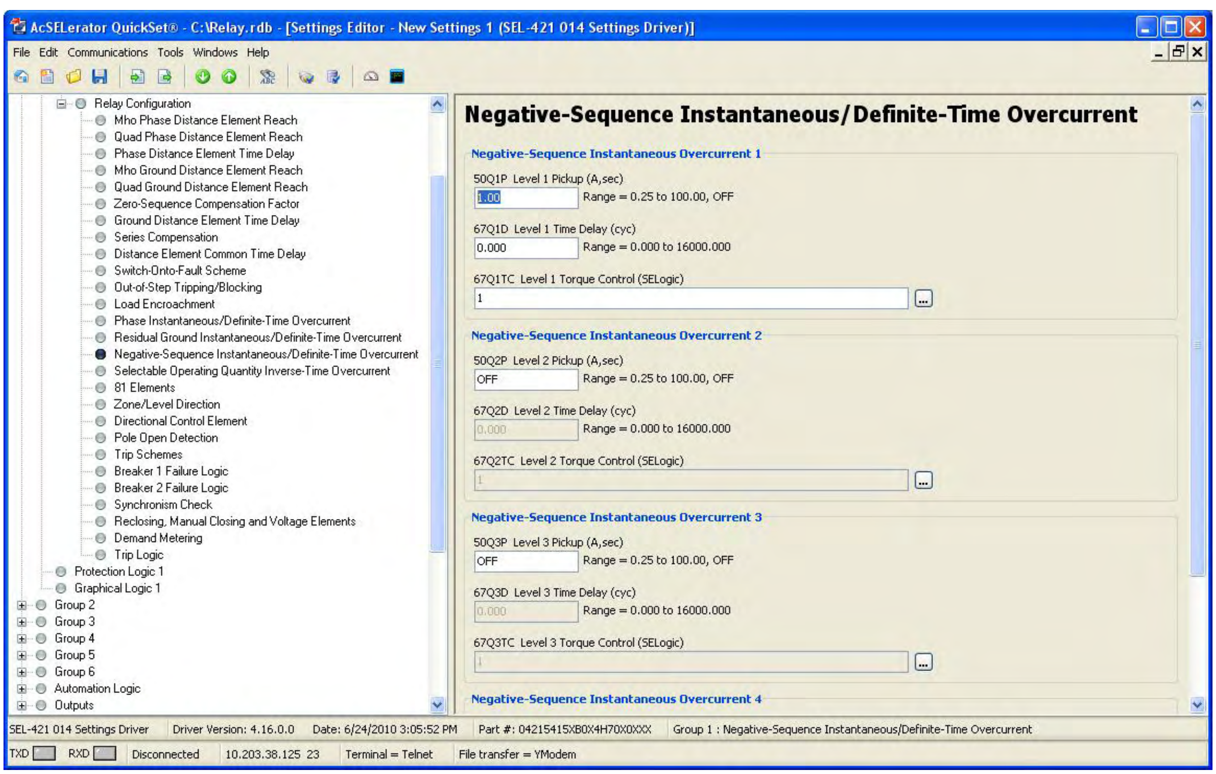


Figure 3.7 Negative-Sequence Instantaneous Overcurrent Element Settings: QuickSet

Step 2. Upload the new setting to the SEL-421.

a. Click **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box in *Figure 3.8*.

b. Click the check box for **Group 1**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box similar to *Figure 3.8*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in Figure 6.19 are for the SEL-421-5. The SEL-421-4 dialog boxes do not contain Automation 2 through Automation 10 setting instances.

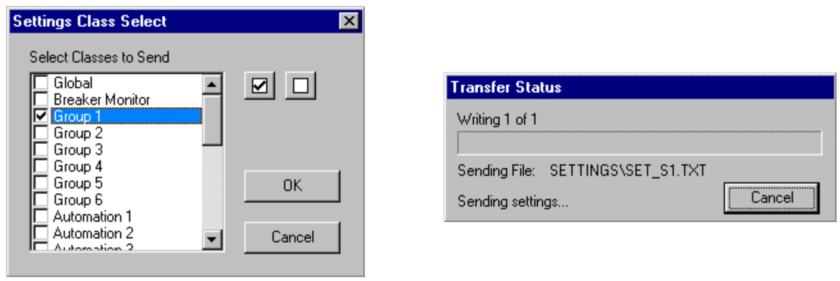


Figure 3.8 Uploading Group 1 Settings to the SEL-421

Step 3. Display the 50Q1 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **ENT**.

c. Press **ENT** to go to the `ELEMENT SEARCH` submenu shown in *Figure 3.9*.

d. Use the navigation keys to highlight `5` and then press **ENT** to enter characters in the text input field.

e. Enter the `0`, `Q`, and `1` characters in turn.

f. Highlight `ACCEPT` and press **ENT**.

The relay displays the screen containing the 50Q1 element, as shown in *Figure 3.10*.

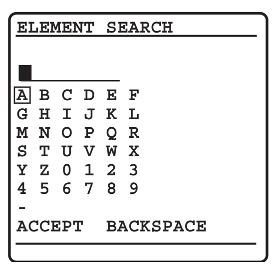


Figure 3.9 ELEMENT SEARCH Screen

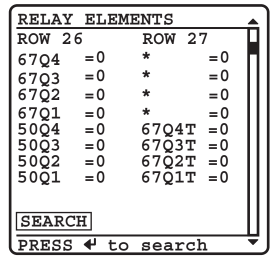


Figure 3.10 RELAY ELEMENTS Screen Containing Element 50Q1

Step 4. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input (see *Figure 3.5* and *Secondary Circuits on page 2.5*).

Step 5. Increase the current source to produce a current magnitude greater than 1.00 A secondary in the relay.

You will see that the 50Q1 element state changes on the LCD screen from 50Q1 = 0 to 50Q1 = 1.

Negative-Sequence Directional Element for Phase Faults

The SEL-421 features a phase directional element (represented by Relay Word bits F32P/R32P) to supervise the phase-distance elements and to control phase directional elements. The negative-sequence directional element, F32Q/R32Q, is a part of the phase directional element, F32P/R32P. Whenever the negative-sequence directional element asserts, the phase directional element asserts.

The relay also contains a ground directional element, F32G/R32G, for directional control of the ground-distance elements and ground overcurrent elements. For more information on directional elements, see *Ground Directional Element on page 5.33*, and *Section 6: Protection Applications Examples*.

The SEL-421 calculates the negative-sequence impedance Z2 from the magnitudes and angles of the negative-sequence voltage and current. *Equation 3.1* defines this function (the ‘c’ in Z2c indicates “calculated”).

$$
\begin{aligned}
Z2c &= \frac{\mathrm{Re}[V_2 \bullet (1\angle Z1ANG \bullet I_2)^*]}{|I_2|^2} \\
&= \frac{|V_2|}{|I_2|} \bullet \cos(\angle V_2 - \angle Z1ANG - \angle I_2)
\end{aligned}
$$

Equation 3.1

where:

V2 = the negative-sequence voltage
I2 = the negative-sequence current
Z1ANG = the positive-sequence line impedance angle
Re = the real part of the term in brackets, for example, (Re[A + jB] = A)
* = the complex conjugate of the expression in parentheses, (A + jB)* = (A – jB)

The result of *Equation 3.1* is an impedance magnitude that varies with the magnitude and angle of the applied current. Normally, a forward fault results in a negative Z2c relay calculation.

Test Current

Solve *Equation 3.1* to find the test current values that you need to apply to the relay to test the element. For the negative-sequence current I_2, the result is

$$|I_2| = \frac{|V_2|}{Z2c}$$

Equation 3.2

when:

$$\angle I_2 = \angle V_2 - \angle Z1ANG$$

Equation 3.3

Multiply the quantities in *Equation 3.2* by three to obtain $3I_2$, the negative-sequence current that the relay processes. With a fixed applied negative-sequence voltage V_A, the relay negative-sequence voltage is $3V_2$. Set Z2c = Z2F to find the test current magnitude at the point where the impedance calculation equals the forward fault impedance threshold. *Equation 3.2* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2F}$$

Equation 3.4

when:

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG$$

Equation 3.5

For a reverse fault impedance threshold, where Z2c = Z2R, *Equation 3.2* becomes:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2R}$$

Equation 3.6

when the angle calculation is the same as *Equation 3.5*.

For more information on the directional elements, see *Ground Directional Elements on page 1.18* and *Quadrilateral Ground-Distance Elements on page 1.18*. For settings and application information, see *Section 6: Protection Applications Examples*.

Checking the Negative-Sequence Directional Element (Phase Faults)

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

This test confirms operation of the F32Q and the R32Q negative-sequence directional elements. This test procedure is for a 5 A relay; scale values appropriately for a 1 A relay.

Step 1. Configure the relay.

a. Open QuickSet and read the present configuration in the SEL-421.

b. Click **Settings > Read**.

The relay sends all settings and configuration data to QuickSet.

c. Expand the **Group 1** settings and click the **Relay Configuration** branch of the Settings tree view as shown in *Figure 3.11*.

d. Disable supervisory elements.

Confirm that **ELOP** is set to **N**.

e. In a similar sequence, click on the **+** button to expand the **Relay Configuration** tree view, click on **Load Encroachment**, and confirm that **ELOAD** is set to **N**.

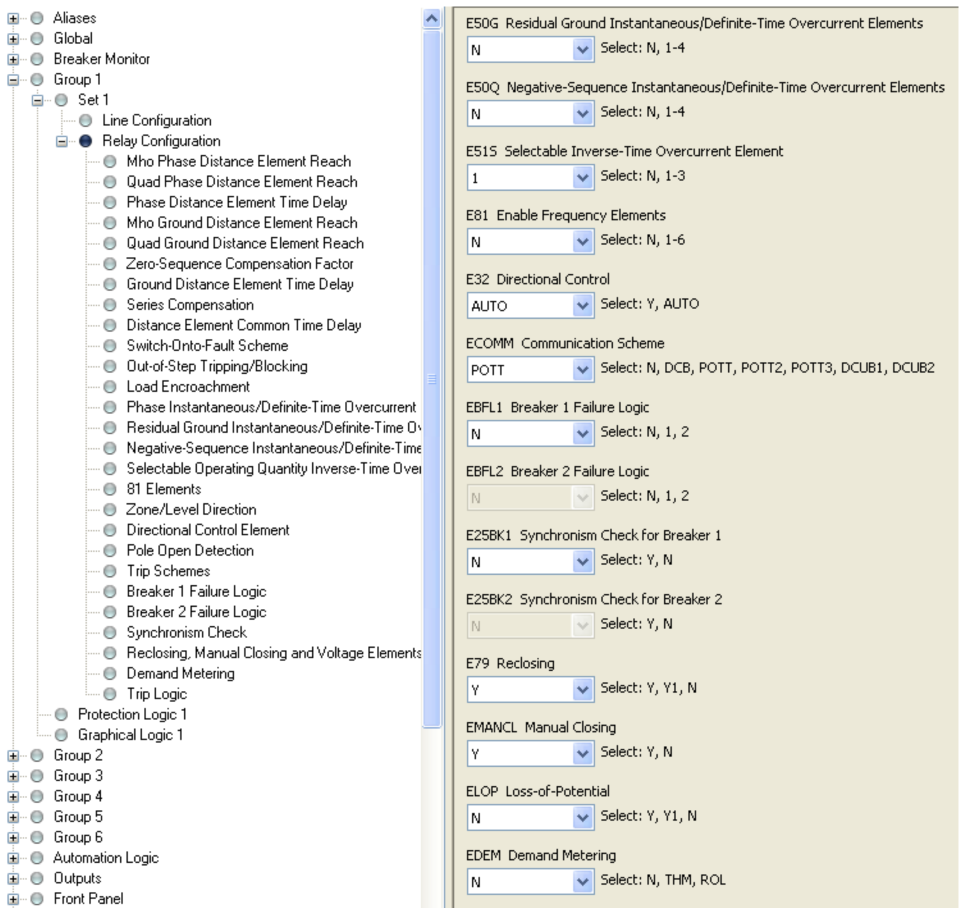


Figure 3.11 Group 1 Relay Configuration Settings: QuickSet

f. Defeat the pole-open logic.

g. Click the **+** button next to **Breaker Monitor** to expand the **Breaker Monitor** branch of the **Settings** tree view (see *Figure 3.12*).

h. Click **Breaker 1**.

You will see the **Breaker 1** dialog box similar to *Figure 3.12*.

i. Enter **1** in the text boxes for **52AA1 A-Phase N/O Contact Input -BK1, 52AB1 B-Phase N/O Contact Input -BK1**, and **52AC1 C-Phase N/O Contact Input -BK1**.

   The text boxes in *Figure 3.12* appear if Breaker Monitor setting BK1TYP := 1.

j. If BK1TYP := 3, enter **1** in the **52AA1 N/O Contact Input -BK1** text box (the other circuit breaker input boxes are dimmed.)

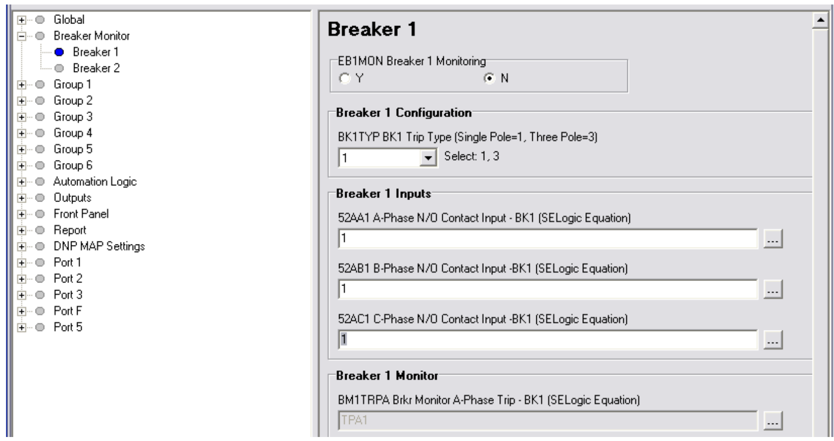


Figure 3.12 Breaker 1 Breaker Monitor Settings: QuickSet

Step 2. Set test values in the relay.

a. Expand the **Group 1** settings as shown in *Figure 3.13* and select the **Line Configuration** button.

   You will see the **Line Configuration** dialog box of *Figure 3.13*.

b. Confirm the default settings of **Z1MAG** at **7.80** and **Z1ANG** at **84.00**.

c. Click the **+** mark next to the **Relay Configuration** branch to expand that **Settings** branch.

d. Select the **Directional** button.

   You will see the Directional dialog box similar to *Figure 3.14*.

e. Confirm the following settings: **E32** is **AUTO**, **ORDER** is **Q**, **50FP** is **0.60**, **50RP** is **0.40**, **Z2F** is **3.90**, **Z2R** is **4.00**, **a2** is **0.10**, and **k2** is **0.2**.

   The dialog box is dim since there are no settings to change.

   The relay calculates these numeric settings automatically because **E32** is set to **AUTO**.

f. If you need to change these settings, set **E32** to **Y**.

   Table 3.3 shows the calculations.

   See *Ground Directional Elements on page 1.18* for details on these relay calculations.

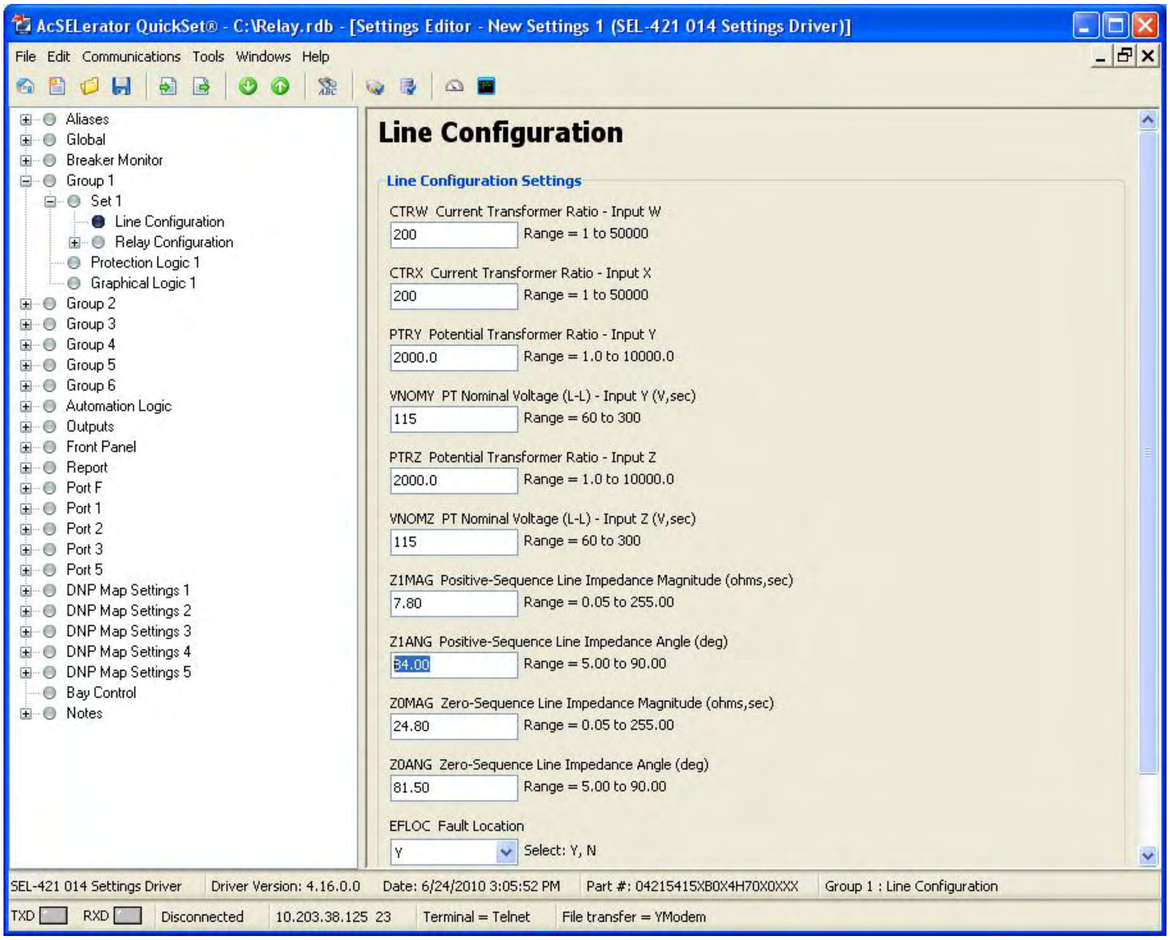


Figure 3.13 Group 1 Line Configuration Settings: QuickSet

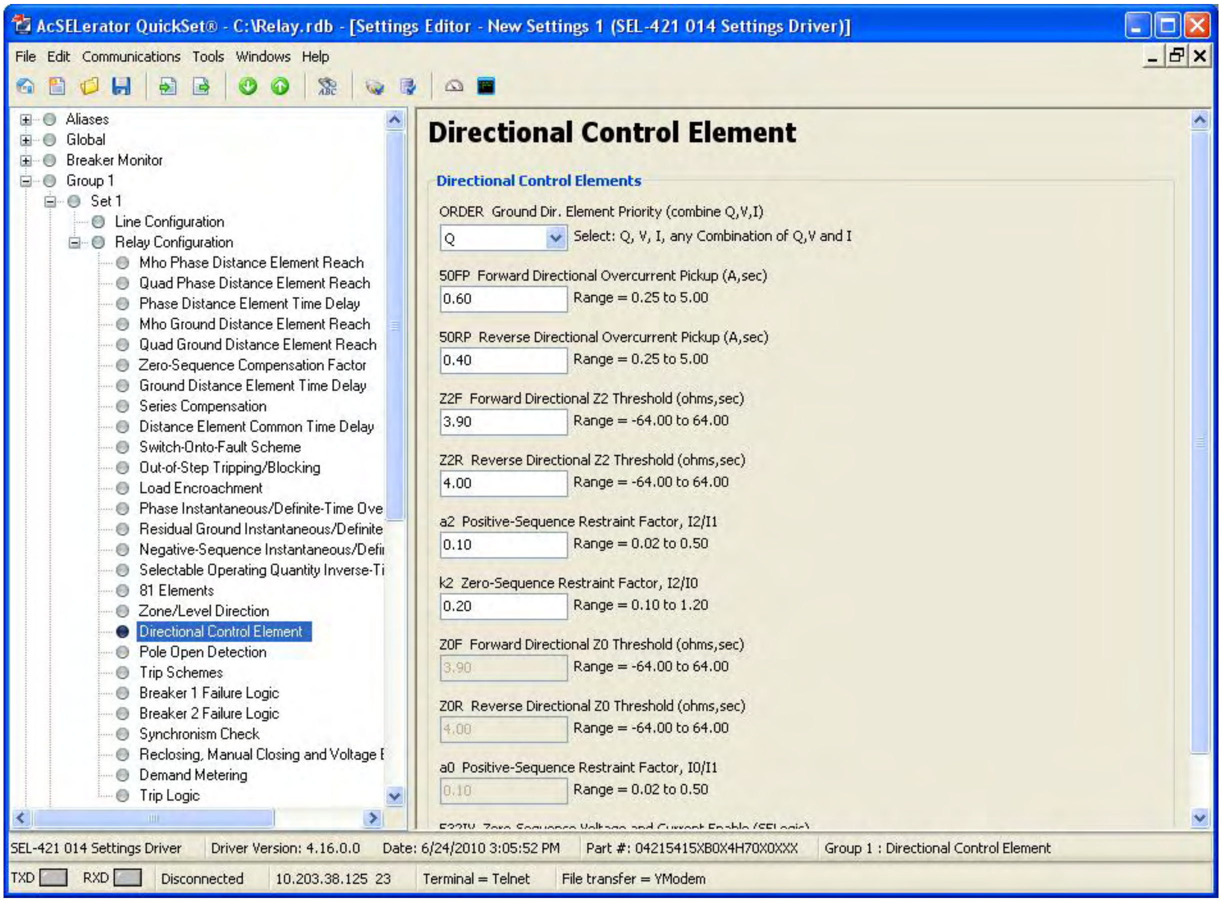


Figure 3.14 Directional Settings: QuickSet

Table 3.3 Negative-Sequence Directional Element Settings AUTO Calculations

Setting	Calculation
50FP	$0.12 \bullet I_{NOM}$
50RP	$0.08 \bullet I_{NOM}$
Z2F	0.5 • Z1MAG
Z2R	$Z2F + 1/(2 \bullet I_{NOM})$
a2	0.1
k2	0.2

Step 3. Upload the new settings to the SEL-421.

a. Click **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Select Groups** dialog box in *Figure 3.15*.

b. Click the check box for **Group 1** and for **Breaker Monitor**.

c. Click **OK**.

d. QuickSet responds with a **Transfer Status** dialog box as in *Figure 3.15*.

If you see no error message, the new settings are loaded in the relay.

NOTE: The **Relay Editor** dialog boxes shown in *Figure 3.15* are for the SEL-421-5. The SEL-421-4 dialog boxes do not contain Automation 2 through Automation 10 setting

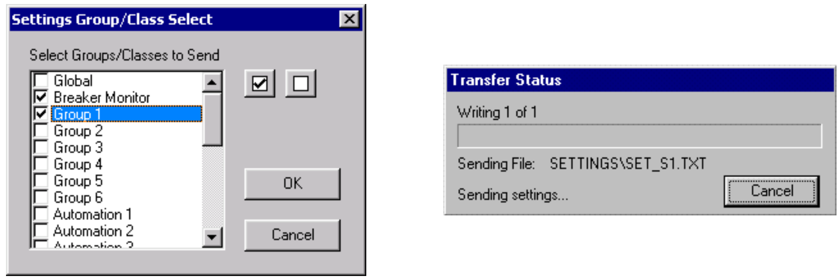


Figure 3.15 Uploading Group 1 and Breaker Monitor Settings to the SEL-421

Step 4. Display the F32Q and R32Q Relay Word bits on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **ENT**.

You will see a `RELAY ELEMENTS` screen with `SEARCH` highlighted at the bottom of the screen.

c. Press **ENT** to go to the `ELEMENT SEARCH` submenu shown in *Figure 3.9*.

d. Enter characters in the text input field using the navigation keys.

e. Highlight `F` and press **ENT** to enter the `F` character.

f. Enter the `3`, `2`, and `Q` characters in like manner.

g. Highlight `ACCEPT` and press **ENT**.

The relay displays the screen containing the F32Q and R32Q elements, as shown in *Figure 3.16*.

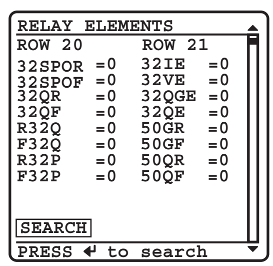


Figure 3.16 RELAY ELEMENTS LCD Screen Containing Elements F32Q and R32Q

Step 5. Calculate impedance thresholds.

a. For this test, apply an A-Phase voltage of $V_A = 3V_2 = 18.0 \angle 180°$ V secondary.

b. Use *Equation 3.6* to find the current that is equal to the reverse impedance threshold Z2R:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2R} = \frac{|18.0\angle 180°V|}{4.00} = 4.50 \text{ A}$$

Equation 3.7

Step 6. Use *Equation 3.4* to find the current that is equal to the forward impedance threshold Z2F:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2RF} = \frac{|18.0\angle 180°V|}{3.90} = 4.62 \text{ A}$$

Equation 3.8

Step 7. Use *Equation 3.5* to determine the applied current angle ($\angle I_{TEST}$):

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG = 180° - 84° = 96°$$

Step 8. Apply a test current to confirm operation of R32Q and F32Q.

a. Connect a single current test source as shown in *Figure 3.5*.

b. Apply an A-Phase voltage of $V_A = 18.0 \angle 180°$ V secondary.

c. Set the current source for $I_A = 0.0 \angle 96°$ A.

d. Slowly increase the magnitude of I_A to apply the source test current.

e. Observe the RELAY ELEMENT LCD screen.

Relay Word bit R32Q asserts when $|I_A| = 0.4$ A, indicating that the relay negative-sequence current is greater than the 50RP pickup threshold.

R32Q deasserts when $|I_A| = 4.5$ A, indicating that the relay negative-sequence calculation Z2c is now less than the Z2 reverse threshold Z2R (see *Forward Threshold on page 5.43* and *Reverse Threshold on page 5.44*).

f. Continue to increase the current source while you observe the RELAY ELEMENT LCD screen.

Relay Word bit F32Q asserts when $|I_A| = 4.62$ A, indicating that the relay negative-sequence calculation Z2c is less than the Z2 forward threshold Z2F.

Distance Elements

Apply voltages and currents to the relay analog inputs that simulate fault and load conditions to test distance elements. The relay supervises distance elements so that these elements operate under the appropriate conditions. Be sure to satisfy all the element supervisory conditions before testing a relay element. For supervisory conditions for a particular element, see *Mho Ground-Distance Elements on page 5.72*.

Phase-to-Phase Distance Element MBC2

The SEL-421 contains mho phase-distance elements among the many protection elements in the relay. The relay has phase-distance elements to detect phase-to-phase faults, phase-to-phase-to-ground faults, and three-phase faults. The SEL-421 has five independent zones of mho phase-distance protection; each zone consists of phase-to-phase elements that the relay combines to produce a particular zone output.

For example, the OR combination of MAB2, MBC2, and MCA2 produces the Z2P Zone 2 mho phase element. For more information on the mho phase elements and other distance elements, see *Section 5: Protection Functions* and *Section 6: Protection Applications Examples*.

Test Current and Voltage for a Phase-to-Phase Fault

To find the test current for a phase-to-phase fault, consider *Equation 3.9* for a B-Phase to C-Phase fault:

$$I_{TEST} = I_B = -I_C$$

Equation 3.9

The B-Phase to C-Phase current vector, I_{BC}, is:

$$I_{BC} = I_B - I_C = I_B + (I_B) = 2 \bullet I_B = 2 \bullet I_{TEST}$$

Equation 3.10

Choose a convenient test source current magnitude, $|I_{TEST}| = 2.5$ A; then $|I_{BC}| = 2 \bullet |I_{TEST}| = 5$ A.

Find the magnitude of the test source voltage $|V_{TEST}|$:

$$\begin{aligned} |V_{TEST}| &= |V_{BC}| = |I_{BC}| \bullet |Z_{BC}| = |I_{BC}| \bullet Z2MP \\ &= 2 \bullet |I_{TEST}| \bullet Z2MP \end{aligned}$$

Equation 3.11

where relay setting Z2MP (Zone 2 Reach) substitutes for the B-Phase to C-Phase impedance Z_{BC}. For setting Z2MP of 9.36 Ω, the test voltage magnitude $|V_{BC}|$ is:

$$\begin{aligned} |V_{TEST}| &= 2 \bullet |I_{TEST}| \bullet Z2MP \\ &= 2 \bullet 2.5 \bullet 9.36 = 46.8 \text{ V} \end{aligned}$$

Equation 3.12

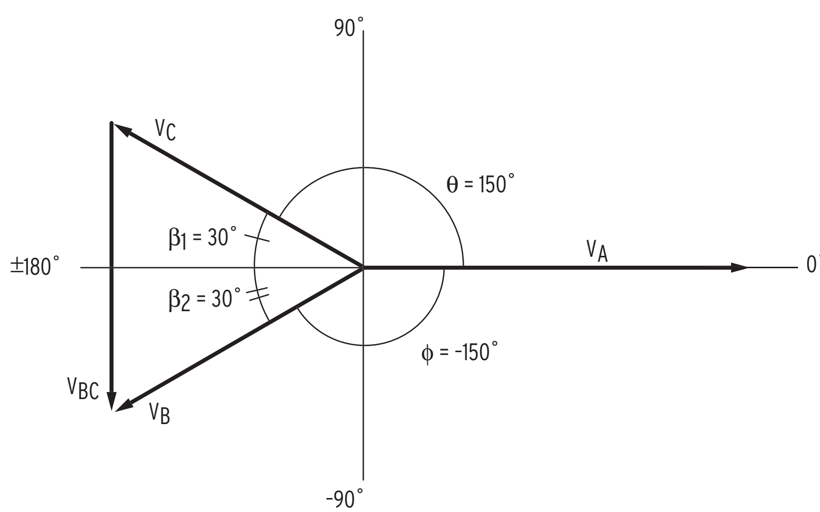


Figure 3.17 Finding Phase-to-Phase Test Quantities

One way to create a V_{BC} phasor is to equate $|V_B|$ and $|V_C|$ and determine the appropriate angles to make an equilateral triangle, as shown in *Figure 3.17*.

Subtract 30 degrees (angle β_1) from 180 degrees to obtain the angle for test source V_C phasor; $V_C = 46.8 \angle 150°$ V.

Similarly, add 30 degrees (angle β_2) to –180 degrees to obtain test source V_B phasor; $V_B = 46.8 \angle{-150°}$ V.

Test voltage V_A can be the nominal value, $V_A = 67 \angle 0°$ V.

Thus, the resulting phase-to-phase voltage is $V_{BC} = 46.8 \angle{-90°}$ V, referenced to the V_A phasor at 0 degrees.

The relay measures phase-distance element maximum reach when the faulted phase-to-phase current lags the faulted phase-to-phase voltage by the distance element maximum torque angle. In the SEL-421, the phase-distance element maximum torque angle is setting Z1ANG. Current I_{BC} should lag voltage V_{BC} by Z1ANG.

In this example, Z1ANG is 84.0 degrees. From *Equation 3.9*, the angle of I_B is the angle of I_{TEST}, and the angle of I_C is 180 degrees from the angle of I_{TEST}. The test source current for I_B is the following:

$$\begin{aligned} I_B &= 2.5\angle(-90° - Z1ANG)A \\ &= 2.5\angle(-90° - 84°)A \\ &= 2.5\angle{-174°}A \end{aligned}$$

Equation 3.13

And the test source current for I_C is the following:

$$I_C = -I_B = -(2.5\angle{-174°}A) = 2.5\angle 6°A$$

Equation 3.14

Checking the MBC2 Portion of the Z2P Phase-Distance Element

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

The following procedure describes how to test the B-Phase to C-Phase distance element MBC2. Although this test refers directly to the Zone 2 phase-distance element, you can apply this procedure to any other forward-reaching phase-to-phase distance element zone.

Step 1. Configure the relay.

Perform the procedure listed under *Step 1* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page 3.13*.

Step 2. Set test values in the relay.

Perform the procedure listed under *Step 2* in *Checking the Negative-Sequence Directional Element (Phase Faults) on page 3.13*.

Step 3. Set the phase-distance element reach.

a. Select the **Phase Distance** button of the QuickSet **Settings** tree view.

You will see the **Phase Distance Elements** dialog box similar to *Figure 3.18*.

b. Confirm the settings of **E2IP** at **2**, **Z1MP** at **6.24** and **Z2MP** at **9.36**.

Figure 3.18 Phase-Distance Elements Settings: QuickSet

Step 4. Upload the new settings to the SEL-421.

a. Click **File > Send**.

b. QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 3.15*.

c. Click the check box for **Group 1**.

d. Click **OK**.

QuickSet responds with a dialog box similar to the second dialog box of *Figure 3.15*.

If you see no error message, the new settings are loaded in the relay.

Step 5. Display the MBC2 Relay Word bit on the front-panel LCD screen.

a. Access the front-panel LCD `MAIN MENU`.

b. Highlight `RELAY ELEMENTS` and press **ENT**.

c. You will see a `RELAY ELEMENTS` screen with `SEARCH` highlighted at the bottom of the screen.

d. Press **ENT** to go to the `ELEMENT SEARCH` submenu shown in *Figure 3.9*.

e. Use the navigation keys to highlight `M` and press **ENT** to enter character in the text input field.

f. Enter the `B`, `C`, and `2` characters in like manner.

g. Highlight `ACCEPT` and press **ENT**.

The relay displays the LCD screen containing the MBC2 element, as shown in *Figure 3.19*.

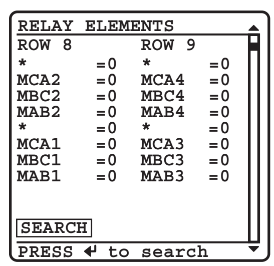


Figure 3.19 RELAY ELEMENTS LCD Screen Containing Element MBC2

Step 6. Set the magnitudes and angles of the test signals for a B-Phase-to-C-phase fault.

a. Connect the test sources (with power off) to the relay, as in *Figure 3.6*.

This connection is a B-Phase-to-C-Phase fault where $I_A \approx 0$ and $I_B = -I_C$.

b. Adjust the voltage sources to provide the following test voltages: $V_A = 67$ V $\angle 0°$, $V_B = 46.8$ V $\angle -150°$, and $V_C = 46.8$ V $\angle 150°$.

c. Set the current source for $I_B = 0.0$ A $\angle -174°$.

Step 7. Apply the sources to confirm operation of MBC2.

a. Apply the source test current by slowly increasing the magnitude of I_B.

b. Observe the RELAY ELEMENT LCD screen.

Relay Word bit MBC2 asserts when $|I_B| \geq 2.5$ A, indicating that the relay impedance calculation is less than the Z2MP reach setting.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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SECTION 4

Front-Panel Operations

The SEL-421 Relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can analyze power system operating information, view and change relay settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED indicators give a quick look at SEL-421 operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

- ➤ Reading metering
- ➤ Inspecting targets
- ➤ Accessing settings
- ➤ Controlling relay operations

General front-panel operations are described in the *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual*. This section provides additional information that is unique to the SEL-421. This section includes the following:

Front-Panel LCD Default Displays

The SEL-421 has two screen scrolling modes: autoscrolling mode and manual-scrolling mode. After front-panel time out, the LCD presents each of the display screens in this sequence:

- ➤ One-line diagram
- ➤ Any active (filled) alarm points screens
- ➤ Any active (filled) display points screens
- ➤ Enabled metering screens

The relay displays enabled metering screens in the order listed in *Table 4.1*. (see *Figure 4.4* for samples of the metering screens.) This sequence comprises the ROTATING DISPLAY.

Table 4.1 Metering Screens Enable Settings

Name	Prompt	Range	Default
RMS_V	RMS Line Voltage Screen	Y, N	N
RMS_I	RMS Line Current Screen[a]	Y, N	Y
RMS_VPP	RMS Line Voltage Phase-to-Phase Screen	Y, N	N
RMS_W	RMS Active Power Screen	Y, N	N
FUNDVAR	Fundamental Reactive Power Screen	Y, N	N
RMS_VA	RMS Apparent Power Screen	Y, N	N
RMS_PF	RMS Power Factor Screen	Y, N	N
RMS_BK1	RMS Breaker 1 Currents Screen	Y, N	N
RMS_BK2	RMS Breaker 2 Currents Screen	Y, N	N
STA_BAT	Station Battery Screen	Y, N	N
FUND_VI	Fundamental Voltage and Current Screen[a]	Y, N	Y
FUNDSEQ	Fundamental Sequence Quantities Screen	Y, N	N
FUND_BK	Fundamental Breaker Currents Screen	Y, N	N
ONELINE	One Line Bay Control Diagram	Y, N	N

[a] The default displays are RMS_I and FUND_VI.

NOTE: The initial display can present only the RMS_I line-current screen. This can occur when you have not enabled any of the metering screens, alarm points, and display points.

Use the front-panel settings (the **SET F** command from a communications port or the Front Panel settings in ACSELERATOR QuickSet SEL-5030 Software) to access the metering screen enables. Entering a **Y** (Yes) for a metering screen enable setting causes the corresponding metering screen to appear in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. *Figure 4.1* shows a sample ROTATING DISPLAY consisting of an example alarm points screen, an example display points screen, and the two factory-default metering screens, RMS_I and FUND_VI (the screen values in *Figure 4.1* are representative values).

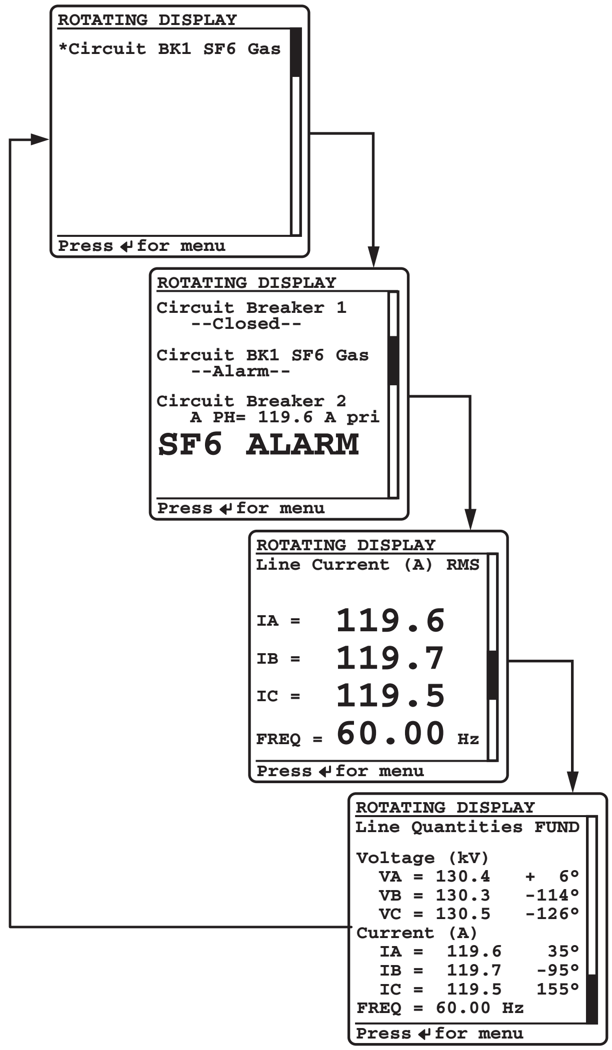


Figure 4.1 Sample ROTATING DISPLAY

The active alarm points are the first screens in the ROTATING DISPLAY (see *Alarm Points on page 4.7 in the SEL-400 Series Relays Instruction Manual*). Each alarm points screen shows as many as eleven alarm conditions. The SEL-421 can present a maximum of six alarm points screens.

The active display points are the next screens in the ROTATING DISPLAY (see *Display Points on page 4.10 in the SEL-400 Series Relays Instruction Manual*). Each display points screen shows as many as 11 enabled display points. (With 96 display points, the SEL-421 can present a maximum of 9 display points screens.) If a display point does not have text to display, the screen space for that display point is maintained.

Front-Panel Menus and Screens

Operate the SEL-421 front panel through a sequence of menus that you view on the front-panel display. The MAIN MENU is the introductory menu for other front-panel menus. These additional menus allow you on-site access to metering, control, and settings for configuring the SEL-421 to your specific application needs. Use the following menus and screens to set the relay, perform local control actions, and read metering:

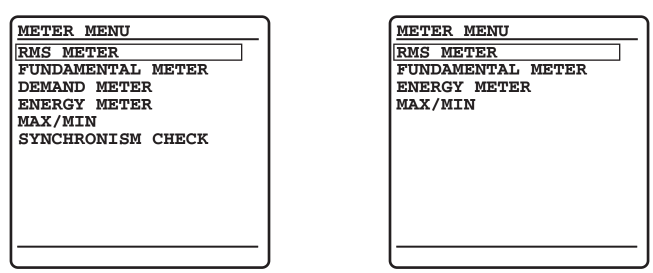
- Support Screens
  - Contrast
  - Password
- MAIN MENU
  - METER
  - EVENTS
  - BREAKER MONITOR
  - RELAY ELEMENTS
  - LOCAL CONTROL
  - SET/SHOW
  - RELAY STATUS
  - VIEW CONFIGURATION
  - DISPLAY TEST
  - RESET ACCESS LEVEL
  - ONELINE DIAGRAM

See *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual* for information on most of these screens. The following screen descriptions are unique to the SEL-421.

Meter

The SEL-421 displays metering screens on the LCD. Highlight METER on the MAIN MENU screen to select these screens. The METER MENU, shown in *Figure 4.2*, allows you to choose the following metering screens corresponding to the relay metering modes:

- RMS METER
- FUNDAMENTAL METER
- DEMAND METER (if enabled)
- ENERGY METER
- MAX/MIN
- SYNCHRONISM CHECK (if enabled)



Demand Meter Enabled (EDEM := ROL or EDEM := THM) Synchronism Check Enabled (E25BK1 := Y, Y1, Y2 or E25BK2 := Y, Y1, Y2)

No Synchronism Check No Demand Metering (E25BK1 := N) (E25BK2 := N) (EDEM := OFF)

Figure 4.2 METER MENU Screens

NOTE: Global settings ESS (Enable Source Selection) and NUMBK (Number of Circuit Breakers) affect how the SEL-421 determines the line current and the voltage source for protection functions (directional elements, load encroachment, out-of-step logic, distance element, and loss-of-potential).

Combinations of relay Global settings ESS and NUMBK give you metering data for Line, Circuit Breaker 1, and Circuit Breaker 2 when you view RMS METER, FUNDAMENTAL METER, and MAX/MIN metering screens. The relay shows the METER SUBMENU of *Figure 4.3* so you can choose the line or circuit breaker data that you want to display.

For example, if you have two sources feeding a transmission line through two circuit breakers and you set ESS := 3, NUMBK := 2, then the SEL-421 measures BREAKER 1 currents, BREAKER 2 currents, and combined (Circuit Breakers 1 and 2) currents for LINE. The relay displays the METER SUBMENU screen when you make this settings configuration.

Other combinations of settings ESS and NUMBK do not require separate circuit breaker metering screens; for these configurations, the relay does not present the METER SUBMENU screen. See *Section 5: Protection Functions* and *Global Settings on page 6.3* for information on configuring global settings ESS, NUMBK, LINEI, BK1I, and BK2I.

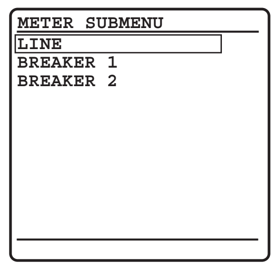


Figure 4.3 METER SUBMENU

The relay presents the meter screens in the order shown in each column of *Figure 4.4* and *Figure 4.5*. Once you have selected the type of metering data to display (RMS METER, FUNDAMENTAL METER, DEMAND METER, ENERGY METER, MAX/MIN, or SYNCHRONISM CHECK), you can scroll through the particular display column by pressing the **Down Arrow** pushbutton. Return to a previously viewed screen in each column by pressing the **Up Arrow** pushbutton. Press **ESC** to revert the LCD screen to the METER SUBMENU and METER MENU screens.

The metering screens show reset options for the MAX/MIN, ENERGY METER, PEAK DEMAND METER, and DEMAND METER metering quantities at the end of each screen column. Use the **Left Arrow** and **Right Arrow** pushbuttons to select a NO or YES response to the reset prompt, and then press **ENT** to reset the metering quantity.

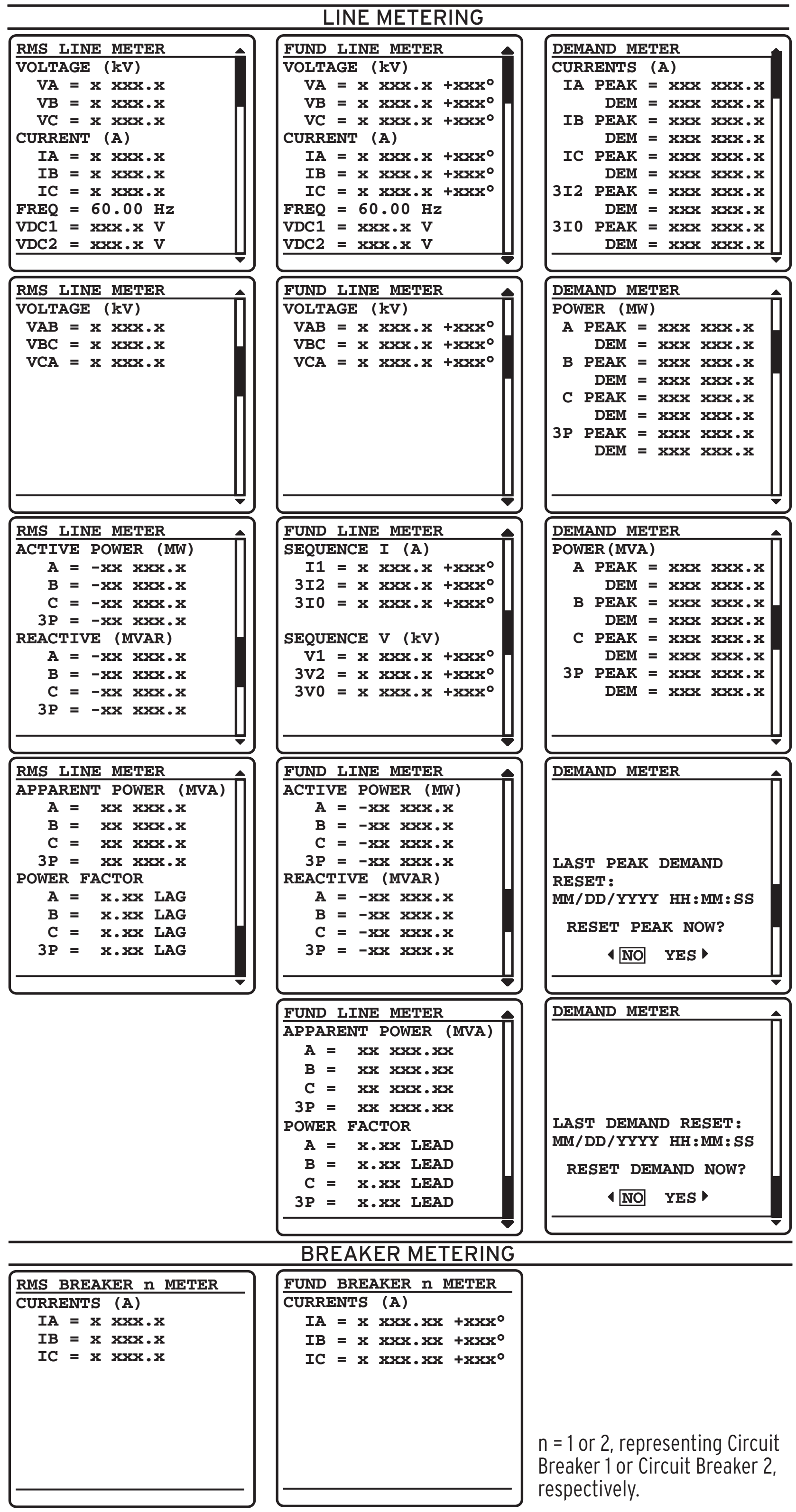


Figure 4.4 RMS, FUND, and DEMAND Metering Screens

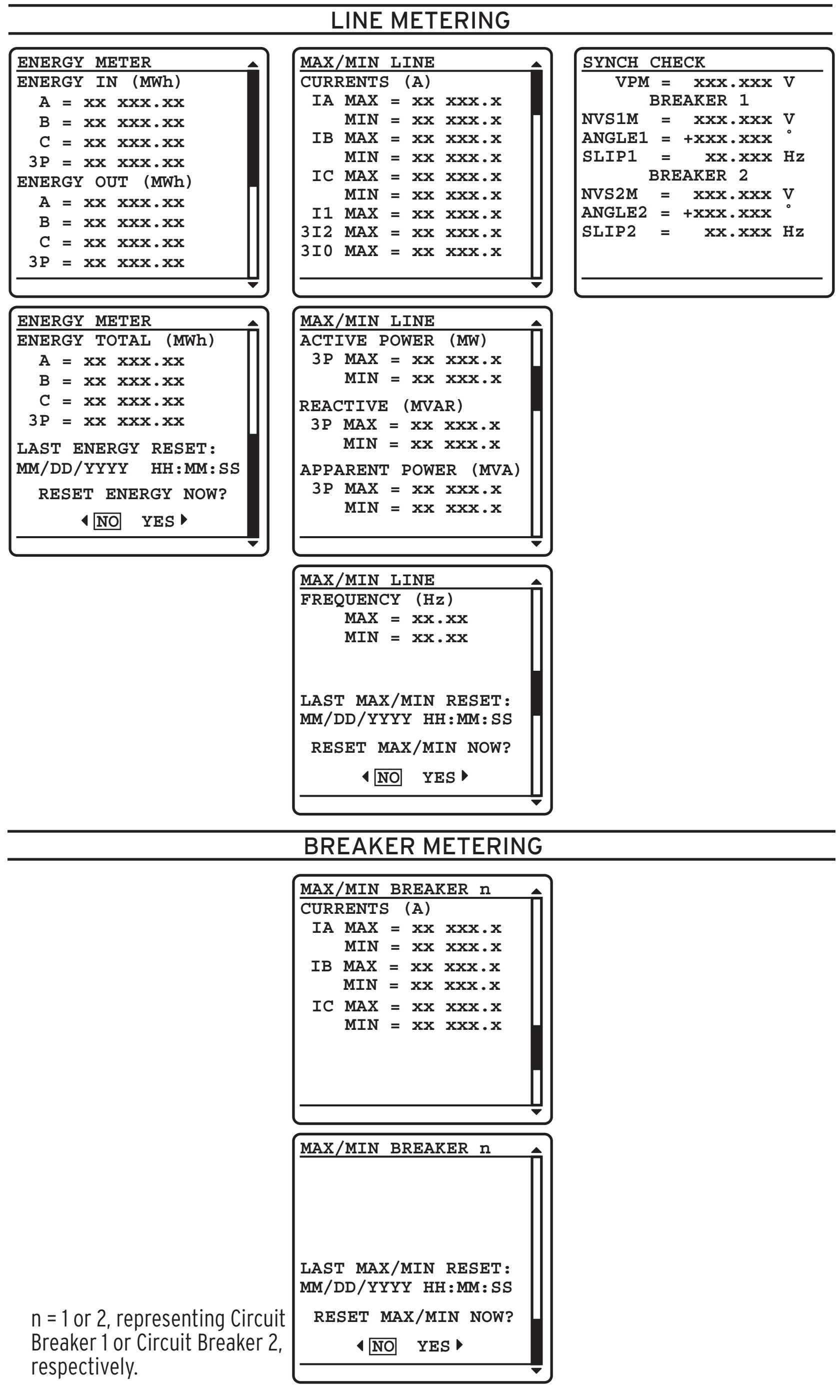


Figure 4.5 ENERGY, MAX/MIN, and SYNCH CHECK Metering Screens

Events

The *Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual* describes how to view summary events from the front panel. *Figure 4.6* illustrates what a summary event report looks like in a SEL-421.

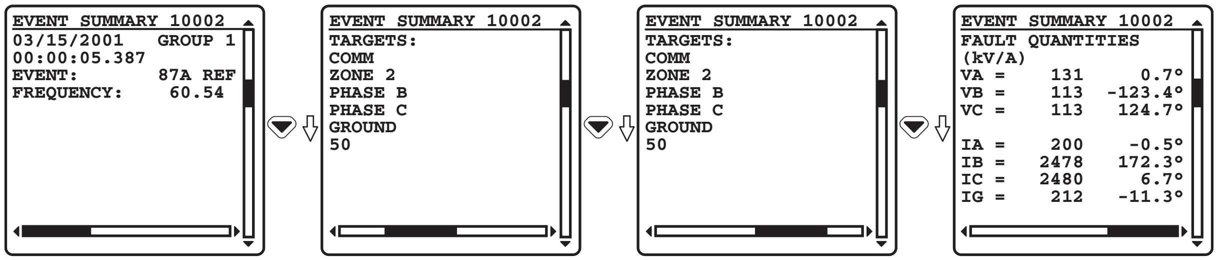


Figure 4.6 EVENT SUMMARY Screens

Breaker Monitor

The SEL-421 features an advanced circuit breaker monitor. Select BREAKER MONITOR screens from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display.

Figure 4.7 shows sample breaker monitor display screens. The BKR n ALARM COUNTER screen displays the number of times the circuit breaker exceeded certain alarm thresholds (see *Circuit Breaker Monitor on page 7.7*).

If you have two circuit breakers and have set NUMBK := 2, the alarm submenu in *Figure 4.7* appears first. Use the navigation pushbuttons to choose either Circuit Breaker 1 or Circuit Breaker 2. Press **ENT** to view the selected circuit breaker monitor information. An example of the Circuit Breaker 1 ALARM COUNTER screen for a single-pole tripping circuit breaker is shown on the right side of *Figure 4.7*.

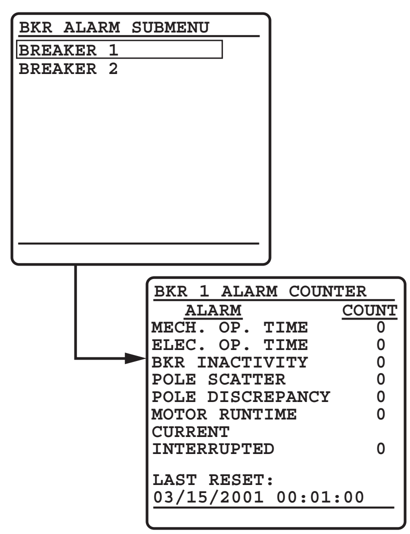


Figure 4.7 BREAKER MONITOR Report Screens

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-421 Relay. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. The relay presents four screens in the order shown in *Figure 4.8*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **ESC** to return to the MAIN MENU.

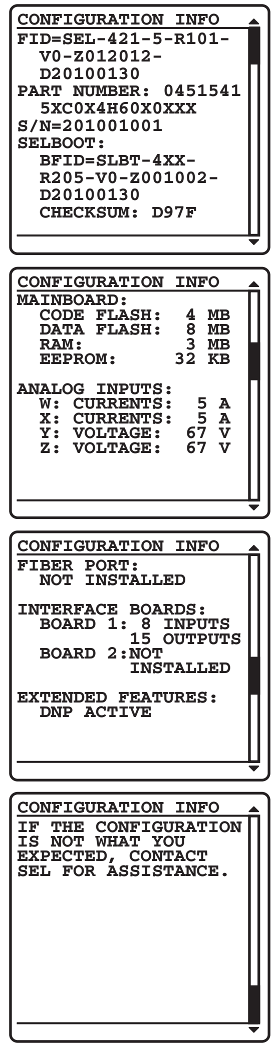


Figure 4.8 VIEW CONFIGURATION Sample Screens

Target LEDs

The SEL-421 gives you at-a-glance confirmation of relay conditions via operation and target LEDs. These LEDs are located in the middle of the relay front panel. The SEL-421 provides either 16 or 24 LEDs depending on ordering option.

Section 4: Front-Panel Operations in the SEL-400 Series Relays Instruction Manual describes the general operation and configuration of these LEDs. In the SEL-421, targets latch when a trip occurs. For a concise listing of the default programming on the front-panel LEDs, see *Front-Panel Settings on page 8.35*.

Use the slide-in labels to mark the LEDs with custom names. Included on the SEL-421 Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier.

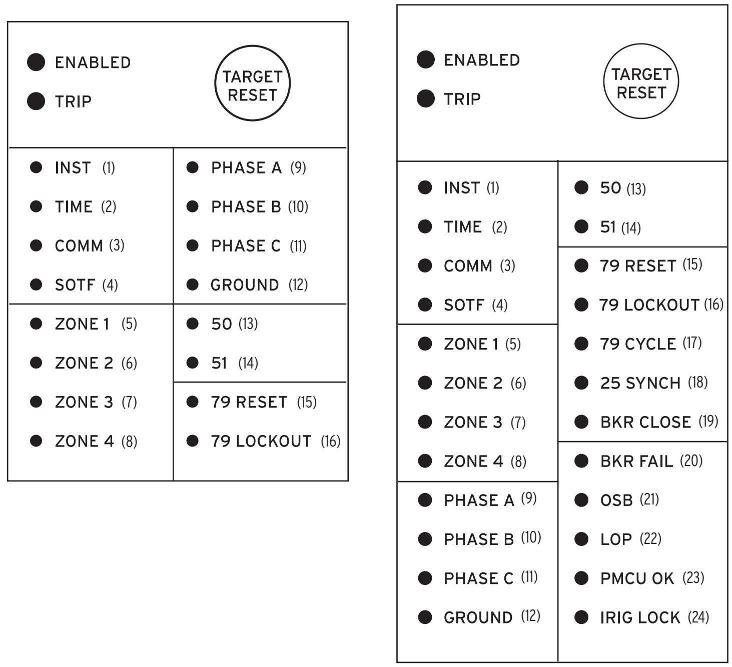


Figure 4.9 Factory-Default Front-Panel Target Areas (16 or 24 LEDs)

Figure 4.9 shows the arrangement of the operation and target LEDs region into several areas described in *Table 4.2*.

Table 4.2 Front-Panel Target LEDs

Label	Function
ENABLED, TRIP	Operational
INST, TIME, COMM, SOTF	Trip Type
ZONE 1, ZONE 2, ZONE 3, ZONE 4	Zone Activated
PHASE A, PHASE B, PHASE C, GROUND	Phase(s) or Ground
50, 51	Instantaneous and Time-Delayed Overcurrent
79 RESET, 79 LOCKOUT, 79 CYCLE[a]	Recloser Status
25 SYNCH[a], BKR CLOSE[a], BKR FAIL[a], OSB[a], LOP[a]	Miscellaneous Status
PMCU OK[a], IRIG LOCKED[a]	Synchrophasor Status

[a] Only available in 24 LED models.

Trip Type

The SEL-421 indicates essential information about the most recent relay trip event with the LEDs of the Trip Type area. These trip types are INST, TIME, COMM, and SOTF. For information on setting the corresponding trip logic, see *Trip Logic on page 5.137*.

The INST target LED illuminates, indicating operation of the SEL-421 instantaneous elements. This LED lights if elements Z1P (the Zone 1 mho phase-distance element) or Z1G (the Zone 1 mho ground-distance element) pick up and the relay has not illuminated the COMM or SOTF targets.

The TIME target LED indicates that a timed relay element caused a relay trip. *Table 4.3* lists the elements that activate the TIME LED in the factory-default settings.

Table 4.3 TIME Target LED Trigger Elements—Factory Defaults

Mho	Quadrilateral
M2PT	Z2GT
M3PT	Z3GT
M4PT	Z4GT
M5PT	Z5GT

The COMM LED illuminates, indicating that tripping resulted from a communications-assisted trip. The relay lights the COMM target when there is a relay tripping condition and the Relay Word bit COMPRM (communications-assisted trip permission) asserts.

The SOTF target LED indicates that the switch-onto-fault protection logic operated. The relay illuminates the SOTF target when there is a relay tripping condition and the Relay Word bit SOTFT (switch-onto-fault trip) asserts.

Zone Activated

The zone activated area target indicators are the ZONE 1, ZONE 2, ZONE 3, and ZONE 4 LEDs. These targets illuminate when the corresponding zone distance elements pick up and there is a relay tripping condition.

In factory-default programming, the lowest zone LED has priority; only the LED corresponding to the closest protection zone latches for distance element pickups.

The ZONE 1 target illuminates if either the Z1P or Z1G distance elements operated or if the high-speed Zone 1 elements operated.

The ZONE 2 target illuminates if either the Z2P or Z2G distance elements operated or if the high-speed Zone 2 elements operated and the similar elements in Zone 1 did not operate.

The ZONE 3 target illuminates if either the Z3P or Z3G distance elements operated or if the high-speed Zone 3 elements operated and the similar elements in Zone 1 and Zone 2 did not operate.

The ZONE 4 target illuminates if either the Z4P or Z4G distance elements operated and the similar elements in Zone 1, Zone 2, and Zone 3 did not operate.

Phase(s) or Ground

The phase(s) or ground targets illuminate according to the SEL-421 special targeting logic. This logic accurately classifies which phase, phases, and/or ground were involved in a trip event.

The PHASE A target LED lights for faults on the power system A-Phase. Single-phase-to-ground faults from A-Phase to ground illuminate both the PHASE A and GROUND targets. A phase-to-phase fault between A-Phase and B-Phase illuminates the PHASE A target and the PHASE B target.

The relay displays faults involving other phase combinations similarly. If the phase-to-phase fault includes ground, the relay also lights the GROUND target. The relay lights the PHASE A, PHASE B, and PHASE C target LEDS for a three-phase fault.

Instantaneous and Time-Delayed Overcurrent

The **50** target LED indicates that an instantaneous overcurrent element picked up. These elements are the nondirectional 50P*n* phase overcurrent elements, 50Q*n* negative-sequence overcurrent elements, and the 50G*n* ground overcurrent elements, where *n* is the overcurrent level; *n* = 1, 2, 3, and 4.

The **51** target LED illuminates if a time-overcurrent element has timed out. The relay lights this LED if any of the selectable operating quantity inverse-time overcurrent elements 51S1T, 51S2T, and 51S3T assert.

Recloser Status

The **79 RESET**, **79 LOCKOUT**, and **79 CYCLE** target LEDs show the operating status of the SEL-421 reclosing function.

The **79 RESET** LED indicates that the relay recloser is in the reset or ready-to-reclose state for Circuit Breaker 1 (Relay Word bit BK1RS is asserted).

The **79 LOCKOUT** target illuminates when the relay has completed the reclose attempts unsuccessfully (a drive-to-lockout condition), or when other programmed lockout conditions exist.

The **79 CYCLE** target illuminates when the relay the relay is in the autoreclose cycle state for Circuit Breaker 1.

Miscellaneous Status

The **25 SYNCH**, **BKR CLOSE**, **BKR FAIL**, **OSB**, and **LOP** target LEDs illuminate in the SEL-421 for miscellaneous status conditions.

The **25 SYNCH** LED illuminates when the relay detects that the Circuit Breaker 1 voltages are within Synchronism Angle 1 (Relay Word bit 25A1BK1 is asserted). See *Synchronism Check on page 5.158* for complete details.

The **BKR CLOSE** LED illuminates when the relay detects a breaker close command for Circuit Breaker 1 (Relay Word bit BK1CL is asserted).

The **BKR FAIL** LED illuminates when the relay detects a breaker failure trip for Circuit Breaker 1 (Relay Word bit BFTRIP1 is asserted). See *Circuit Breaker Failure Trip Logic on page 5.154* for complete details.

The **OSB** LED illuminates when the relay detects an out-of-step condition (Relay Word bit OSB is asserted). See *Out-of-Step Logic (Conventional) on page 5.50* for complete details.

The **LOP** LED illuminates when the relay detects a loss-of-potential condition (Relay Word bit LOP is asserted). See *Loss-of-Potential Logic on page 5.28* for complete details.

Synchrophasor Status

The **PMCU OK** target LED illuminates when the relay is enabled for synchrophasor measurement (Relay Word bits TSOK and PMDOK are asserted).

The **IRIG LOCKED** target LED illuminates when the relay detects synchronization to an external clock with less than 500 ns of jitter (Relay Word bit TIRIG is asserted). See *Configuring Timekeeping on page 3.75 in the SEL-400 Series Relays Instruction Manual* for complete details.

Front-Panel Operator Control Pushbuttons

The SEL-421 front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 4.10* shows this region of the relay front panel with factory-default configurable front-panel label text. The SEL-421 provides either 8 or 12 pushbuttons depending on ordering option.

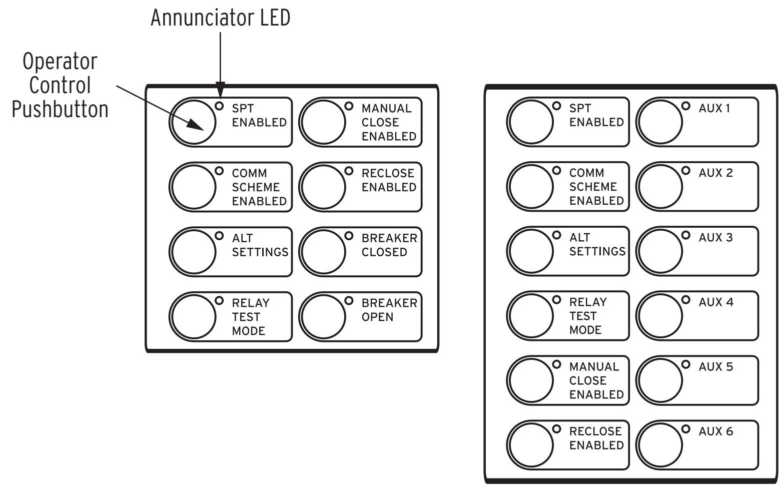


Figure 4.10 Operator Control Pushbuttons and LEDs (8 or 12 Pushbuttons)

Factory-default programming associates specific relay functions with the eight pushbuttons and LEDs, as listed in *Table 4.4*. For a concise listing of the default programming for the front-panel pushbuttons and LEDs, see *Front-Panel Settings on page 8.35*.

Table 4.4 Operator Control Pushbuttons and LEDs—Factory Defaults

Label	Function
SPT ENABLED	Enable single-pole tripping
COMM SCHEME ENABLED	Enable communications scheme
ALT SETTINGS	Switch between setting group 1 and setting group 2[a]. The LED is illuminated when group 1 is not the active setting group.
RELAY TEST MODE	Enter test mode
MANUAL CLOSE ENABLED	Enable manual closing
RECLOSE ENABLED	Enable automatic reclosing
AUX n[b]	Auxiliary
BREAKER CLOSED[c]	Close Circuit Breaker 1
BREAKER OPEN[c]	Open Circuit Breaker 1

[a] With factory settings, the ALT SETTINGS pushbutton must be pressed and held for three seconds before the SEL-421 will change setting groups.

[b] Available on 12-pushbutton models; n is the number of AUX buttons available depending on ordering option.

[c] Not available on models with auxiliary TRIP/CLOSE pushbuttons.

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination. The **CLOSE** and **TRIP** pushbuttons momentarily assert the close and trip relay outputs after a short delay.

The operator control pushbuttons and LEDs are programmable. *Figure 4.11* describes the factory defaults for the operator controls.

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*n*_HMI. These settings allow any of the operator control pushbuttons to be programmed to display a particular HMI screen category. The HMI screen categories available are Alarm Points, Display Points, and Event Summaries, and SER. Front-panel setting NUM_ER allows the user to define the number of event summaries that are displayed via the operator control pushbutton; it has no effect on the event summaries automatically displayed or the event summaries available through the main menu. Each HMI screen category can be assigned to a single pushbutton. Attempting to program more than one pushbutton to a single HMI screen category will result in an error. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category. If more than one screen is available, a navigation scroll bar will be displayed. Pressing the navigation arrows will scroll through the available screens. Subsequent pressing of the operator control pushbutton will advance through the available screens, behaving the same as the **Right Arrow** or the **Down Arrow** pushbutton. Pressing the ESC pushbutton will return the user to the ROTATING DISPLAY. The second way to program the operator control pushbutton is through SELogic control equations, using the pushbutton output as a programming element.

Using SELogic control equations, you can readily change the default LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Included on the SEL-421 Relay Product Literature CD are word processor templates for printing slide-in labels. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

The SEL-421 has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. One set of Relay Word bits follows the pushbutton and another set pulses for one processing interval when the button is pressed. Relay Word bits PB1 through PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL through PB12PUL are the pulsed outputs.

Annunciator LEDs for each operator control pushbutton are PB1_LED through PB12LED. The factory defaults programmed for these LEDs are protection latches (PLT01, for example), settings groups, Relay Word bits (NOT SG1), and the status of the circuit breaker auxiliary contacts (52AA1). The asserted and deasserted colors for the LED are determined with settings PB*n*COL. Options include red, green, amber, or off.

You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

SELOGIC Factory Setting	Operator Control Pushbutton / LED	Description
PBn_LED = NOT E3PT #SPT ENABLED	SPT ENABLED	Press this operator control pushbutton to enable/disable single-pole tripping. The corresponding LED illuminates to indicate the SPT ENABLED state.
PBn_LED = PLT02 #COMM SCHEME ENABLED	COMM SCHEME ENABLED	Press this operator control pushbutton to enable/disable communications-assisted tripping. The corresponding LED illuminates to indicate the COMM SCHEME ENABLED state.
PBn_LED = NOT SG1 #ALT SETTINGS	ALT SETTINGS	Press this operator control pushbutton for three seconds to switch the active setting group between the main setting group (Setting Group 1) and the alternate setting group (Setting Group 2). The corresponding LED illuminates to indicate the ALT SETTINGS state.
PBn_LED = PLT04 #RELAY TEST MODE	RELAY TEST MODE	Press this operator control pushbutton to enable/disable the relay test mode. The corresponding LED illuminates to indicate the RELAY TEST MODE state.
PBn_LED = PLT05 #MANUAL CLOSE ENABLED	MANUAL CLOSE ENABLED	Press this operator control pushbutton to enable/disable local front-panel circuit breaker closing using the CLOSE pushbutton. The corresponding LED illuminates to indicate the MANUAL CLOSE ENABLED state.
PBn_LED = PLT06 #RECLOSE ENABLED	RECLOSE ENABLED	Press this operator control pushbutton to enable/disable the automatic recloser. The corresponding LED illuminates to indicate the RECLOSE ENABLED state.
PBn_LED = 0 #AUX	AUX	Press this operator control pushbutton to enable/disable user-programmed auxiliary control. Program the corresponding LED to indicate the required state. NOTE: This operator control does not perform any function with the factory settings.
PBn_LED = 52ACL1 and 52BCL1 and 52CCL1 #BREAKER CLOSED	BREAKER CLOSED	Press this operator control pushbutton to close Circuit Breaker 1. The corresponding BREAKER CLOSED LED illuminates indicating that Circuit Breaker 1 is closed. The MANUAL CLOSE ENABLED function above enables and disables the CLOSE pushbutton.
PBn_LED = NOT 52ACL1 and 52BCL1 and 52CCL1 #BREAKER OPEN	BREAKER OPEN	Press this operator control pushbutton to trip Circuit Breaker 1. The corresponding BREAKER OPEN LED illuminates, indicating that Circuit Breaker 1 is open.

Figure 4.11 Factory-Default Operator Control Pushbuttons

One-Line Diagrams

See *Section 5: Control in the SEL-400 Series Relays Instruction Manual* for a full explanation of one-line diagrams. The SEL-421 supports 25 selectable predefined single-screen one-line diagrams.

You can include the bay control screen in the rotating display. Set ONELINE = Y (found under Front Panel settings), selectable screens, as shown in *Figure 4.12*.

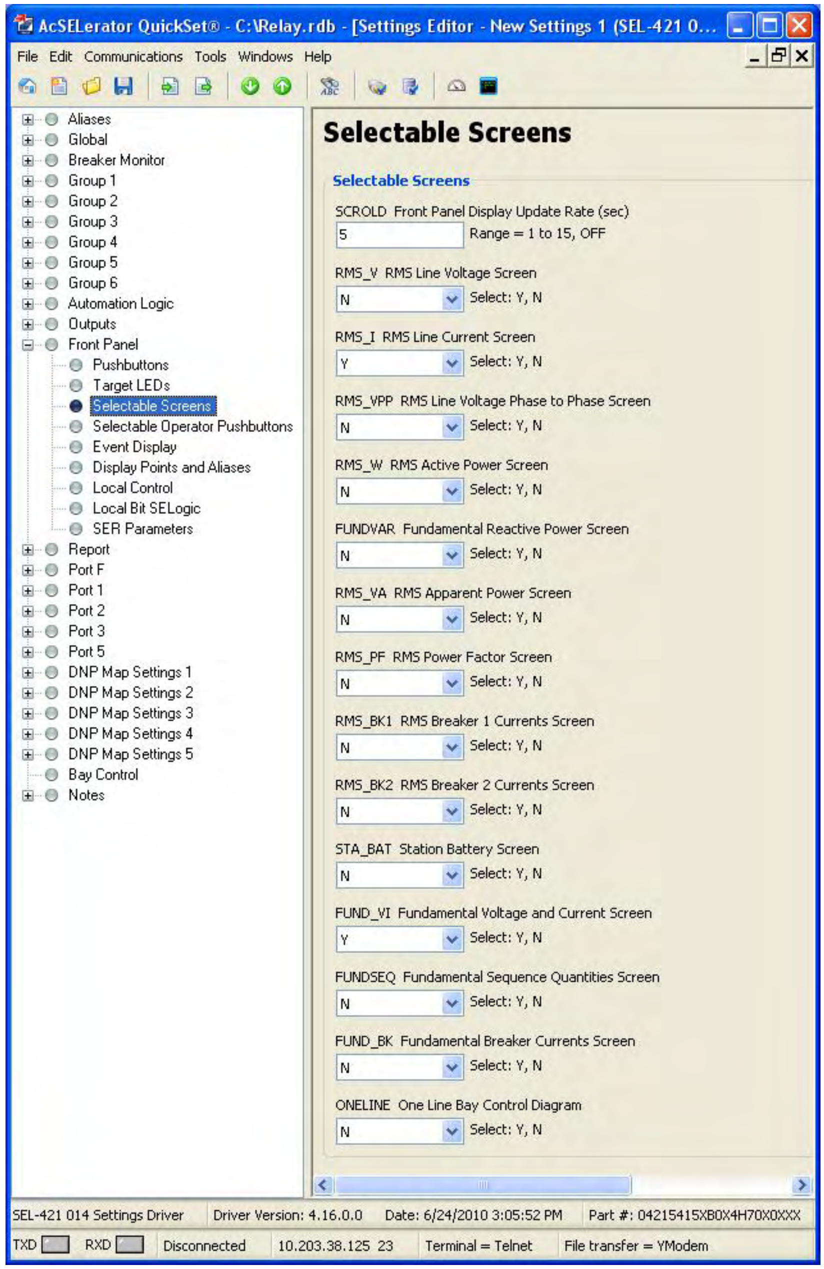


Figure 4.12 Bay Control Screen Selected for Rotating Display

You can also configure an HMI pushbutton to give you direct access to the bay control screen. *Figure 4.13* shows an example of how to configure HMI Pushbutton 1 by selecting the **BC** option from the drop-down menu.

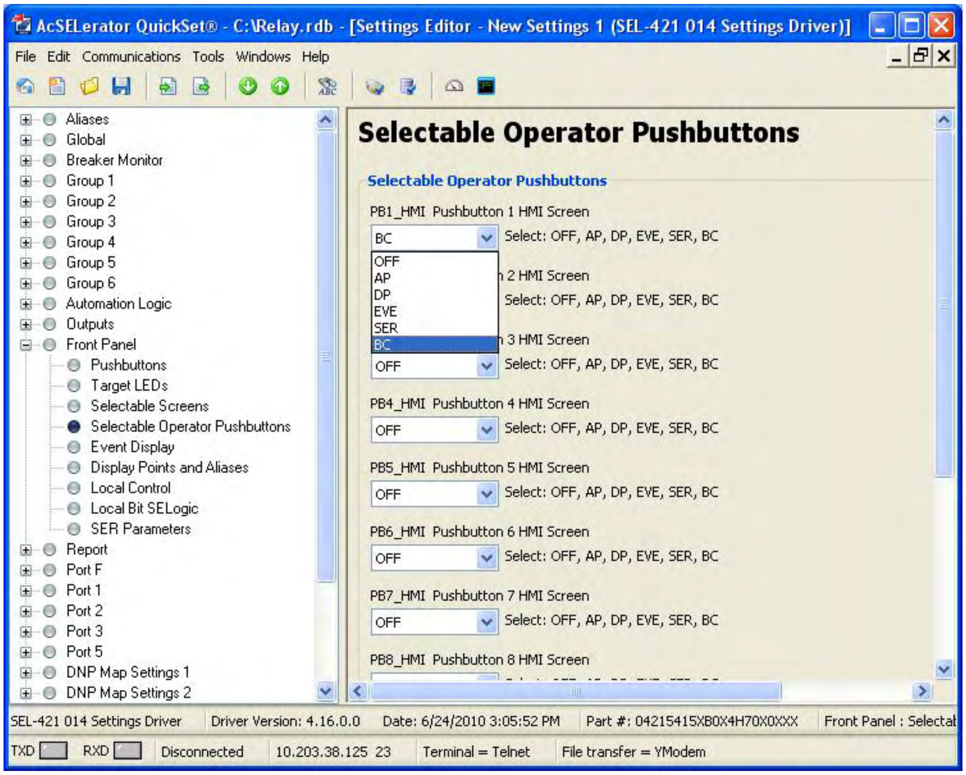


Figure 4.13 Configuring PB1_HMI for Direct Bay Control Access

The Bay Control indicates the status of breakers in the one-line diagrams. The setting EPOLDIS, Enable Single-Pole Discrepancy Logic, controls the behavior. If the breaker is a single-pole type, Global Setting BK*n*TYP = 1, where *n* is 1 or 2, the breaker status will be determined based on the EPOLDIS setting. If EPOLDIS = Y, then the breaker status is indicated by the Relay Word bits 52ACL*n*, 52BCL*n*, and 52CCL*n*, which check for current to determine the breaker status. This setting is useful to identify a pole discrepancy, where a pole may not open but the other two do. In this case, the breaker status would display a pole discrepancy screen as shown below in *Figure 4.14*. If EPOLDIS = N, the single-pole discrepancy logic is disabled, and the breaker status will follow the 52*n*CLSM SELOGIC setting.

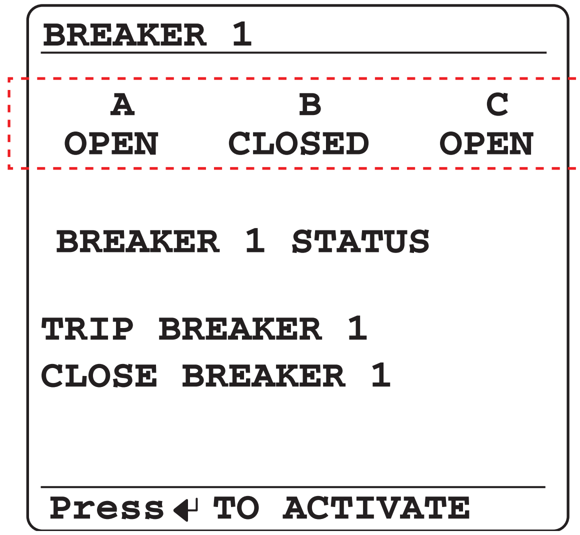


Figure 4.14 Pole Discrepancy

Predefined Bay Control One-Line Diagrams

Configurations

The following pages illustrate all of the predefined busbar and bay control configurations in the SEL-421 defined by the (MIMIC settings). Select the bay screen that exactly matches the bay configuration being controlled from the following figures.

- *Figure 4.15–Figure 4.17*: Main Bus and Auxiliary Bus one-line diagram
- *Figure 4.18–Figure 4.19*: Bus 1, Bus 2, and Transfer Bus one-line diagram
- *Figure 4.20*: Transfer Bay one-line diagram
- *Figure 4.21*: Tie Breaker Bay one-line diagram
- *Figure 4.22–Figure 4.23*: Main Bus and Transfer Bus one-line diagram
- *Figure 4.24–Figure 4.25*: Main Bus one-line diagram
- *Figure 4.26–Figure 4.30*: Breaker-and-a-Half one-line diagram
- *Figure 4.31–Figure 4.32*: Ring Bus one-line diagram
- *Figure 4.33–Figure 4.36*: Double Bus Double Breaker one-line diagram
- *Figure 4.37*: Source Transfer Bus one-line diagram
- *Figure 4.38–Figure 4.39*: Throw-Over Bus one-line diagram

Busbar Configurations

Main Bus and Auxiliary Bus

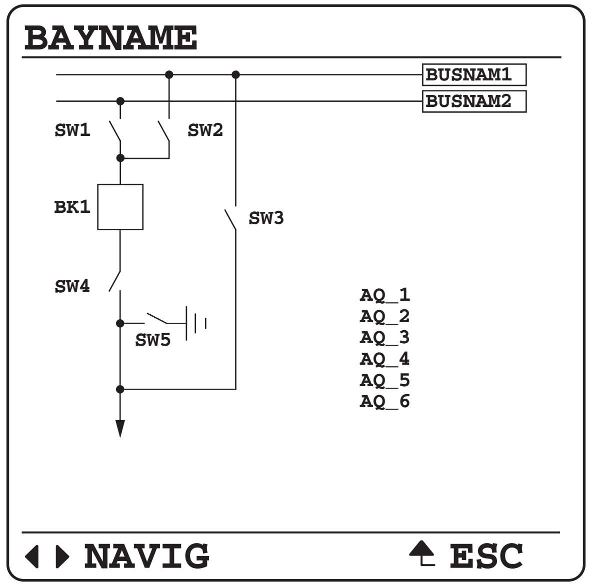


Figure 4.15 Bay With Ground Switch (Option 1)

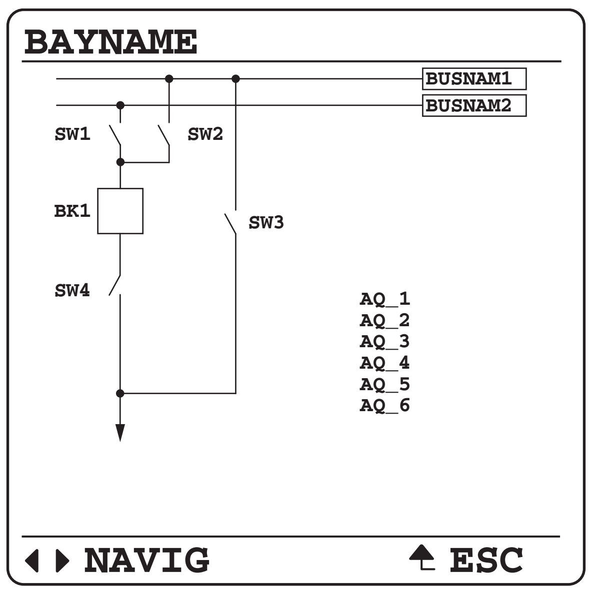


Figure 4.16 Bay Without Ground Switch (Option 2)

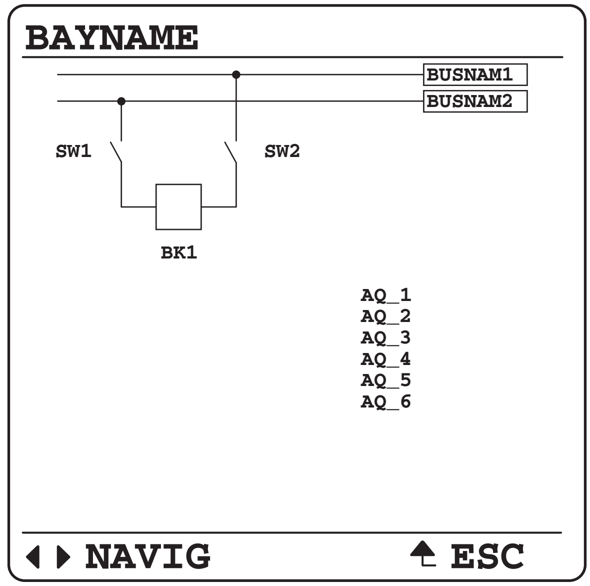


Figure 4.17 Tie Breaker Bay (Option 3)

Bus 1, Bus 2, and Transfer Bus

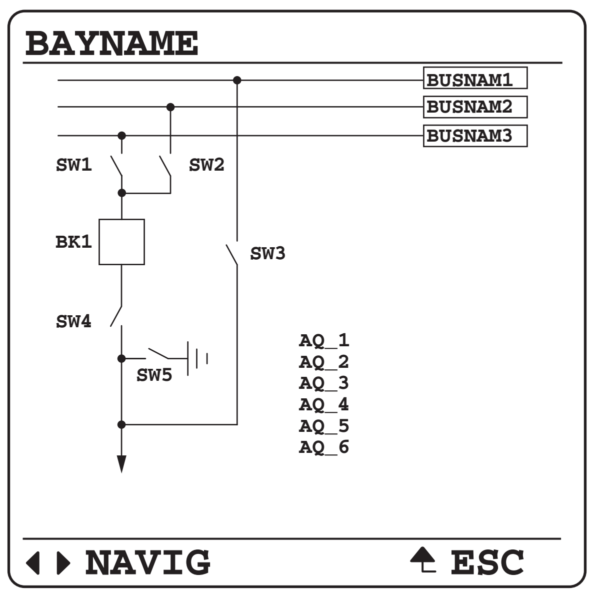


Figure 4.18 Bay With Ground Switch (Option 4)

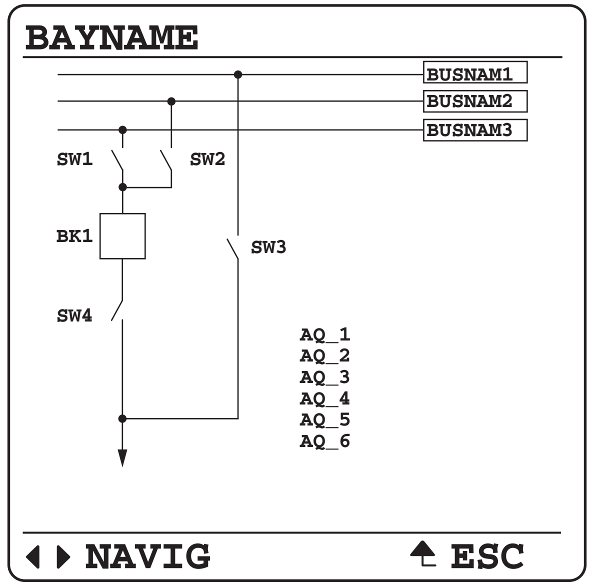


Figure 4.19 Bay Without Ground Switch (Option 5)

Transfer Bay

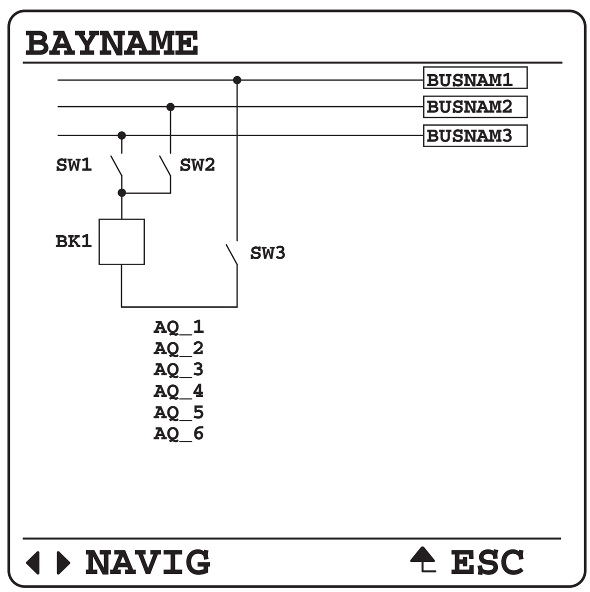


Figure 4.20 Transfer Bay (Option 6)

Tie Breaker Bay

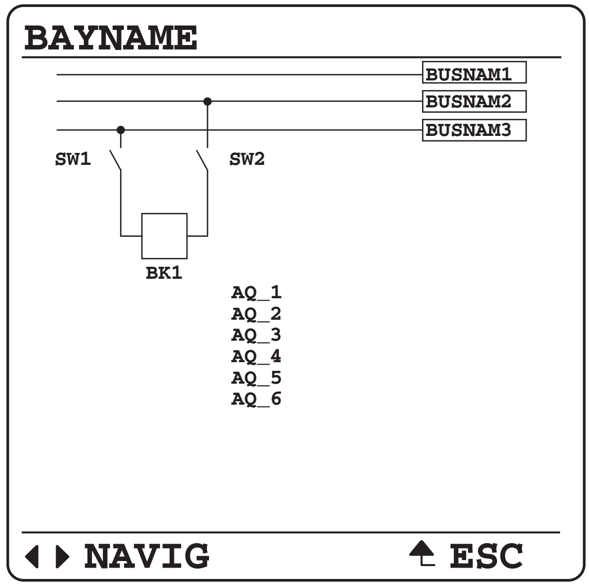


Figure 4.21 Tie Breaker Bay (Option 7)

Main Bus and Transfer Bus

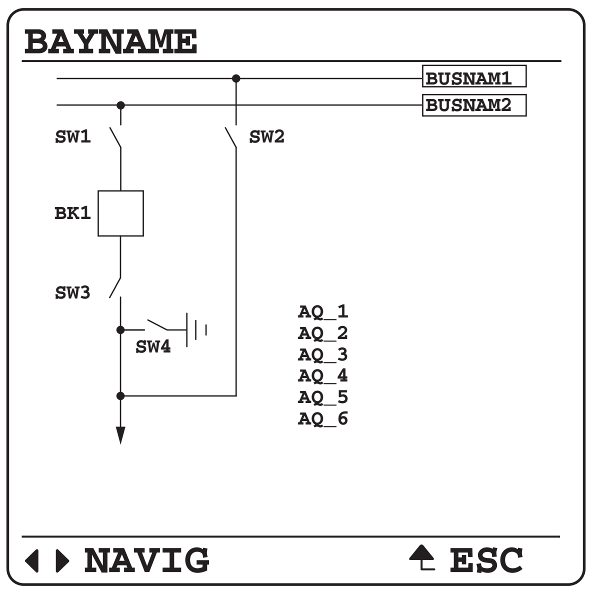


Figure 4.22 Bay With Ground Switch (Option 8)

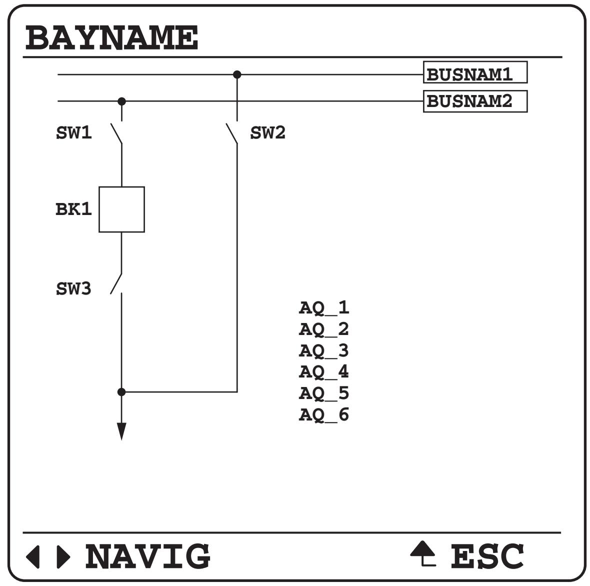


Figure 4.23 Bay Without Ground Switch (Option 9)

Main Bus

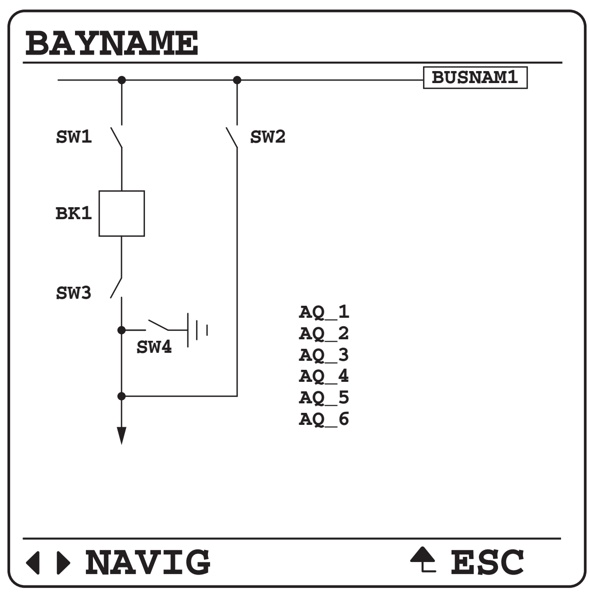


Figure 4.24 Bay With Ground Switch (Option 10)

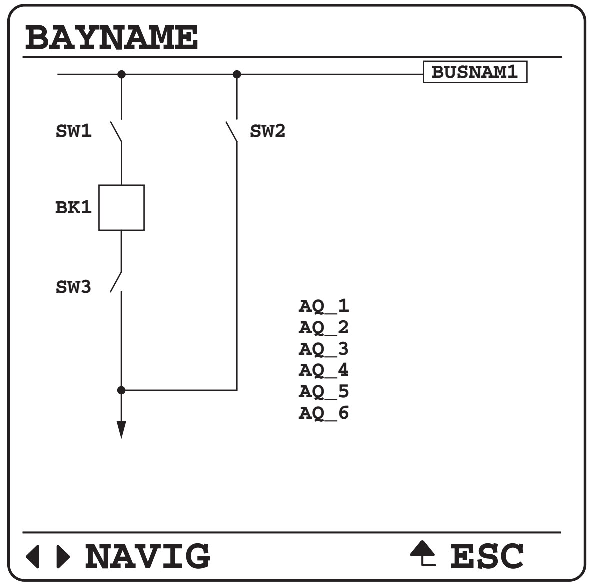


Figure 4.25 Bay Without Ground Switch (Option 11)

Breaker-and-a-Half

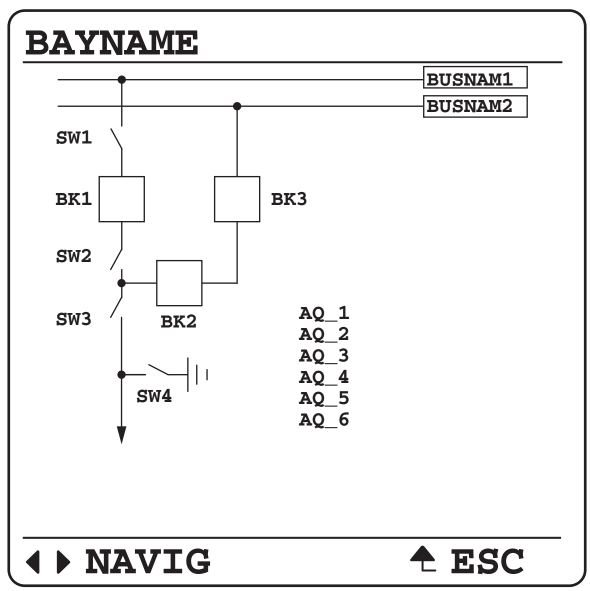


Figure 4.26 Left Breaker Bay With Ground Switch (Option 12)

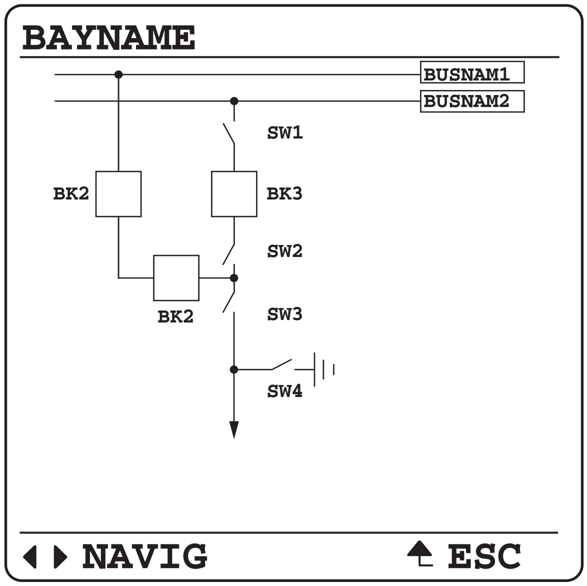


Figure 4.27 Right Breaker Bay With Ground Switch (Option 13)

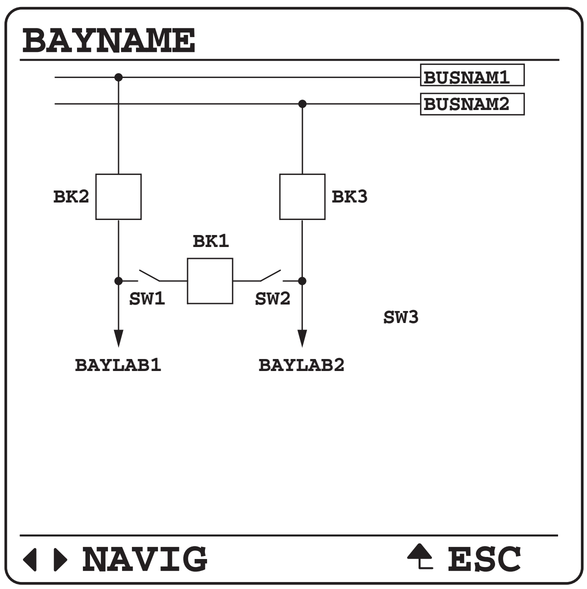


Figure 4.28 Middle Breaker Bay (Option 14)

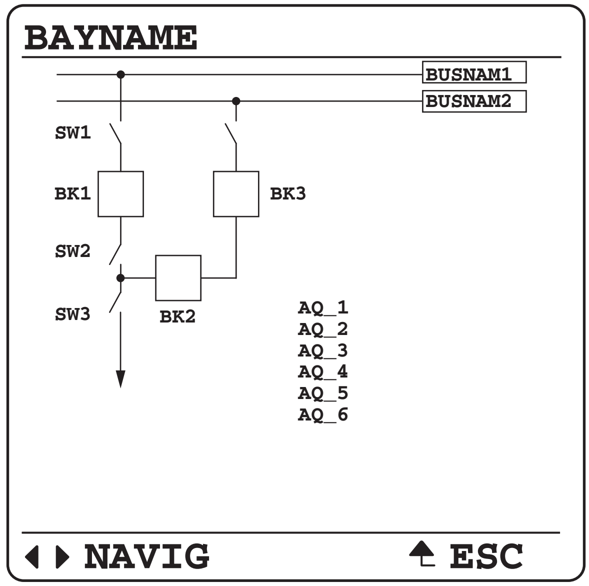


Figure 4.29 Left Breaker Bay Without Ground Switch (Option 15)

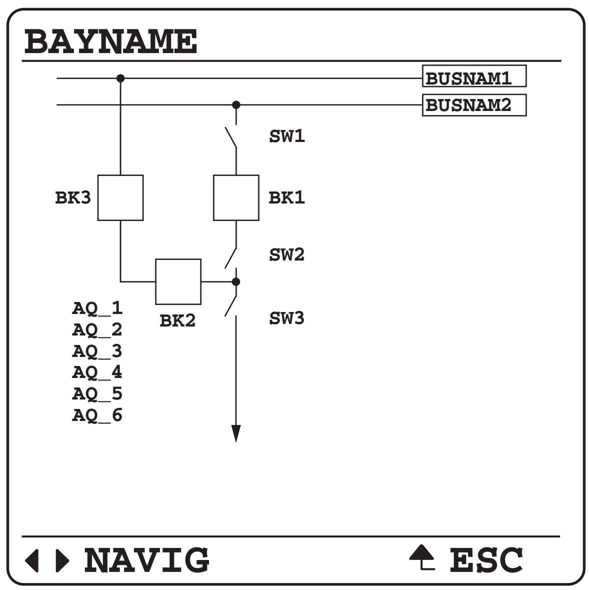


Figure 4.30 Right Breaker Bay Without Ground Switch (Option 16)

Ring Bus

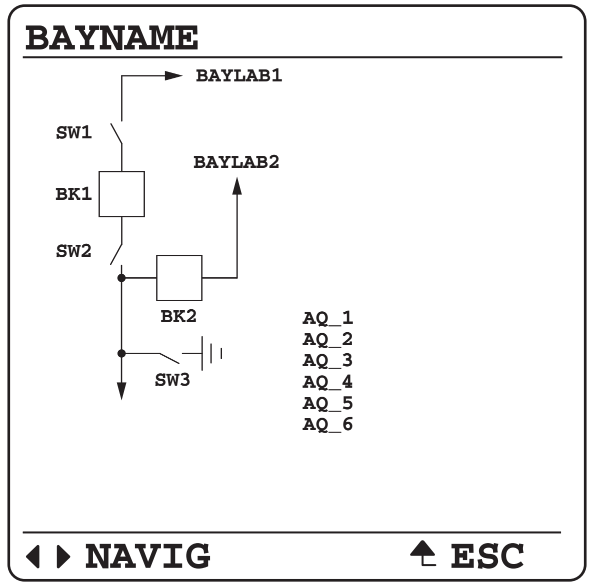


Figure 4.31 Bay With Ground Switch (Option 17)

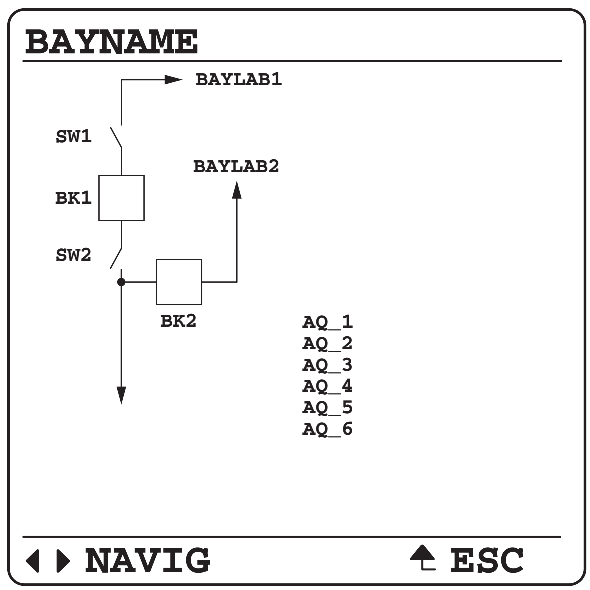


Figure 4.32 Bay Without Ground Switch (Option 18)

Double-Bus Double Breaker

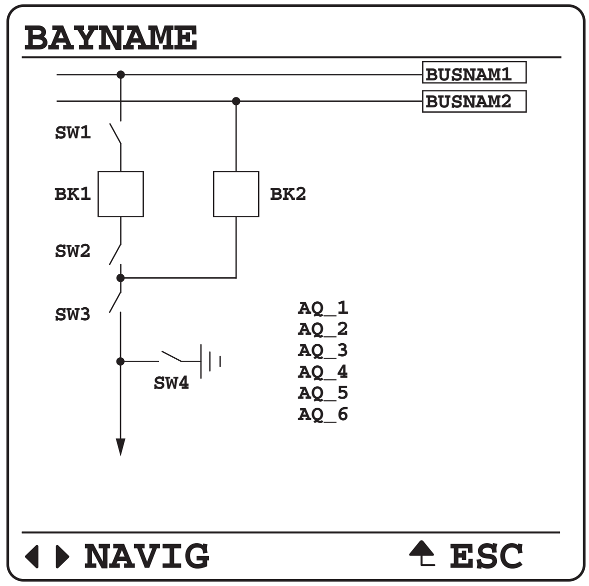


Figure 4.33 Left Breaker Bay With Ground Switch (Option 19)

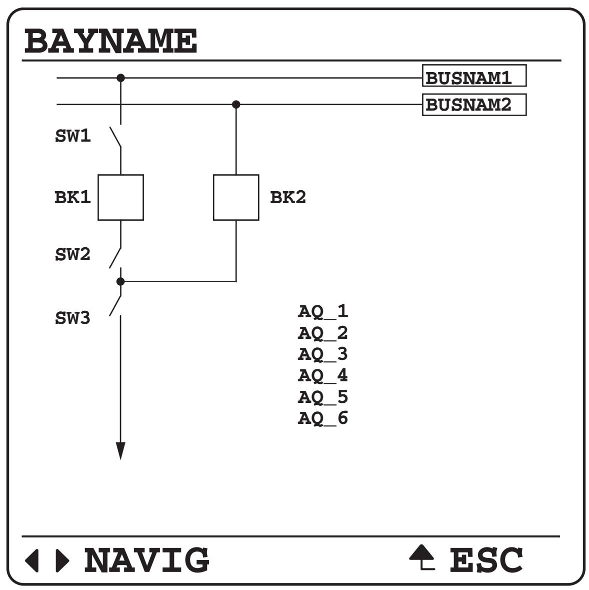


Figure 4.34 Left Breaker Bay Without Ground Switch (Option 20)

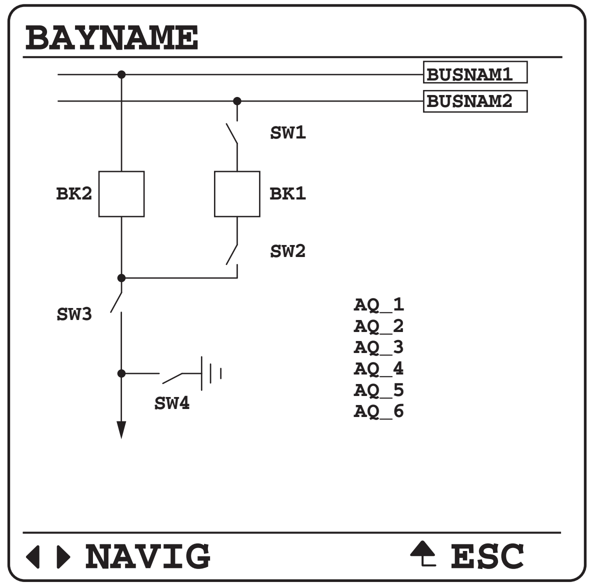


Figure 4.35 Right Breaker Bay With Ground Switch (Option 21)

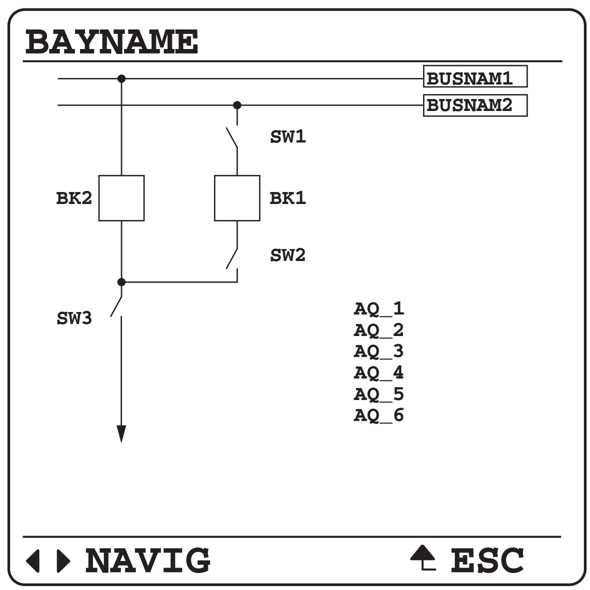


Figure 4.36 Right Breaker Bay Without Ground Switch (Option 22)

Source Transfer Bus

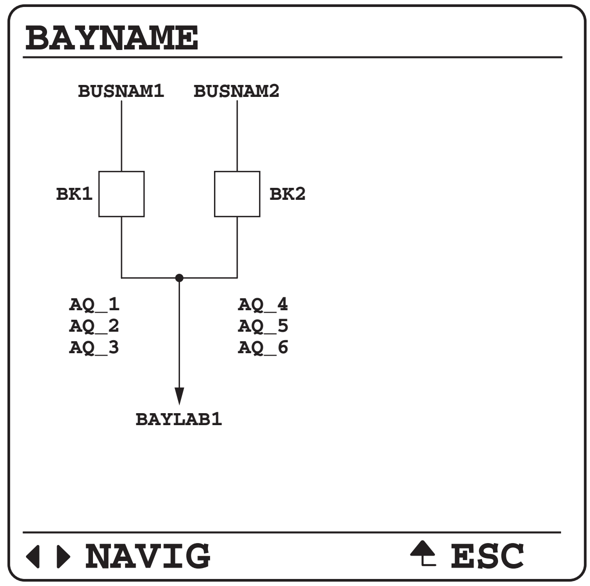


Figure 4.37 Source Transfer (Option 23)

Throw-Over Bus

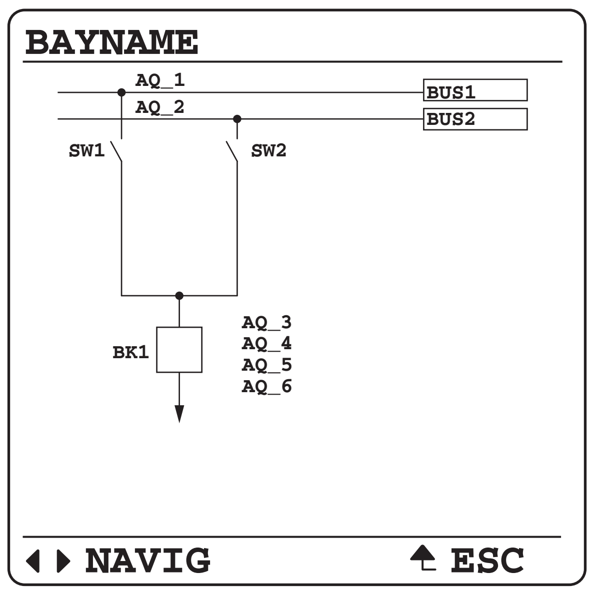


Figure 4.38 Throw-Over Bus Type 1 Switch (Option 24)

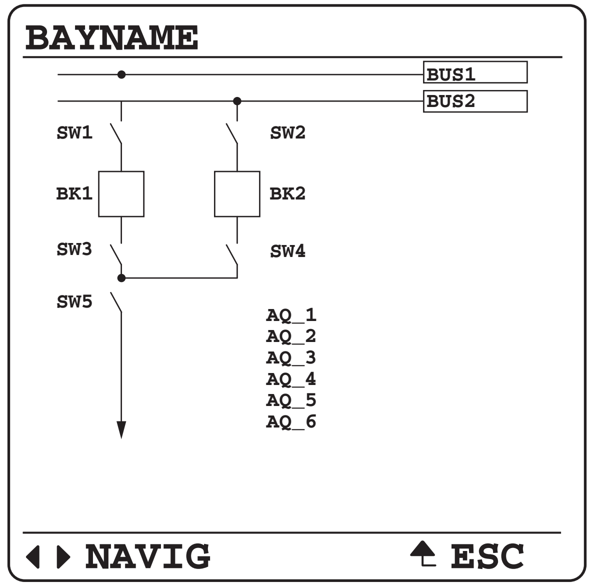


Figure 4.39 Throw-Over Bus Type 2 Switch (Option 25)

Panning

When you specify a custom layout that is too large for one screen, you can take advantage of the panning feature to display sections not visible in the present screen view. *Figure 4.40* shows an example station with a breaker-and-a-half application.

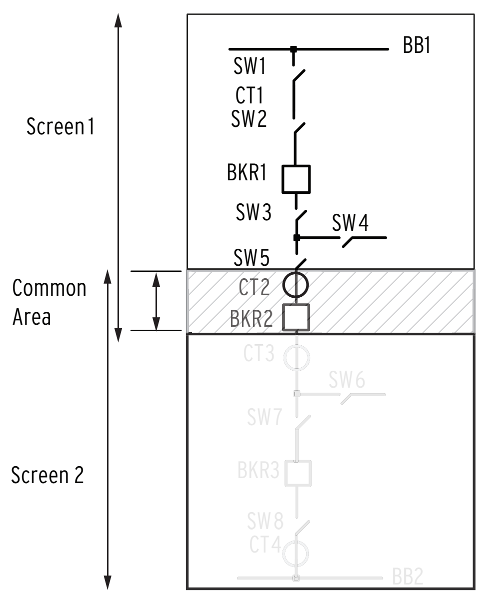


Figure 4.40 Screen 1

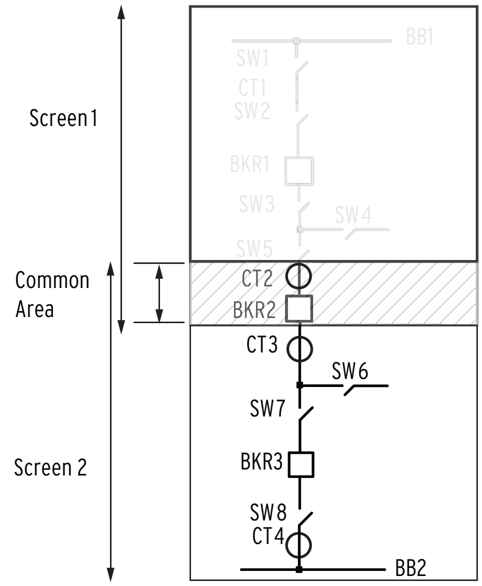


Figure 4.41 Screen 2

As *Figure 4.40* and *Figure 4.41* show, panning is discontinuous and necessitates your toggling between two front-panel screens.

- Screen 1 plus the common area (*Figure 4.40*)
- Screen 2 plus the common area (*Figure 4.41*)

When you specify a custom screen, be sure to separately specify these three areas.

SECTION 5

Protection Functions

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

This section provides a detailed explanation for each of the many SEL-421 Relay protection functions. Each subsection provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits. Logic diagrams and other figures are included.

Functions discussed in this section are listed below.

- ➤ *Trip Logic on page 5.137*
- ➤ *Circuit Breaker Failure Protection on page 5.146*
- ➤ *Synchronism Check on page 5.158*

Current and Voltage Source Selection

The SEL-421 has two sets of three-phase current inputs (IW and IX) and two sets of three-phase voltage inputs (VY and VZ), as shown in *Figure 5.1*. Currents IW and IX are also combined internally (COMB = IW + IX) on a per-phase basis and made available as the line-current option for protection, metering, etc. You can select the current and voltage sources for a wide variety of applications, using the global settings in *Table 8.13 on page 8.5*. The SEL-421 provides five default application settings (ESS := N, 1, 2, 3, or 4) that cover common applications (see *Table 5.1*). When you set ESS := Y, you can set the current and voltage sources for other applications (see *Table 5.2* and *Table 5.3*). ESS settings examples are given later in this subsection.

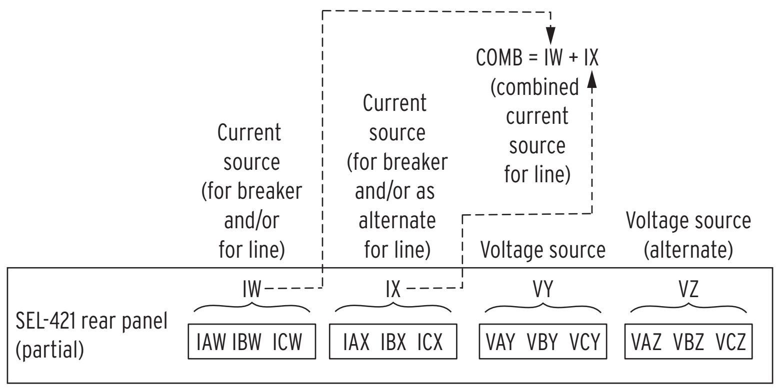


Figure 5.1 Current and Voltage Source Connections for the SEL-421 Relay

Current Source Switching

Figure 5.2 through *Figure 5.4* show the basic application of some of these settings. *Figure 5.2* shows an alternate breaker that can be substituted for the main breaker (bus switching details not shown). Normally, current IW (main breaker) is used as the line-current source. But, if the alternate breaker substitutes for the main breaker, then current IX is used as the line-current source, instead. SELOGIC setting ALTI controls the switching between currents IW and IX as the line-current source (assert setting ALTI to switch to designated alternate line current ALINEI := IX). Alternate line-current source settings ALINEI and ALTI are not used often and thus are usually set to NA. Setting ALTI is automatically hidden and set to NA if ALINEI := NA (no line-current switching can occur).

NOTE: If a current source is set to "combine" (e.g., LINEI := COMB), then the current transformer ratios for the respective IW and IX secondary circuits have to be the same (i.e. group settings CTRW = CTRX). Starting in firmware R318, the current transformer ratios can be different when the current source is set to "combine" (e.g. LINEI := COMB).

Figure 5.3 shows combined currents IW and IX (see COMB = IW + IX in *Figure 5.1*) set for line protection, metering, etc. (LINEI := COMB). To combine these currents correctly inside the relay to produce the effective line current, when the CT ratios are different, the relay divides IX by TAPX before adding IX to IW. The relay automatically calculates TAPX from the CTRW and CTRX setting values (TAPX = CTRW/CTRX).

Figure 5.4 shows the assignment of breaker currents for as many as two circuit breakers. These assigned breaker currents are used in breaker monitoring and breaker failure functions. These same breaker currents can also be assigned as line currents (e.g., line-current assignment LINE1 := IW in *Figure 5.2*).

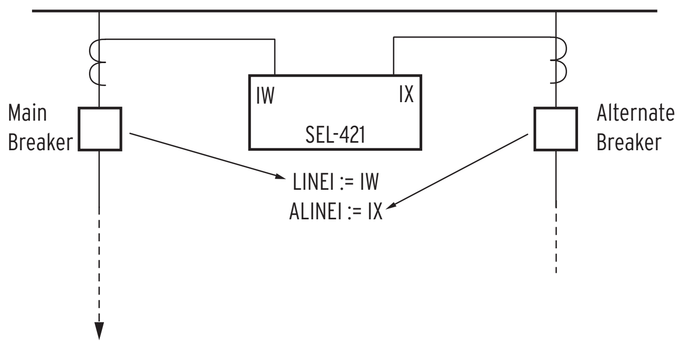


Figure 5.2 Main and Alternate Line-Current Source Assignments

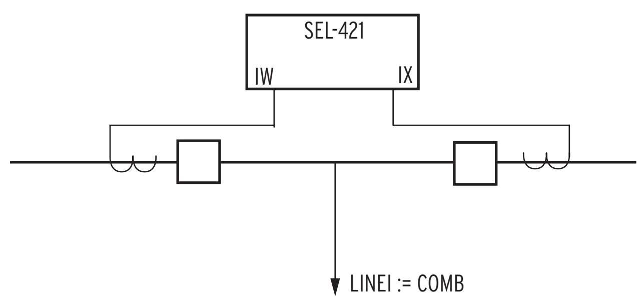


Figure 5.3 Combined Currents for Line-Current Source Assignment

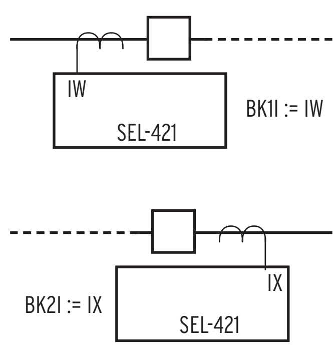


Figure 5.4 Breaker Current Source Assignments

All the available current and voltage source selection settings combinations are covered in *Table 5.1*, *Table 5.2*, and *Table 5.3*. Notice that global setting NUMBK (Number of Breakers in Scheme; see *Table 8.3 on page 8.2*) influences available settings combinations covered in *Table 5.1*, *Table 5.2*, and *Table 5.3*. In general, if NUMBK := 1, then no settings directly involving a second circuit breaker are made (i.e., Breaker 2 current source setting BK2I is automatically set to NA and hidden, as indicated with the shaded cells in the BK2I columns in *Table 5.1* and *Table 5.2*). Also, for source-selection setting ESS := N, the settings are forced to certain values and hidden, as indicated with the shaded cells in the ESS := N rows in *Table 5.1*.

Table 5.1 Available Current Source Selection Settings Combinations[a]

NUMBK (number of breakers)	ESS (source selection)	LINEI (line-current source)	ALINEI (alternate line-current source)	BK1I(Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y	see *Table 5.2*				
1	N	IW	NA	IW	NA	NA
1	1	IW	IX	IW	NA	NA
1	1	IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	2	IW	IX	IX	NA	NA
1	2	IW	NA	IX	NA	NA
1	3	not allowed				
1	4	not allowed				
2	Y	see *Table 5.3*				
2	N	IW	NA	IW	NA	NA
2	1	not allowed				
2	2	not allowed				
2	3	COMB	NA	IW	IX	NA
2	4	IW	NA	IX	COMB	NA

[a] NA = not applicable.
Shaded cells indicate settings forced to given values and hidden.

Table 5.2 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 1[a]

NUMBK (number of breakers)	ESS (source selection)	LINEI (line-current source)	ALINEI (alternate line-current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
1	Y	IW	IX	IW	NA	NA
1	Y	IW	IX	IX	NA	NA
1	Y	IW	IX	NA	NA	NA
1	Y	IW	NA	IW	NA	IAX, IBX, ICX, or NA
1	Y	IW	NA	IX	NA	NA
1	Y	IW	NA	NA	NA	IAX, IBX, ICX, or NA
1	Y	COMB	IX	IW	NA	NA
1	Y	COMB	IX	IX	NA	NA
1	Y	COMB	IX	NA	NA	NA
1	Y	COMB	NA	IW	NA	NA
1	Y	COMB	NA	IX	NA	NA
1	Y	COMB	NA	NA	NA	NA

[a] NA = not applicable.
Shaded cells indicate settings forced to given values and hidden.

Table 5.3 Available Current Source Selection Settings Combinations When ESS := Y, NUMBK := 2[a]

NUMBK (number of breakers)	ESS (source selection)	LINEI (line-current source)	ALINEI (alternate line-current source)	BK1I (Breaker 1 current source)	BK2I (Breaker 2 current source)	IPOL (polarizing current)
2	Y	IW	IX	IW	IX	NA
2	Y	IW	IX	IW	COMB	NA
2	Y	IW	IX	IW	NA	NA
2	Y	IW	IX	IX	COMB	NA
2	Y	IW	IX	IX	NA	NA
2	Y	IW	IX	NA	IX	NA
2	Y	IW	IX	NA	COMB	NA
2	Y	IW	IX	NA	NA	NA
2	Y	IW	NA	IW	IX	NA
2	Y	IW	NA	IW	COMB	NA
2	Y	IW	NA	IW	NA	IAX, IBX, ICX, or NA
2	Y	IW	NA	IX	COMB	NA
2	Y	IW	NA	IX	NA	NA
2	Y	IW	NA	NA	IX	NA
2	Y	IW	NA	NA	COMB	NA
2	Y	IW	NA	NA	NA	IAX, IBX, ICX, or NA
2	Y	COMB	IX	IW	IX	NA
2	Y	COMB	IX	IW	NA	NA
2	Y	COMB	IX	IX	NA	NA
2	Y	COMB	IX	NA	IX	NA
2	Y	COMB	IX	NA	NA	NA
2	Y	COMB	NA	IW	IX	NA
2	Y	COMB	NA	IW	NA	NA
2	Y	COMB	NA	IX	NA	NA
2	Y	COMB	NA	NA	IX	NA
2	Y	COMB	NA	NA	NA	NA

[a] NA = not applicable.

Current Source Uses

Refer to the global settings in *Table 8.13 on page 8.5*. Line-current source setting LINEI and alternate line-current source settings ALINEI and ALTI, if used, identify the currents used in the following elements/features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- CVT (capacitor voltage transformer) transient detection logic

- Series-compensation line logic
- Load-encroachment logic
- OOS (out-of-step) logic
- Distance elements
- Instantaneous line overcurrent elements
- Inverse-time overcurrent elements
- DCUB (directional comparison unblocking) trip scheme logic
- *Metering on page 7.1*, except synchrophasors

Breaker current-source settings (BK1I and BK2I) identify the currents used in the following elements/features described in later in this section and in other sections:

- Open-phase detection logic
- Inverse-time overcurrent elements
- Circuit breaker failure protection
- *Circuit Breaker Monitor on page 7.7*
- *Metering on page 7.1*

Polarizing current-source setting IPOL identifies the single current input connected to a zero-sequence current source (e.g., transformer bank neutral). This zero-sequence current is used as a reference in the zero-sequence current-polarized directional element. Such a directional element is applied to ground overcurrent elements (see *Table 5.31* and *Table 5.27*). Setting IPOL is not used often and thus is usually set to NA. Notice that in *Table 5.1*, *Table 5.2* and *Table 5.3* there are relatively few scenarios where setting IPOL can be set to a current channel selection (only those cases where three-phase current input IX is not used for any other function). An example of using setting IPOL is found later in this subsection.

Voltage Source Switching and Uses

Refer to the global settings in *Table 8.13 on page 8.5*. Alternate voltage source switching between VY and VZ in *Table 5.1* is more straightforward (as shown in *Table 5.4*) than the preceding discussion on current-source selection/switching (compare to *Table 5.1* through *Table 5.3*).

Table 5.4 Available Voltage Source Selection Setting Combinations[a] (Sheet 1 of 2)

NUMBK (number of breakers)	ESS (source selection)	Line Voltage Source	ALINEV (alternate line voltage source)
1	Y	VY	VZ or NA
1	N	VY	NA
1	1	VY	VZ or NA
1	2	VY	VZ or NA
1	3	not allowed	
1	4	not allowed	
2	Y	VY	VZ or NA
2	N	VY	NA
2	1	not allowed	
2	2	not allowed	

Table 5.4 Available Voltage Source Selection Setting Combinations[a] (Sheet 2 of 2)

NUMBK (number of breakers)	ESS (source selection)	Line Voltage Source	ALINEV (alternate line voltage source)
2	3	VY	VZ or NA
2	4	VY	VZ or NA

[a] NA = not applicable.
Shaded cells indicate settings forced to given values and hidden.

SELOGIC setting ALTV controls the switching between voltages VY and VZ for line voltage (assert setting ALTV to switch to designated alternate line voltage ALINEV := VZ). Setting ALTV is automatically hidden and set to NA if ALINEV := NA (no voltage switching can occur). Reasons for switching from one three-phase voltage to another may be for loss-of-potential or bus switching/rearrangement.

Default line voltage source VY and alternate line voltage source settings (ALINEV and ALTV) identify the voltages used in the following elements/features described later in this section and in other sections:

- Fault location
- Open-phase detection logic
- LOP (loss-of-potential) logic
- FIDS (fault-type identification selection) logic
- Directional elements
- CVT (capacitor voltage transformer) transient detection logic
- Series-compensation line logic
- Load-encroachment logic
- OOS (out-of-step) logic
- Distance elements
- SOTF (switch-onto-fault) logic
- POTT (permissive overreaching transfer tripping) scheme logic
- *Metering on page 7.1*, including synchrophasors

Default Applications

Use setting ESS (Current and Voltage Source Selection) to easily configure the relay for your particular application. Five application settings (ESS := N, 1, 2, 3, or 4) cover both single circuit breaker and two circuit breaker configurations. If you select one of these five setting choices, the relay automatically determines the following settings:

NOTE: Setting BK2I is hidden if setting NUMBK, Number of Breakers in the Scheme, is set to 1.

- LINEI—Line Current Source (IW, COMB)
- BK1I—Breaker 1 Current Source (IW, IX, NA)
- BK2I—Breaker 2 Current Source (IX, COMB, NA)

ESS := N, Single Circuit Breaker Configuration—One Current Input

Set ESS to N for single circuit breaker applications with one current input. *Figure 5.5* illustrates this application along with the corresponding current and voltage sources. When ESS equals N, you cannot use alternate sources (ALINEI and ALINEV) and the relay hides the Global settings LINEI, ALINEI, ALTI, BK1I, BK2I, IPOL, ALINEV, and ALTV.

Table 5.5 ESS := N, Current and Voltage Source Selection

Setting	Prompt	Entry	Comments
NUMBK	Number of Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	Hidden
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	Hidden

ESS := 1, Single Circuit Breaker Configuration—One Current Input

Set ESS to 1 for single circuit breaker applications with one current input. *Figure 5.5* illustrates this application along with the corresponding current and voltage sources.

With ESS := 1, the IX current channels have the option to be used as an alternate line-current source (ALINEI := IX) or as a polarizing current channel (e.g., IPOL := IBX), but not both (see *Table 5.1*).

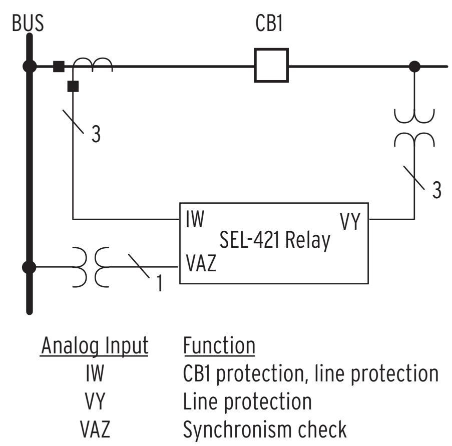


Figure 5.5 ESS := 1, Single Circuit Breaker Configuration

Table 5.6 ESS := 1, Current and Voltage Source Selection (Sheet 1 of 2)

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	

Table 5.6 ESS := 1, Current and Voltage Source Selection (Sheet 2 of 2)

Setting	Prompt	Entry	Comments
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 2, Single Circuit Breaker Configuration—Two Current Inputs

Set ESS to 2 for single circuit breaker applications using two current sources. *Figure 5.6* illustrates this application along with the corresponding current and voltage sources. The relay uses current source IW for line relaying and current source IX for Circuit Breaker 1 failure protection.

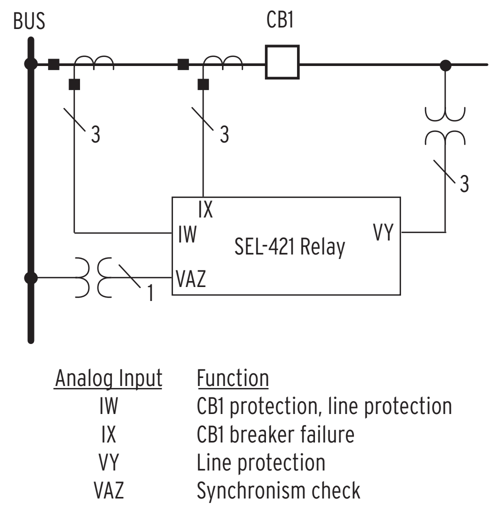


Figure 5.6 ESS := 2, Single Circuit Breaker Configuration

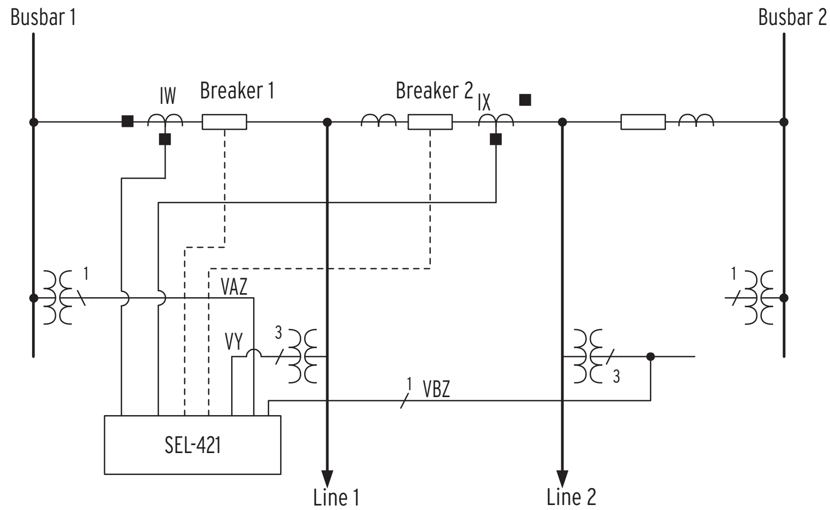
Table 5.7 ESS := 2, Current and Voltage Source Selection

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Line Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

ESS := 3, Double Circuit Breaker Configuration—Independent Current Inputs

Set ESS to 3 for circuit breaker-and-a-half applications using independent current sources. *Figure 5.7* illustrates this application along with the corresponding current and voltage sources. This selection provides independent circuit breaker failure protection for Circuit Breaker 1 and Circuit Breaker 2.



Analog Input	Function
IW+IX	Line protection
IW	CB1 protection
IX	CB2 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

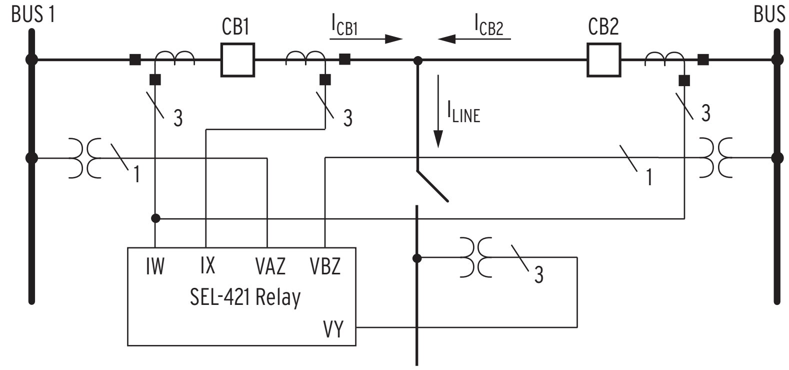
Figure 5.7 ESS := 3, Double Circuit Breaker Configuration

Table 5.8 ESS := 3, Current and Voltage Source Selection

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (COMB)	COMB	Automatic
ALINEI	Alternate Line Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW)	IW	Automatic
BK2I	Breaker 2 Current Source (IX)	IX	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := 4, Double Circuit Breaker Configuration—Common Current Inputs

Set ESS to 4 for circuit breaker-and-a-half applications using combined current input IW. *Figure 5.8* illustrates this application along with the corresponding current and voltage sources. Current input IX provides circuit breaker failure protection for Circuit Breaker 1; the corresponding CTs are located on the line-side of Circuit Breaker 1. The relay calculates the current flowing through Circuit Breaker 2 (I_{CB2} = IW + IX= $I_{CB1} + I_{CB2}$ + IX = $I_{CB1} + I_{CB2} - I_{CB1}$) to provide independent circuit breaker failure for Circuit Breaker 2.



Analog Input	Function
IW+IX	CB2 protection
IW	Line protection
IX	CB1 protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 5.8 ESS := 4, Double Circuit Breaker Configuration

Table 5.9 ESS := 4, Current and Voltage Source Selection

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW)	IW	Automatic
ALINEI	Alternate Current Source (NA)	NA	Automatic
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IX)	IX	Automatic
BK2I	Breaker 2 Current Source (COMB)	COMB	Automatic
IPOL	Polarizing Current (NA)	NA	Automatic
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

ESS := Y, Other Applications

Set ESS to Y for applications that are not covered under the five default applications.

Tapped Line

Figure 5.9 illustrates a tapped EHV transmission overhead line. A power transformer is located at Substation T along the tapped line. An SEL-421 is located at all three EHV terminals (Substations S, R, and T). The SEL-421 Relays operate in a DCB (directional comparison blocking) trip scheme to provide high-speed clearance for all faults internal to the tapped EHV transmission line. For a complete explanation of this example, see *230 kV Tapped Transmission Line Application Example on page 6.170*.

Set NUMBK (Number of Breakers in Scheme) to 2 so you can program the autoreclosing function and synchronism-check elements to control both of the low-side circuit breakers.

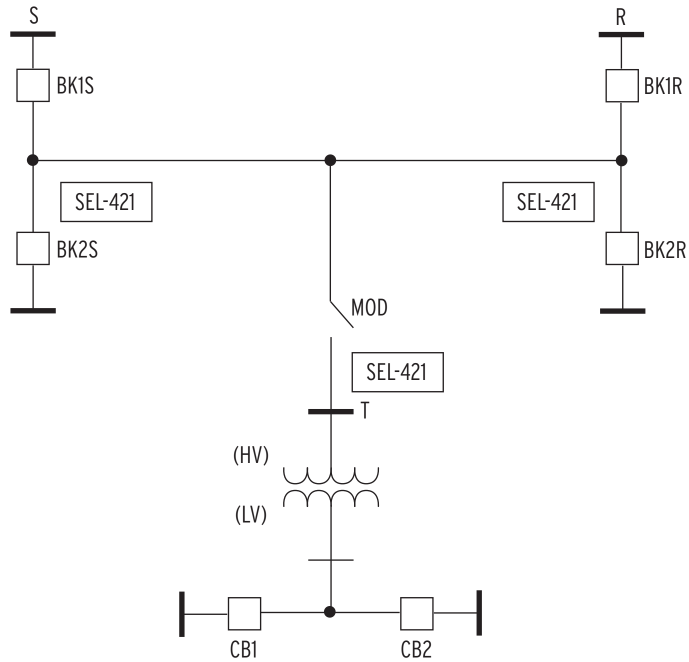
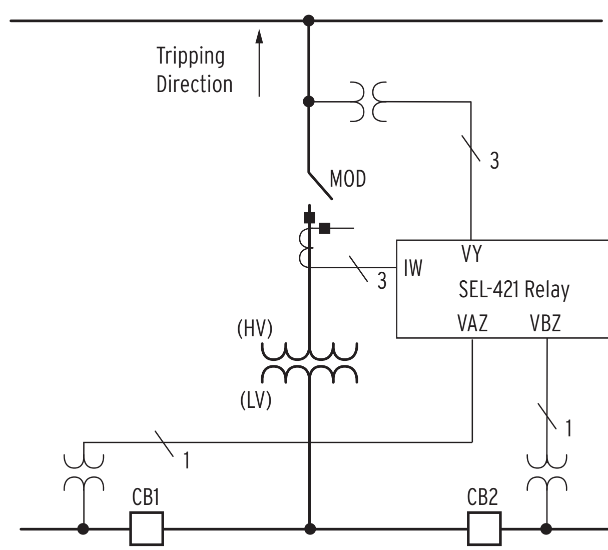


Figure 5.9 Tapped EHV Overhead Transmission Line

Figure 5.10 illustrates the tapped overhead transmission line with a motor-operated disconnect (MOD) on the high side of a power transformer and two circuit breakers on the low side.



Analog Input	Function
IW	Line protection
VY	Line protection
VAZ	Synchronism check Circuit Breaker 1
VBZ	Synchronism check Circuit Breaker 2

Figure 5.10 ESS := Y, Tapped Line

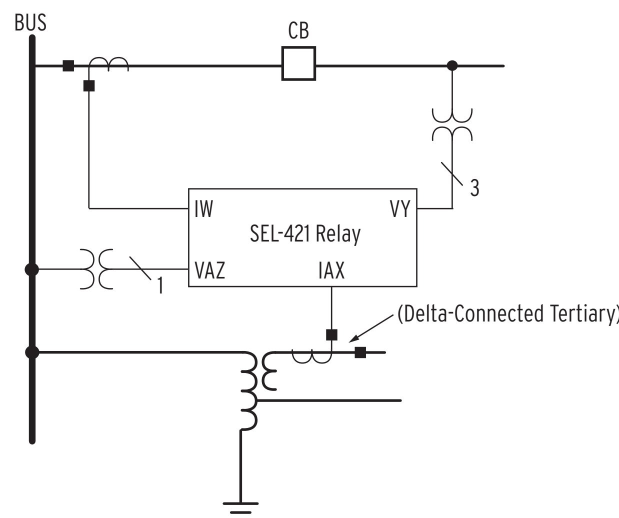
Table 5.10 ESS := Y, Tapped Line

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	2	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden[a]
BK1I	Breaker 1 Current Source (IW, IX, NA)	NA	
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA	
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

[a] Hidden when preceding setting is NA.

Single Circuit Breaker With Current Polarizing Source

Figure 5.11 shows a single circuit breaker situated by an autotransformer. The SEL-421 uses the delta-connected tertiary as a current polarizing source for the zero-sequence current-polarized directional element 32I. For example, connect to current to input IAX (set IPOL := IAX).



Analog Input	Function
IW	Line protection
IAX	Ground directional element current polarization
VY	Line protection
VAZ	Synchronism check

Figure 5.11 ESS := Y, Single Circuit Breaker With Current Polarizing Source Tapped Power Transformer

Table 5.11 ESS := Y, Current Polarizing Source (Sheet 1 of 2)

Setting	Prompt	Entry	Comments
NUMBK	Number of Circuit Breakers in Scheme (1, 2)	1	
LINEI	Line Current Source (IW, COMB)	IW	
ALINEI	Alternate Current Source (IX, NA)	NA	

Table 5.11 ESS := Y, Current Polarizing Source (Sheet 2 of 2)

Setting	Prompt	Entry	Comments
ALTI	Alternate Current Source (SELOGIC Equation)	NA	Hidden
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW	
BK2I	Breaker 2 Current Source (NA)	NA	Hidden
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	IAX	
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA	Default
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA	Hidden

Using ALTI and ALTV

SELOGIC control equations ALTI and ALTV give great flexibility in choosing alternate CT and PT inputs to the SEL-421. The relay switches to the alternate source when these SELOGIC control equations become true. The relay delays a subsequent ALTI or ALTV switch for eight cycles after the initial switch to give time for the system to settle. The status of ALTI and ALTV will be displayed in the SER report. This confirms if the relay has switched the source it was using.

Test the SELOGIC control equation programming that you use to switch ALTI and ALTV alternate sources. It is possible to create a toggling condition where the relay repeatedly switches between sources. Examine each line of SELOGIC control equation programming to verify that this toggling condition does not occur in your protection/control scheme.

One method for exercising caution when implementing alternate current source and alternate voltage source switching is to use SELOGIC control equation protection latches (PLT01–PLT32) to switch alternate sources. For example, to switch to an alternate voltage, set ALINEV to VZ (enables setting ALTV) and then set ALTV to PLT31. To perform the switch use the protection latch control inputs PLT31S and PLT31R (Set and Reset, respectively).

Polarizing Quantity for Distance Element Calculations

The relay uses positive-sequence memory voltage as the polarizing quantity for distance element calculations. Memory polarization ensures proper operation during zero-voltage three-phase faults and provides expansion of the mho characteristic back to the source impedance, improving fault-resistance coverage. However, longer memory may impair distance element security when a power system disturbance causes a fast frequency excursion.

The polarization memory is adaptive. The relay normally uses positive-sequence voltage with short or medium length memory. This short or medium length memory works satisfactorily for all faults other than zero-voltage three-phase faults. When the relay measures positive-sequence voltage magnitude lower than a threshold, it automatically switches to a long memory polarizing quantity.

The VMEMC setting allows you to choose between short or medium length memory voltage for the normal polarizing quantity. To closely follow the power system frequency, set VMEMC = 0. When VMEMC is deasserted (logical 0), the relay normally uses a short memory time constant that closely follows the positive-sequence voltage, yet automatically switches to the long memory when necessary. This setting provides less expansion of the distance element characteristics, while still providing security for zero-voltage three-phase faults. SEL recommends that you use this setting.

If your application requires more expansion of the distance element characteristics, set VMEMC = 1. When VMEMC is asserted, the relay normally uses medium length memory and automatically switches to the long memory when necessary. This setting provides the same element operation as provided in firmware R312 and earlier, including greater expansion of the distance element characteristics and the same security for zero-voltage three-phase faults.

The short memory is not available for series-compensated lines (ESERCMP = Y). When ESERCMP = Y, the relay uses the medium length memory and automatically switches to the long memory polarizing quantity when the relay detects voltage inversion or positive-sequence voltage magnitude lower than a threshold.

Table 5.12 VMEMC Relay Setting

Setting	Prompt	Range	Default
VMEMC[a]	Memory Voltage Control (SELOGIC Equation)	SV	0[b]

[a] If the Advanced Settings are not enabled (setting EADVS :=N), the relay hides the setting. If the Series Compensation Line Logic Setting is enabled (setting ESERCMP := Y), the relay hides the setting.

[b] Setting VMEMC is forced to 1 if the Series Compensation Line Logic Setting is enabled (setting ESERCMP := Y).

Frequency Estimation

The relay uses filtered analog values related to the system frequency to calculate internal quantities such as phasor magnitudes and phase angles. When the system frequency changes, the relay measures these frequency changes and adapts the processing rate of the protection functions accordingly. Adapting the processing rate is called frequency tracking.

Note that frequency measurement is not the same as frequency tracking. The relay first measures the frequency and then tracks the frequency by changing the processing rate.

The relay measures the frequency over the 20–80 Hz range (protection frequency, see FREQP in *Table 5.16*), but only tracks the frequency over the 40–65 Hz range (see FREQ in *Table 5.16*). If the system frequency is outside the 40–65 Hz range, the relay does not track the frequency. Instead, it clamps the frequency to either limit. For frequencies below 40 Hz, the relay clamps the frequency at 40 Hz. For frequencies above 65 Hz, the relay clamps the frequency at 65 Hz.

To measure the frequency, the relay calculates the alpha component quantity and then estimates the frequency based on the zero-crossings of the alpha component. Relay Word bit FREQOK asserts when the relay measures the frequency over the range 20–80 Hz. If the frequency is below 40 Hz or above 65 Hz, FREQ reports the clamped values of either 40 Hz or 65 Hz. In this case, the relay no longer tracks the frequency. Instead, it uses either 40 Hz or 65 Hz to calculate the internal quantities.

If the frequency is in the 20–80 Hz range, but outside the 40–65 Hz range (for example, 70 Hz), FREQP shows the frequency the relay measures and FREQ shows the clamped frequency. In this case, FREQP = 70 Hz and FREQ = 65 Hz. *Table 5.13* summarizes the frequency measurement and frequency tracking ranges.

If the frequency is below 20 Hz or above 80 Hz, the relay no longer measures the frequency. Relay Word bit FREQFZ asserts and Relay Word bit FREQOK deasserts to indicate this condition. FREQ and FREQP are no longer valid, but they display the frequency at the time that the relay stopped measuring the frequency.

NOTE: The relay measures/tracks the frequency to a rate of 15 Hz/s.

Table 5.13 Frequency Measurement and Frequency Tracking Ranges

Frequency Range (Hz)	Measures Frequency	Tracks Frequency	FREQOK	FREQFZ
40–65	Y	Y	1	0
20–39.99	Y	N	1	0
65.01–80	Y	N	1	0
Below 20 or above 80	N	N	0	1

The relay has six voltage inputs (VAY, VBY, VCY, VAZ, VBZ, and VCZ) that can be used as sources for estimating the frequency. Assign any of the six voltage inputs to VF01, VF02, and VF03. Note that assigning **ZERO** will set that input to zero. The relay also provides an alternate frequency source selection where you can assign any of the six voltage inputs to VF11, VF12, and VF13. The relay uses VF01, VF02, and VF03 as sources if the SELOGIC evaluation of EAFSRC is 0. The relay uses VF11, VF12, and VF13 as sources if EAFSRC is 1. The relay calculates the alpha quantity, Valpha, as shown in *Figure 5.12* using the mapped sources. Note that the alpha quantity is based on the instantaneous secondary voltage samples from the mapped resources and is an instantaneous quantity.

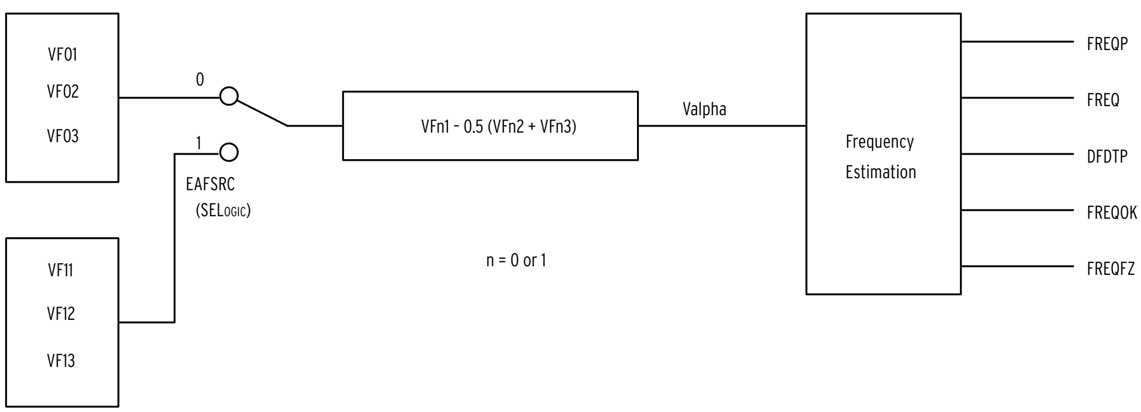


Figure 5.12 SEL-421 Alpha Quantity Calculation

NOTE: These settings are available only if you have enabled Global advanced settings, EGADVS := Y.

Although you have the flexibility to select any of the available voltages for the frequency estimation, the correlation between the selected voltages and the breaker poles is fixed as shown in *Table 5.15*.

Table 5.14 Frequency Estimation (Sheet 1 of 2)

Label	Prompt	Default Value
EAFSRC	Alt. Freq. Source (SELOGIC Equation)	NA
VF01	Local Freq. Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY

Table 5.14 Frequency Estimation (Sheet 2 of 2)

Label	Prompt	Default Value
VF02	Local Freq. Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Freq. Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alt. Freq. Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF12	Alt. Freq. Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alt. Freq. Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

Table 5.15 Voltage and Breaker Pole Correlation

Relay Word Bit	Phase A	Phase B	Phase C
SPOA = 0	VF01/VF11	–	–
SPOA = 1	0	–	–
SPOB = 0	–	VF02/VF12	–
SPOB = 1	–	0	–
SPOC = 0	–	–	VF03/VF13
SPOC = 1	–	–	0

The single pole-open Relay Word bits SPOA, SPOB and SPOC control the correlation. During an open-pole condition, the relay assigns a value of zero volts to the phase associated with the open pole. For example, if the A-Phase of a single pole breaker (BK1TYP = 1 or BK2TYP = 1) is open, SPOA asserts to indicate the open-pole condition. When SPOA asserts, the relay substitutes zero volts for the VF01 and VF11 values. If you selected VF01/VF11 = VAY, then the VF01/VF11 voltages are set to zero when SPOA asserts. Likewise, if you selected VF01/VF11 = VBY, then the VF01/VF11 voltages are still set to zero and not VF02 and VF12. Take care to assign the appropriate phase voltages to match the correlation shown in *Table 5.15* when using single-pole breakers.

Table 5.16 Frequency Estimation Outputs

Name	Description	Type
FREQ	Measured system frequency (40–65 Hz)	Analog Quantity
FREQP	Measured frequency (20–80 Hz)	Analog Quantity
FREQOK	Measured frequency is valid	Relay Word bit
FREQFZ	Measured frequency is frozen	Relay Word bit

Undervoltage Supervision Logic

Relay Word bit 27B81, the output of the logic shown in *Figure 5.13*, supervises the frequency elements for system undervoltage conditions. In the logic, the comparator compares the absolute value of the alpha component voltage (Valpha) against the 81UVSP setting value. *Equation 5.1* shows the equation for calculating Valpha.

$$\text{Valpha} = \text{VF01} - \left[\frac{\text{VF02}}{2} + \frac{\text{VF03}}{2}\right]$$

Equation 5.1

Generally, settings VF01, VF02, VF03 correlate to VA, VB, and VC. *Equation 5.2* shows the relationship between the peak amplitude of Valpha and the root-mean-square (RMS) value of the system voltage phasors for three-phase voltage inputs.

NOTE: The relay uses the alpha component voltage to track the system frequency. To ensure the relay uses the same voltage for frequency tracking and frequency elements undervoltage supervision, the operating quantity in *Figure 5.13* was changed from the positive-sequence voltage to the alpha component voltage. This change affects firmware versions R310 and higher and may require a revision of the 81UVSP setting.

$$\text{Valpha} = \sqrt{2} \bullet 1.5 \bullet \text{VRMS}$$

Equation 5.2

where VRMS is the root-mean-square value of the voltage phasor.

Relay Word bit 27B81 asserts if Valpha falls below the 81UVSP setting value for longer than a cycle.

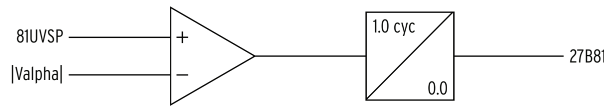


Figure 5.13 Undervoltage Supervision Logic

Calculate the 81UVSP Setting Value

Because the relay accepts voltage input from the potential transformers (PTs) in any combination, Valpha can have different values, depending on the voltage inputs. In general, the following examples use the average (60 percent) of the 50 to 70 percent undervoltage range that IEEE C37.117 Guide recommends. Also, the calculations are based on an RMS phase-to-neutral value of 67 V for the PT inputs, although the 81UVSP setting is a peak value and not an RMS value.

Case 1: Three-Phase PT Inputs

In this case, VF01 = VA, VF02 = VB, and VF03 = VC (with default settings). Use *Equation 5.2* to calculate the nominal value of Valpha as follows:

$$\text{Valpha} = 1.5 \bullet \sqrt{2} \bullet 67 \text{ V}$$

Equation 5.3

$$\text{Valpha} = 142.13 \text{ V}$$

Equation 5.4

Set 81UVSP to 60 percent of this value:

$$81\text{UVSP} = 0.6 \bullet 142.13 \text{ V}$$

Equation 5.5

$$81\text{UVSP} = 85.28 \text{ V}$$

Equation 5.6

Case 2: Single-Phase PT Input, Connected to the A-Phase Input

In this case, VF01 = VA, VF02 = ZERO, and VF03 = ZERO.

$$\text{Valpha} = \sqrt{2} \bullet 67\text{ V}$$

Equation 5.7

$$\text{Valpha} = 94.75\text{ V}$$

Equation 5.8

Set 81UVSP to 60 percent of this value:

$$\text{81UVSP} = 0.6 \bullet 94.75\text{ V}$$

Equation 5.9

$$\text{81UVSP} = 56.85\text{ V}$$

Equation 5.10

Case 3: Single-Phase PT Input, Connected to the B- or C-Phase Input

In this case, VF01 = ZERO, VF02 = VB, and VF03 = ZERO.

$$\text{Valpha} = \sqrt{2} \bullet \frac{67}{2}\text{V}$$

Equation 5.11

$$\text{Valpha} = 47.37\text{ V}$$

Equation 5.12

Set 81UVSP to 60 percent of this value:

$$\text{81UVSP} = 0.6 \bullet 47.37\text{ V}$$

Equation 5.13

$$\text{81UVSP} = 28.43\text{ V}$$

Equation 5.14

Table 5.17 summarizes the results of the three cases.

Table 5.17 Table Y12. Summary of the Valpha and 81UVSP Calculations

Case	PT Connections	VA	VB	VC	Valpha	0.6 • Valpha
Case 1	Three-phase	67 ∠0°	67 ∠–120°	67 ∠120°	142.13	85.28
Case 2	Single-phase, VA	67 ∠0°	0	0	94.75	56.85
Case 3	Single-phase, VB/VC	0	67 ∠–120°	0	47.38	28.43

Over- and Underfrequency Elements

Use the relay frequency elements for such abnormal frequency protection as underfrequency load shedding.

Figure 5.15 shows the logic for the six levels of over- and underfrequency elements in the relay.

Each frequency element can operate as an overfrequency or as an underfrequency element, depending on its pickup setting. If the element pickup setting (81D*n*P, *n* = 1–6) is less than the nominal system frequency setting, NFREQ, the element operates as an underfrequency element, picking up if measured frequency is less than the set point. If the pickup setting is greater than NFREQ, the element operates as an overfrequency element, picking up if measured frequency is greater than the set point.

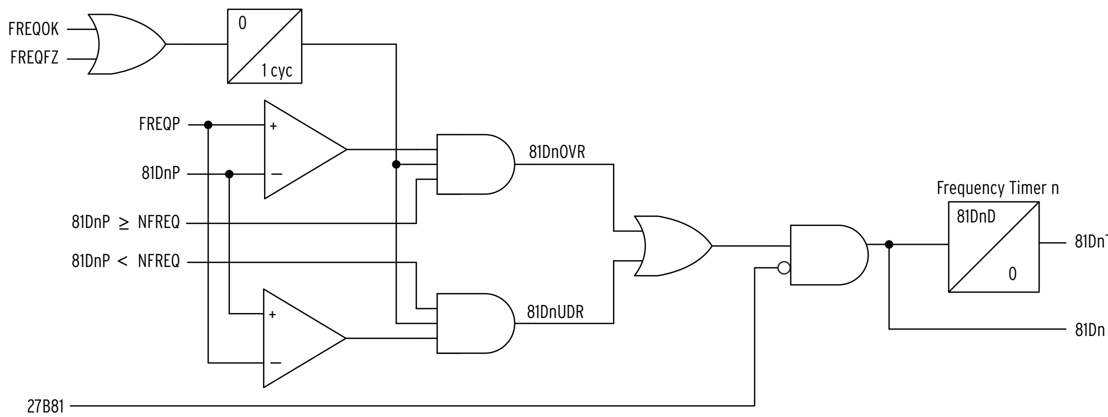


Figure 5.14 Frequency Element Logic

Note that Relay Word bit 27B81 controls all six frequency elements. This undervoltage supervision control prevents erroneous frequency element operations during system faults.

Over- and Underfrequency Element Settings

E81 (Enable 81 Elements)

Set E81 to enable as many as six over- and underfrequency elements. When E81 = N, the relay disables the frequency elements and hides corresponding settings; you do not need to enter these hidden settings.

Setting	Prompt	Range	Default	Category
E81	Enable Frequency Elements	N, 1–6	N	Group

81UVSP (81 Element Undervoltage Supervision)

NOTE: See *Undervoltage Supervision Logic on page 5.17* for a discussion on the 81UVSP setting.

This setting applies to all six frequency elements. If the instantaneous alpha voltage falls below the 81UVSP setting, all frequency elements are disabled.

Setting	**Prompt**	**Range**	**Default**	**Category**
81UVSP	81 Element Under Voltage Super	20.00–200 V, sec	85	Group

81D*n*P (Level *n* Pickup)

Set the value at which you want the frequency element for each of six levels to assert. For a value of 81D*n*P less than the nominal system frequency NFREQ (50 or 60 Hz), the element operates as an underfrequency element. For a value greater than NFREQ, the element operates as an overfrequency element. Note that *n* can be one of six levels, 1–6.

Setting	Prompt	Range	Default	Category
81D*n*P[a]	Level *n* Pickup	40.01–69.99 Hz	61.00	Group

[a] *n* = 1–6.

81D*n*D (Level *n* Time Delay)

Select a time in seconds that you want frequency elements to wait before asserting.

Setting	Prompt	Range	Default	Category
81D*n*D[a]	Level *n* Delay	0.04–400.00 sec	2	Group

[a] *n* = 1–6.

Time-Error Calculation

Description and Settings

The time-error calculation function in the SEL-421 measures the amount of time that an ac clock running from the same line frequency measured by the relay would differ from a reference clock. The relay integrates the difference between the measured power system frequency and the nominal frequency (Global setting NFREQ) to create a time-error analog quantity, TE.

NOTE: The LOADTE SELOGIC equation is processed once per cycle. A momentary assertion must be conditioned to be at least one cycle in duration. A rising edge operator (R_TRIG) should not be used in the LOADTE setting.

A correction feature allows the present time-error estimate (TE) to be discarded, and a new value (TECORR) loaded when SELOGIC control equation LOADTE asserts. For example, if the TECORR value is set to zero, and then LOADTE is momentarily asserted, the TE analog quantity will be set to 0.000 seconds.

The TECORR analog quantity can be pre-loaded by the **TEC** command (see *TEC on page 14.54 in the SEL-400 Series Relays Instruction Manual*), or via DNP3, object 40, 41 index 01 (see *Table 16.8 on page 16.12 in the SEL-400 Series Relays Instruction Manual*). In either case, Relay Word bit PLDTE asserts for approximately 1.5 cycles to indicate that the preload was successful.

A separate SELOGIC control equation, STALLTE, when asserted, causes time-error calculation to be suspended.

Table 5.18 lists the inputs and outputs of the time-error function.

Table 5.18 Time-Error Calculation Inputs and Outputs (Sheet 1 of 2)

INPUTS	Description
Analog Quantities	
FREQ	Measured system frequency (see *Table 5.16*).
TECORR	Time-error correction factor. This value can be preloaded via the **TEC** command, or DNP3.

Table 5.18 Time-Error Calculation Inputs and Outputs (Sheet 2 of 2)

INPUTS	Description
Global Settings	
NFREQ	Nominal frequency (see *Table 8.3 on page 8.2*)
LOADTE	Load time-error correction factor (SELOGIC control equation). A rising edge will cause the relay to load the TECORR analog quantity into TE. LOADTE has priority over STALLTE.
STALLTE	Stall time-error calculation (SELOGIC control equation). A logical 1 will stall (freeze) the time-error function. The TE value will not change when STALLTE is asserted (unless LOADTE asserts).
Relay Word bit	
FREQOK	Frequency measurement valid. If this Relay Word bit deasserts, the TE quantity is frozen (see *Table 5.16*).
OUTPUTS	**Description**
Analog Quantity	
TE	Time-error estimate, in seconds. Positive numbers indicate that the ac clock would be fast (ahead of the reference clock). Negative numbers indicate that the ac clock would be slow (behind the reference clock).
Relay Word bit	
PLDTE	Preload Time-Error value updated. This element asserts for approximately 1.5 cycles after TECORR is changed by the TEC command or by DNP3.

Time-Error Command (TEC)

The **TEC** serial port command provides easy access to the time-error function. See *TEC on page 14.54 in the SEL-400 Series Relays Instruction Manual* for command access-level information.

Enter the **TEC** command to view the time-error status. A sample display is given in *Figure 5.15*.

```
=>TEC <Enter>

Relay 1                                  Date: 11/02/2004  Time: 11:25:50.460
Station A                                Serial Number: 0000000000

Time Error Correction Preload Value
TECORR = 0.000 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -7.838 s

=>
```

Figure 5.15 Sample TEC Command Response

Enter the **TEC** command with a single numeric argument *n* (–30.000 ≥ *n* ≤ 30.000) to preload the TECORR value. This operation does not affect the TE analog quantity until the SELOGIC control equation LOADTE next asserts. *Figure 5.16* shows an example of the **TEC *n*** command in use.

```
==>TEC 2.25 <Enter>

Relay 1                                  Date: 11/02/2004  Time: 11:53:12.701
Station A                                Serial Number: 0000000000

Change TECORR to 2.250 s:

Are you sure (Y/N)?Y <Enter>
```

Figure 5.16 Sample TEC *n* Command Response

```
Time Error Correction Preload Value
TECORR = 2.250 s

Relay Word Elements
LOADTE = 0, STALLTE = 0, FREQOK = 1

Accumulated Time Error
TE = -5.862 s

==>
```

Figure 5.16 Sample TEC *n* Command Response (Continued)

Fault Location

The SEL-421 computes distance to fault from data stored in the event reports. The relay calculates distance to fault upon satisfaction of all four of the following conditions:

- ➤ The fault locator is enabled, setting EFLOC := Y.
- ➤ A single-pole open condition does not exist (i.e., Relay Word bit SPOA, SPOB, and SPOC equal logical 0).
- ➤ A phase-distance, ground-distance, residual-ground overcurrent, negative-sequence, or time-overcurrent element picks up no later than 15 cycles after the event report trigger.
- ➤ The fault duration is greater than one cycle, as determined by the previously listed asserted protection element(s).

Table 5.19 Fault Location Triggering Elements

Fault Type	Protection Element
Ground Faults	Z1G–Z5G 67G1–67G4 67Q1–67Q4 51S1–51S3[a]
Phase Faults	Z1P–Z5P 67Q1–67Q4 51S1–51S3[b]

[a] Corresponding group setting 51S*k*O must be set to 3I2L or 3I0L (k = 1–3).
[b] Corresponding group setting 51S*k*O must be set to IAL, IBL, ICL, I1L, 3I2L, or IMAXL (k = 1–3).

The relay calculates distance to fault in per unit of the positive-sequence line impedance, Z_1. Use the relay setting LL, Line Length, to determine the units that the relay reports for the distance to a fault. For example, if a fault occurs at the midpoint of the protected line and you set LL to 126 for a line length of 126 kilometers, the result of the relay distance-to-fault calculation is 63.

Distance-to-fault calculation results range from –999.99 to 999.99. If the calculation cannot be determined (e.g., insufficient information) or if the result is outside the specified range, the relay reports the fault location as `$$$$.$$`.

The relay provides an analog fault location value from the most recent event report, labeled FLOC.

The relay specifies fault type along with the distance to fault. The fault type can be one of the types listed in *Table 5.20*.

Table 5.20 Fault Type

Label	Fault Type
AG	A-Phase-to-ground
BG	B-Phase-to-ground
CG	C-Phase-to-ground
AB	A-Phase-to-B-Phase
BC	B-Phase-to-C-Phase
CA	C-Phase-to-A-Phase
ABG	A-Phase-to-B-Phase-to-ground
BCG	B-Phase-to-C-Phase-to-ground
CAG	C-Phase-to-A-Phase-to-ground
ABC	Three-phase

Table 5.21 Fault Location Settings

Setting	Prompt	Range	Default (5 A)
Z1MAG	Positive-Sequence Line Impedance Magnitude (Ω)	$(0.25–1275)/I_{NOM}$	7.80
Z1ANG	Positive-Sequence Line Impedance Angle (°)	5.00–90	84.00
Z0MAG	Zero-Sequence Line Impedance Magnitude (Ω)	$(0.25–1275)/I_{NOM}$	24.80
Z0ANG	Zero-Sequence Line Impedance Angle (°)	5.00–90	81.50
EFLOC	Fault Location	Y, N	Y
LL	Line Length	0.10–999	100.00

Table 5.22 Fault Location Relay Word Bit

Name	Description
RSTFLOC	Fault locator analog quantity reset in progress.[a]

[a] Use Global setting RSTFLOC shown in *Table 8.20 on page 8.8* to reset the stored fault location analog quantity FLOC. Relay Word bit RSTFLOC will assert momentarily while the clearing action proceeds.
When reset, the value contained in FLOC is set to a very large number (greater than 1037). Resetting this value has no effect on the event reports stored in the SEL-421, nor does it have an effect on DNP3 event access.

Open-Phase Detection Logic

Some line-relaying applications (e.g., circuit breaker failure protection) benefit from fast open-phase detection. The resetting time of the instantaneous overcurrent elements using filtered quantities can be extended after the corresponding phase(s) is open if subsidence current is present. The SEL-421 open-phase detector senses an open phase in less than one cycle. This information is used for purposes such as quickly disabling instantaneous overcurrent elements in the circuit breaker failure schemes and open-pole detection.

The open-phase detection logic uses both the half-cycle and one-cycle cosine digital filter data shown in *Figure 9.2 on page 9.5 in the SEL-400 Series Relays Instruction Manual* to achieve the high-speed response to an open-phase condition. *Table 5.23* lists the output Relay Word bits.

Table 5.23 Open-Phase Detection Relay Word Bits

Name	Description
B1OPHA	Breaker 1 A-Phase open
B1OPHB	Breaker 1 B-Phase open
B1OPHC	Breaker 1 C-Phase open
B2OPHA	Breaker 2 A-Phase open
B2OPHB	Breaker 2 B-Phase open
B2OPHC	Breaker 2 C-Phase open
LOPHA	Line A-Phase open
LOPHB	Line B-Phase open
LOPHC	Line C-Phase open

Pole-Open Logic

The SEL-421 pole-open logic detects single-, double-, and three-pole open conditions. The relay uses the same processing for single- and double-pole open conditions. Pole-open logic supervises various protection elements and functions that use analog inputs from the power system (e.g., distance elements, directional elements, LOP logic).

Table 5.24 Pole-Open Logic Settings

Setting	Prompt	Range	Default
EPO	Pole Open Detection	52, V	52
27PO	Undervoltage Pole Open Threshold (V)[a]	1–200	40
SPOD	Single-Pole Open Dropout Delay (cycles)	0.000–60	0.500
3POD	Three-Pole Open Dropout Delay (cycles)	0.000–60	0.500

[a] 1 V steps.

Setting EPO (Enable Pole Open) offers two options for deciding the conditions that signify an open pole. These options are listed in *Table 5.25*.

Table 5.25 EPO Setting Selections

Selection	Description
52	Phase undercurrent and circuit breaker auxiliary contact input status
V	Phase undercurrent and phase undervoltage

NOTE: The 3PO, SPOA, SPOB, SPOC, and SPO Relay Word bits shown in *Figure 5.17* are used in some protective elements of the SEL-421. Separate Relay Word bits SPOBK*n*, 3POBK*n*, 2POBK*n* (*n* = 1 or 2), and 3POLINE are not affected by the EPO setting and are used in the autoreclose logic only (see *Figure 6.5 on page 6.26* and *Figure 6.7 on page 6.27 in the SEL-400 Series Relays Instruction Manual*).

Set EPO to V only if you use line-side potential transformers for relaying purposes. Do not select option V if shunt reactors are applied because the voltage decays slowly after the circuit breaker(s) opens. If you select EPO := V, the relay can incorrectly declare LOP during a pole-open condition if there is charging current that exceeds the open-pole current threshold.

Table 5.26 Pole-Open Logic Relay Word Bits (Sheet 1 of 2)

Name	Description
SPOA	A-Phase open
SPOB	B-Phase open

Table 5.26 Pole-Open Logic Relay Word Bits (Sheet 2 of 2)

Name	Description
SPOC	C-Phase open
SPO	One or two poles open
3PO	All three poles open
27APO	A-Phase undervoltage—pole open
27BPO	B-Phase undervoltage—pole open
27CPO	C-Phase undervoltage—pole open

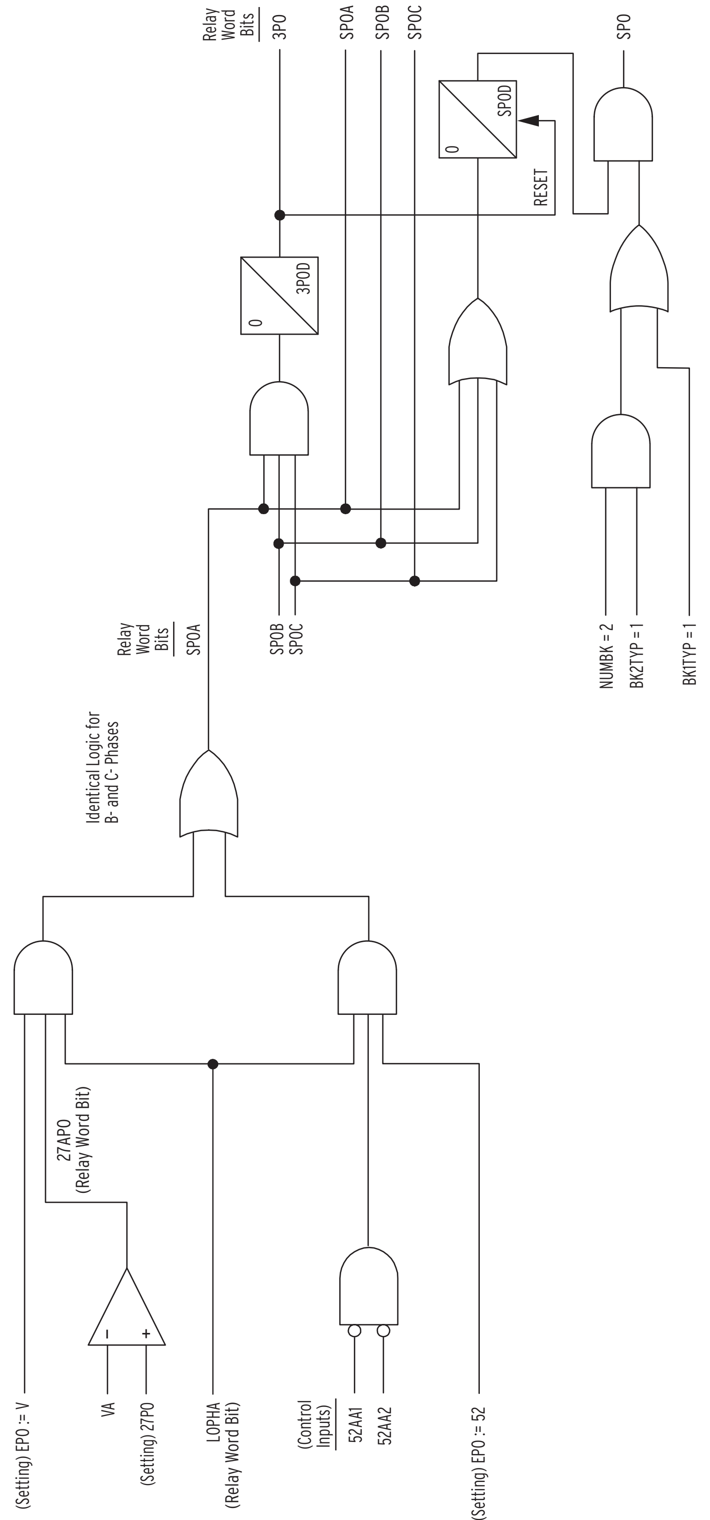


Figure 5.17 Pole-Open Logic Diagram

Loss-of-Potential Logic

Fuses or molded case circuit breakers often protect the secondary windings of the power system potential transformers. Operation of one or more fuses or molded case circuit breakers results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from discriminating fault distance and direction properly.

An occasional loss-of-potential (LOP) at the secondary inputs of a distance relay is unavoidable but detectable. The relay detects a loss-of-potential condition and asserts Relay Word bits LOP (loss-of-potential detected) and ILOP (Internal loss-of-protection from ELOP setting). This allows you to block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true LOP condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect a three-phase LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect an LOP when the circuit breaker(s) closes again.

The SEL-421 also asserts LOP upon circuit breaker closing for one or two missing PTs. If the relay detects a voltage unbalance with balanced currents at circuit breaker close, then the relay declares a loss-of-potential condition.

Inputs into the LOP logic are as follows:

- 3PO—three-pole open condition
- SPO—single-pole open condition
- OOSDET—out-of-step condition detected
- OST—out-of-step tripping assertion
- V_1—positive-sequence voltage (V secondary)
- I_1—positive-sequence current (A secondary)
- V_0—zero-sequence voltage (V secondary)
- I_0—zero-sequence current (A secondary)

All three poles of the circuit breaker(s) must be closed (i.e., Relay Word bit 3PO equals logical 0) and neither Relay Word bit OSB nor OST can be asserted for the LOP logic to operate.

The relay declares an LOP condition (Relay Word bit LOP equals logical 1) if V_1 drops in magnitude by at least ten percent and there is no corresponding change in I_1 or I_0 magnitude or angle. An LOP condition persisting for 15 cycles causes the LOP logic to latch. LOP resets (Relay Word bit LOP equals logical 0) when V_1 returns to a level greater than 85 percent nominal voltage and V_0 is less than 1_0 percent of V_1.

The LOP logic requires no settings other than enable setting ELOP.

Setting ELOP := N

If you set ELOP to N, the LOP logic operates but does not disable any voltage-polarized elements. This option is for indication only.

Setting ELOP := Y

If you set ELOP to Y and an LOP condition occurs, the voltage-polarized directional elements and all distance elements are disabled. The forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.

Setting ELOP := Y1

If you set ELOP to Y1 and an LOP condition occurs, the voltage-polarized directional elements and all distance elements are disabled. This setting for ELOP also disables the overcurrent elements that these voltage-polarized directional elements control.

Table 5.27 LOP Logic Setting

Setting	Prompt	Range	Default
ELOP	Loss-of-Potential	Y, Y1, N	Y1

Table 5.28 LOP Logic Relay Word Bits

Name	Description
ILOP	Internal loss-of-potential from ELOP setting
LOP	Loss-of-potential detected

Figure 5.18 illustrates how the LOP logic processes an LOP decision. *Figure 5.19* provides a logic diagram for the LOP logic.

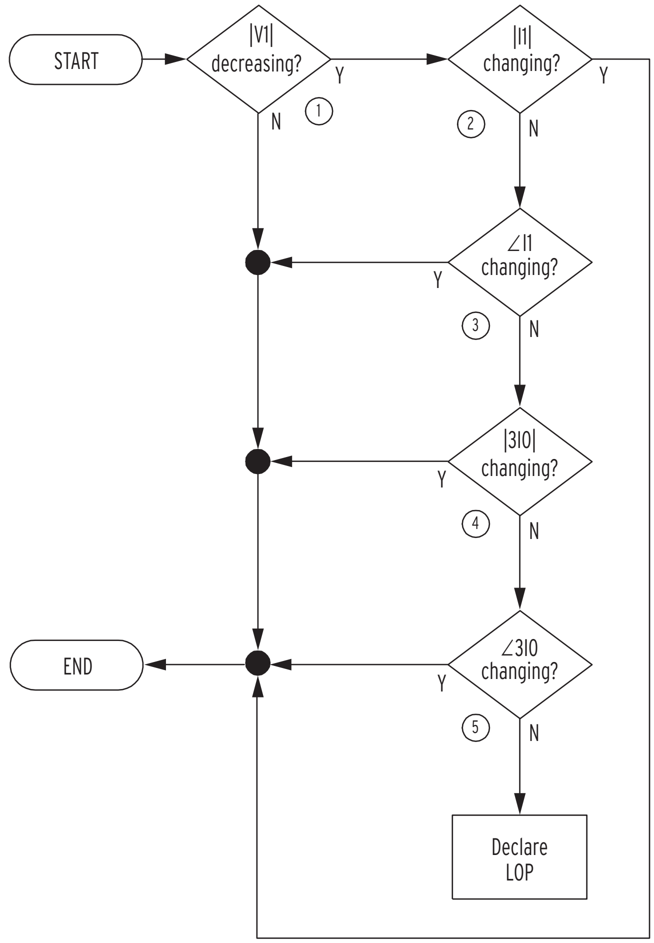


Figure 5.18 LOP Logic Process Overview

The following text gives additional description of the steps shown in *Figure 5.18*:

NOTE: When an enabled breaker is set to single-pole open mode, and a single-pole open condition (SPO) occurs, the open-pole voltages are replaced with 0 in the positive-sequence voltage calculation.

(1) Magnitude of positive-sequence voltage is decreasing. Measure positive-sequence voltage magnitude (called $|V_{1(k)}|$, where k represents the present processing interval result) and compare it to $|V_1|$ from one power system cycle earlier (called $|V_{1(k-1\ cycle)}|$). If $|V_{1(k)}|$ is less than or equal to 90 percent $|V_{1(k-1\ cycle)}|$, assert LOP if all of the conditions in the next four steps are satisfied. This is the decreasing delta change in V_1 ($-\Delta|V_1| > 10\%$) shown as an input in the logic diagram in *Figure 5.19*.

(2) Positive-sequence current magnitude not changing. Measure positive-sequence current magnitude ($|I_{1(k)}|$) and compare it to $|I_{1(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than two percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_1| > 2\%$ in *Figure 5.19*.

(3) Positive-sequence current angle is not changing. Measure positive-sequence current angle ($\angle I_{1k}$) and compare it to $\angle I_{1(k-1\ cycle)}$ from one cycle earlier. If this difference is greater than 5 degrees, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\angle I_1 > 5°$ in *Figure 5.19*. If $|I_1|$ is less than five percent nominal current (I_{NOM}), this angle check does not block LOP.

(4) Zero-sequence current magnitude is not changing. Measure zero-sequence current magnitude ($|I_{0k}|$) and compare it to $|I_{0(k-1\ cycle)}|$ from one cycle earlier. If this difference is greater than six percent nominal current, the condition measured is not an LOP, even if all other conditions are met. This input is labeled as $\Delta|I_0| > 6\%$ in *Figure 5.19*.

(5) Zero-sequence current angle is not changing. Measure zero-sequence current angle ($\angle I_{0k}$) and compare it to $\angle I_{0(k-1\ cycle)}$. If this difference is greater than 5 degrees, the condition measured is not an LOP even if all other conditions are met. This input is labeled as $\angle I_0 > 5°$ in *Figure 5.19*. For security, this declaration requires that $|I_0|$ be greater than five percent of nominal current to override an LOP declaration.

If the criteria identified in all five steps listed above are met, the LOP logic declares an LOP condition.

The relay resets LOP logic when the following conditions are true for 30 cycles:

1. A decreasing delta change in V_1 is less than 1_0 percent (see point (1) above).
2. The magnitude of V_1 is larger than 85 percent of V_{NOM}.
3. The magnitude of $|V_0|$ is not larger than 1_0 percent of magnitude $|V_1|$.

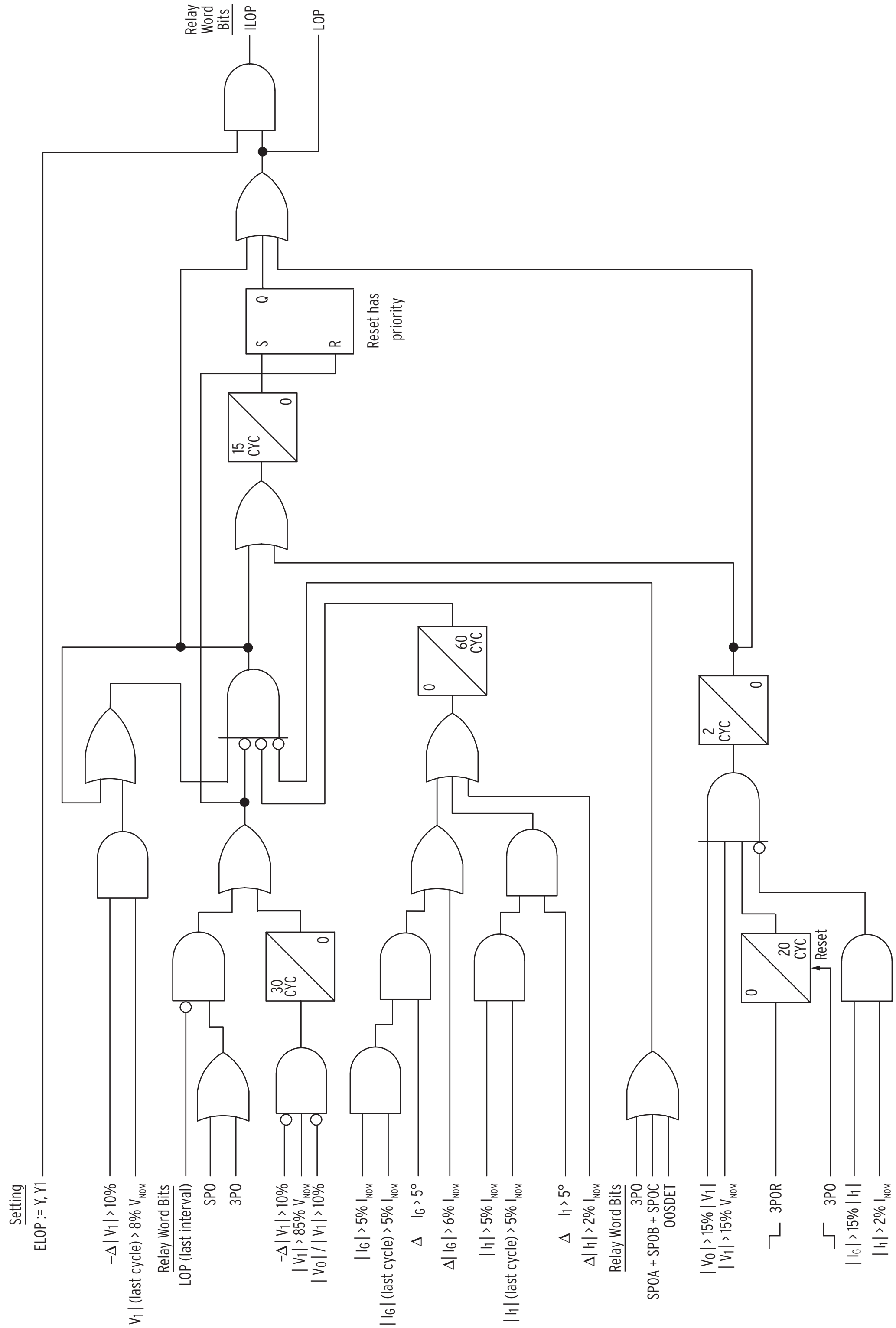


Figure 5.19 LOP Logic

Fault Type Identification Selection Logic

The fault type identification selection (FIDS) logic is enabled by the Group Setting EFID. This logic identifies the faulted phase(s) for all faults involving ground by comparing the angle between I_0 and I_2.

For cases where only zero-sequence current flows through the relay terminal (that is, no negative-sequence current and no positive-sequence current), the (FIDS) logic uses single-phase undervoltage elements for faulted phase selection.

The FIDS logic is not active during a single pole-open (SPO) condition (i.e., when SPO equals logical 1).

Setting EFID should be set equal to N only when the relay is applied in high-resistance grounded transmission systems. These systems can challenge the operation of the FIDS logic for phase-to-phase-to-ground faults. Setting EFID equal to N disables the FIDS logic, thereby removing FIDS supervision of phase-distance elements.

For all other applications, EFID must be set equal to Y to ensure proper operation of the phase and ground-distance elements.

Table 5.29 Fault Type Identification Logic Settings

Setting	Prompt	Range	Default
EFID	Enable fault identification logic	Y, N	Y

Table 5.30 FIDS Relay Word Bits

Name	Description
FIDEN	FIDS logic enabled
FSA	A-Phase-to-ground fault or B-Phase to C-Phase-to-ground fault selected
FSB	B-Phase-to-ground fault or C-Phase to A-Phase-to-ground fault selected
FSC	C-Phase-to-ground fault or A-Phase to B-Phase-to-ground fault selected

Ground Directional Element

The SEL-421 offers a choice of three independent directional elements to supervise the ground-distance elements and directional residual ground overcurrent elements (67G*n*, where *n* equals 1 through 4) during ground faults. You can also use the ground directional element for torque control. Internal logic selects the best choice automatically. *Table 5.31* lists the directional elements the relay uses to provide ground directional decisions.

Table 5.31 Directional Elements Supervising Ground Elements

Directional Elements	Description	Forward Output	Reverse Output
32QG	Negative-sequence voltage polarized for ground faults	F32QG	R32QG
32V	Zero-sequence voltage polarized	F32V	R32V
32I	Zero-sequence current polarized	F32I	R32I

The negative-sequence voltage polarized directional element 32QG listed in *Table 5.31* supervises the ground-distance elements and residual ground directional overcurrent elements. The negative-sequence voltage polarized directional element 32Q illustrated in *Figure 5.28* only supervises the phase-distance elements.

The relay internal logic selects the best choice for directional supervision according to prevailing power system conditions during the ground fault. The logic determines the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), or the zero-sequence current-polarized directional element (32I). The ground directional element also supervises the quadrilateral ground-distance elements.

During the single-pole open condition (SPO is a logical 1), the relay supervises the ground directional element with an open-pole directional element. The purpose of this directional element is to ensure secure operation of the distance elements during the single-pole open condition. The operation of the single-pole open directional element is indicated by the 32SPOF and the 32SPOR Relay Word bits.

As the single-pole open directional element may operate because of unbalance currents generated during the single-pole open condition, it is recommended that ground and negative-sequence overcurrent elements that are used for single-pole tripping be supervised by the single-pole open condition. To supervise overcurrent elements during the single-pole open condition, set the element torque control equation (67G*n*TC or 67Q*n*TC, where *n* equals 1–4) equal to NOT SPO.

Settings

Table 5.32 lists the relay settings corresponding to the ground directional element.

Table 5.32 Ground Directional Element Settings

Setting	Prompt	Range	Default (5 A)
E32	Directional Control	Y, AUTO, AUTO2	AUTO2
ORDER	Ground Directional Element Priority	combine Q, V, I	QV
50FP	Forward Directional Overcurrent Pickup (A)	(0.05–1) • I_{NOM}	0.50
50RP	Reverse Directional Overcurrent Pickup (A)	(0.05–1) • I_{NOM}	0.25
Z2F	Forward Directional Z2 Threshold (Ω)	±320/I_{NOM}	–0.30
Z2R	Reverse Directional Z2 Threshold (Ω)	±320/I_{NOM}	0.30
a2	Positive-Sequence Restraint Factor, I2/I1	0.02–0.5	0.10
k2	Zero-Sequence Restraint Factor, I2/I0	0.1–1.2	0.20
Z0F	Forward Directional Z0 Threshold (Ω)	±320/I_{NOM}	–0.30
Z0R	Reverse Directional Z2 Threshold (Ω)	±320/I_{NOM}	0.30
a0	Positive-Sequence Restraint Factor, I0/I1	0.02–0.5	0.10
E32IV	Zero-Sequence Voltage Current Enable	SELOGIC Equation	1

If you set E32 to AUTO, the relay automatically calculates the settings shown in *Table 5.33*.

Table 5.33 Ground Directional Element Settings AUTO Calculations

Setting	Equation
50FP	$0.12 \cdot I_{NOM}$
50RP	$0.08 \cdot I_{NOM}$
Z2F	0.5 • Z1MAG
Z2R	$Z2F + 1/(2 \cdot I_{NOM})$
a2	0.1
k2	0.2
Z0F	0.5 • Z0MAG
Z0R	$Z0F + 1/(2 \cdot I_{NOM})$
a0	0.1

Use caution when you set E32 = AUTO. It is not appropriate for all applications. Systems with a strong negative-sequence source (e.g., equivalent negative-sequence impedance of less than $2.5/I_{NOM}$ in ohms) can use E32 = AUTO. It is best to use E32 = AUTO2 with the settings in *Table 5.34* if any of the following apply:

- The negative-sequence impedance of the source is greater than $2.5/I_{NOM}$ in ohms
- The line impedance is unknown
- A non-fault condition occurs, such as a switching transformer energization causing the negative-sequence voltage to be approximately zero

Table 5.34 Ground Directional Element Preferred Settings

Name	5 A nominal	1 A nominal
E32	Y	Y
Z2F	–0.30	–1.5
Z2R	0.30	1.5
Z0F	–0.30	–1.5
Z0R	0.30	1.5
50QFP /50GFP	0. 50 A	0.10 A
50QRP /50GRP	0. 25 A	0.05 A
a2	0.10	0.10
k2	0.20	0.20
a0	0.10	0.10

The preferred settings in *Table 5.34* will provide equal or better protection than E32 = AUTO for most systems.

Detailed Settings Description

If you set E32 to Y, you can change the settings listed in *Table 5.33*.

50FP and 50RP

Setting 50FP is the threshold for the current level detector that enables forward decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50FP, the corresponding directional element can process a forward decision.

Setting 50RP is the threshold for the current level detector that enables reverse decisions for both the negative- and zero-sequence voltage-polarized directional elements. If the magnitude of $3I_2$ or $3I_0$ is greater than 50RP, the corresponding directional element can process a reverse decision.

Z2F and Z2R

Setting Z2F is the forward threshold for the negative-sequence voltage-polarized directional element. If the relay measures the apparent negative-sequence impedance z2 less than Z2F, the relay declares the unbalanced fault to be forward.

Setting Z2R is the reverse threshold for the negative-sequence voltage-polarized directional element. If the relay measures apparent negative-sequence impedance z2 greater than Z2R, the relay declares the unbalanced fault to be reverse.

a2 and k2

Positive-sequence current restraint factor a2 compensates for highly unbalanced systems. Unbalance is typical in systems that have many untransposed lines. This factor also helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current, $|I_2|/|I_1|$. If the measured ratio exceeds a2, the negative-sequence voltage-polarized directional element is enabled. Typically, you can apply the default calculations in *Table 5.33*.

Zero-sequence current restraint factor k2 also compensates for highly unbalanced systems. This factor is the ratio of the magnitude of negative-sequence current to the magnitude of zero-sequence current, $|I_2|/|I_0|$. If the measured ratio exceeds k2, the negative-sequence voltage-polarized directional element is enabled. If the measured ratio is less than k2, the zero-sequence voltage polarized directional element is enabled. Typically, you can apply the default calculations that appear in *Table 5.33*.

Z0F and Z0R

Setting Z0F is the forward threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 less than Z0F, the relay declares the unbalanced fault to be forward.

Setting Z0R is the reverse threshold for the zero-sequence voltage-polarized directional element. If the relay measures apparent zero-sequence impedance z0 greater than Z0R, then the relay declares the unbalanced fault to be reverse.

Typically, you can apply the default calculations that appear in *Table 5.33* for the settings Z2F, Z2R, Z0F, and Z0R. For series-compensated lines, calculate each of these settings separately. The forward threshold setting must be less than corresponding reverse threshold setting to avoid the situation where the measured apparent impedance satisfies both forward and reverse conditions.

a0

Positive-sequence current restraint factor a0 is the ratio of the magnitude of zero-sequence current to the magnitude of positive-sequence current, $|I_0|/|I_1|$. If the relay measures a ratio greater than a0, the zero-sequence voltage-polarized directional element is enabled. Typically you can apply the default calculations that appear in *Table 5.33*.

ORDER

The SEL-421 uses Best Choice Ground Directional Element logic to determine the order in which the relay selects 32QG, 32V, or 32I to provide directional decisions for the ground-distance elements and the residual ground directional overcurrent elements. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element (32QG)
- V—Zero-sequence voltage-polarized directional element (32V)
- I—Zero-sequence current-polarized directional element (32I)

You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority that these elements operate to provide the ground directional element.

Set E32 := Y to edit the ground directional element settings. If you set E32 := Y the relay hides certain relay settings depending on the setting ORDER.

If ORDER does not contain Q, the relay hides the Z2F, Z2R, a2, and k2 settings. If ORDER does not contain V, the relay hides the Z0F and Z0R settings. If ORDER contains only Q, the relay hides settings a0, E32IV, Z0F, and Z0R.

E32IV

SELOGIC control equation setting E32IV must be asserted to enable the zero-sequence voltage-polarized or zero-sequence current-polarized directional elements. This provides directional control of the ground-distance elements and directional residual ground overcurrent elements.

Directional Element Enables

The Relay Word bits shown in *Table 5.35* indicate when the relay has enabled the ground directional element.

Table 5.35 Ground Directional Element Enables

Name	Description
32QE	Negative-sequence voltage-polarized directional element enable—phase faults
32QGE	Negative-sequence voltage-polarized directional element enable—ground faults
32VE	Zero-sequence voltage-polarized directional element enable—ground faults
32IE	Zero-sequence current-polarized directional element enable—ground faults

Figure 5.20 and *Figure 5.21* correspond to *Table 5.35*.

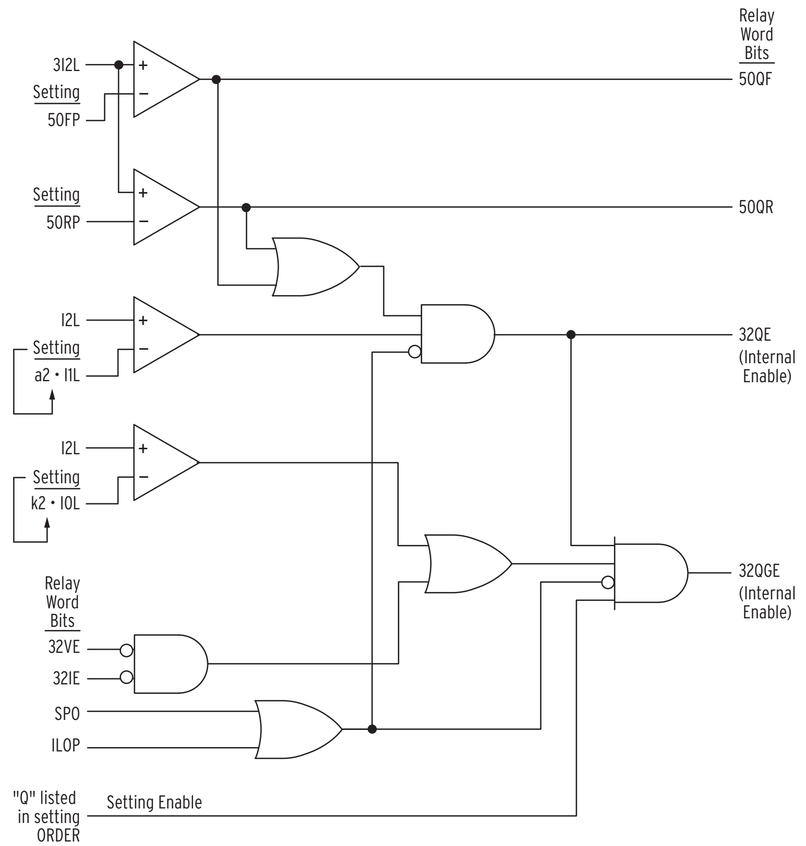


Figure 5.20 32Q and 32QG Enable Logic Diagram

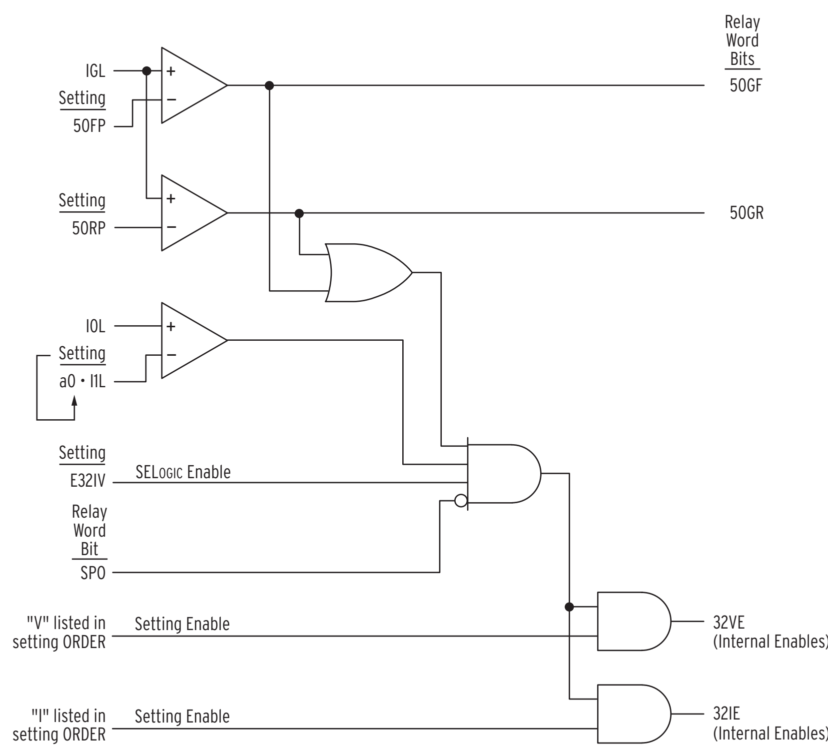
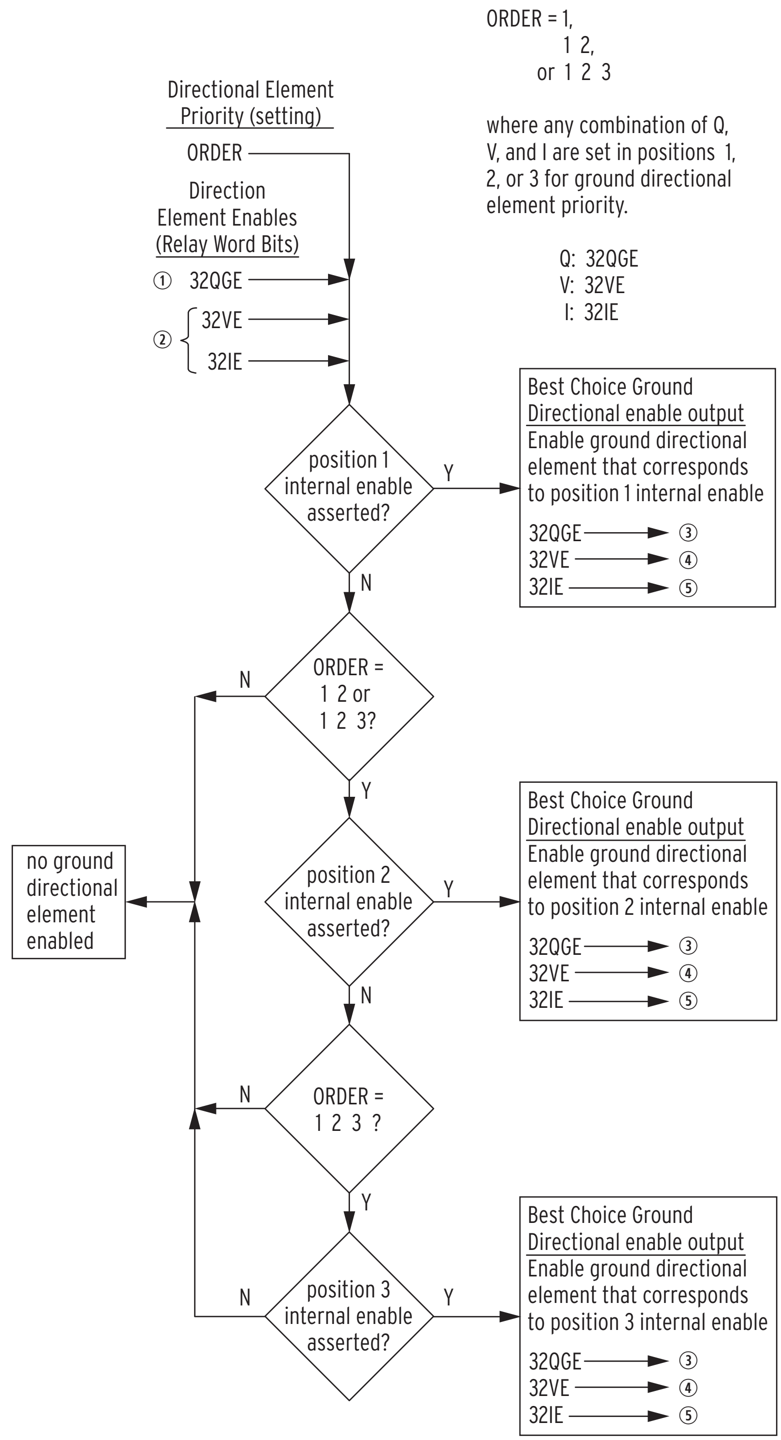


Figure 5.21 32V and 32I Enable Logic Diagram

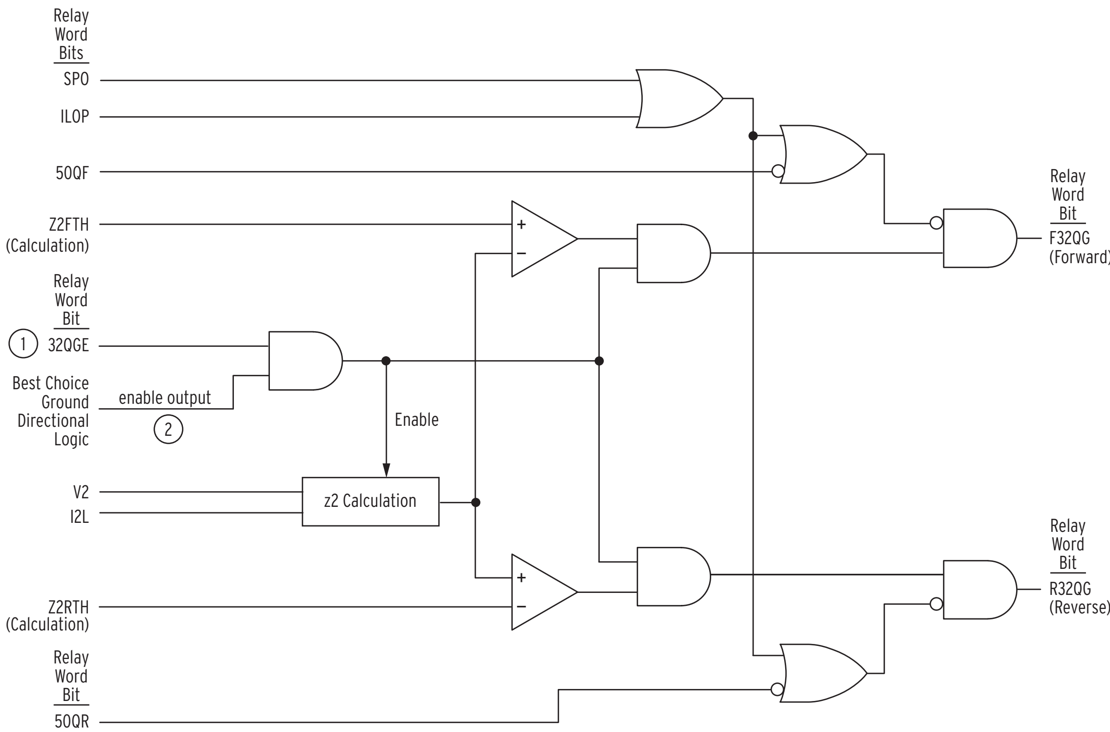
Table 5.36 Ground Directional Element Relay Word Bits

Name	Description
32SPOF	Forward open-pole directional declaration
32SPOR	Reverse open-pole directional declaration
50QF	Forward negative-sequence supervisory current level detector
50QR	Reverse negative-sequence supervisory current level detector
32QE	32Q internal enable
32QGE	32QG internal enable
50GF	Forward zero-sequence supervisory current level detector
50GR	Reverse zero-sequence supervisory current level detector
32VE	32V internal enable
HSDGF	Ground fault, high-speed forward directional element
HSDGR	Ground fault, high-speed reverse directional element
32IE	32I internal enable
32GF	Forward ground directional declaration
32GR	Reverse ground directional declaration
F32I	Forward current polarized zero-sequence directional element
R32I	Reverse current polarized zero-sequence directional element
F32V	Forward voltage polarized zero-sequence directional element
R32V	Reverse voltage polarized zero-sequence directional element
F32QG	Forward negative-sequence ground directional element
R32QG	Reverse negative-sequence ground directional element



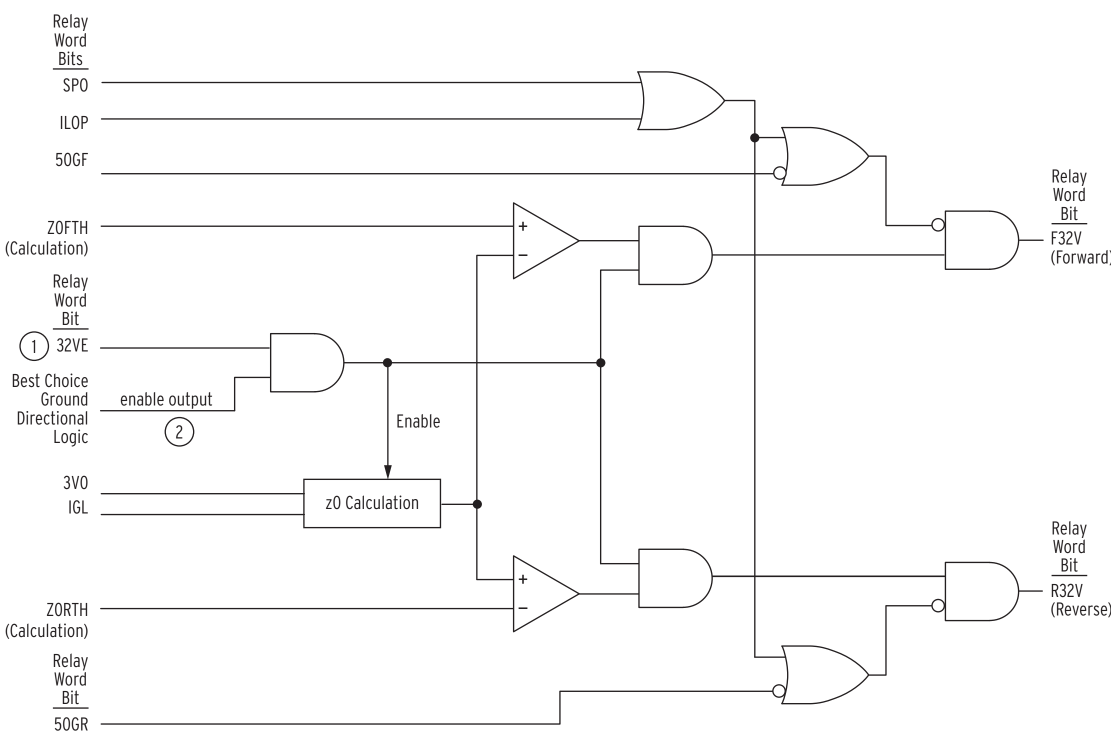
① From *Figure 5.20*, ② From *Figure 5.21*, ③ To *Figure 5.23*, ④ To *Figure 5.24*, ⑤ To *Figure 5.25*

Figure 5.22 Best Choice Ground Directional Element Logic



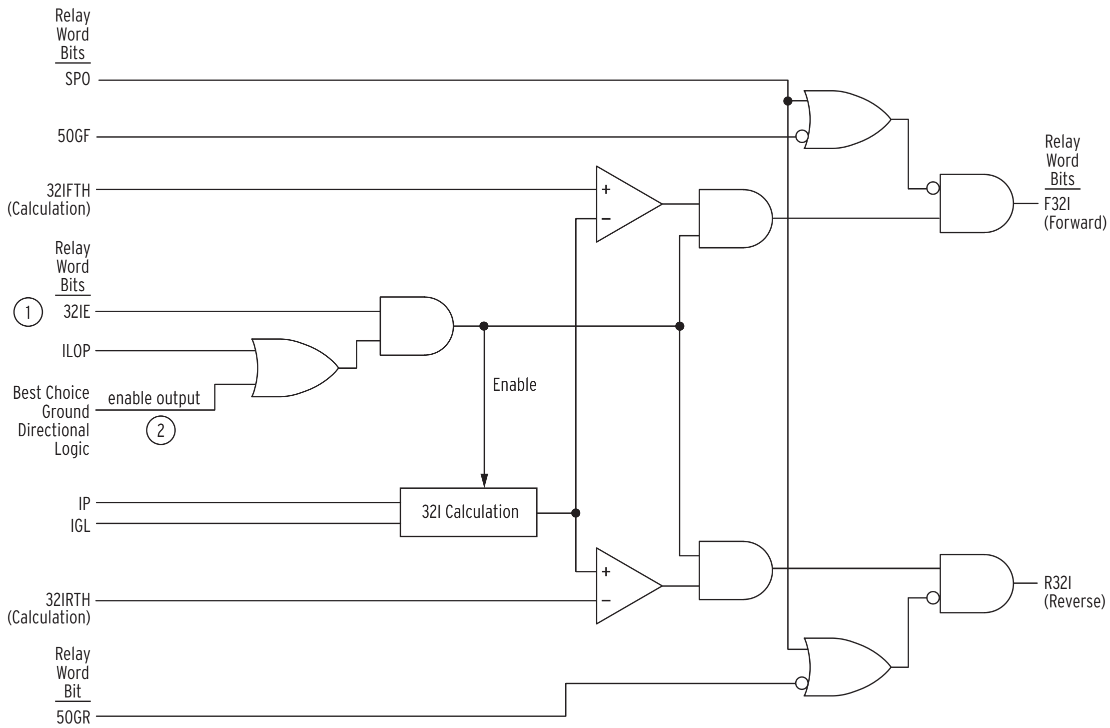
① From *Figure 5.20*; ② From *Figure 5.22*

Figure 5.23 Negative-Sequence Voltage-Polarized Directional Element Logic



① From *Figure 5.20*; ② From *Figure 5.22*

Figure 5.24 Zero-Sequence Voltage-Polarized Directional Element Logic



① From *Figure 5.20*; ② From *Figure 5.22*

Figure 5.25 Zero-Sequence Current-Polarized Directional Element Logic

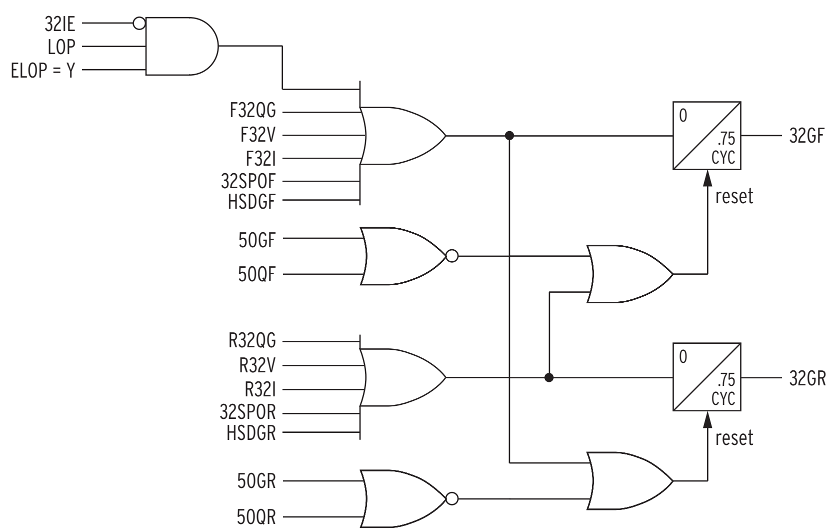


Figure 5.26 Ground Directional Element Output Logic Diagram

Table 5.37 Reference Table for *Figure 5.23*, *Figure 5.24*, and *Figure 5.25* (Sheet 1 of 2)

Name	Description
z2	Negative-sequence voltage-polarized directional element impedance calculation
Z2FTH	Negative-sequence voltage-polarized directional element forward threshold calculation
Z2RTH	Negative-sequence voltage-polarized directional element reverse threshold calculation
z0	Zero-sequence voltage-polarized directional element impedance calculation

Table 5.37 Reference Table for *Figure 5.23*, *Figure 5.24*, and *Figure 5.25* (Sheet 2 of 2)

Name	Description
Z0FTH	Zero-sequence voltage-polarized directional element forward threshold calculation
Z0RTH	Zero-sequence voltage-polarized directional element reverse threshold calculation
32I	Zero-sequence current-polarized directional element calculation
32IFTH	Zero-sequence current-polarized directional element forward threshold calculation
32IRTH	Zero-sequence current-polarized directional element reverse threshold calculation

Ground Directional Element Equations

For legibility, these equations use vector quantities, defined in *Table 5.38*. The analog quantities are listed in *Section 12: Analog Quantities*.

Table 5.38 Vector Definitions for Equation 1.1 Through Equation 1.11

Vector	Analog Quantities	Description
V2	1/3 [3V2FIM] ∠ 3V2FIA	Negative-sequence voltage
V0	1/3 [3V0FIM] ∠ 3V0FIA	Zero-sequence voltage
I2	1/3 [L3I2FIM] ∠ L3I2FIA	Negative-sequence current
IG	LIGFIM ∠ LIGFIA	Zero-sequence current
IP	IPFIM ∠ IPFIA[a]	Polarizing current

[a] The polarizing current angle quantity, IPFIA, is an internal quantity only and is not available as an analog quantity.

32QG

Directional Calculation

$$z2 = \frac{\mathrm{Re}[V_2 \bullet (I_2 \bullet 1\angle Z1ANG)^*]}{|I_2|^2}$$

Equation 5.15

Forward Threshold

If Z2F is less than or equal to 0:

$$Z2FTH = 0.75 \bullet Z2F - \left(0.25 \bullet \left|\frac{V_2}{I_2}\right|\right)$$

Equation 5.16

If Z2F is greater than 0:

$$Z2FTH = 1.25 \bullet Z2F - \left(0.25 \bullet \left|\frac{V_2}{I_2}\right|\right)$$

Equation 5.17

Reverse Threshold

If Z2R is greater than or equal to 0:

$$Z2RTH = 0.75 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 5.18

If Z2R is less than 0:

$$Z2RTH = 1.25 \bullet Z2R + 0.25 \bullet \left|\frac{V_2}{I_2}\right|$$

Equation 5.19

32V

Directional Calculation

$$z0 = \frac{Re[3V_0 \bullet (I_G \bullet 1\angle Z0ANG)^*]}{|I_G|^2}$$

Equation 5.20

Forward Threshold

If Z0F is less than or equal to 0:

$$Z0FTH = 0.75 \bullet Z0F - \left(0.25 \bullet \left|\frac{3V_0}{I_G}\right|\right)$$

Equation 5.21

If Z0F is greater than 0:

$$Z0FTH = 1.25 \bullet Z0F - \left(0.25 \bullet \left|\frac{3V_0}{I_G}\right|\right)$$

Equation 5.22

Reverse Threshold

If Z0R is greater than or equal to 0:

$$Z0RTH = 0.75 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 5.23

If Z0R is less than 0:

$$Z0RTH = 1.25 \bullet Z0R + 0.25 \bullet \left|\frac{3V_0}{I_G}\right|$$

Equation 5.24

32I

Directional Calculation

$$32I = Re[I_G \bullet I_P^*]$$

Equation 5.25

where:

I_P = Polarizing Current

Forward Threshold

$$32IFTH = 0.01 \bullet (InX\ nominal\ rating) \bullet (nominal\ current\ rating)$$

Equation 5.26

$$32IRTH = -0.01 \bullet (InX\ nominal\ rating) \bullet (nominal\ current\ rating)$$

Equation 5.27

Phase and Negative-Sequence Directional Elements

Phase (32P) and negative-sequence voltage-polarized (32Q) directional elements supervise the phase-distance elements. 32Q has priority over 32P. Relay Word bit ZLOAD (Load Impedance Detected) disables the 32P element. The 32Q element operates for all unbalanced faults.

When E32 := AUTO or AUTO2, you do not need to enter settings for 32Q or 32P elements. However, if you set E32 (Directional Control) to Y, the settings you enter for 50FP, 50RP, Z2F, Z2R, and a2 affect the 32Q element (see *Ground Directional Element on page 5.33* for more details).

Table 5.39 Phase and Negative-Sequence Directional Elements Relay Word Bits

Name	Description
F32P	Forward phase directional declaration
R32P	Reverse phase directional declaration
F32Q	Forward negative-sequence directional declaration
R32Q	Reverse negative-sequence directional declaration
32QF	Forward negative-sequence overcurrent directional declaration
32QR	Reverse negative-sequence overcurrent directional declaration
HSDQF	Phase-to-phase fault, high-speed forward directional element
HSDQR	Phase-to-phase fault, high-speed reverse directional element

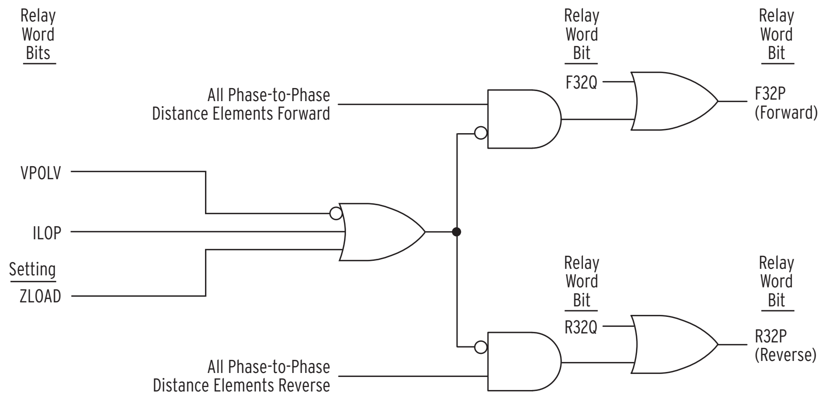
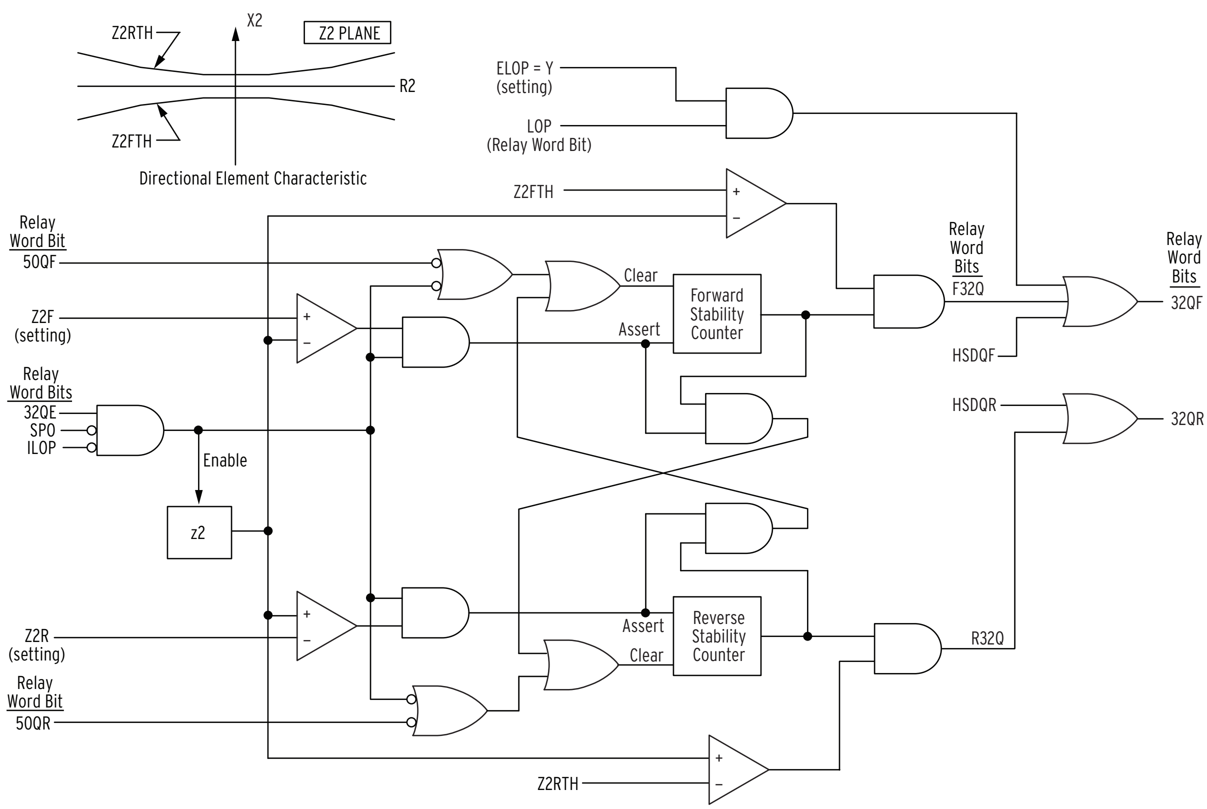


Figure 5.27 32P, Phase Directional Element Logic Diagram



The stability counter can add as much as a 0.5 cycle delay. This prevents the logic from toggling between forward and reverse declarations and gives other protection elements that rely on the directional decision time to operate.

Figure 5.28 32Q, Negative-Sequence Directional Element Logic Diagram

Directionality

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other distance protection zones (Zone 3, Zone 4, and Zone 5) independently as forward-looking (F), or reverse-looking (R) with settings DIR3, DIR4, and DIR5.

Level 1 and Level 2 directional overcurrent element directions are fixed in the forward direction for residual ground and negative-sequence directional overcurrent elements. Level 3 and Level 4 residual and negative-sequence directional overcurrent elements (67Q3, 67Q4, 67G3, and 67G4) share the same direction as the corresponding zones of distance protection, also using settings DIR3 and DIR4.

This directional control option is performed in addition to the regular torque control settings for each element (the torque control setting acts as a supervisory input).

The phase directional overcurrent elements (67P1–67P4) and the selectable operating quantity time-overcurrent elements (51S1–51S3) do not have any built-in directional control. The torque control settings (67P1TC, 67P2TC, 67P3TC, 67P4TC, 51S1TC, 51S2TC, 51S3TC) can be used to achieve directional control, as shown in the *230 kV Overhead Distribution Line Example on page 6.1*.

Table 5.40 Zone Directional Settings

Setting	Prompt	Range	Default
DIR3	Zone/Level 3 Directional Control	F, R	R
DIR4	Zone/Level 4 Directional Control	F, R	F
DIR5	Zone/Level 5 Directional Control	F, R	F

CVT Transient Detection

The SEL-421 detects CVT (Capacitor Voltage Transformer) transients that can cause Zone 1 distance elements to overreach during external faults. If CVT transient blocking is enabled and the relay detects a high SIR (source-to-impedance ratio) when a Zone 1 distance element is picked up, the relay delays tripping for as long as 1.5 cycles to allow the CVT transients to stabilize.

You do not need to enter settings. The relay adapts automatically to different system SIR conditions by monitoring the measured voltage and current.

If the distance calculation does not change significantly (i.e., is smooth), the SEL-421 unblocks CVT transient blocking resulting from low voltage and low current during close-in faults driven by a source with a high SIR. Therefore, Zone 1 distance elements operate without significant delay for close-in faults.

Consider using CVT transient detection logic when you have either of the following two conditions:

- SIR greater than or equal to five
- CVTs with AFSC (active ferroresonance-suppression circuits)

The following conditions can aggravate CVT transients:

- CVT secondary with a mostly inductive burden
- A low C value CVT, as defined by the manufacturer

Table 5.41 CVT Transient Detection Logic Setting

Setting	Prompt	Range	Default
ECVT	CVT Transient Detection	Y, N	N

Table 5.42 CVT Transient Detection Logic Relay Word Bit

Name	Description
CVTBL	CVT transient blocking active

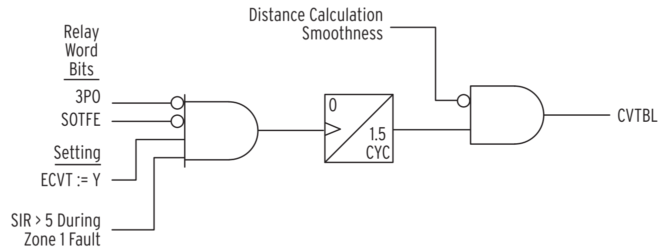


Figure 5.29 CVT Transient Detection Logic

SIR is defined as follows:

$$SIR = \frac{Z_{1S}}{Z_R}$$

where:

Z_{1S} = positive-sequence source impedance
Z_R = distance element reach

Use the Zone 1 distance element reach (Z1MP, Z1MG, XP1, or XG1) because the CVT transient detection logic only supervises Zone 1 distance protection.

Series-Compensation Line Logic

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

The SEL-421 includes logic to detect when a fault is beyond a series capacitor (a series capacitor can possibly cause Zone 1 overreach). The relay blocks the Zone 1 elements until the series-compensation logic determines that the fault is between the relay and the series capacitor (i.e., the fault is on the protected line section).

The value that you enter for setting XC depends on the position of the series-compensation capacitor(s) relative to the relay potential transformers. Capacitors can be on either end of a line, in the middle of a line, or at both ends of a line. Capacitors that are external to a protected line section can have an effect if infeed conditions are present.

In applications where there is a series capacitor on an adjacent line, for any SEL-421 Relays on non-compensated lines, set ESERCMP := Y and XC := OFF. This allows the Zone 1 element to be set to the desired sensitivity, yet still be secure during the voltage reversal that will occur when a neighboring compensated line experiences a fault.

For more information on setting the relay for series-compensated lines see SEL Application Guide AG2000-11, *Applying the SEL-321 Relay on Series-Compensated Systems*.

Table 5.43 Series-Compensation Line Logic Relay Settings

Setting	Prompt	Range	Default (5 A)
ESERCMP	Series-Compensation Line Logic	Y, N	N
XC	Series Capacitor Reactance (Ω)	(OFF, 0.25–320 Ω)/I_{NOM}	OFF

Load-Encroachment Logic

The load-encroachment logic prevents load from causing phase protection to operate. You can set the phase-distance and phase overcurrent elements independent of load. Two independent positive-sequence impedance characteristics monitor the positive-sequence load impedance (Z_1) for both export and import load. The positive-sequence voltage-polarized directional element (32P) is blocked when the load-encroachment logic is enabled and load is detected. The phase-distance elements cannot operate during balanced system conditions unless the logic asserts the 32P element.

Figure 5.30 illustrates the load-encroachment logic. The logic operates only if the positive-sequence current (I_1) is greater than the positive-sequence threshold (10 percent of the nominal relay current). Relay Word bit ZLOUT indicates that load is flowing out with respect to the relay (an export condition). Relay Word bit ZLIN indicates that load is flowing in with respect to the relay (an import condition). *Figure 5.31* illustrates load-encroachment settings and corresponding characteristics in the positive-sequence impedance plane. Either Relay Word bit ZLOUT or ZLIN asserts if the relay measures a positive-sequence impedance that lies within the corresponding hatched region. Relay Word bit ZLOAD is the OR combination of ZLOUT and ZLIN.

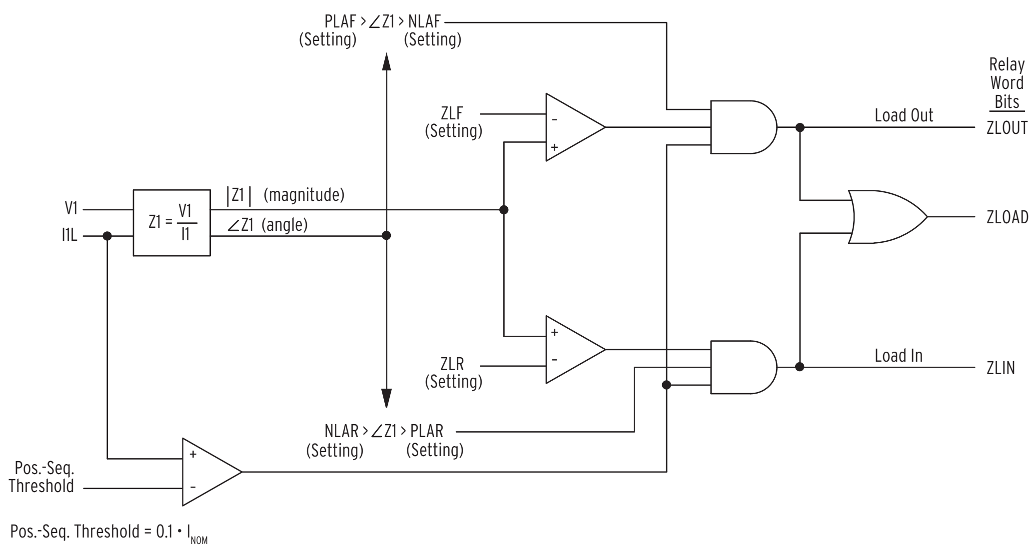


Figure 5.30 Load-Encroachment Logic Diagram

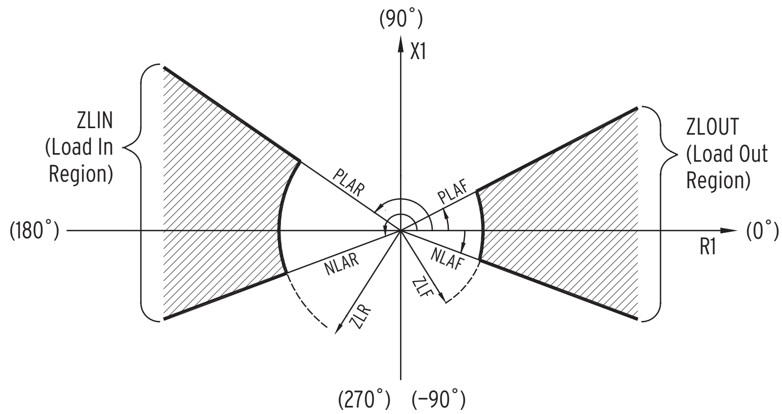


Figure 5.31 Load-Encroachment Characteristics

Table 5.44 Load-Encroachment Logic Relay Settings

Setting	Prompt	Range	Default (5 A)
ELOAD	Load Encroachment	Y, N	Y
ZLF	Forward Load Impedance (Ω)	$(0.25–320)/I_{NOM}$	9.22
ZLR	Reverse Load Impedance (Ω)	$(0.25–320)/I_{NOM}$	9.22
PLAF	Forward Load Positive angle (°)	–90.0 to +90	30.0
NLAF	Forward Load Negative angle (°)	–90.0 to +90	–30.0
PLAR	Reverse Load Positive angle (°)	90.0–270	150.0
NLAR	Reverse Load Negative angle (°)	90.0–270	210.0

Table 5.45 Load-Encroachment Logic Relay Word Bits

Name	Description
ZLOAD	ZLIN OR ZLOUT
ZLIN	Import load impedance detected
ZLOUT	Export load impedance detected

Out-of-Step Logic (Conventional)

The SEL-421 offers both conventional and settingless (zero-setting) out-of-step (OOS) functions. To use the conventional OOS function, set EOOS = Y. To use the zero-setting OOS function, set EOOS = Y1.

The out-of-step (OOS) logic determines whether a power swing is stable. This relay logic can be set to either block distance protection or allow tripping when the measured positive-sequence impedance (Z_1) remains between inner Zone 6 and outer Zone 7 longer than either the OOS blocking delay (setting OSBD) or the OOS tripping delay (setting OSTD), respectively (refer to *Figure 5.32*).

NOTE: E50Q must be set to 1 or greater for enabling 67Q1T override of OOS blocking for Zone 1 (see *Figure 5.57*, *Figure 5.60*, and *Figure 5.63*).

The OOS logic detects all power swings that enter the OOS characteristics, even if a single-pole open condition exists (Relay Word bit SPO equals logical 1). If either negative-sequence directional element 67QUBF or 67QUBR (67Q1T for Zone 1) picks up during a power swing and a single-pole open condition does not exist (Relay Word bit SPO equals logical 0), the logic overrides OOS blocking (i.e., an unbalanced fault has occurred). The negative-sequence current level detector 50QUB determines the sensitivity of the 67QUBF or 67QUBR elements, for all zones except Zone 1.

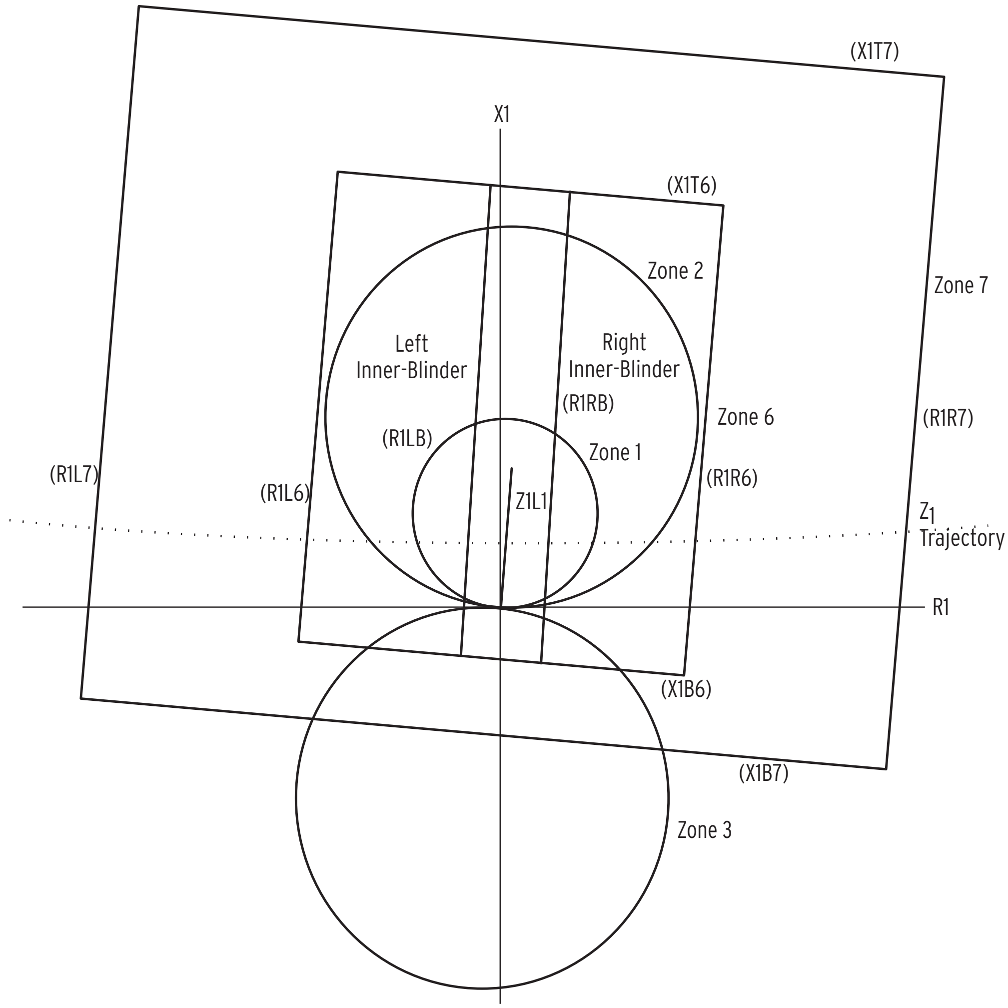


Figure 5.32 OOS Characteristics

If a three-phase fault occurs during a power swing that has operated the OOS logic, the logic also overrides OOS blocking; a set of internally derived inner blinders encompasses the protected line and detects internal three-phase faults. The OOS logic can also detect a power swing when a single-pole open condition exists; for such a case, the logic can block both phase and ground-distance protection.

Refer to *Section 6: Protection Applications Examples* for detailed descriptions of the various functions utilized by the OOS logic.

The following rules apply when you set the OOS logic:

- You can enable the OOS logic when setting Z1ANG is greater than 45 degrees.
- Settings X1T6, X1T7, R1R6, and R1R7 must be set to a positive value.
- Settings X1B6, X1B7, R1L6, and R1L7 must be set to a negative value.
- Setting R1R6 must be set less than R1R7.

- Setting R1L6 must be set greater than R1L7.
- Setting X1T6 must be set less than X1T7.
- Setting X1B6 must be set greater than X1B7.
- The minimum separation between settings R1R6 and R1R7 is $0.25/I_{NOM}$.
- The minimum separation between settings R1L6 and R1L7 is $0.25/I_{NOM}$.
- The minimum separation between settings X1T6 and X1T7 is $0.25/I_{NOM}$.
- The minimum separation between settings X1B6 and X1B7 is $0.25/I_{NOM}$.
- Setting OSBD must be greater than OSTD by a minimum of 0.5 cycle.

Table 5.46 OOS Logic Relay Settings

Setting	Prompt	Range	Default (5 A)
EOOS	Out-of-Step	Y, Y1, N	N
OOSB1	Block Zone 1	Y, N	Y
OOSB2	Block Zone 2	Y, N	Y
OOSB3	Block Zone 3	Y, N	Y
OOSB4	Block Zone 4	Y, N	N
OOSB5	Block Zone 5	Y, N	N
OSBD[a]	Out-of-Step Block Time Delay (cycles)	0.500–8000	2.000
OSBLTCH[a]	Latch Out-of-Step Blocking[b]	Y, N	N
EOOST	Out-of-Step Trip Delay[c]	N, I, O, C	N
OSTD[a]	Out-of-Step Trip Delay (cycles)	0.500–8000	0.500
X1T7[a]	Zone 7 Reactance—Top (Ω)	$(0.25–700)/I_{NOM}$	23.00
X1T6[a]	Zone 6 Reactance—Top (Ω)	$(0.25–700)/I_{NOM}$	21.00
R1R7[a]	Zone 7 Resistance—Right (Ω)	$(0.25–700)/I_{NOM}$	23.00
R1R6[a]	Zone 6 Resistance—Right (Ω)	$(0.25–700)/I_{NOM}$	21.00
X1B7[a,d]	Zone 7 Reactance—Bottom (Ω)	$(–0.25–700)/I_{NOM}$	–23.00
X1B6[a,d]	Zone 6 Reactance—Bottom (Ω)	$(–0.25–700)/I_{NOM}$	–21.00
R1L7[a,d]	Zone 7 Resistance—Left (Ω)	$(–0.25–700)/I_{NOM}$	–23.00
R1L6[a,d]	Zone 6 Resistance—Left (Ω)	$(–0.25–700)/I_{NOM}$	–21.00
50ABCP[d]	Pos.-Seq. Current Supervision (A)	$(0.20–20) \cdot I_{NOM}$	1.00
50QUBP[a,d]	Neg.-Seq. Current Supervision (A)	$(OFF, 0.10–20) \cdot I_{NOM}$	OFF
UBD[a,d]	Neg.-Seq. Current Unblock Delay (cycles)	0.500–120	0.500
UBOSBF[a,d]	Out-of-Step Angle Unblock Rate	1–10	4
OOSPSC	No. of Pole Slips Before Tripping	1–10	1

[a] Hidden when EOOS = Y1.

[b] The OSB (Out-of-Step Blocking) logic resets automatically after it asserts for more than 2 seconds. You can latch OSB if the power swing moves outside of Zone 6 before the two-second timer expires.

[c] Option I enables tripping on the way into Zone 6; option O enables tripping on the way out of Zone 6; option N disabled OST (Out-of-Step Trip).

[d] Advanced Setting if EADVS := Y. If the Advanced Settings are not enabled (setting EADVS := N), the relay hides the setting.

Table 5.47 OOS Logic Relay Word Bits

Name	Description
50ABC	Positive-sequence current level detector
X6ABC	Zone 6
X7ABC	Zone 7
UBOSB	Unblock out-of-step blocking
OSB	Out-of-step blocking
OSTI	Incoming out-of-step tripping
OSTO	Outgoing out-of-step tripping
OST	Out-of-step tripping
67QUBF	Negative-sequence forward directional element
67QUBR	Negative-sequence reverse directional element
OOSDET	OOS condition detected
OSB1	Block Zone 1 during out-of-step condition
OSB2	Block Zone 2 during out-of-step condition
OSB3	Block Zone 3 during out-of-step condition
OSB4	Block Zone 4 during out-of-step condition
OSB5	Block Zone 5 during out-of-step condition
OSBA	A-Phase out-of-step blocking
OSBB	B-Phase out-of-step blocking
OSBC	C-Phase out-of-step blocking

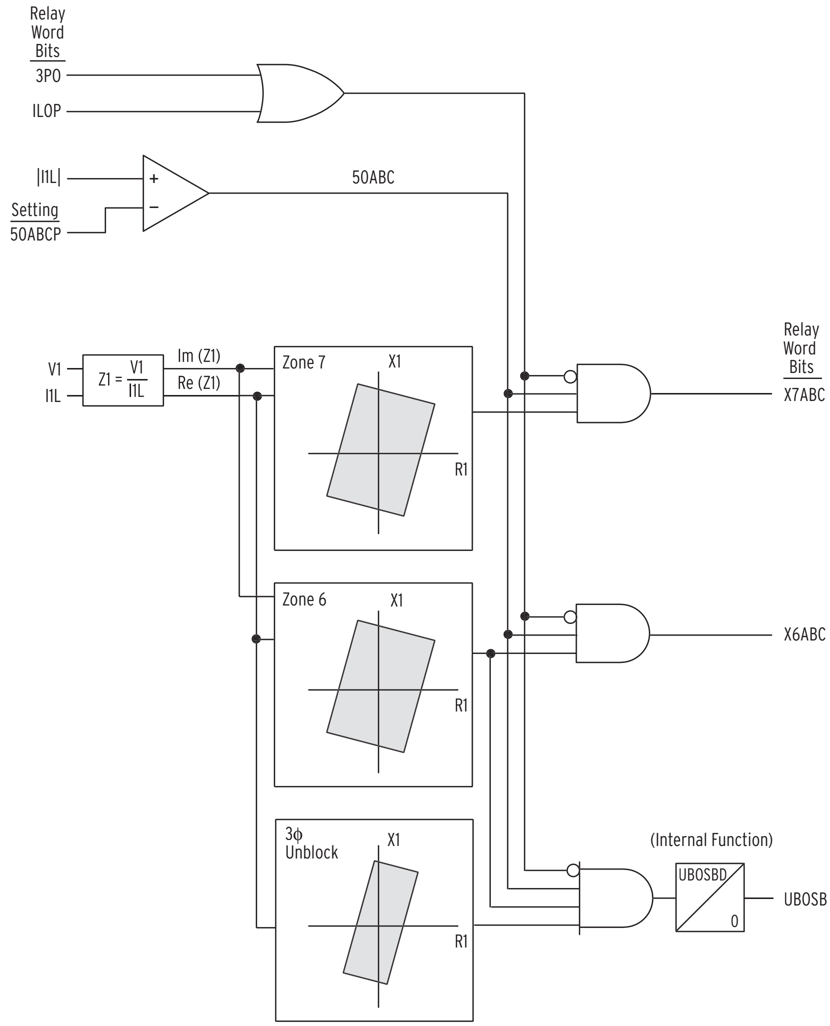


Figure 5.33 OOS Positive-Sequence Measurements

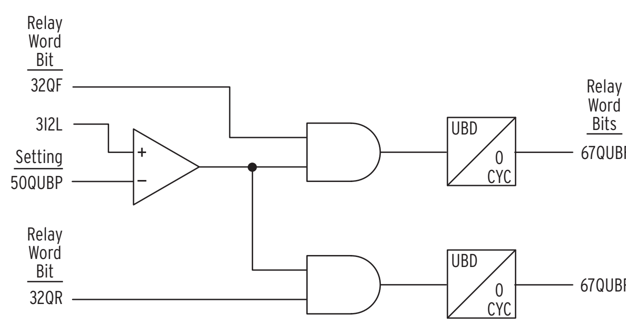


Figure 5.34 OOS Override Logic

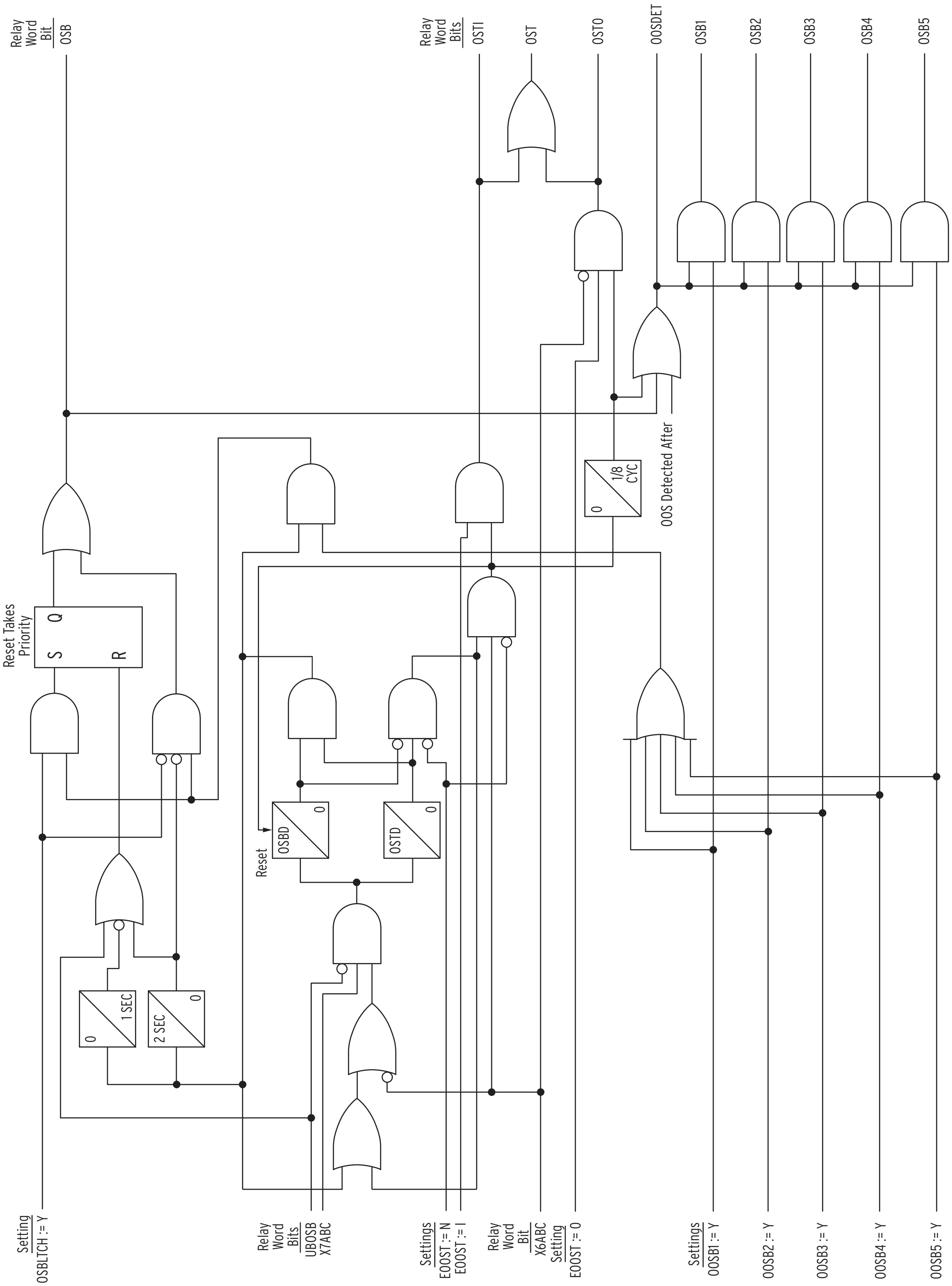


Figure 5.35 OOS Logic Diagram

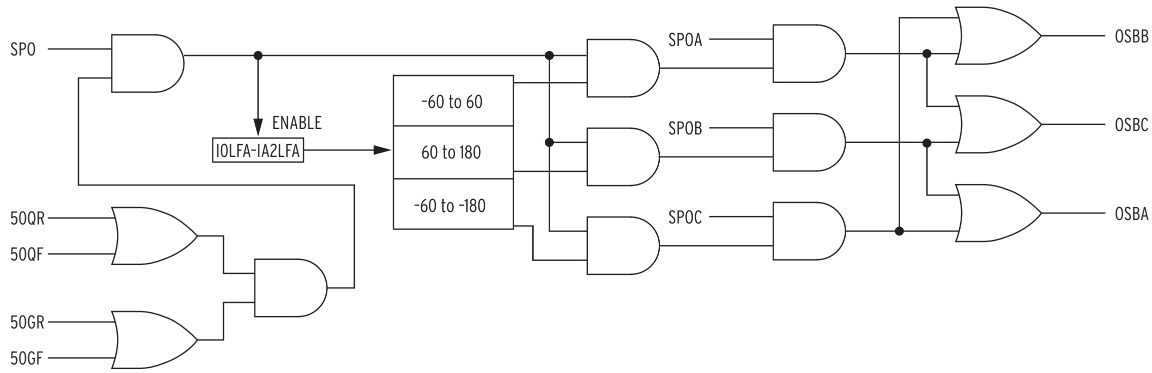


Figure 5.36 Open-Pole OSB Unblock Logic

Out-of-Step Logic (Zero Settings)

Use the zero-setting out-of-step (OOS) blocking function element when the slip frequency of your system is in the 0.1 to 7 Hz range. (Download the technical paper "Zero-Setting Power-Swing Blocking Protection" by G. Benmouyal, Daqing Hou, and Demetrios Tziouvaras from the SEL website for more information).

To use the conventional power swing blocking function, set EOOS = Y.

To use the zero-setting power swing blocking function, set EOOS = Y1.

No-Setting OOS Blocking Base Block Diagram

The zero-setting out-of-step blocking function is based on the five functional blocks shown in *Figure 5.37*. These blocks are the swing-center voltage slope detector, the swing signature detector, the reset conditions, the dependable out-of-step blocking detector, and the three-phase fault detector. Notice that when either SD (swing-center voltage slope detector) or SSD (swing signature detector) asserts, the Latch is set, and OSB_I and OSB are also latched.

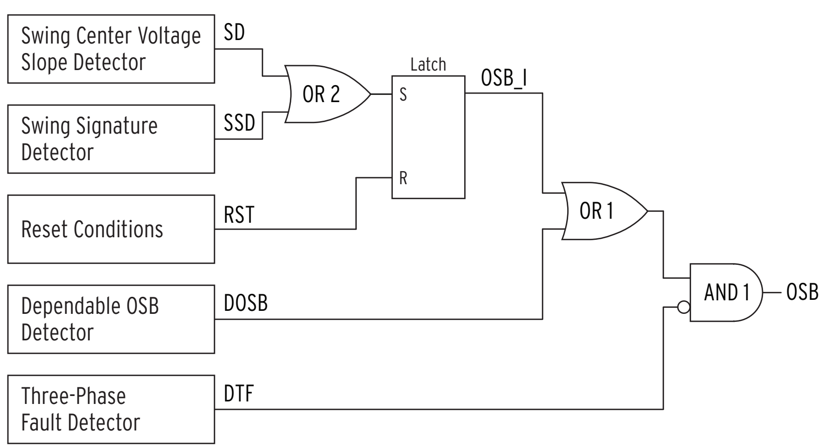


Figure 5.37 Zero-Setting OOS Blocking Function

Swing Center Voltage (SCV) Processing and Analog Variables

The detection of a network power swing condition is based on monitoring the rate-of-change of the positive-sequence swing-center voltage. For the purpose of implementing the function, the following analog variables are used:

- SCV1: per-unit positive-sequence swing-center voltage
- dSCV1_Unflt: unfiltered derivative of the positive-sequence swing-center voltage
- dSCV1_UF: ultra-fast derivative (filtered) of the positive-sequence swing-center voltage
- dSCV1_F: fast derivative (moderately filtered) of the positive-sequence swing-center voltage
- dSCV1_S: slow derivative (most filtered) of the positive-sequence swing-center voltage
- d2SCV1_UF: ultra-fast second derivative (not filtered) of the positive-sequence swing-center voltage

Swing Center Voltage Slope Detector

In *Figure 5.38*, the top four comparators determine whether the swing is fast (dSCV1_F remains asserted for 1.75 cycles) or slow (dSCV1_S remains asserted for 5 cycles) for both negative and positive slopes, if the supervision condition are met. The supervision conditions are:

- No power swing is in progress (OSB_I is de-asserted), and no Zone 2 through Zone 5 distance elements are asserted *or*
- The absolute value of dSCV1_UF is greater than 0.55) *or*
- The absolute value of dSCV1_UF is lower than 0.55 but greater than 0.2 *and* the absolute value of d2SCV1_UF is greater than 0.23.

Therefore, if OR Gate OR 1 does not assert, one of the timers (Timer 1 through Timer 4) starts timing. If the conditions prevail, the top input of AND Gate AND 5 asserts after the appropriate timer expires.

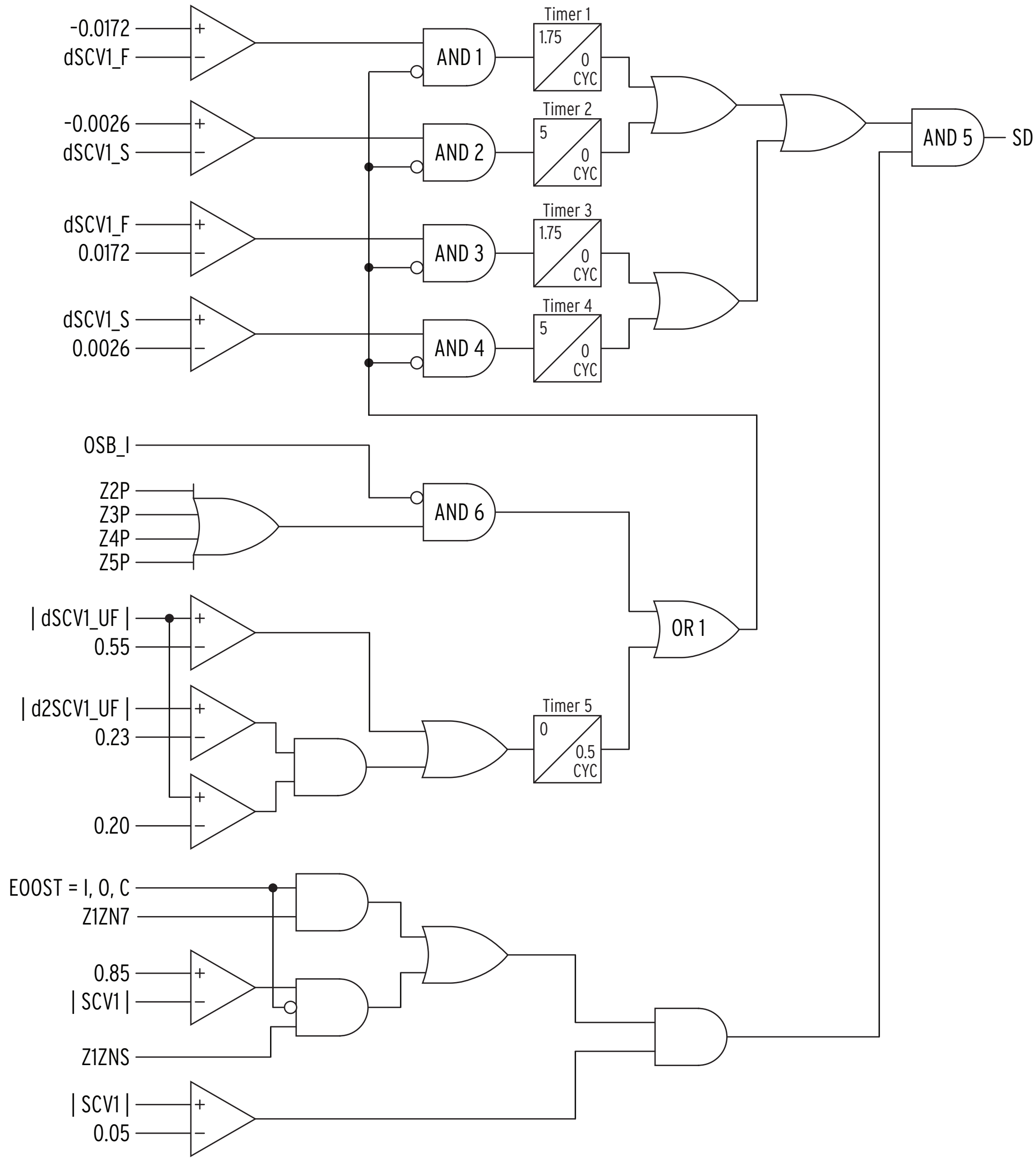


Figure 5.38 Swing Center Voltage Slope Detection Logic

The bottom input of AND Gate AND 5 asserts when the following is true:

- The absolute value of the SCV1 is above 0.05 *and*
- The enable out-of-step setting (EOOST) is either I, O, or C *and* the positive-sequence impedance is in Zone 7 (Z1ZN7) *or*
- If out-of-step tripping is not selected (EOST = N), then the following conditions must be true: the absolute value of the SCV1 is below 0.85 *and* the positive-sequence impedance is in the Starter Zone (Z1ZNS)

When AND Gate AND 5 asserts, SD asserts. When SD asserts, the Latch in *Figure 5.37* asserts, causing OSB_I and OSB to assert.

Figure 5.38 includes two checks for Z1, the positive-sequence impedance: whether Z1 is in the Starter Zone (see *Figure 5.39*) and whether Z1 is in Zone 7 (see *Figure 5.32*).

The purpose of the starter zone is to reduce the sensitivity of the power-swing detector by allowing the PSB elements to assert only for those trajectories of the positive-sequence impedance (Z1) that could possibly move into the characteristic of any distance element during a power swing. The area of the starter zone is a rectangle that encompasses all the distance characteristics that must be blocked during a power swing, as shown in *Figure 5.39*. Furthermore, if the out-of-step tripping (OST) is enabled, the starter zone also encompasses the largest relay characteristic set for the OST logic (Zone 7; see *Out-of-Step Tripping (OST)—Zero Settings Element on page 5.68*). The algorithm automatically calculates the Starter Zone from the Z2MP–Z5MP, XP2–XP5, and RP2–RP5 Group settings, using the following equations:

R_SZ = max (2 • Z2P, OOSB2, 1.5 • Z3P, OOSB3, 1.5 • Z4P, OOSB4, 1.5 • Z5P, OOSB5)

X_SZ = max (3 • Z2P, OOSB2, 2 • Z3P, OOSB3, 2 • Z4P, OOSB4, 2 • Z5P, OOSB5)

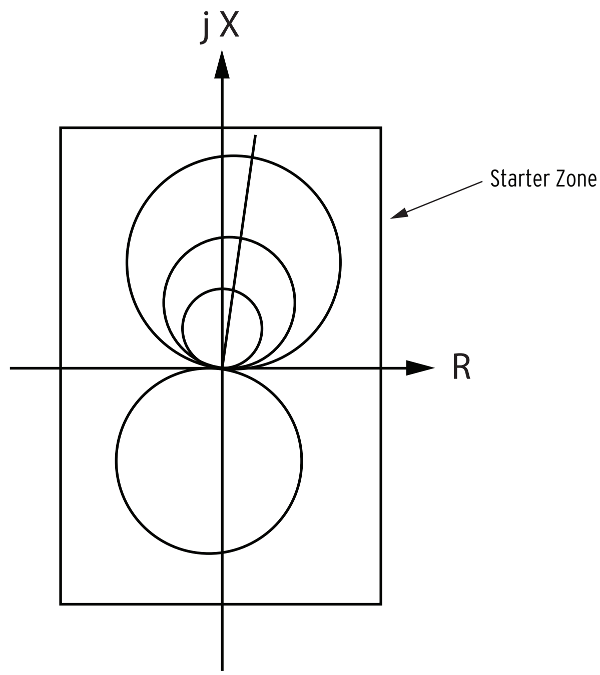


Figure 5.39 Starter Zone Characteristic

The slope detector typically detects the majority of power-swing conditions. However, there are some system conditions for which the slope detector may not operate. To ensure correct relay power-swing operation, the OSB function also includes two additional detectors: a swing signature detector and a dependable PSB detector.

The Swing Signature Detector

The swing signature detector (SSD) complements the slope detector and supplements the dependable PSB logic. To distinguish a power swing from a system fault, the swing signature detector uses the combination of a step change in the system voltage and the assertion of distance-element-based protection elements (see *Figure 5.40*).

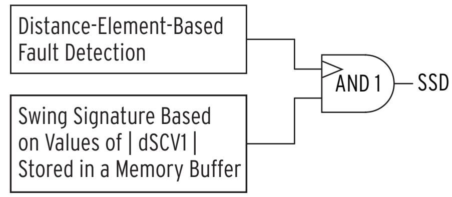


Figure 5.40 Swing Signature Detector Logic

In particular, if distance elements pick up without an associated step change in the system voltage, the swing signature detector declares this as a power swing condition and asserts Output SSD. However, if distance elements pick up and there is an associated step change in the system voltage, the swing signature detector does not assert as this is considered a system fault.

Figure 5.41 shows the logic for the swing signature detector. When both inputs into AND 1 asserts, SSD (the swing signature detection) asserts. The top input into AND 1 consists of the phase-distance elements (Z2P–Z5P) and ground-distance elements (Z2G–Z5G) set to be blocked during a power swing.

Enable each distance zone you want included in the power swing blocking function on an individual basis with the OOSB2–OOSB5 settings. Note that you include both phase-distance element (Z2P–Z5P) and ground-distance elements (Z2G–Z5G) with the OOSB2–OOSB5 settings. Phase-distance elements included in the power swing blocking function are further supervised by the OSB unbalance reset conditions (67QUBF, see *Figure 5.52*) and open-pole conditions. Similarly, ground-distance elements included in the power swing blocking function are further supervised by open-pole conditions.

If any of these distance elements asserts (no supervisory conditions), then the top input into AND 1 asserts.

In a separate calculation, the algorithm calculates and stores three cycles of the absolute values of the first order derivative, dSCV1_unfilt, in a buffer. From these values, the algorithm calculates dSCV1_unfiltMAX, the maximum value of dSCV1_unfilt over the three cycles.

For the summation, the logic uses values from the oldest cycle of the three-cycle buffer (i.e., two cycle old values). This choice of values effectively delays the assertion of the bottom leg of AND 1 for at least two and a half cycles. If three samples in the buffer exceed 5 percent of dSCV1_unfiltMAX, and if dSCV1_unfiltMAX is greater than 0.001, the bottom leg of AND 1 asserts.

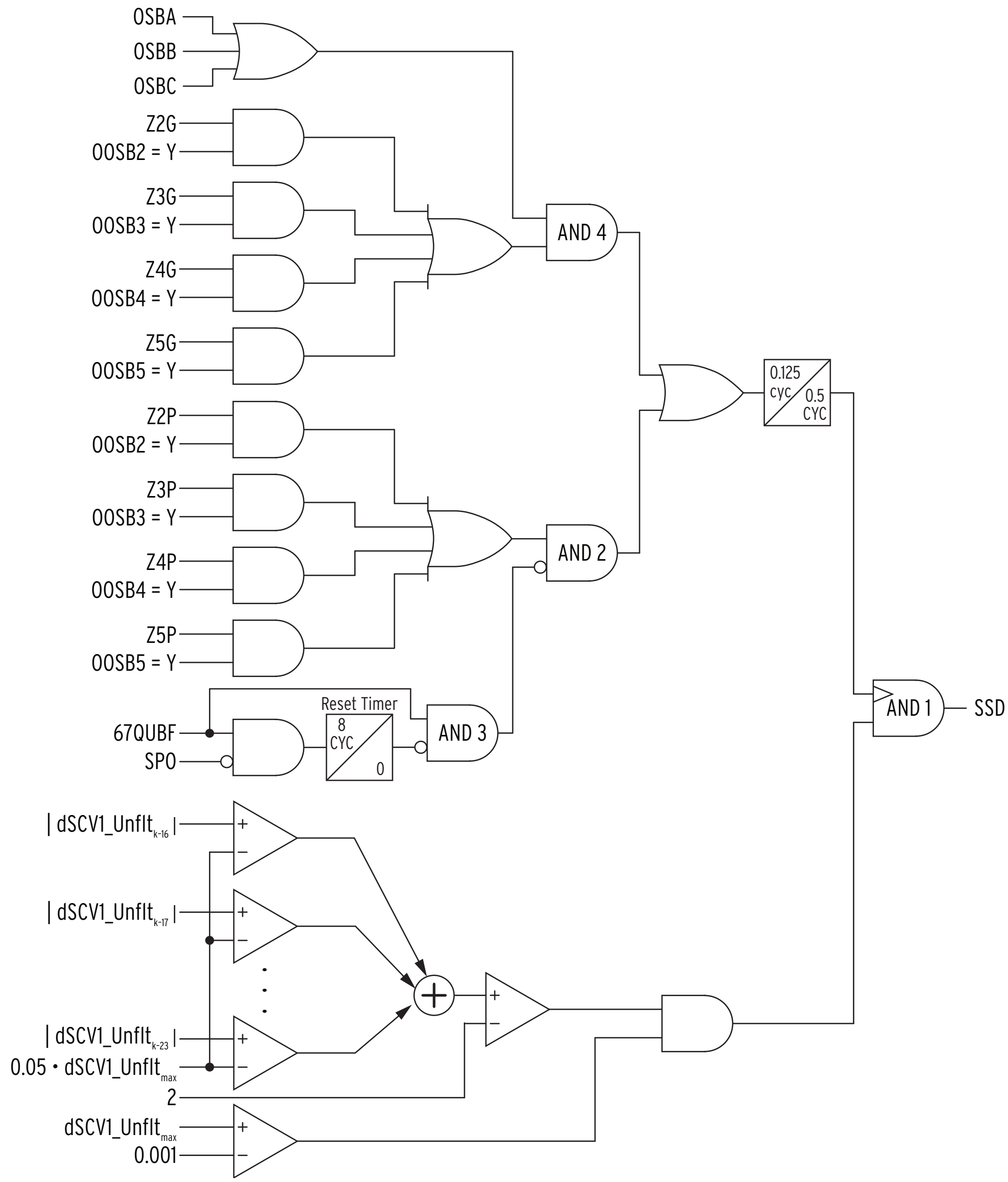


Figure 5.41 Swing Signature Detector Logic

Reset Conditions Function

The Reset Conditions logic corresponding to the block with the same name in *Figure 5.37* is shown in *Figure 5.42*.

As shown in *Figure 5.37*, the OSB function will reset under the following conditions:

1. The SCV1 magnitude will be greater than 0.85 or the positive-sequence impedance Z1 will be outside the starter zone for more than 0.5 s or the OST function will be enabled and Z1 will stay outside Zone 7 for more than 30 cycles.
2. The slow derivative dSCV1_S will be smaller than 0.0026 (pu V/cyc) for more than 10 cycles under a no-fault condition.

3. The ultra-fast derivative dSCV1_UF will be greater than 0.55 (pu V/cyc) for more than 4 cycles.
4. Either all three poles are open (3PO) or an internal loss-of-potential (ILOP) occurred.

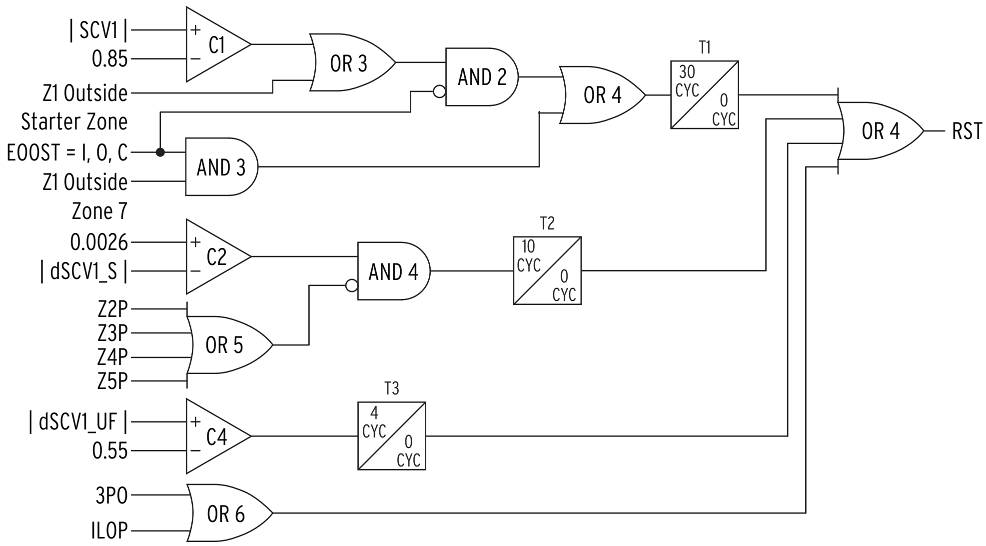


Figure 5.42 Reset Conditions Logic

The Dependable Power-Swing Blocking Function

The dependable PSB detector function asserts the DOSB signal for power-swing conditions where neither the slope detector nor the swing signature detector can detect a power swing fast enough. An example of this type of situation might occur after a slow-clearing fault right behind or at the remote end of a transmission line on a marginally stable network.

As shown in *Figure 5.43*, if a close reverse or forward fault clears with a significant delay, there is a possibility that the network has entered a power swing. In this case, the Z1 trajectory at the relay may cross into the Zone 2 or Zone 1 phase-mho characteristic right after the fault clears, but before the slope detector has detected the power swing. In this case, the phase mho elements of the relay may issue a trip signal as a result of the power swing and not because of a real fault. To overcome this problem, the dependable power-swing detector asserts the DOSB (see *Figure 5.37*) signal to block the distance elements until the slope detector has had time to detect a power swing.

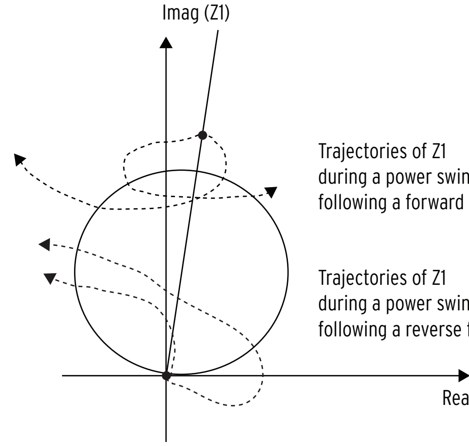


Figure 5.43 Type of Power Swings Detected by the DOSB Function

In summary, for an external forward fault, the logic issues a DOSB signal if the signal from a fault detector has lasted several cycles, no power swing has been detected, the relay has issued no trip, and at least one of the Zone 1 phase-mho has picked up or when FZAVG asserts. For a reverse fault, the logic issues a DOSB signal if a power swing has not been detected, the signal from a fault detector has lasted several cycles and been cleared, the relay has issued no trip signal, and a Zone 2 mho-phase has picked up within a time delay.

Depending on the EOOS setting, the relay selects either the logic shown in *Figure 5.44* (EOOS = Y1) or the logic shown in *Figure 5.45* (EOOS = Y). *Figure 5.44* shows the dependable power-swing block detector logic.

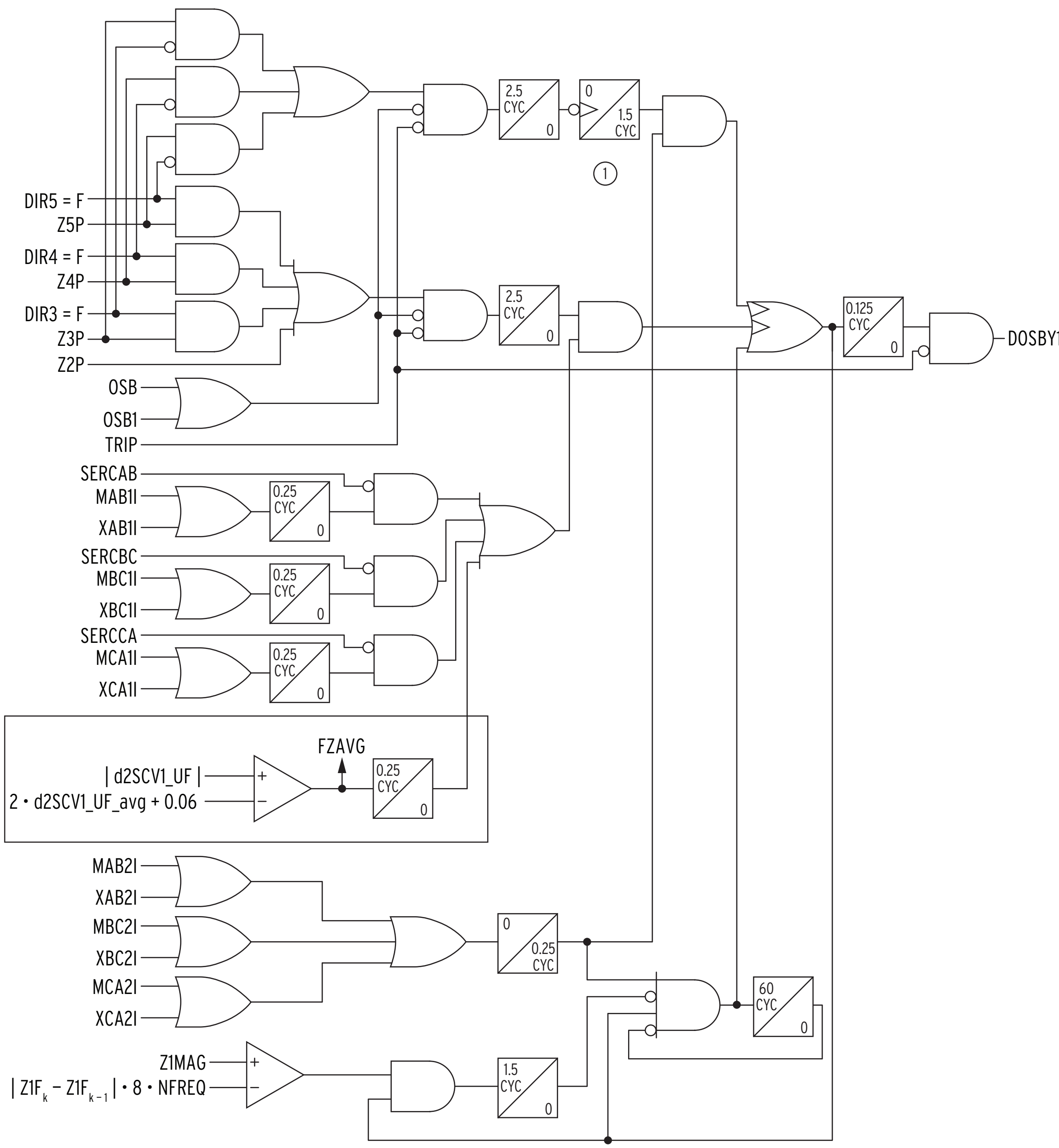


Figure 5.44 Dependable Power-Swing Block Detector Logic (EOOS = Y1)

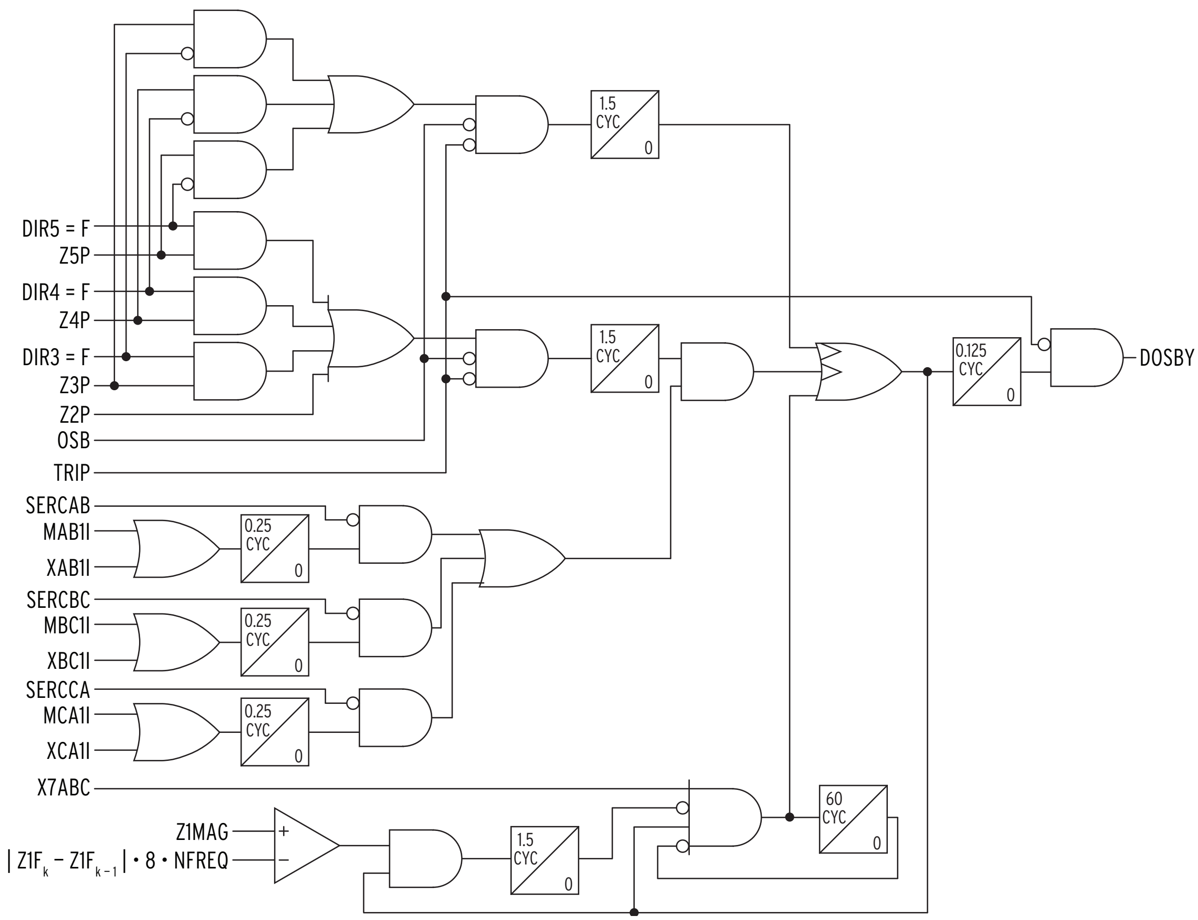


Figure 5.45 Dependable Power-Swing Block Detector Logic (EOOS = Y)

Figure 5.46 shows DOSB, the OR combination of the output from *Figure 5.44* (DOSBY1) and the output from *Figure 5.45* (DOSBY). Only Relay Word bit DOSB is available; DOSBY1 and DOSBY are for internal use in the relay.

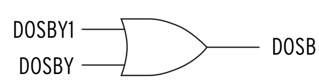


Figure 5.46 Relay Word Bit DOSB Is the OR Combination of DOSBY1 and DOSBY

Three-Phase Fault Detector

Figure 5.47 shows the logic diagram of the three-phase fault detector. If a three-phase fault occurs on a transmission line during a power swing, a step change occurs in the SCV1 waveform. This step change can be identified when the second derivative of SCV1 has a higher than usual value. Furthermore, the SCV1 has a low value and its rate of change is very small. These properties are taken into account in the three-phase fault detector so as to implement a very fast detector, independent from the swing speed. Three-phase faults will be detected with a minimum and maximum time delay of two and five cycles, respectively.

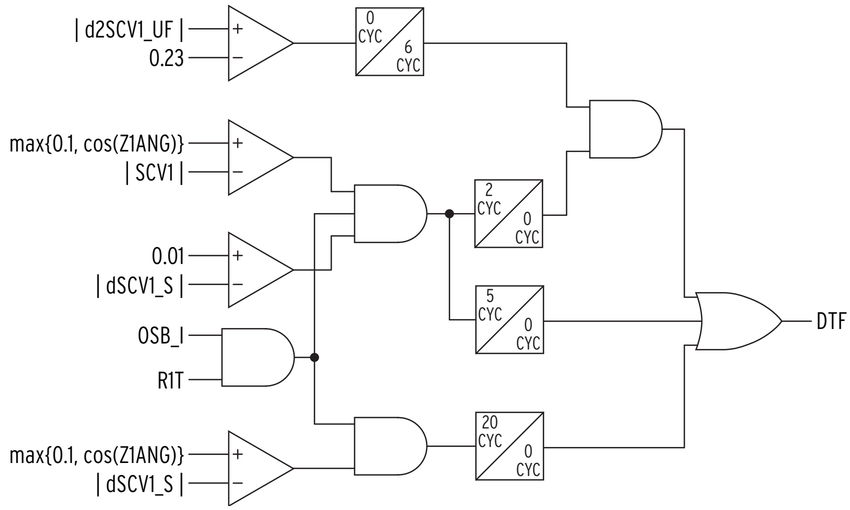


Figure 5.47 Logic Diagram of the Three-Phase Fault Detector

Detection of Ground Faults During a Pole-Open

Regarding the ground-distance elements supervision, if the pole-open OOS logic (OSBA, OSBB, OSBC, see *Figure 5.41*) is de-asserted, AND 4 turns off. When AND 4 turns off, the ground-distance elements cannot cause the swing signature detector to assert. *Figure 5.48* shows the pole-open logic that blocks the ground-distance elements during a power swing condition.

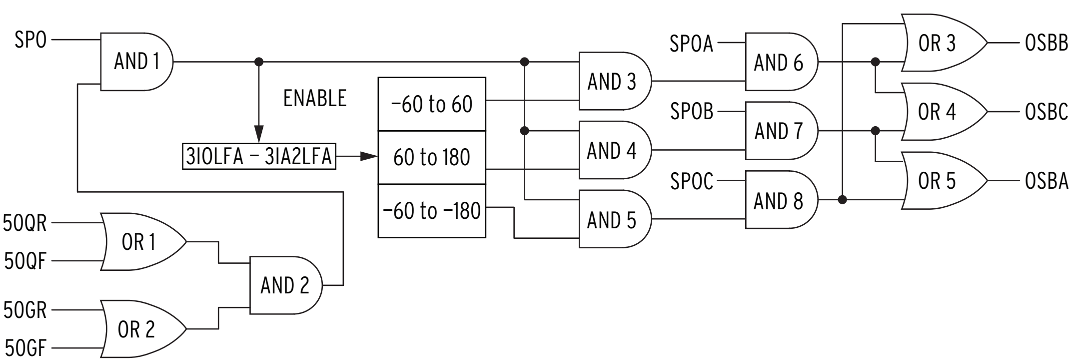


Figure 5.48 Pole-Open OOS Blocking Logic

If a power swing occurs during an open-pole condition, the power swing as seen by the relay is no longer balanced. The open-pole OOS blocking logic determines which phase is open so that the relay can correctly identify faults that may occur on the closed phases during the power swing. To identify the open phase, the relay calculates the angle of the ratio of the zero-sequence current and the negative-sequence currents. If the angular relationship indicates a fault, the logic shown in *Figure 5.41* turns off AND 4, thus preventing the swing signature detection (SSD) from asserting. When SSD is deasserted, the distance elements can clear the fault.

For example, if the A-Phase is open, the angle of the ratio normally lies between –60 and +60 degrees. If a fault now occurs on B- or C-Phase (or both), this angular relationship is no longer true. In *Figure 5.48*, OSBA asserts if either B-Phase or C-Phase is open, and no fault is present. If a fault occurs on B-Phase or C-phase (or both), OSBA deasserts because the angular relationship indicates a fault.

Figure 5.49 shows the I0/I2 angular relationship during a single pole-open condition, and no system fault present. *Figure 5.50* shows the blocking principle of the A-Phase-to-ground mho element by the de-asserted OSBA signal.

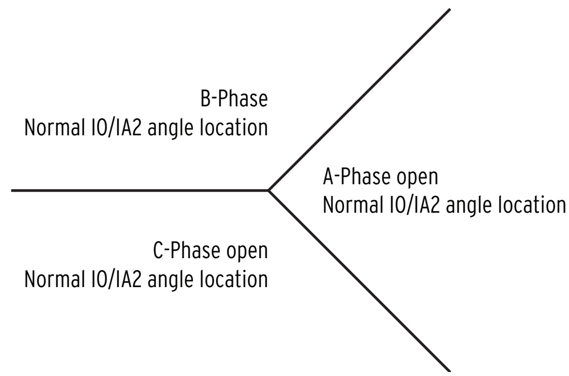


Figure 5.49 I0/IA2 Angle Supervision During Pole-Open Situation

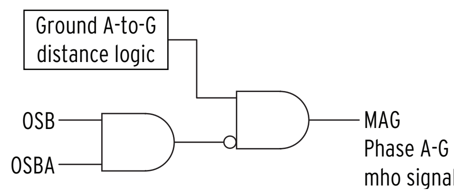


Figure 5.50 Blocking of the MAG Signal by the OSBA Fault Detection

The same principle applies to OSBB and OSBC. When all three poles are closed, OSBA, OSBB, and OSBC are de-asserted and the distance elements can trip normal, even during a power swing.

In *Figure 5.48*, the logic is enabled when the zero-sequence supervisory directional overcurrent element (50GR or 50GF) and negative-sequence supervisory directional overcurrent element (50QR or 50QF) pick up during a single pole-open condition (SPO). *Table 5.48* shows the input/output combinations of the logic.

Table 5.48 Input/Output Combinations of the Pole-Open OOS Blocking Logic

Gate Turned On	Open Phase	Phases to Block
AND 6	Phase A	Phases B and C
AND 7	Phase B	Phases A and C
AND 8	Phase C	Phases C and A

Phase Mho Element Reset Logic

If the OSB function is enabled and a power swing occurs, the OSB signal blocks the phase-fault detectors, but not the ground-fault detectors. Therefore, to remove the OSB signal and clear a fault that occurs during an OOS condition, the relay must detect three-phase and phase-to-phase faults (see *Figure 5.51*).

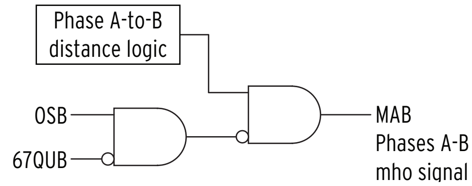


Figure 5.51 Unblocking of the MAB Signal by the 67QUB Element

To detect phase-to-phase faults, the relay uses a directional overcurrent element, 67QUBF, based on a negative-sequence directional element, 32QF, as shown in *Figure 5.52*. 3IA2LFM is the negative-sequence current that the relay measures. If 3IA2LFM exceeds a reference value (a2 • 3 • IA1LFM), Timer 1 starts. If Timer 1 expires and the flow of negative-sequence current is in the forward direction (32QF asserted), then 67QUBF asserts.

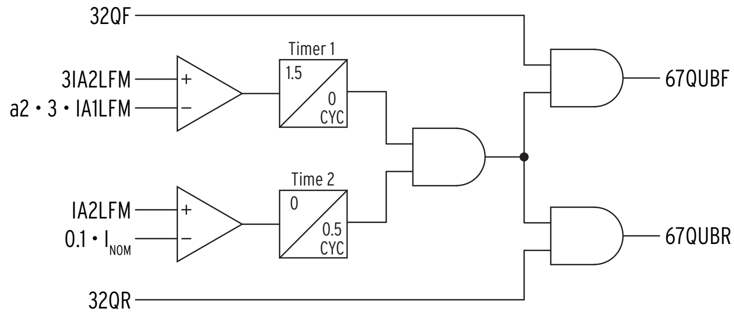


Figure 5.52 Directional Element Signals 67QUBF and 67QUBR

Out-of-Step Tripping (OST)—Zero Settings Element

While the zero-setting out-of-step blocking function requires no settings, the out-of-step tripping function requires eight blinder settings. These eight blinder settings are the Zone 6 and Zone 7 blinder settings, and are common for the conventional and the zero-setting OST function (see *Figure 5.32*).

Figure 5.53 shows the resistive and reactive blinders used in the OST scheme logic. The OST logic uses the traditional OOS calculations for the left (R1R6), right (R1R7), top (X1T6), and bottom (X1T7) blinders of Zone 6 and Zone 7. Specify Settings X1B6 and X1B7 under the advanced settings option. For on-the-way-out (TOWO) out-of-step tripping, these settings do not require any stability studies. However, the out-of-step tripping on-the-way-in (TOWI) still requires stability studies to determine the proper OST settings for right- and left-hand blinders RR6 and RR7.

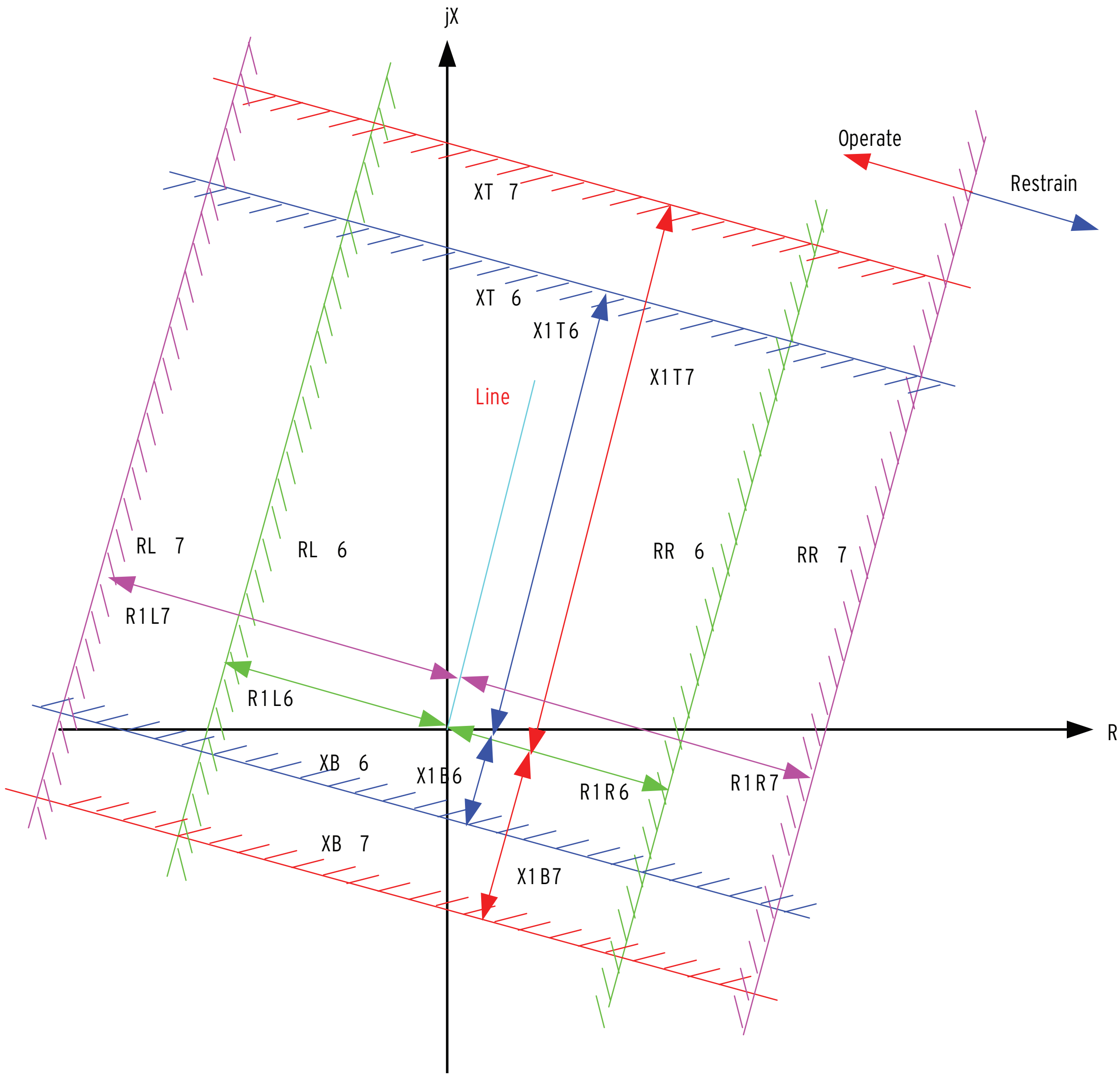


Figure 5.53 OST Scheme Logic Resistive and Reactive Blinders

Figure 5.54 shows the logic that determines whether the positive-sequence impedance (Z1) falls within the Zone 6 and/or Zone 7 polygons, provided there is no three-pole open (3PO) or loss-of-potential (ILOP) conditions.

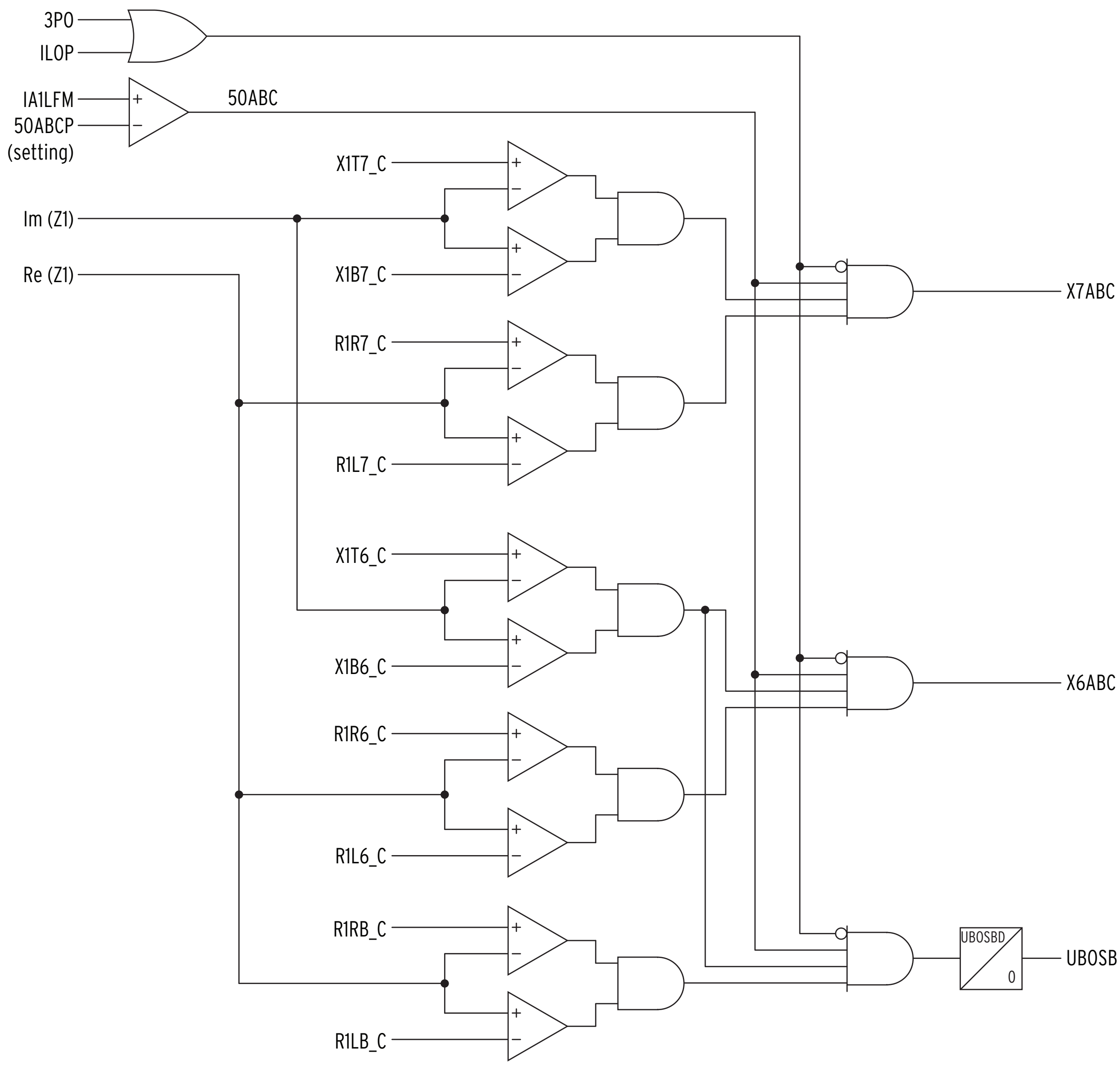


Figure 5.54 Logic That Determines Positive-Sequence Impedance Trajectory (EOOS = Y1)

Figure 5.55 shows the logic for the different EOOST settings (EOOST = N, I, O, C) when EOOS = Y1. Setting EOOST = N turns gate AND 1 off. When AND 1 turns off, all three outputs (OSTI, OST, and OSTO) are also turned off.

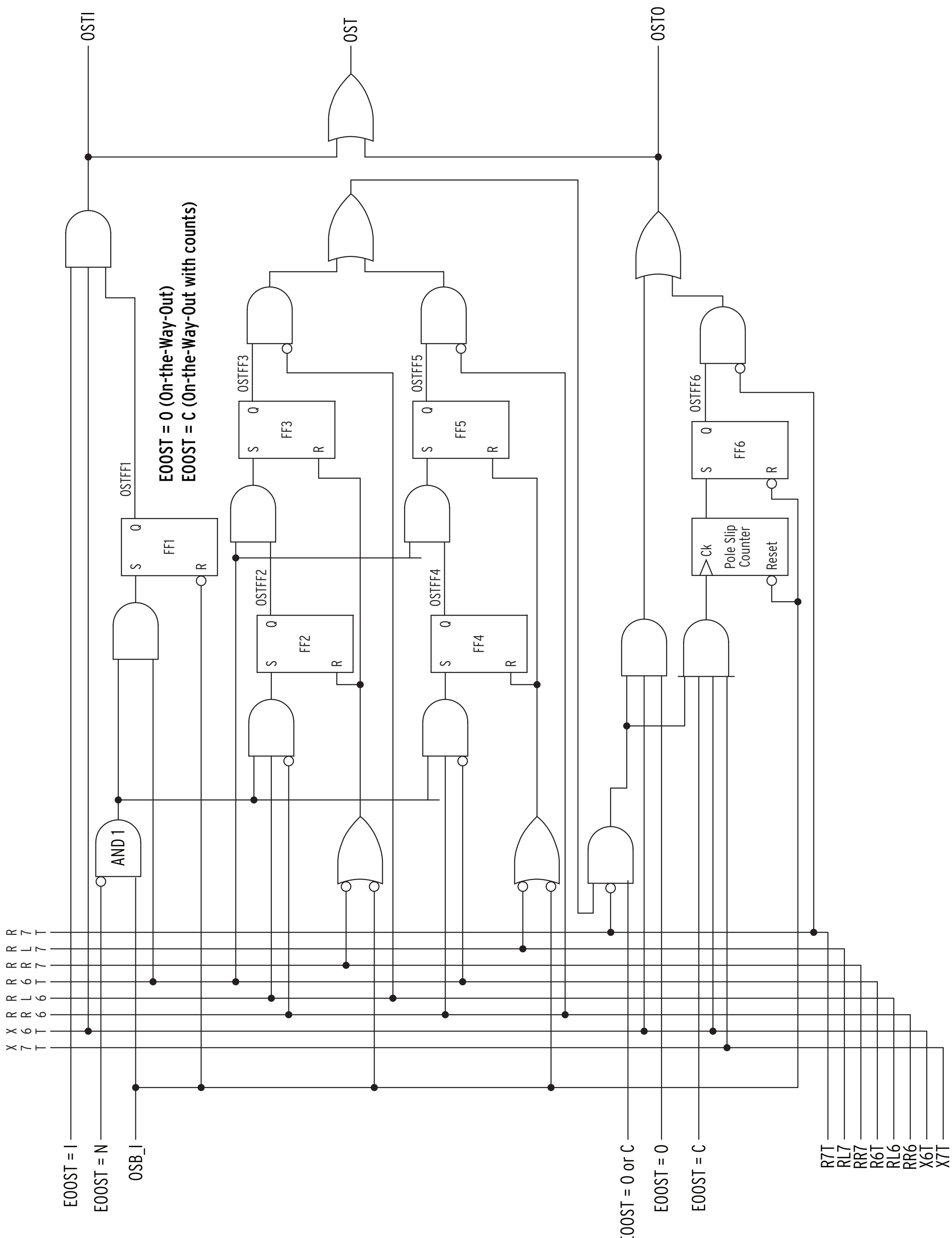


Figure 5.55 Out-of-Step Trip Logic (EOOS = Y1)

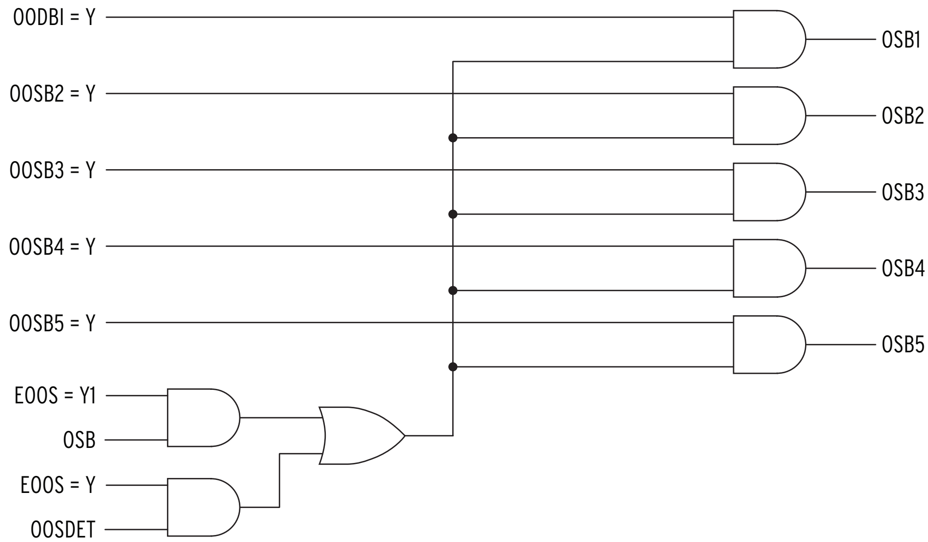


Figure 5.56 Out-of-Step Blocking for Zone 1 Through Zone 5

Mho Ground-Distance Elements

The SEL-421 has five independent zones of mho ground-distance protection. The mho ground-distance protection operates only for single phase-to-ground faults. You can set the reach for each zone independently. Zone 1 and Zone 2 distance elements are forward only; you can set Zone 3 through Zone 5 distance elements either forward or reverse. The mho ground-distance elements use positive-sequence voltage polarization for security and generate a dynamic expanding mho characteristic.

NOTE: The SEL-421-4 provides fast and secure tripping but does not have high-speed distance elements. Typical detection time for the SEL-421-4 is 1.5 cycles.

The SEL-421-5 has three independent zones of high-speed mho ground-distance protection. The high-speed mho ground-distance protection operates for single phase-to-ground faults. The first three zones of mho ground-distance protection (Zone 1 through Zone 3) are for high-speed operation; typical detection time is less than one cycle.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The Zone 1 zero-sequence compensation factor (k01) is independent from the forward and reverse compensation factors (k0 and k0R) the relay uses for the other zones.

If you set k0M1 to AUTO, the relay automatically calculates the values k01, k0, and k0R based on the following equation:

$$k0 = \frac{Z_{0L} - Z_{1L}}{3 \bullet Z_{1L}}$$

Equation 5.28

where:

Z_{1L} = positive-sequence transmission line impedance
Z_{0L} = zero-sequence transmission line impedance

The SEL-421 has a settable Zone 1 overcurrent supervision setting for phase-distance elements (Z50P1) and for ground-distance elements (Z50G1). These advanced settings (EADVS = Y) apply to both mho and quadrilateral distance elements and are useful in applications with series compensation. For more information on setting relays to protect series-compensated lines, see AG2000-11: *Applying the SEL-321 Relay on Series-Compensated Systems*.

Table 5.49 Mho Ground-Distance Elements Relay Word Bits

Name	Description
MAG1	Zone 1 A-Phase mho ground-distance element
MBG1	Zone 1 B-Phase mho ground-distance element
MCG1	Zone 1 C-Phase mho ground-distance element
MAG2	Zone 2 A-Phase mho ground-distance element
MBG2	Zone 2 B-Phase mho ground-distance element
MCG2	Zone 2 C-Phase mho ground-distance element
MAG3	Zone 3 A-Phase mho ground-distance element
MBG3	Zone 3 B-Phase mho ground-distance element
MCG3	Zone 3 C-Phase mho ground-distance element
MAG4	Zone 4 A-Phase mho ground-distance element
MBG4	Zone 4 B-Phase mho ground-distance element
MCG4	Zone 4 C-Phase mho ground-distance element
MAG5	Zone 5 A-Phase mho ground-distance element
MBG5	Zone 5 B-Phase mho ground-distance element
MCG5	Zone 5 C-Phase mho ground-distance element
Z1G	Zone 1 ground-distance element
Z2G	Zone 2 ground-distance element
Z3G	Zone 3 ground-distance element
Z4G	Zone 4 ground-distance element
Z5G	Zone 5 ground-distance element

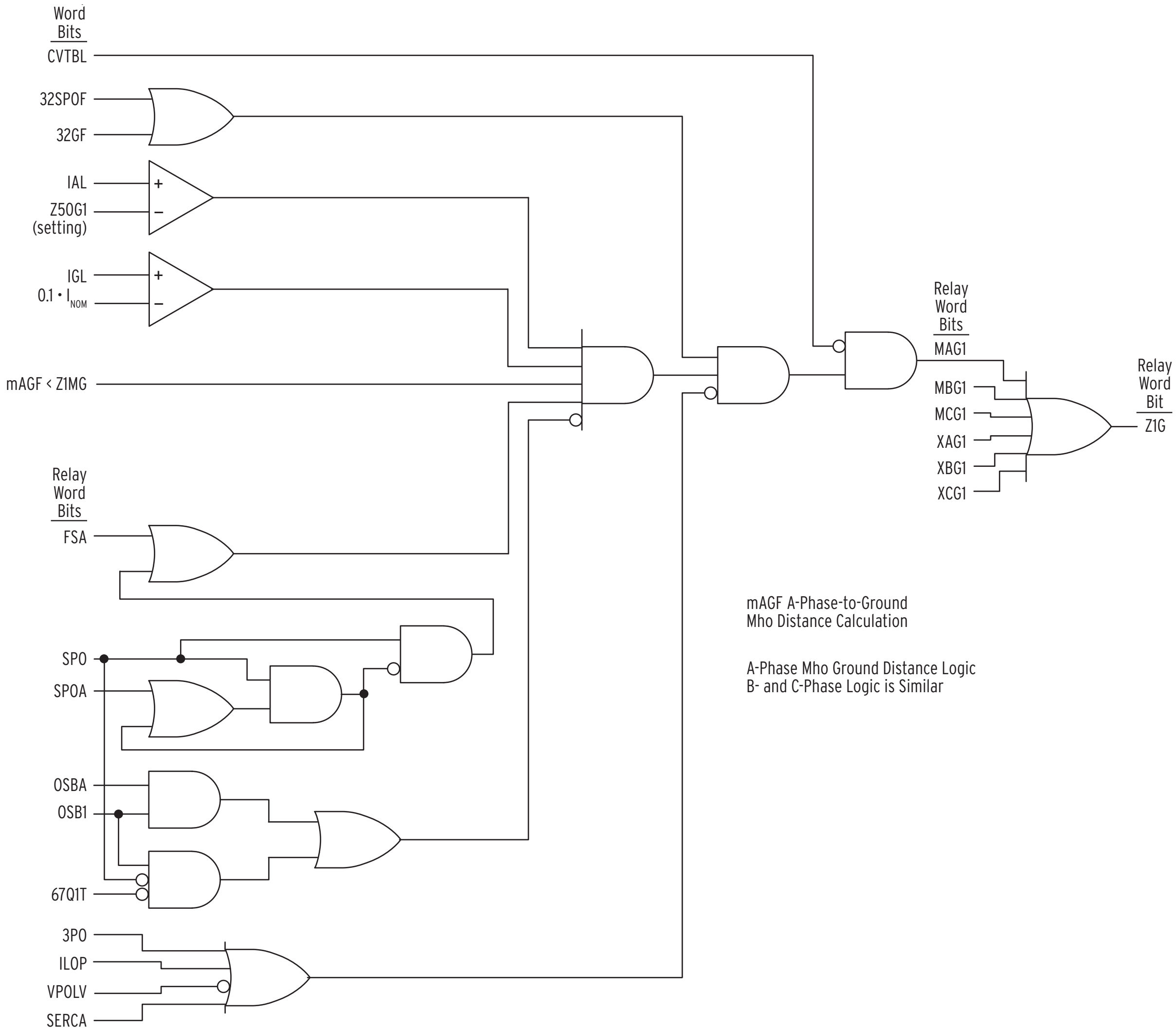


Figure 5.57 Zone 1 Mho Ground-Distance Element Logic Diagram

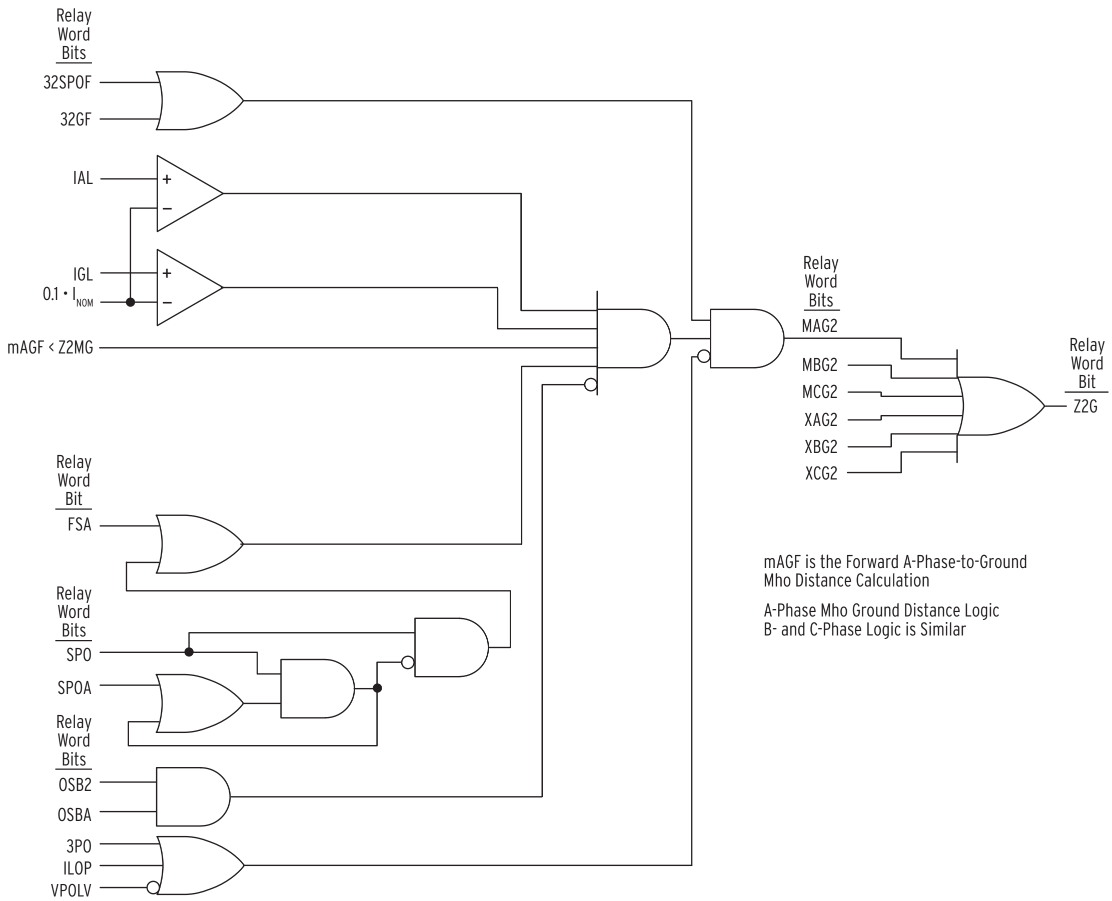


Figure 5.58 Zone 2 Mho Ground-Distance Element Logic Diagram

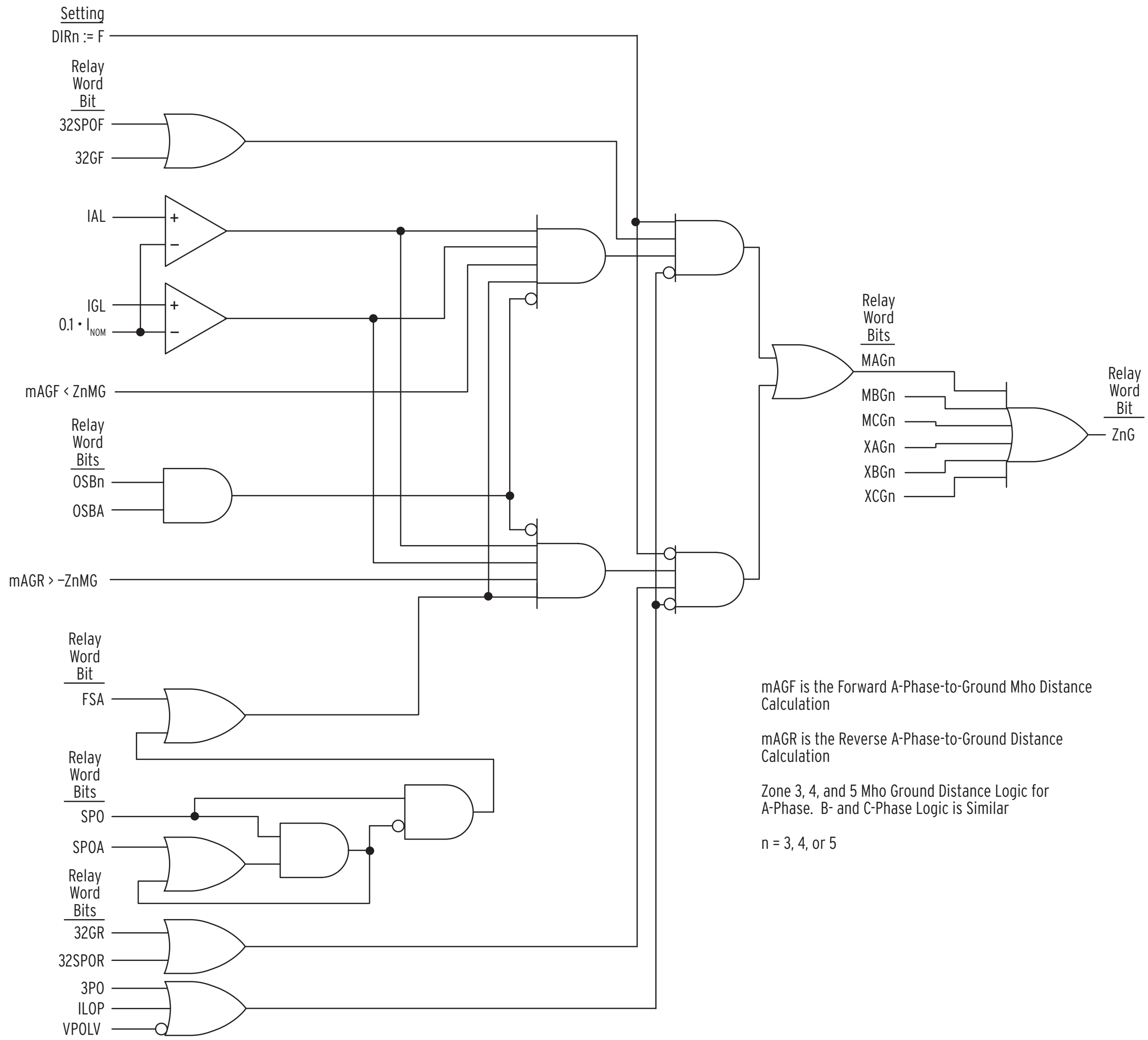


Figure 5.59 Zones 3, 4, and 5 Mho Ground-Distance Element Logic Diagram

Quadrilateral Ground-Distance Elements

The SEL-421 has five independent zones of quadrilateral ground-distance protection. The quadrilateral ground-distance protection only operates for single phase-to-ground faults.

Set the reactance (XG) and resistive (RG) reach for each zone independently. Rather than 90 degrees (purely reactive), the reactance measurement lies along the setting Z1ANG (complex).

Zone 1 and Zone 2 distance elements are forward only, while you can set Zone 3 through Zone 5 distance elements either forward or reverse.

You select whether the quadrilateral ground-distance elements use negative- or zero-sequence current to polarize the reactance line when the Advanced Settings are enabled (setting EADVS := Y); otherwise, negative-sequence current is the default setting.

The Zone 1 zero-sequence compensation factor (k01) is independent from the forward and reverse compensation factors (k0 and k0R) that the relay uses for quadrilateral ground-distance protection for the other zones.

When setting E21XG (Quadrilateral Ground-Distance Zones) is 1 or more, there are two selections for setting XGPOL (Quadrilateral Ground Polarizing Quantity): I2 or IG. When the setting XGPOL is I2, set the first selection in the setting ORDER (Ground Directional Element Priority) to Q. When the setting XGPOL is IG, the first selection in the setting ORDER must be Q or V.

The quadrilateral element in the relay includes an option by which the right resistance blinder can be adapted to load conditions. This adaptive function applies to the ground quadrilateral elements only; the phase quadrilateral elements are not affected. The purpose of the adaptive resistance function is to increase fault resistance coverage, particularly for remote faults. To enable the adaptive resistance function, set ARESE = Y.

A supervisory condition is applied to force the resistive blinders to be self-polarized under unusual unbalanced loads. The adaptivity of the resistive blinder is enabled by the setting ARESE when the corresponding Relay Word bit CNR2AG, CNR2BG, or CNR2CG, is asserted. When the adaptivity of the right resistive blinder is disabled, it uses self-polarization.

Table 5.50 shows the differences between behavior of the adaptive right resistance blinder and the existing resistance blinder.

Each quadrilateral ground-distance element is supervised by the Relay Word bit ENX2*n*G, where n is the A, B, or C phase. This supervisory condition secures the reactance blinder in the quadrilateral ground-distance element against unusual unbalanced load conditions.

Table 5.50 Differences Between the Adaptive Right Resistance Blinder and the Existing Resistance Blinder

Existing Resistance Blinder	Adaptive Resistance Blinder
The left blinder is the negative of the right-blinder setting.	The left blinder is the minimum of the enabled right blinder settings, (min [RG1, RG2, . . . RG*n*]).
The right resistance blinder is fixed.	The right resistance blinder adapts to the changing load conditions.

For more information on the element, see the technical paper *Adaptive Phase and Ground Quadrilateral Distance Elements*, available at selinc.com.

Table 5.51 Quadrilateral Ground-Distance Elements Relay Word Bits (Sheet 1 of 2)

Name	Description
XAG1	Zone 1 A-Phase quadrilateral ground-distance element
XBG1	Zone 1 B-Phase quadrilateral ground-distance element
XCG1	Zone 1 C-Phase quadrilateral ground-distance element
XAG2	Zone 2 A-Phase quadrilateral ground-distance element
XBG2	Zone 2 B-Phase quadrilateral ground-distance element
XCG2	Zone 2 C-Phase quadrilateral ground-distance element
XAG3	Zone 3 A-Phase quadrilateral ground-distance element
XBG3	Zone 3 B-Phase quadrilateral ground-distance element
XCG3	Zone 3 C-Phase quadrilateral ground-distance element

Table 5.51 Quadrilateral Ground-Distance Elements Relay Word Bits (Sheet 2 of 2)

Name	Description
XAG4	Zone 4 A-Phase quadrilateral ground-distance element
XBG4	Zone 4 B-Phase quadrilateral ground-distance element
XCG4	Zone 4 C-Phase quadrilateral ground-distance element
XAG5	Zone 5 A-Phase quadrilateral ground-distance element
XBG5	Zone 5 B-Phase quadrilateral ground-distance element
XCG5	Zone 5 C-Phase quadrilateral ground-distance element

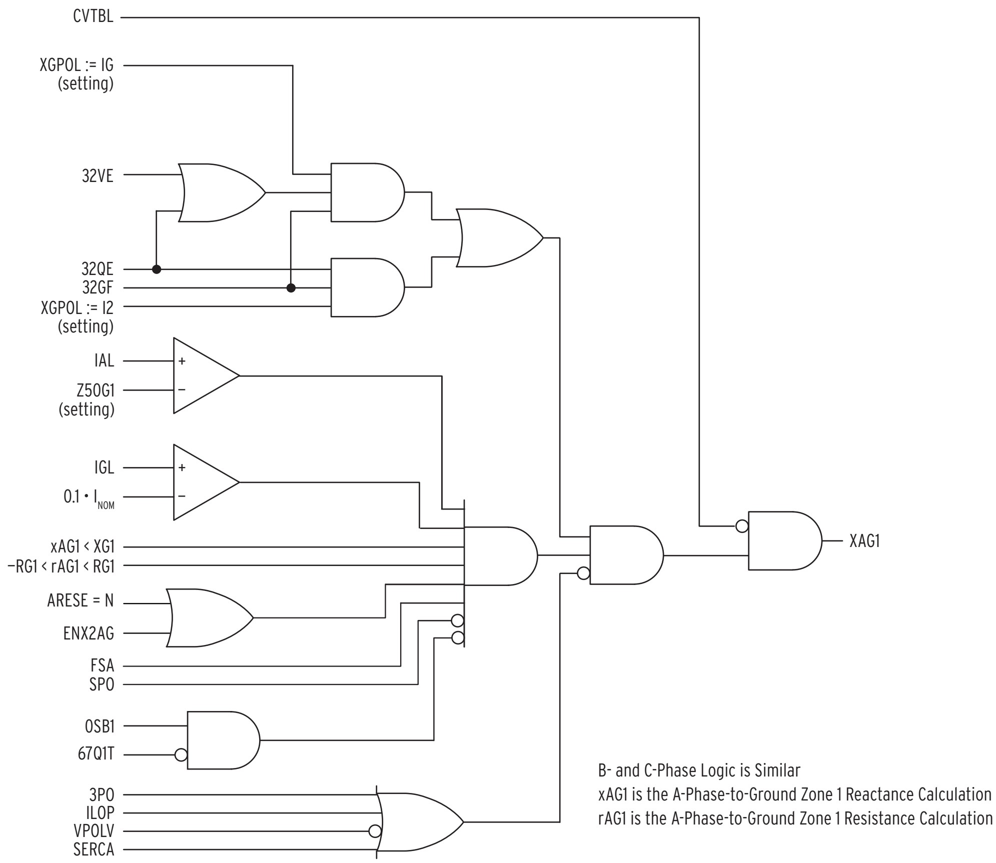


Figure 5.60 Zone 1 Quadrilateral Ground-Distance Element Logic Diagram

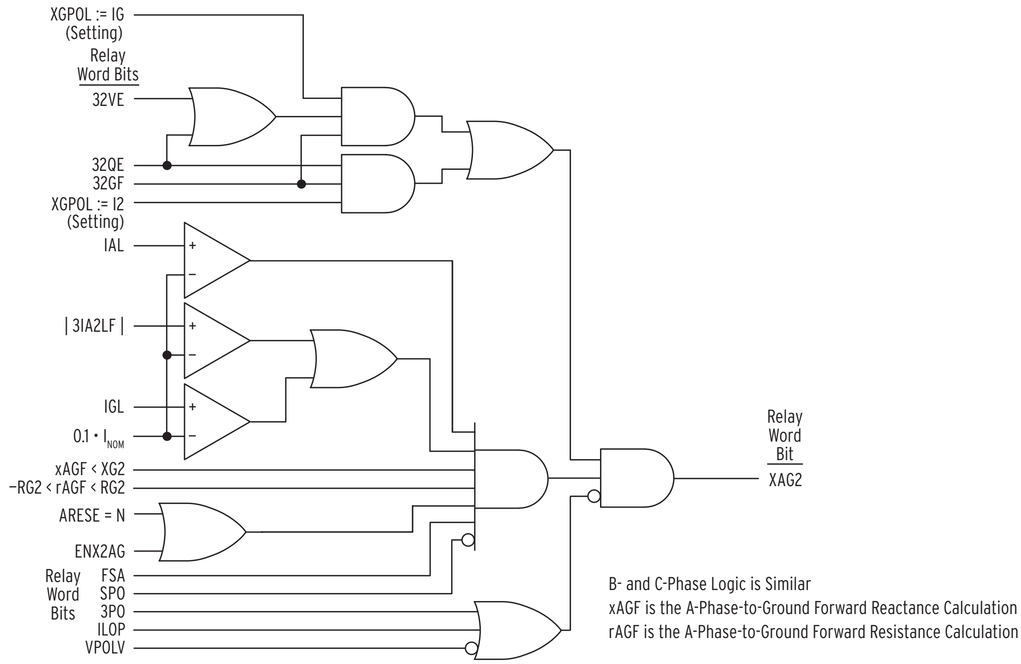


Figure 5.61 Zone 2 Quadrilateral Distance Element Logic Diagram

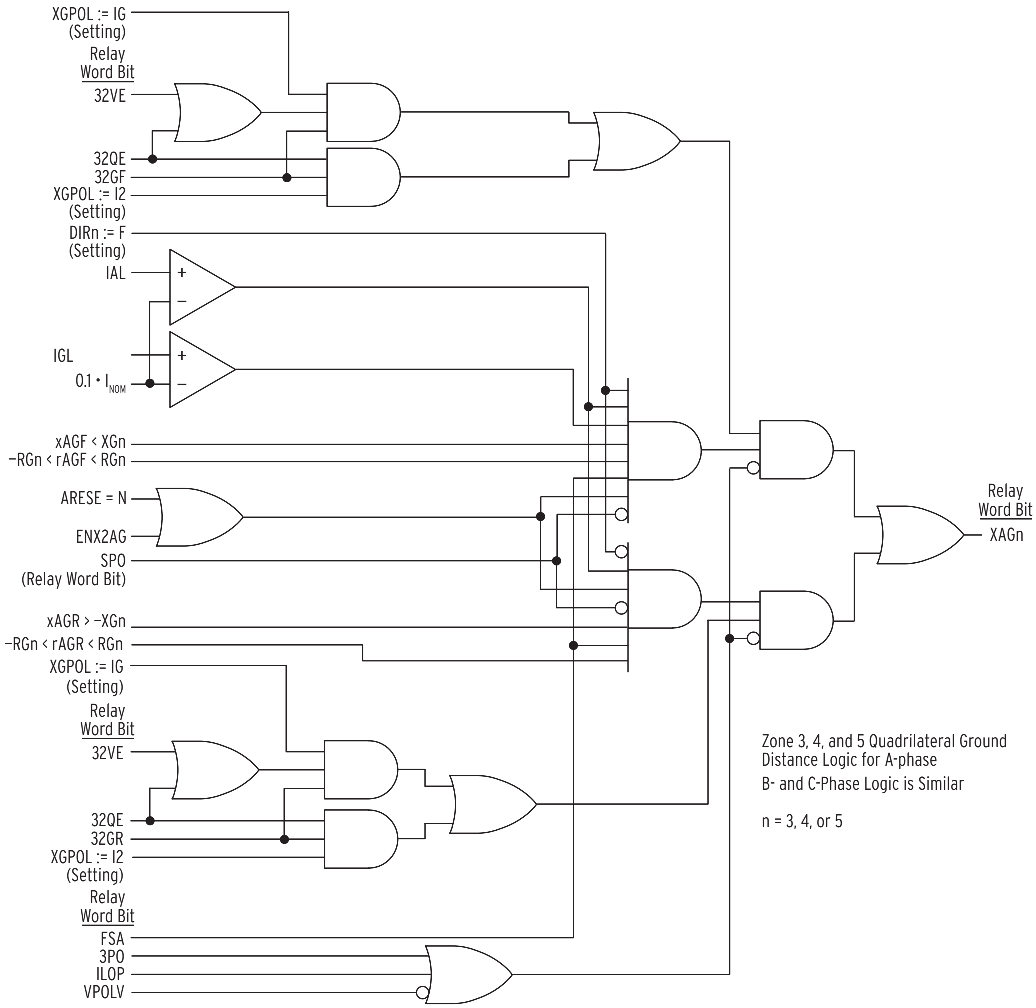


Figure 5.62 Zones 3, 4, and 5 Quadrilateral Ground-Distance Element Logic

Mho Phase-Distance Elements

The SEL-421 has five independent zones of mho phase-distance protection. The mho phase-distance protection operates for phase-to-phase, phase-to-phase-to-ground, and three-phase faults. Set the reach for each zone independently. Zone 1 and Zone 2 distance elements are forward only, while you can set Zone 3 through Zone 5 distance elements either forward or reverse. The mho phase-distance elements use positive-sequence voltage polarization for increased reliability and also generate a dynamic expanding mho characteristic that provides additional fault resistance coverage.

NOTE: The SEL-421-4 provides fast and secure tripping but does not have high-speed distance elements. Typical detection time for the SEL-421-4 is 1.5 cycles.

The SEL-421 has five independent zones of quadrilateral phase-distance protection (see *Quadrilateral Phase-Distance Elements on page 5.85*). Although the mho and quadrilateral phase elements are independent, you can enable both at the same time. To this end, the outputs from the mho and quadrilateral phase elements are ORed to a single protection output (see *Figure 5.61*, *Figure 5.64*, and *Figure 5.65*).

The SEL-421 has a settable Zone 1 overcurrent supervision setting for phase-distance elements (Z50P1) and for ground-distance elements (Z50G1). These advanced settings (EADVS = Y) apply to both mho and quadrilateral distance elements and are useful in applications with series compensation. For more information on setting relays to protect series-compensated lines, see AG2000-11: *Applying the SEL-321 Relay on Series-Compensated Systems*.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The SEL-421-5 has three independent zones of high-speed mho phase-distance protection. The high-speed mho phase-distance protection operates for phase-to-phase, phase-to-phase-to-ground, and three-phase faults. The first three zones of mho phase-distance protection (Zone 1, Zone 2, and Zone 3) are for high-speed operation; typical detection time is less than one cycle.

Table 5.52 Mho Phase-Distance Elements Relay Word Bits

Relay Word Bit	Description
MAB1	Zone 1 mho A-B phase element
MBC1	Zone 1 mho B-C phase element
MCA1	Zone 1 mho C-A phase element
Z1P	Zone 1 phase-distance element
MAB2	Zone 2 mho A-B phase element
MBC2	Zone 2 mho B-C phase element
MCA2	Zone 2 mho C-A phase element
Z2P	Zone 2 phase-distance element
MAB3	Zone 3 mho A-B phase element
MBC3	Zone 3 mho B-C phase element
MCA3	Zone 3 mho C-A phase element
Z3P	Zone 3 phase-distance element
MAB4	Zone 4 mho A-B phase element
MBC4	Zone 4 mho B-C phase element
MCA4	Zone 4 mho C-A phase element
Z4P	Zone 4 phase-distance element
MAB5	Zone 5 mho A-B phase element
MBC5	Zone 5 mho B-C phase element
MCA5	Zone 5 mho C-A phase element
Z5P	Zone 5 phase-distance element

Figure 5.63 shows the Zone 1 phase-distance element logic. The other fault calculations (BC, CA) have similar logic. In *Figure 5.63*, Output Z1P is the OR combination of the following Zone 1 elements (ØØ = AB, BC, CA):

- ➤ Conventional mho elements (MØØ1)
- ➤ Conventional quadrilateral elements (XØØ1)

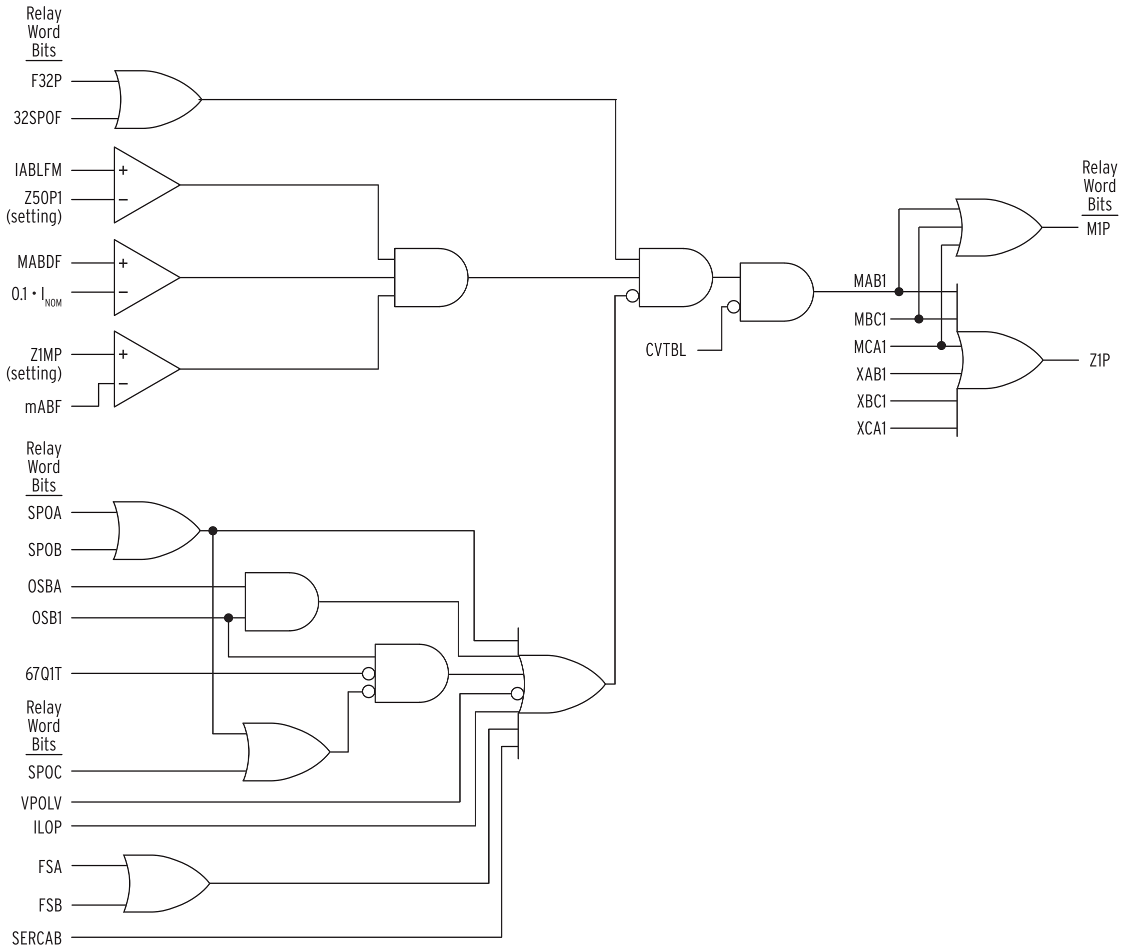


Figure 5.63 Zone 1 Mho Phase-Distance Element Logic Diagram

Figure 5.64 shows the Zone 2 phase-distance element logic. The other fault calculations (BC, CA) have similar logic. In *Figure 5.64*, Output Z2P is the OR combination of the following Zone 2 elements (ØØ = AB, BC, CA):

- ➤ Conventional mho elements (MØØ2)
- ➤ Conventional quadrilateral elements (XØØ2)

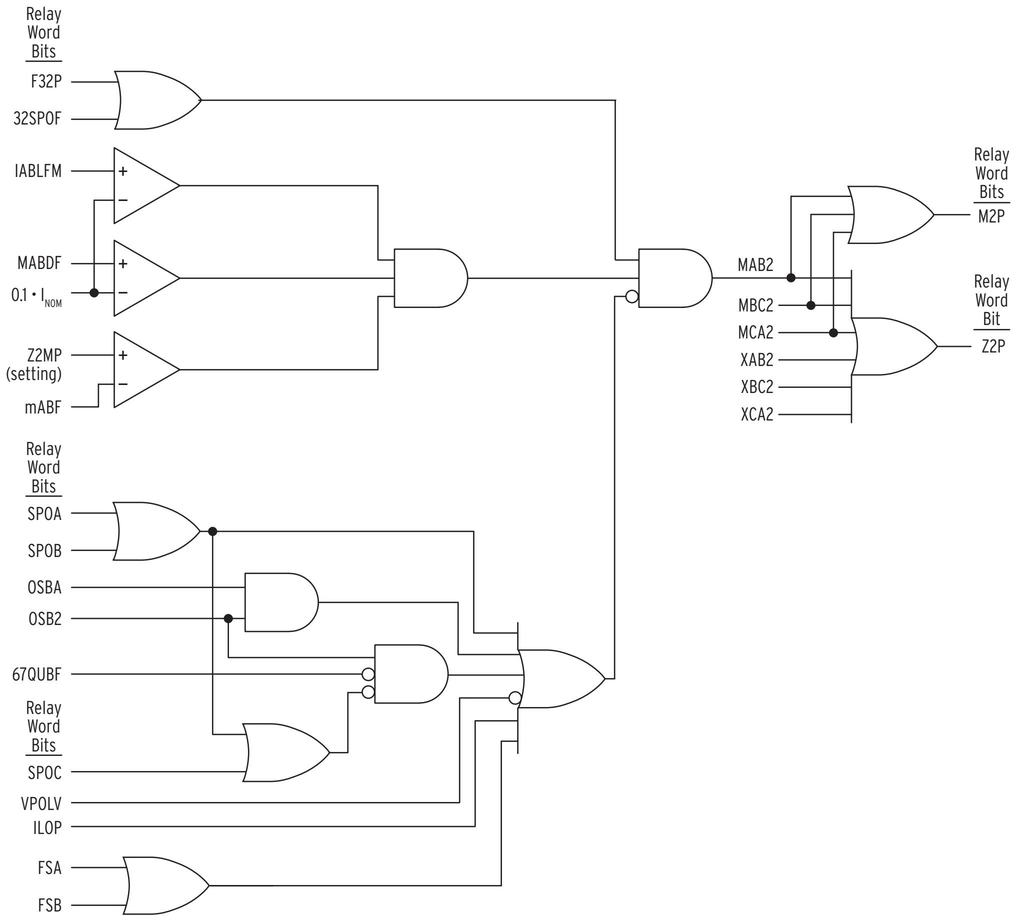


Figure 5.64 Zone 2 Mho Phase-Distance Element Logic Diagram

Figure 5.65 shows the Zone 3, 4 and 5 phase-distance element logic. Other fault calculations (BC, CA) have similar logic. In *Figure 5.65*, Output Z*n*P is the OR combination of the following Zone *n* (*n* = 3, 4, 5) elements (ØØ = AB, BC, CA):

- ➤ Conventional mho elements (MØØ*n*)
- ➤ Conventional quadrilateral elements (XØØ*n*)

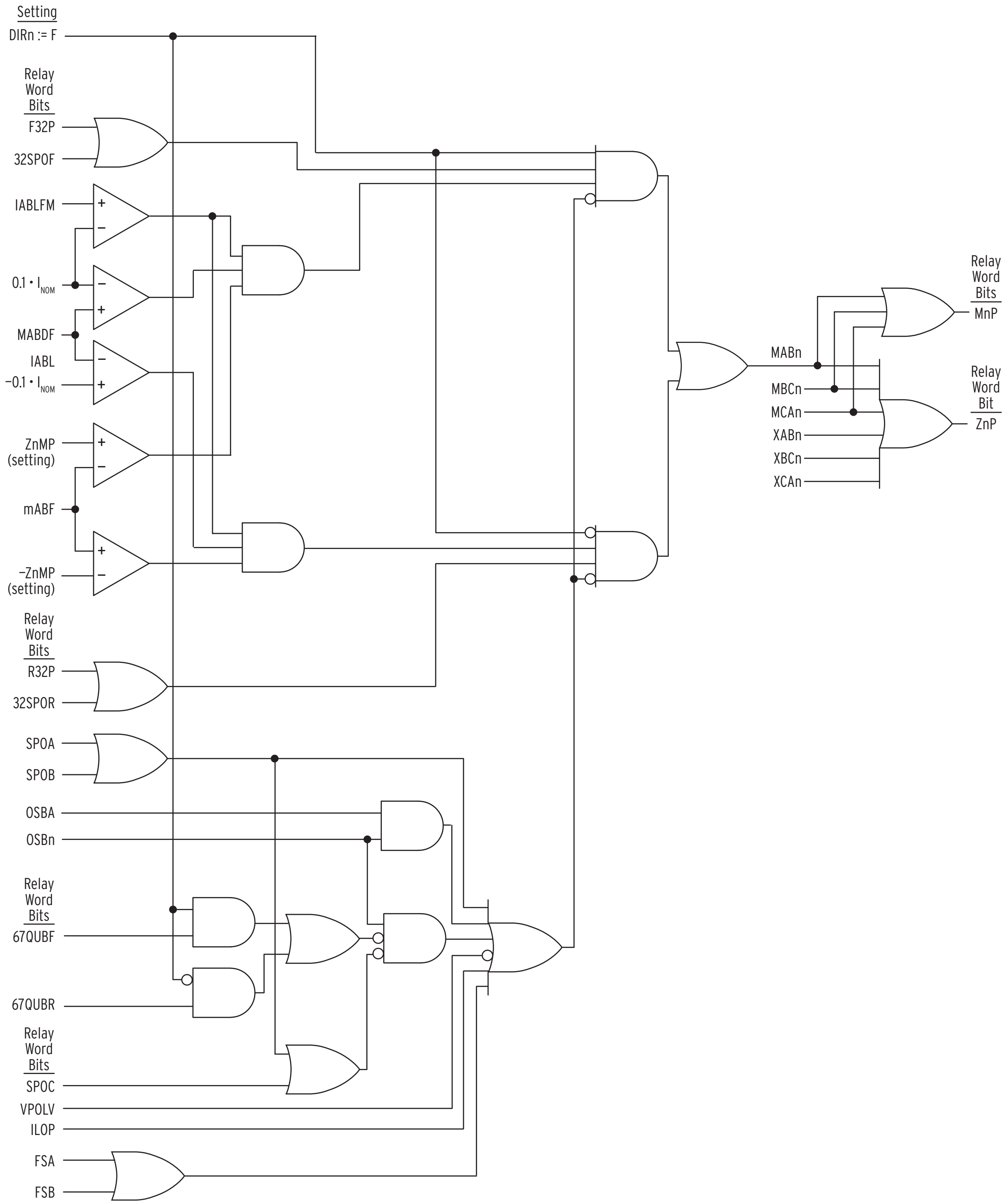


Figure 5.65 Zones 3, 4, and 5 Mho Phase-Distance Element Logic Diagram

Quadrilateral Phase-Distance Elements

NOTE: The SEL-421-4 provides fast and secure tripping, but does not have high-speed distance elements. Typical detection time for the SEL-421-4 is 1.5 cycles.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The SEL-421-5 has two groups of quadrilateral phase-distance elements: high-speed elements and conventional elements. There are five zones (Zone 1 through Zone 5) of conventional elements, and three zones of high-speed elements (Zone 1 through Zone 3). Reach settings for the Zone 1 through Zone 3 elements are the same for the two groups. For example, setting XP1 = 4 Ω sets the Zone 1 reactance reach for both high-speed elements and conventional elements to 4 Ohms secondary.

Notice that setting XP*x* (*x* = 1–5 or *x* = 1–3) is an impedance (not reactance) setting. You can set the impedance and resistive (RP*x*) reach for each zone independently.

NOTE: It is recommended to enable the phase mho elements in conjunction with the phase quadrilateral elements to provide detection for phase-to-phase faults during SPO conditions.

The SEL-421 also has five independent zones of mho phase-distance protection (see *Mho Phase-Distance Elements on page 5.80* for more information). Although the mho and quadrilateral phase elements are independent, you can enable both at the same time. To this end, the outputs from the mho and quadrilateral phase elements are ORed to a single protection output (see *Figure 5.62*, *Figure 5.64*, and *Figure 5.65*).

For both the high-speed and conventional quadrilateral phase-distance elements, Zone 1 and Zone 2 distance elements operate in the forward direction only. You can set Zone 3 for the high-speed elements and Zone 3 through Zone 5 for the conventional elements to operate in either forward or reverse directions. *Table 5.53* summarizes the zone directional settings for the high-speed and conventional elements.

Table 5.53 High-Speed and Conventional Element Directional Setting Summary

Zones	High-Speed Elements	Conventional Elements
Zone 1	Forward only	Forward only
Zone 2	Forward only	Forward only
Zone 3	Forward/Reverse	Forward/Reverse
Zone 4	NA	Forward/Reverse
Zone 5	NA	Forward/Reverse

The impedance reach for each zone of quadrilateral phase-distance protection lies on the line positive-sequence impedance angle (Z1ANG) rather than on the ordinate (reactance) of the impedance plane. When setting the reactance reach of the relay, do not convert the line impedance to a reactance. Enter the impedance value at the line angle in the same way you would enter the impedance value when setting a mho element. For example, if the line impedance is Z = 2 +j15 Ω (15.13 ∠82.4° Ω) secondary, enter the following settings for an 85 percent Zone 1 reach:

Z1ANG = 82.4°

XP1 = 12.86 Ω (15.13 • 0.85)

NOTE: The resistive reach of the quadrilateral phase-distance element setting RP*n* is reduced to RPP*n* based on the ratio of I2/I1 using the following equation if 32QE is not asserted:

$$RPPn = \left(0.25 + \frac{I2}{I1} \bullet 0.75\right) \bullet \mathrm{RP}n$$

Figure 5.66 shows the first three zones of the quadrilateral phase characteristic. Notice that the right blinders are parallel to the line impedance, and not parallel to the reactance axis. There is no setting for –RP, the left blinder; this value is fixed at the negative value of the lowest forward looking resistive RP*n* setting (*n* = 1–5). For example, if RP1 is set to RP1 = 3.8 Ω, and if RP1 is the minimum of RP1 through RP5, then the left blinder setting becomes –3.8 Ω. Zones set to OFF (XP*n* = OFF), reverse looking zones (DIR*n* = R) and zones not included in the E21XP setting are excluded from the calculations to determine the minimum RP value in the forward direction.

Because Zone 1 and Zone 2 operate in the forward direction, the left blinder in the reverse direction is the lowest setting among Zones *m* (*m* = 3–5). Zones set to OFF (XP*m* = OFF), forward looking zones (DIR*m* = F) and zones not included in the E21XP setting are excluded from the calculations to determine the minimum RP value in the reverse direction.

TANGP, the tilt angle setting, tilts the reactance values, but does not affect the resistance values. *Figure 5.66* shows the quadrilateral phase characteristic with TANGP = 0 degrees.

Figure 5.67 shows the quadrilateral phase-distance element characteristic with TANGP = –10 degrees. Notice that the reactance elements are tilted by 10 degrees, but the resistance blinders are unaffected by this setting. Also notice that the pivot point of the tilt is the line impedance and not the reactance axis. Furthermore, there are no individual TANGP settings for each zone; when you enter a value other than zero for TANGP, all enabled zones are tilted by the same value.

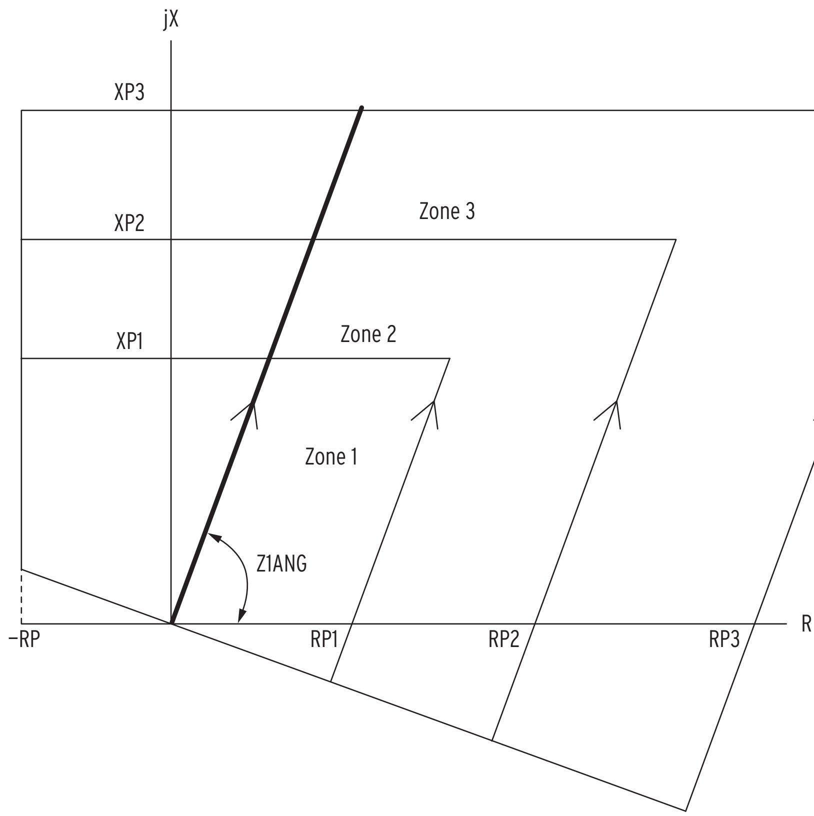


Figure 5.66 Quadrilateral Phase-Distance Element Characteristic (TANGP = 0)

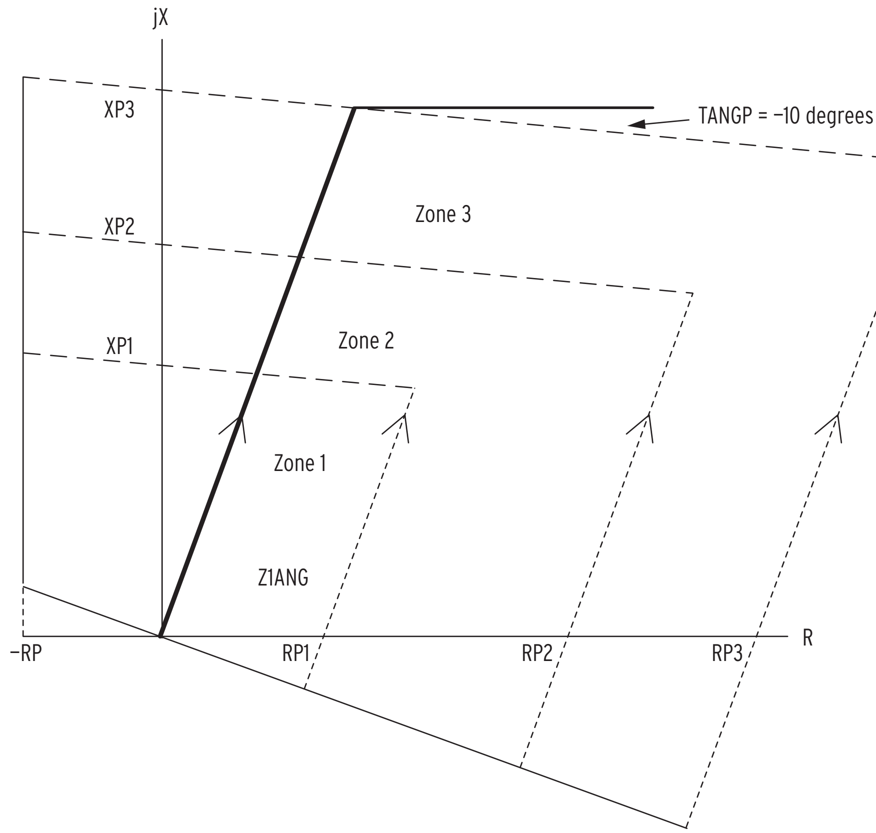


Figure 5.67 Quadrilateral Phase-Distance Element Characteristic (TANGP = –10 degrees)

Quadrilateral Phase Nonhomogeneous Setting (TANGP)

Nonhomogeneous negative-sequence networks can cause distance elements to underreach or overreach. Use the network in *Figure 5.68* to determine whether the negative-sequence network is homogeneous. Z_{LEFT} is the total impedance up to the fault (F) on the left-hand side, while Z_{RIGHT} is the total impedance up to the fault on the right-hand side.

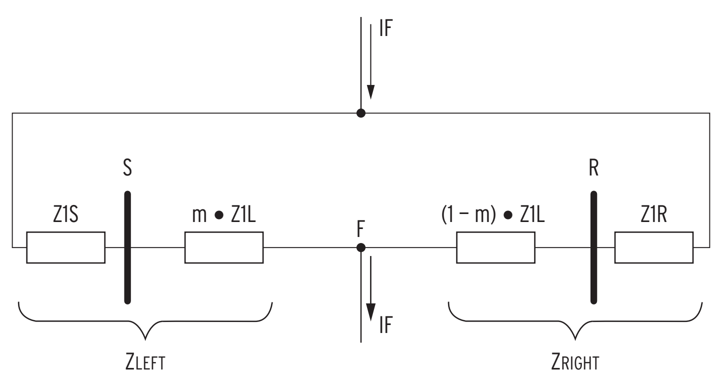


Figure 5.68 Network to Determine Homogeneity

A network is homogeneous with respect to the particular fault location if *Equation 5.29* is satisfied:

$$\frac{X_{LEFT}}{R_{LEFT}} = \frac{X_{RIGHT}}{R_{RIGHT}}$$

Equation 5.29

If *Equation 5.29* is not satisfied, use *Equation 5.30* to determine the negative-sequence nonhomogeneity:

$$T = \arg\left(\frac{Z1S + Z1L + Z1R}{(1 - m) \bullet Z1L + Z1R}\right)$$

Equation 5.30

The value of T represents how much the apparent fault impedance (ZF) measured by the relay tilts up or down (electrical degrees) because of the nonhomogeneity of the corresponding network for a fault at location m (see *Figure 5.69*).

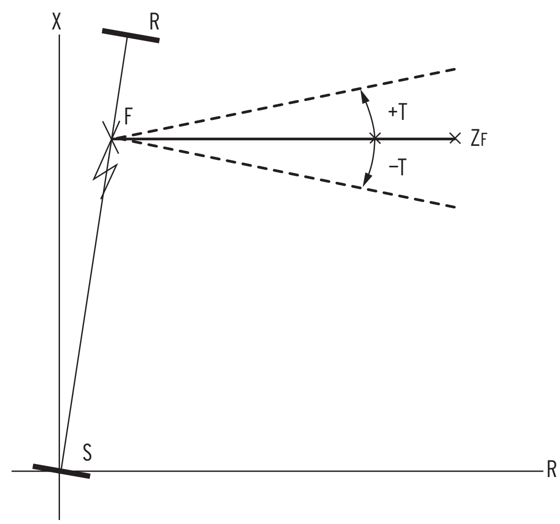


Figure 5.69 Tilt in Apparent Fault Impedance Resulting From Nonhomogeneity

Calculate T for a phase-to-phase fault at the remote bus (i.e., *m* equals one per unit). The remote bus is selected for the fault location to prevent Zone 1 phase-distance element overreach.

Each quadrilateral phase-distance element is supervised by the corresponding Relay Word bit ENX2AB, ENX2BC, or ENX2CA during unbalanced fault conditions (32QE = 1). This supervisory condition secures the reactance element in the quadrilateral phase-distance element against unusual unbalanced load conditions where currents (but not voltages) are unbalanced.

A supervisory condition is applied to force the right-resistive blinders to be self-polarized under the previous unusual unbalanced loads. The adaptability of the positive-sequence polarized resistive blinder is enabled during balanced operating conditions (32QE = 0). This adaptability is also enabled during unbalanced fault conditions (32QE = 1) when the corresponding Relay Word bit CNR1AB, CNR1BC, or CNR1CA is asserted. The adaptability of the negative-sequence polarized resistive blinder is enabled during unbalanced fault conditions (32QE = 1) when the corresponding Relay Word bit CNR2AB, CNR2BC, or CNR2CA is asserted. When the adaptability of any of the right resistive blinders is disabled, the corresponding blinder uses self polarization.

When you set the number of zones you want to enable (E21XP), this setting applies to both the high-speed and conventional elements. For example, E21XP = 2 makes two zones (Zone 1 and Zone 2) available for both the high-speed and conventional elements and hides the remaining zones.

Table 5.54 shows the Relay Word bits for quadrilateral phase-distance elements.

Table 5.54 Quadrilateral Phase-Distance Elements Relay Word Bits

Relay Word Bit	Description
XAB1	Zone 1 quad A-B phase element
XBC1	Zone 1 quad B-C phase element
XCA1	Zone 1 quad C-A phase element
XAB2	Zone 2 quad A-B phase element
XBC2	Zone 2 quad B-C phase element
XCA2	Zone 2 quad C-A phase element
XAB3	Zone 3 quad A-B phase element
XBC3	Zone 3 quad B-C phase element
XCA3	Zone 3 quad C-A phase element
XAB4	Zone 4 quad A-B phase element
XBC4	Zone 4 quad B-C phase element
XCA4	Zone 4 quad C-A phase element
XAB5	Zone 5 quad A-B phase element
XBC5	Zone 5 quad B-C phase element
XCA5	Zone 5 quad C-A phase element

Figure 5.70 shows the logic of the Zone 1 conventional quadrilateral phase-distance element for the AB loop. Fault calculations for BC and CA faults have similar logics.

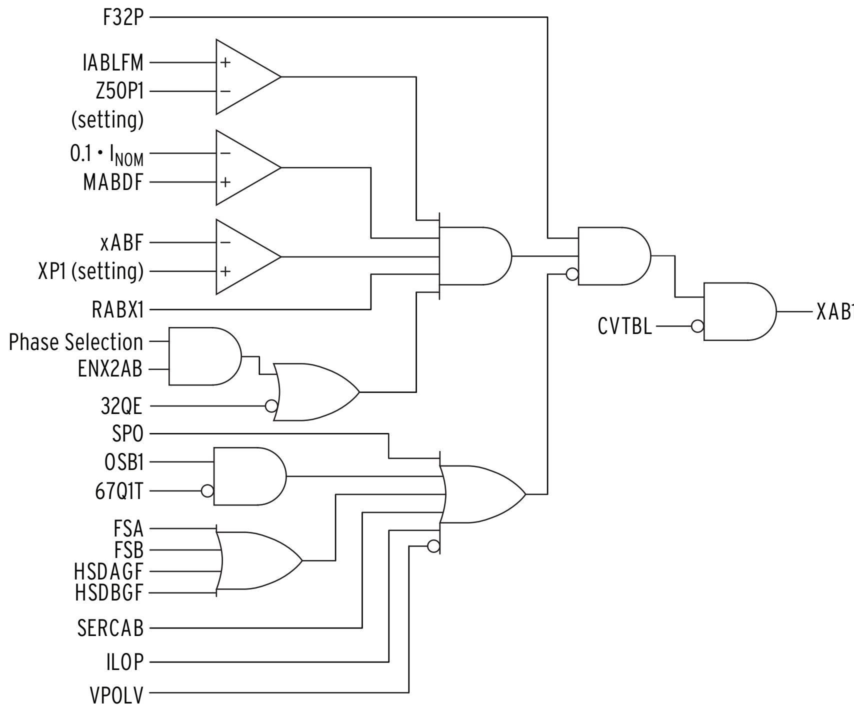


Figure 5.70 Zone 1 AB Loop Conventional Quadrilateral Phase-Distance Element Logic

Figure 5.71 shows the logic of the Zone 2 quadrilateral phase-distance element for the AB loop. Fault calculations for BC and CA faults have similar logics.

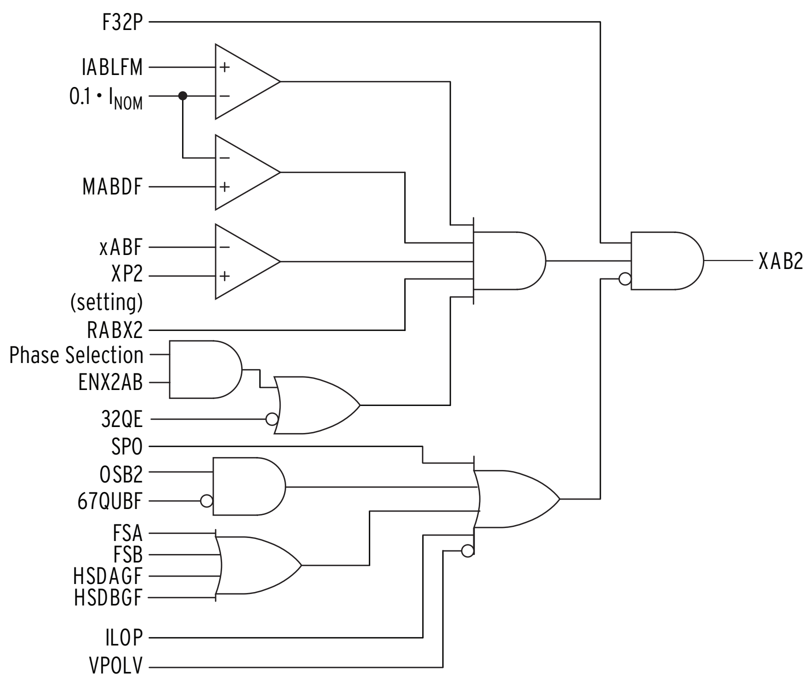


Figure 5.71 Zone 2 AB Loop Conventional Quadrilateral Phase-Distance Element Logic

Figure 5.72 shows the logic of the Zone 3, 4, and 5 conventional quadrilateral phase-distance element for the AB loop. Fault calculations for BC and CA faults have similar logics.

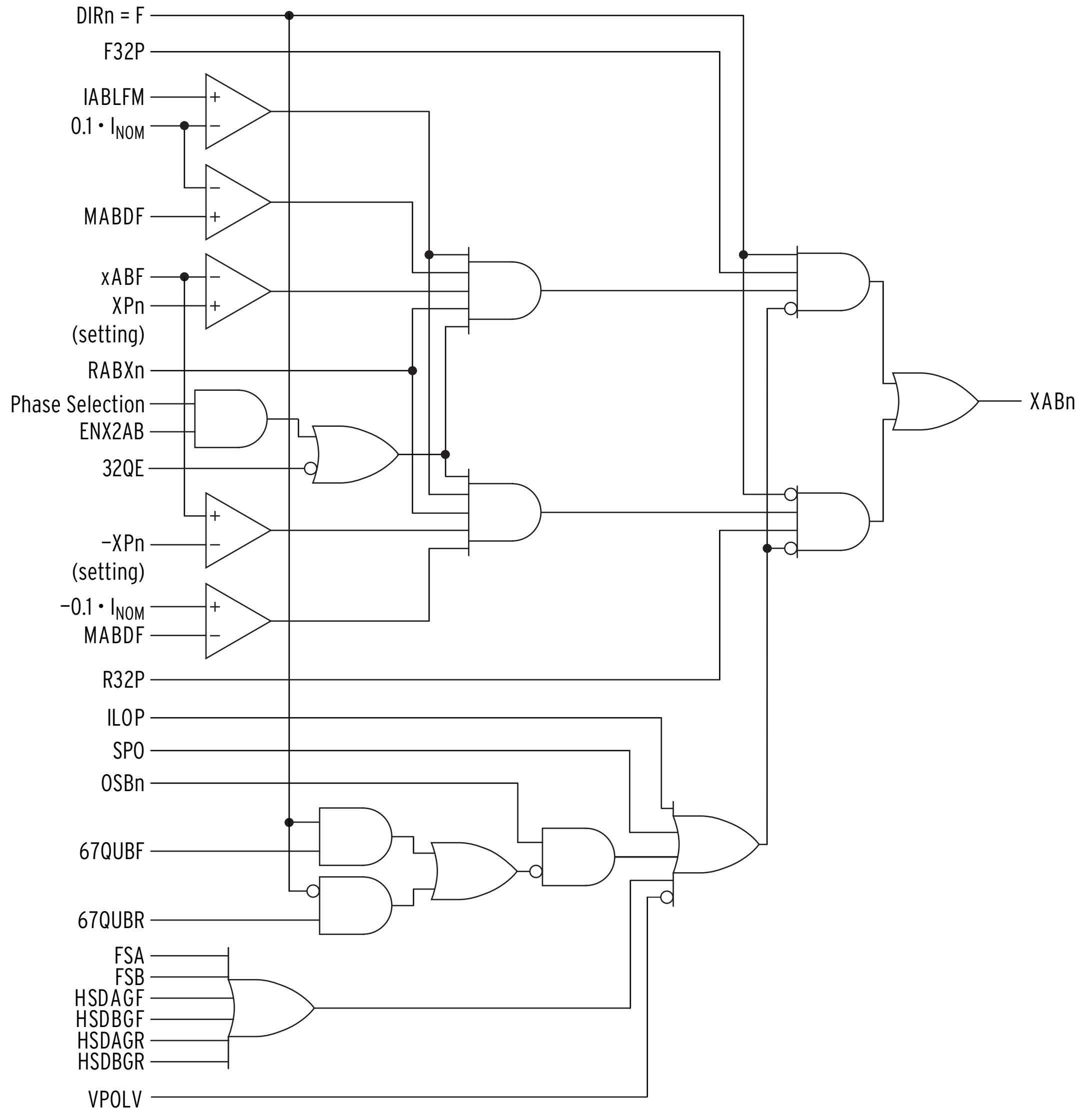


Figure 5.72 Zone 3, 4, and 5 AB Loop Conventional Quadrilateral Phase-Distance Element Logic

Zone Time Delay

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The SEL-421 supports two philosophies of zone timing:

- Independent timing—the phase and ground-distance elements drive separate timers for each zone
- Common timing—the phase and ground-distance elements both drive a common timer

Independent Zone Timing

Use Relay Word bits Z*n*PT (Time-Delayed Zone Phase-Distance Protection) and Z*n*GT (Time-Delayed Zone Ground-Distance Protection) to select independent zone timing in SELOGIC control equation TR (Trip) (*n* = 1–5).

The example below uses independent timing for Zone 2 phase and ground-distance protection:

TR := Z1P OR Z1G OR Z2PT OR Z2GT

Common Zone Timing

Use Relay Word bits Z*n*T (Zone *n* Distance Protection) to select common zone timing in SELOGIC control equation TR (Trip) (*n* = 1–5).

The next example uses common timing for Zone 2 distance protection:

TR := Z1P OR Z1G OR Z2T

If the timer input drops out while timing, the relay suspends the common zone timer for two cycles. This feature prevents resetting the timer when a fault evolves (e.g., the fault changes from a single phase-to-ground to phase-to-phase-to-ground). If the timer expires, the relay blocks the suspend-timing logic. When the zone timer is set to OFF, the output from the timer is blocked.

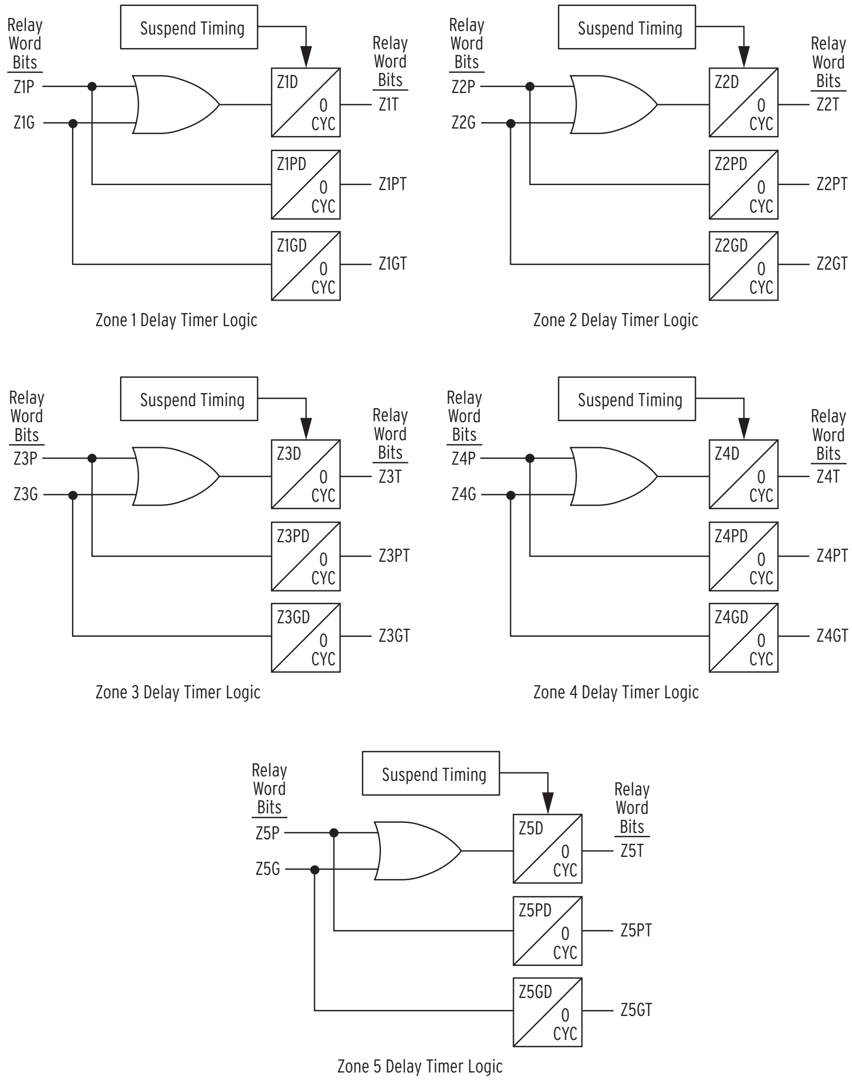


Figure 5.73 Zone Timers

Instantaneous Line Overcurrent Elements

The SEL-421 calculates instantaneous overcurrent elements for phase (P), residual ground (G, vector sum of I_A, I_B, and I_C), and negative-sequence (Q) quantities. Four levels of instantaneous elements are available named 50P1–50P4, 50Q1–50Q4, and 50G1–50G4, as shown in *Table 5.58* through *Table 5.60*, with settings shown in *Table 5.55* through *Table 5.57*.

These overcurrent elements always operate on the line current (IW terminal current or the sum of the IW and IX terminal currents) according to the global setting LINEI (Line Current Source). The instantaneous overcurrent elements are inputs to the instantaneous directional (67P*n*, 67Q*n*, 67G*n*, where *n* = 1–4) and definite-time directional overcurrent elements (67P*n*T, 67Q*n*T, 67G*n*T, where *n* = 1–4). See *Directionality on page 5.46* for details on the directional control option. Note that the 67P*n* and 67P*n*T elements are not directionally controlled by the built-in logic; they can be made directional through the use of torque control settings 67P1TC–67P4TC.

Each of the instantaneous directional elements includes a torque control setting (67P*n*TC, 67Q*n*TC, 67G*n*TC, where *n* = 1–4) to supervise the element operation.

The enable settings (E50P, E50Q, E50G) control how many of each type of instantaneous/definite-time overcurrent elements are available. For example, if E50P := 2, only 50P1, 67P1, 67P1T, 50P2, 67P2, and 67P2T are processed. The remaining phase instantaneous/definite-time overcurrent elements (*n* = 3–4) are defeated, and the output Relay Word bits are forced to logical 0.

Table 5.55 Phase Overcurrent Element Settings

Setting	Prompt	Range	Default (5 A)
Phase Instantaneous Overcurrent Elements			
E50P	Phase Inst./Def.-Time O/C Elements	N, 1–4	1
50P1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	10.00
50P2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50P3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50P4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Phase Definite-Time Overcurrent Elements			
67P1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67P2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67P3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67P4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67P1TC	Level 1 Torque Control	SELOGIC Equation	1
67P2TC	Level 2 Torque Control	SELOGIC Equation	1
67P3TC	Level 3 Torque Control	SELOGIC Equation	1
67P4TC	Level 4 Torque Control	SELOGIC Equation	1

Table 5.56 Negative-Sequence Overcurrent Element Settings

Setting	Prompt	Range	Default (5 A)
Negative-Sequence Instantaneous Overcurrent Elements			
E50Q	Neg.-Seq. Inst./Def.-Time O/C Elements	N, 1–4	N
50Q1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50Q4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Negative-Sequence Definite-Time Overcurrent Elements			
67Q1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67Q2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67Q3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67Q4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67Q1TC	Level 1 Torque Control	SELOGIC Equation	1
67Q2TC	Level 2 Torque Control	SELOGIC Equation	1
67Q3TC	Level 3 Torque Control	SELOGIC Equation	1
67Q4TC	Level 4 Torque Control	SELOGIC Equation	1

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 5.57 Residual Ground Overcurrent Element Settings

Setting	Prompt	Range	Default (5 A)
Residual Ground Instantaneous Overcurrent Elements			
E50G	Residual Ground Inst./Def.-Time O/C Elements	N, 1–4	N
50G1P	Level 1 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G2P	Level 2 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G3P	Level 3 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
50G4P	Level 4 Pickup (A)	OFF, (0.05–20) • I_{NOM}	OFF
Residual Ground Definite-Time Overcurrent Elements			
67G1D	Level 1 Time Delay (cycles)	0.000–16000	0.000
67G2D	Level 2 Time Delay (cycles)	0.000–16000	0.000
67G3D	Level 3 Time Delay (cycles)	0.000–16000	0.000
67G4D	Level 4 Time Delay (cycles)	0.000–16000	0.000
67G1TC	Level 1 Torque Control	SELOGIC Equation	1
67G2TC	Level 2 Torque Control	SELOGIC Equation	1
67G3TC	Level 3 Torque Control	SELOGIC Equation	1
67G4TC	Level 4 Torque Control	SELOGIC Equation	1

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 5.58 Phase Instantaneous/Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50P1	Level 1 instantaneous phase overcurrent element
50P2	Level 2 instantaneous phase overcurrent element
50P3	Level 3 instantaneous phase overcurrent element
50P4	Level 4 instantaneous phase overcurrent element
67P1	Level 1 definite-time phase directional overcurrent element
67P2	Level 2 definite-time phase directional overcurrent element
67P3	Level 3 definite-time phase directional overcurrent element
67P4	Level 4 definite-time phase directional overcurrent element
67P1T	Level 1 time-delayed definite-time phase directional overcurrent element
67P2T	Level 2 time-delayed definite-time phase directional overcurrent element
67P3T	Level 3 time-delayed definite-time phase directional overcurrent element
67P4T	Level 4 time-delayed definite-time phase directional overcurrent element

Table 5.59 Negative-Sequence Instantaneous/Definite-Time Line Overcurrent Relay Word Bits (Sheet 1 of 2)

Name	Description
50Q1	Level 1 instantaneous negative-sequence overcurrent element
50Q2	Level 2 instantaneous negative-sequence overcurrent element
50Q3	Level 3 instantaneous negative-sequence overcurrent element
50Q4	Level 4 instantaneous negative-sequence overcurrent element
67Q1	Level 1 definite-time negative-sequence directional overcurrent element
67Q2	Level 2 definite-time negative-sequence directional overcurrent element

Table 5.59 Negative-Sequence Instantaneous/Definite-Time Line Overcurrent Relay Word Bits (Sheet 2 of 2)

Name	Description
67Q3	Level 3 definite-time negative-sequence directional overcurrent element
67Q4	Level 4 definite-time negative-sequence directional overcurrent element
67Q1T	Level 1 time-delayed definite-time negative-sequence directional overcurrent element
67Q2T	Level 2 time-delayed definite-time negative-sequence directional overcurrent element
67Q3T	Level 3 time-delayed definite-time negative-sequence directional overcurrent element
67Q4T	Level 4 time-delayed definite-time negative-sequence directional overcurrent element

Table 5.60 Residual Ground Instantaneous/Definite-Time Line Overcurrent Relay Word Bits

Name	Description
50G1	Level 1 instantaneous residual ground overcurrent element
50G2	Level 2 instantaneous residual ground overcurrent element
50G3	Level 3 instantaneous residual ground overcurrent element
50G4	Level 4 instantaneous residual ground overcurrent element
67G1	Level 1 definite-time residual ground directional overcurrent element
67G2	Level 2 definite-time residual ground directional overcurrent element
67G3	Level 3 definite-time residual ground directional overcurrent element
67G4	Level 4 definite-time residual ground directional overcurrent element
67G1T	Level 1 time-delayed definite-time residual ground directional overcurrent element
67G2T	Level 2 time-delayed definite-time residual ground directional overcurrent element
67G3T	Level 3 time-delayed definite-time residual ground directional overcurrent element
67G4T	Level 4 time-delayed definite-time residual ground directional overcurrent element

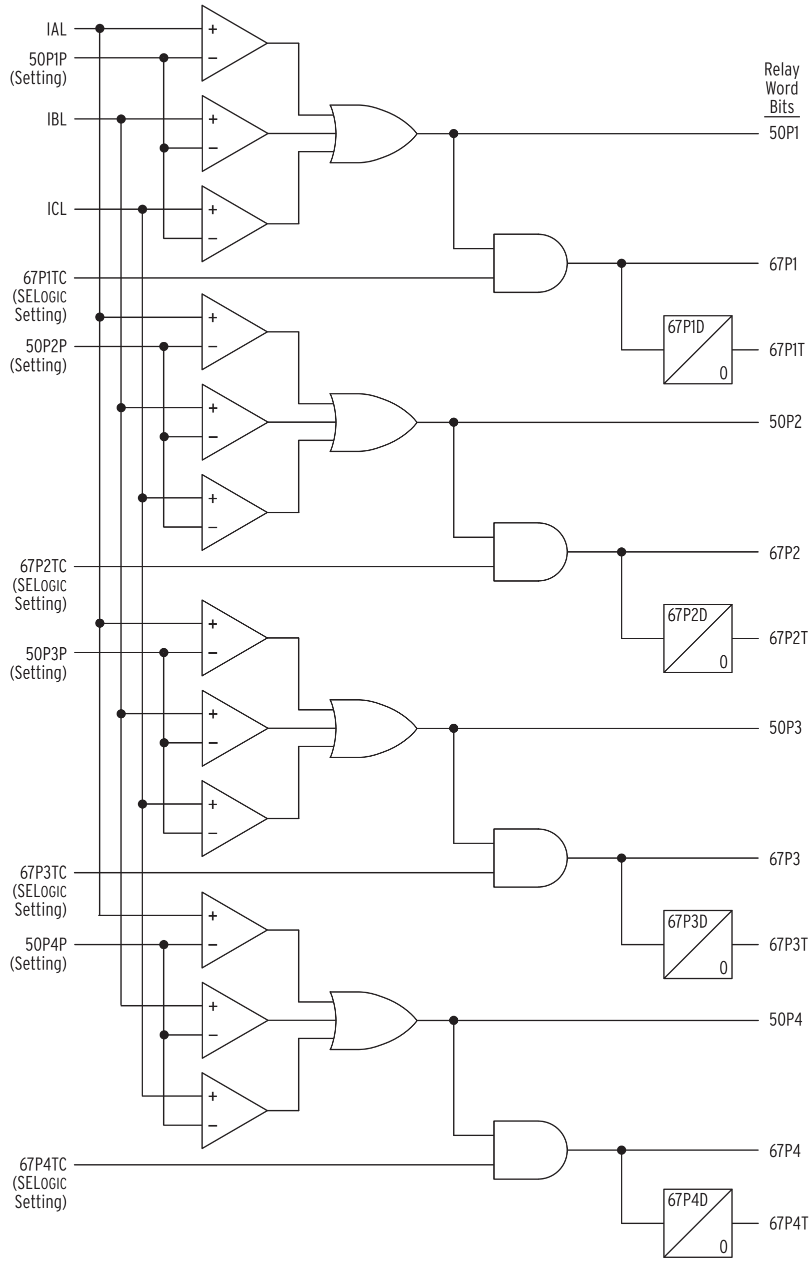


Figure 5.74 Phase Instantaneous/Definite-Time Overcurrent Elements

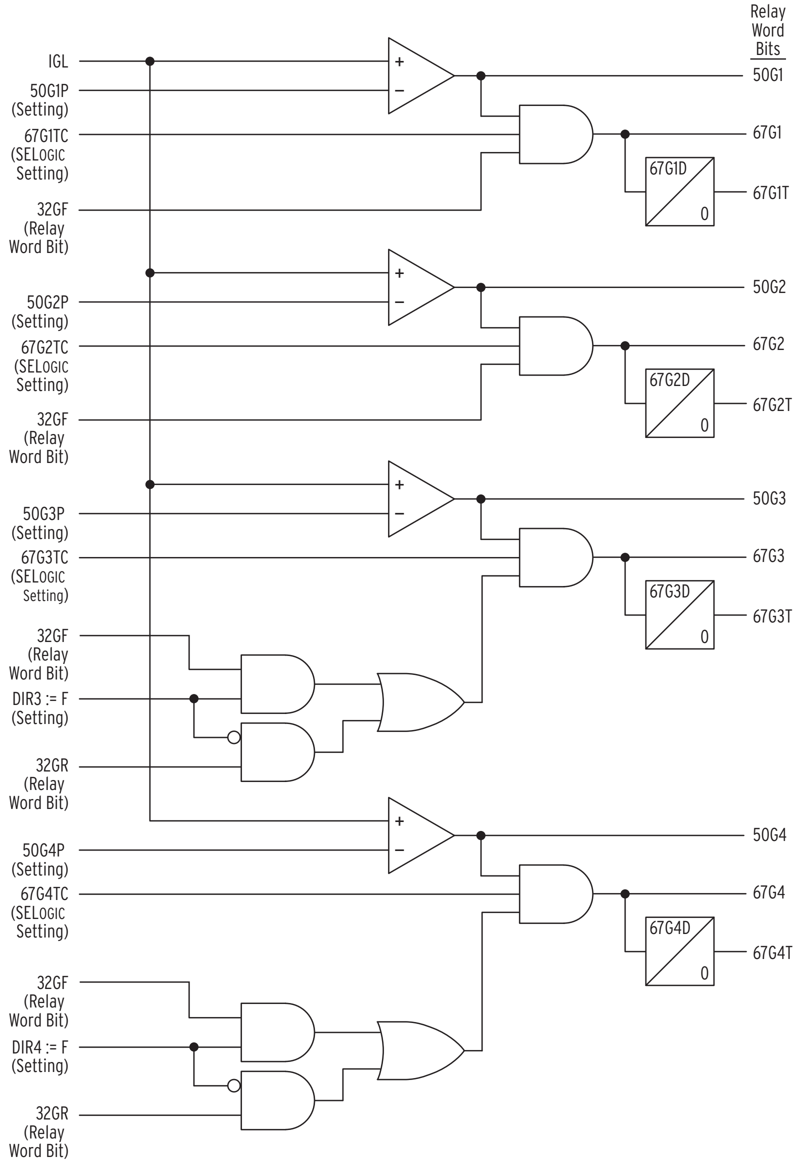


Figure 5.75 Residual Ground Instantaneous/Directional Overcurrent Elements

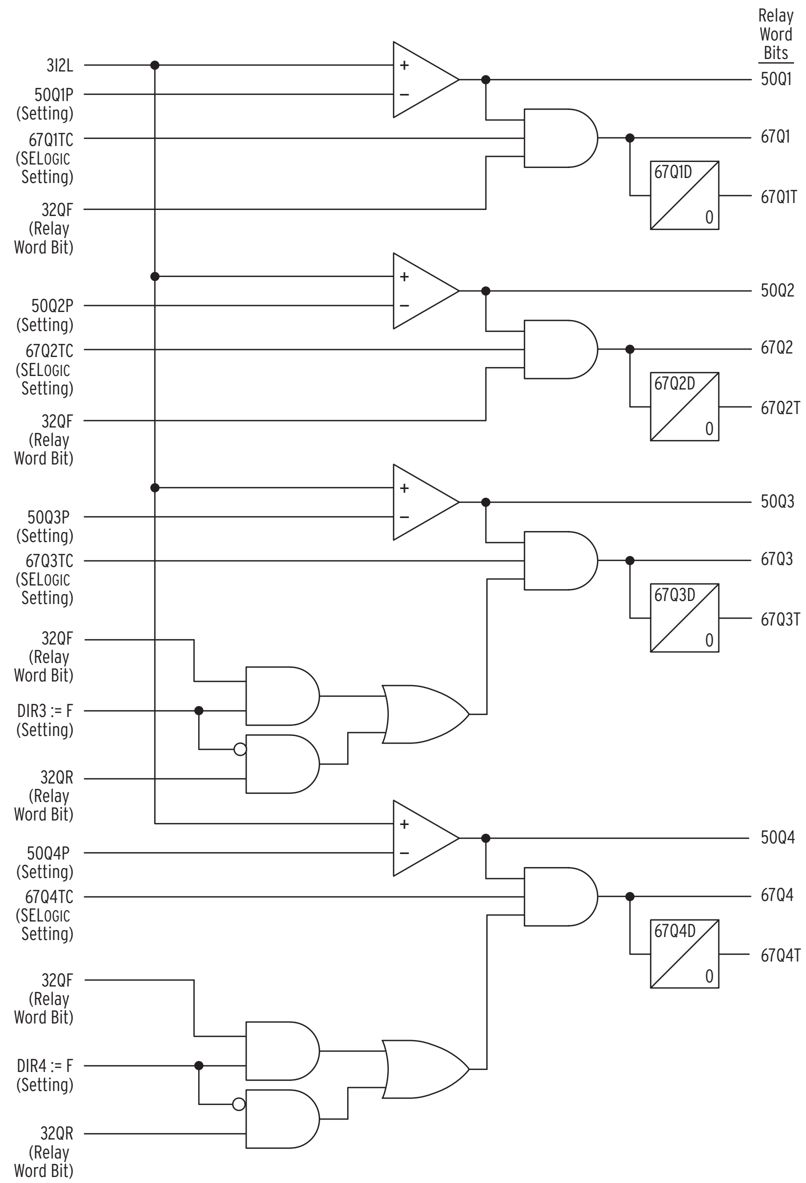


Figure 5.76 Negative-Sequence Instantaneous/Directional Overcurrent Elements

Inverse-Time Overcurrent Elements

The SEL-421 provides three selectable operating quantity inverse-time overcurrent elements. Ten different time-overcurrent characteristics (5 U.S. and 5 IEC curves) are available.

Each time-overcurrent element can be configured to operate on the line current (i.e., IW terminal current or the sum of the IW and IX terminal currents) depending upon setting LINEI; or circuit breaker operating quantities, with the terminal source depending upon settings BK1I and BK2I.

Symmetrical component current quantities are available only for the line-current source. *Table 5.61* defines the available setting choices for operating quantities and the corresponding analog quantity name as found in *Section 12: Analog Quantities*.

NOTE: In the SEL-421, the time-overcurrent elements are not directionally controlled in the internal logic. Directional control may be achieved through the use of torque control settings, as shown in *Section 6: Protection Applications Examples*. Also refer to *Directionality on page 5.46*.

Each time-overcurrent element has a torque control SELOGIC equation 51S*k*TC (*k* = 1–3) that enables the element when the equation evaluates to logical 1, and disables the element when the equation evaluates to logical 0. See *Figure 5.66* for a logic diagram of the time-overcurrent elements, including the torque control input.

The enable setting (E51S) controls how many time-overcurrent elements are available. For example, if E51S := 1, only 51S1 is processed. The remaining time-overcurrent elements 51S*k* (*k* = 2–3) are defeated, and the output Relay Word bits are forced to logical 0.

Table 5.61 Selectable Current Quantities

Quantity[a]	Description	Analog Quantities
IA*n*	A-Phase	LIAFIM, B1IAFIM, B2IAFIM
IB*n*	B-Phase	LIBFIM, B1IBFIM, B2IBFIM
IC*n*	C-Phase	LICFIM, B1ICFIM, B2ICFIM
IMAX*n*	Maximum Phase	N/A
I1L	Line positive-sequence current	LI1FIM
3I2L	Line negative-sequence current	L3I2FIM
3I0*n*	Zero-sequence current	LIGFIM, B1IGFIM, B2IGFIM

[a] Parameter *n* is L for Line, 1 for BK 1, and 2 for BK 2.

Table 5.62 Selectable Inverse-Time Overcurrent Settings

Setting[a]	Prompt	Range	Default (5 A)
E51S	Selectable Inverse-Time Overcurrent Element	N, 1–3	1
51S1O	Operating Quantity Element 1	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	3I0L
51S1P	51S1 O/C Pickup Element 1 (A)	(0.05–3.2) • I_{NOM}	0.75
51S1C	51S1 Inverse-Time O/C Curve Element 1	U1–U5, C1–C5	U3
51S1TD	51S1 Inverse-Time O/C Time-Dial Element 1	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1.0
51S1RS	51S1 Inverse-Time O/C Electromechanical Reset Element 1	Y, N	N
51S1TC	51S1 Inverse-Time O/C Torque Control Element 1	SELOGIC Equation	32GF
51S2O	Operating Quantity Element 2	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	3I2L
51S2P	51S2 O/C Pickup Element 2 (A)	(0.05–3.2) • I_{NOM}	5.00
51S2C	51S2 Inverse-Time O/C Curve Element 2	U1–U5, C1–C5	U3
51S2TD	51S2 Inverse-Time O/C Time-Dial Element 2	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1
51S2RS	51S2 Inverse-Time O/C Electromechanical Reset Element 2	Y, N	N
51S2TC	51S2 Inverse-Time O/C Torque Control Element 2	SELOGIC Equation	32QF
51S3O	Operating Quantity Element 3	IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*	IMAXL
51S3P	51S3 O/C Pickup Element 3 (A)	OFF, (0.05–3.2) • I_{NOM}	5.00
51S3C	51S3 Inverse-Time O/C Curve Element 3	U1–U5, C1–C5	U3
51S3TD	51S3 Inverse-Time O/C Time-Dial Element 3	0.50–15.00 (U*x*)[b] 0.05–1.00 (C*x*)[b]	1
51S3RS	51S3 Inverse-Time O/C Electromechanical Reset Element 3	Y, N	N
51S3TC	51S3 Inverse-Time O/C Torque Control Element 3	SELOGIC Equation	Z2P

[a] Parameter *n* is L for Line, 1 for BK1, and 2 for BK2.
[b] Parameter *x* is a number from 1–5 indicating the operating curve (see *Figure 5.77* through *Figure 5.86*).

Table 5.63 Selectable Inverse-Time Overcurrent Relay Word Bits

Name	Description
51S1	Inverse-Time Overcurrent Element 1 pickup
51S1T	Inverse-Time Overcurrent Element 1 timed out
51S1R	Inverse-Time Overcurrent Element 1 reset
51S2	Inverse-Time Overcurrent Element 2 pickup
51S2T	Inverse-Time Overcurrent Element 2 timed out
51S2R	Inverse-Time Overcurrent Element 2 reset
51S3	Inverse-Time Overcurrent Element 3 pickup
51S3T	Inverse-Time Overcurrent Element 3 timed out
51S3R	Inverse-Time Overcurrent Element 3 reset

Time-Current Operating Characteristics

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The following information describes curve timing for time-overcurrent element curve and time-dial settings. The time-overcurrent relay curves in *Figure 5.77* through *Figure 5.86* conform to IEEE C37.112–1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

T_p = operating time in seconds
T_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (T_p), $M > 1$; for reset time (T_r), $M \leq 1$]

Table 5.64 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$T_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 5.77*
U2 (Inverse)	$T_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 5.78*
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 5.79*
U4 (Extremely Inverse)	$T_p = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$	*Figure 5.80*
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 5.81*

Table 5.65 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$T_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 5.82*
C2 (Very Inverse)	$T_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 5.83*
C3 (Extremely Inverse)	$T_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_r = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 5.84*
C4 (Long-Time Inverse)	$T_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$T_r = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 5.85*
C5 (Short-Time Inverse)	$T_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_r = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 5.86*

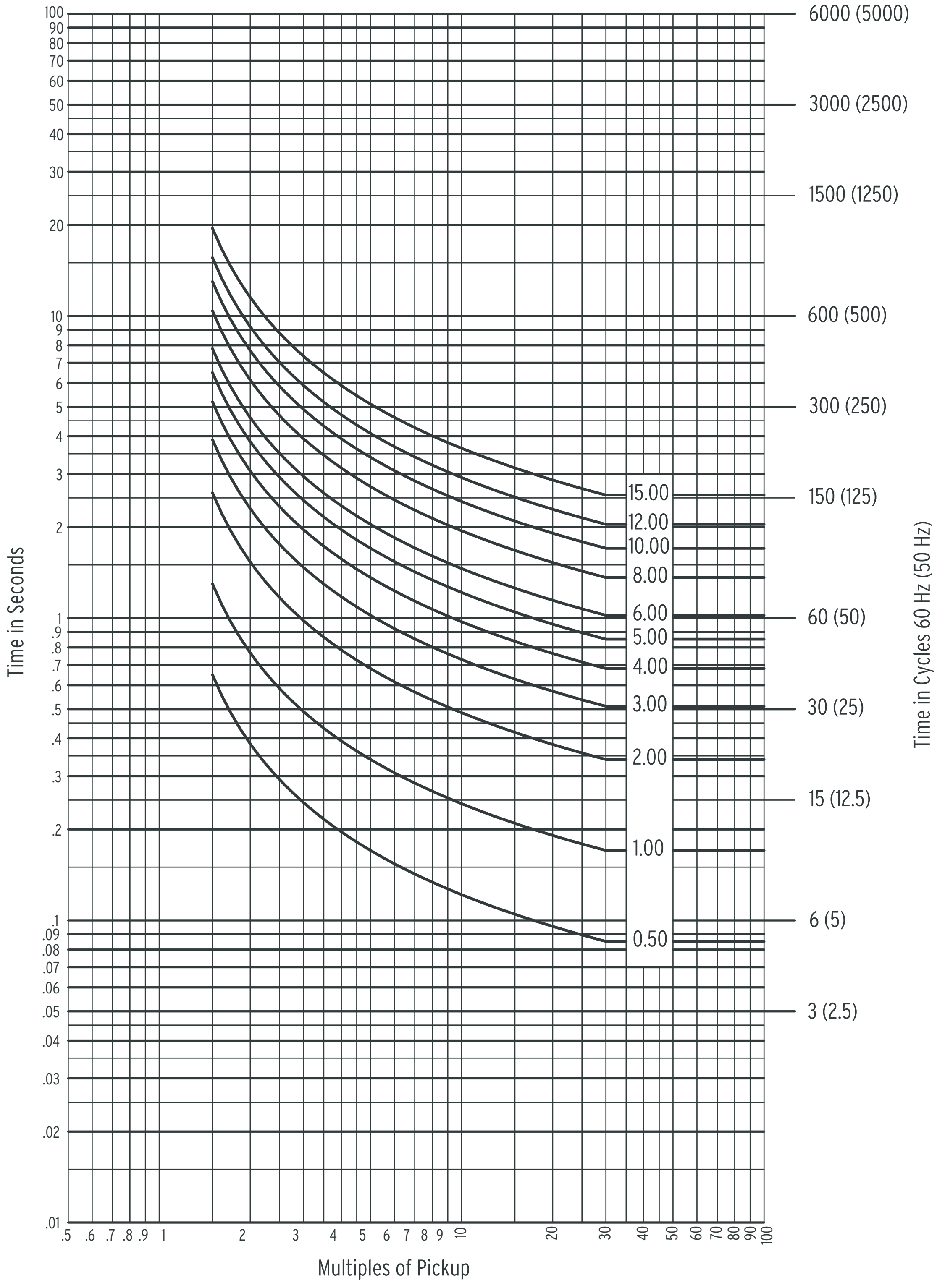


Figure 5.77 U.S. Moderately Inverse—U1

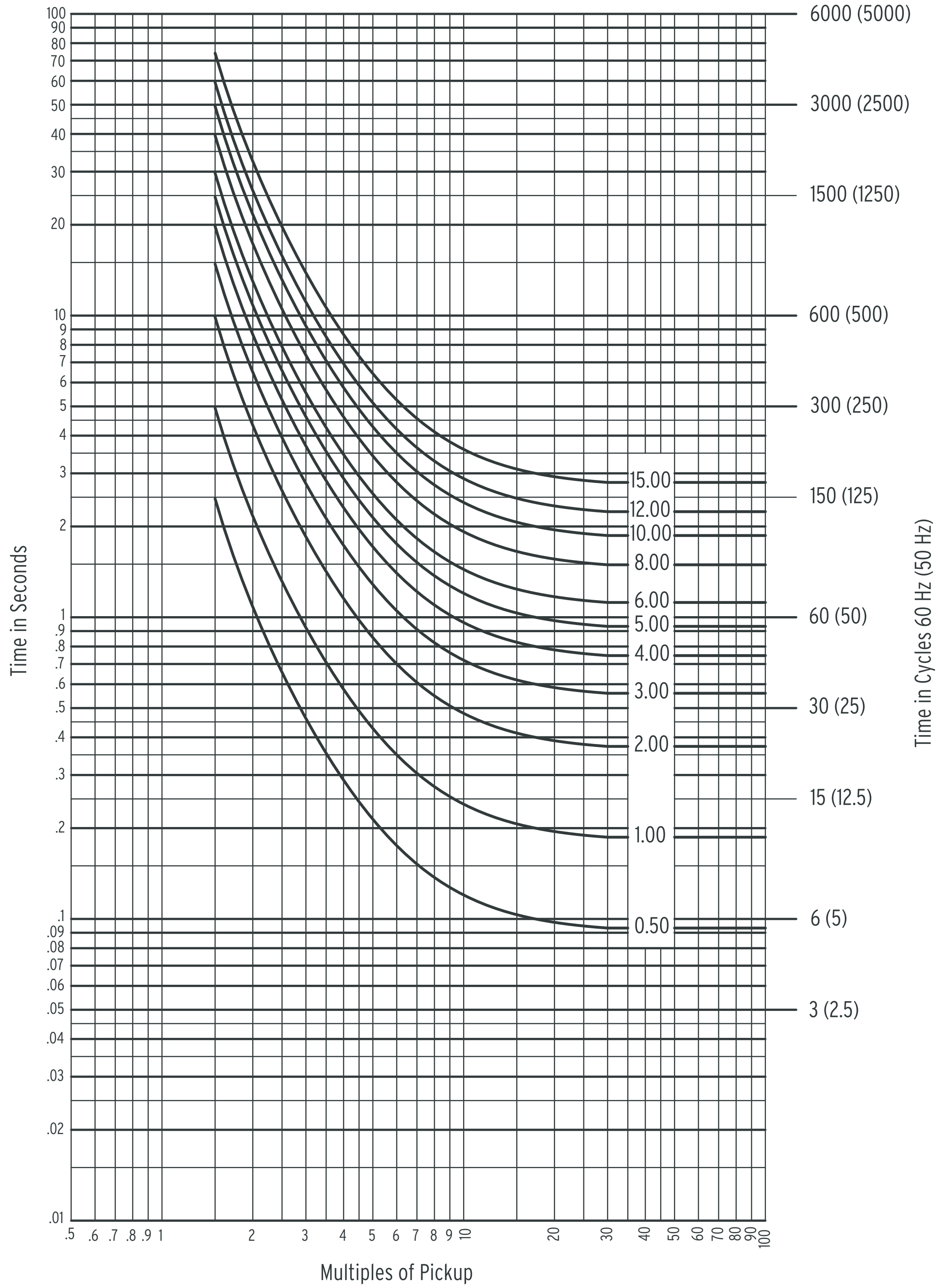


Figure 5.78 U.S. Inverse—U2

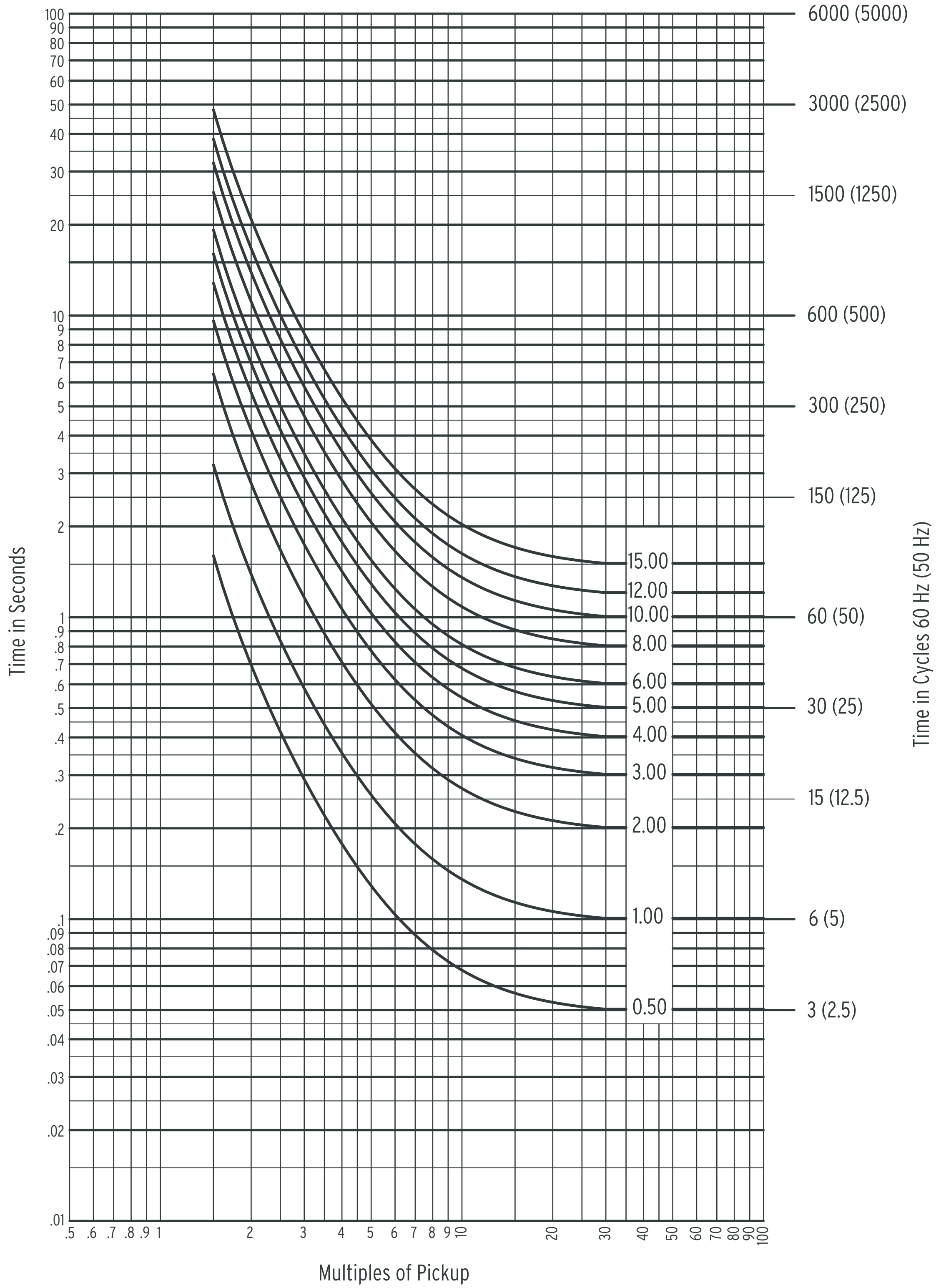


Figure 5.79 U.S. Very Inverse—U3

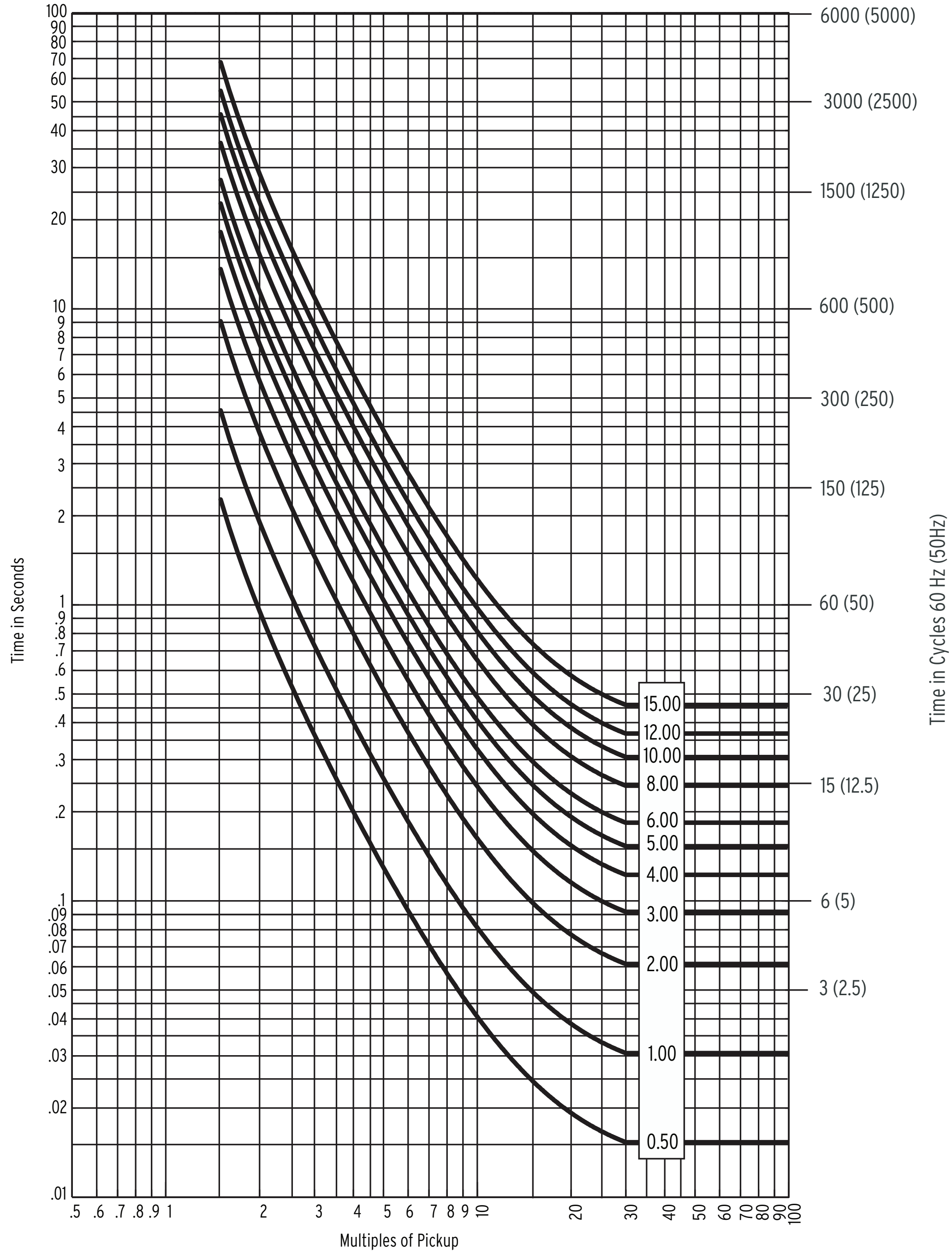


Figure 5.80 U.S. Extremely Inverse—U4

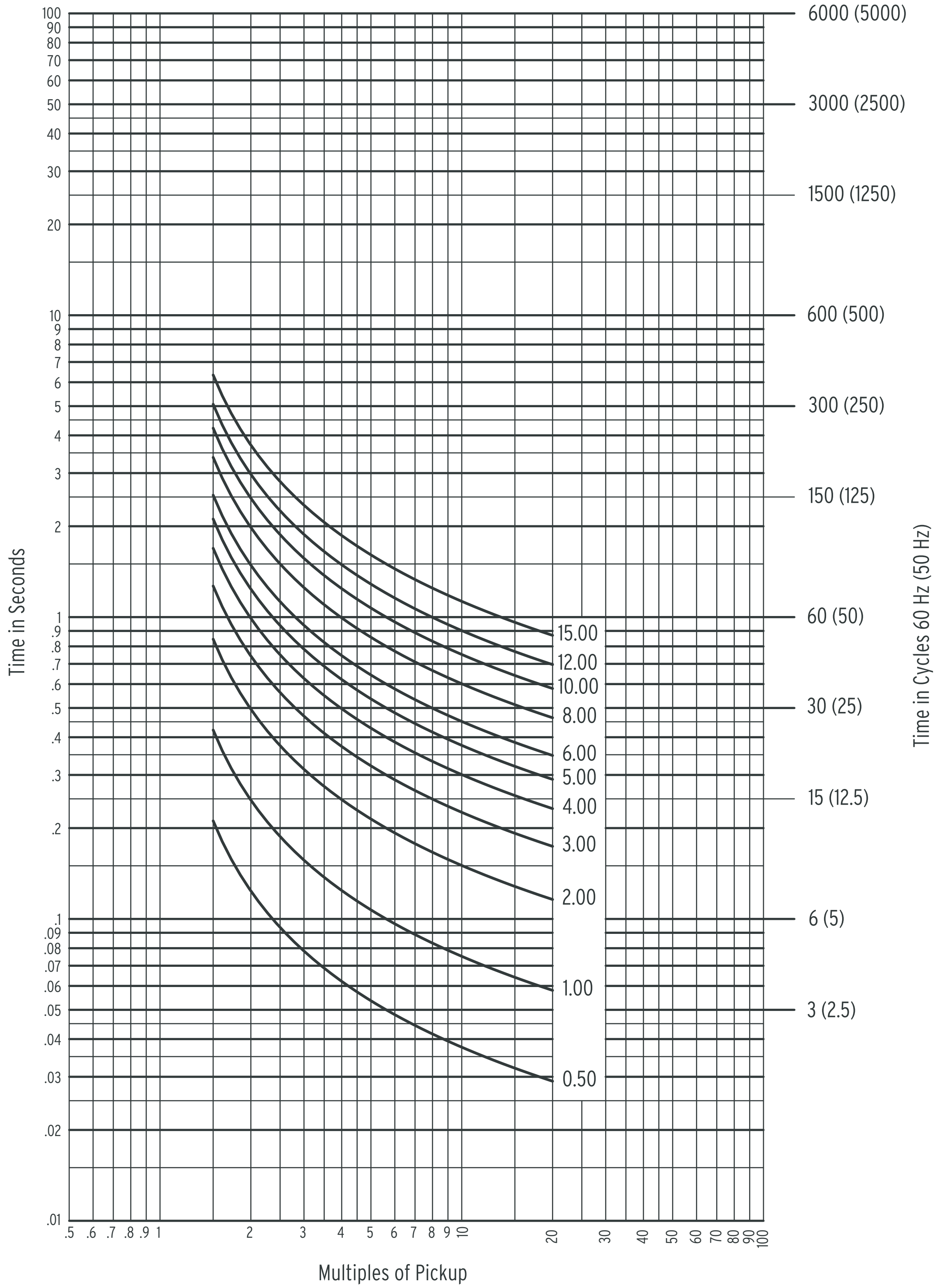


Figure 5.81 U.S. Short-Time Inverse—U5

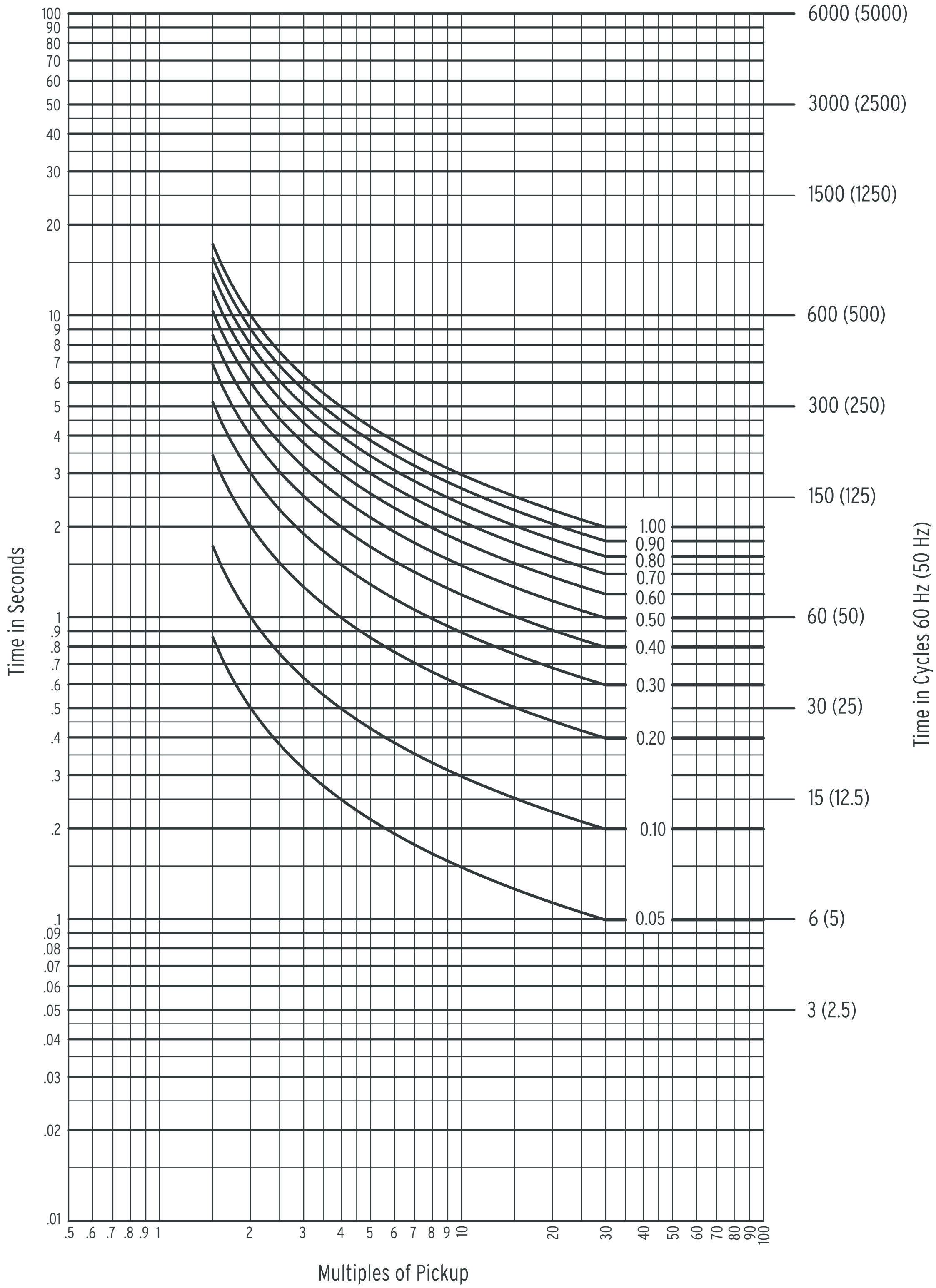


Figure 5.82 IEC Standard Inverse—C1

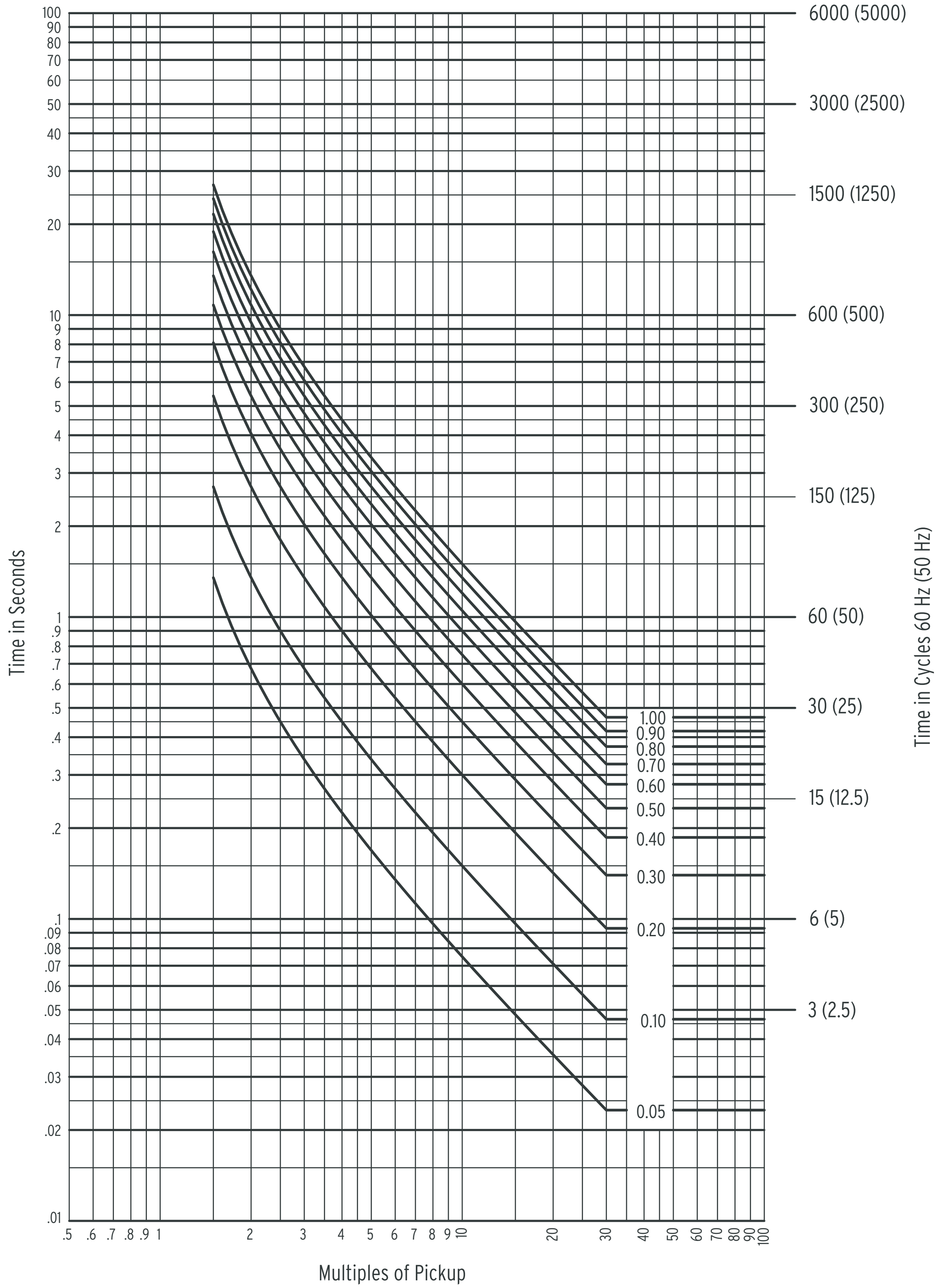


Figure 5.83 IEC Very Inverse—C2

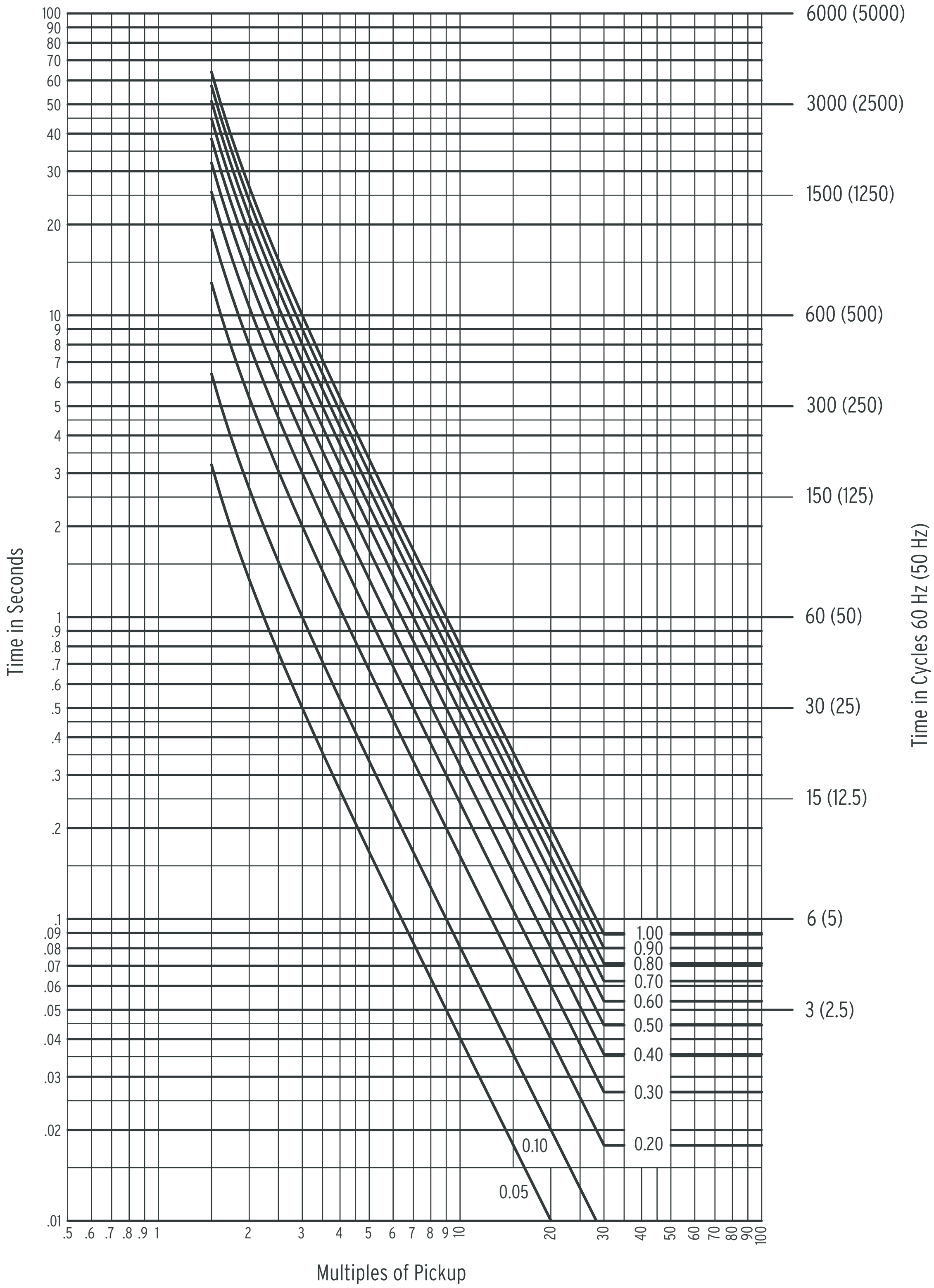


Figure 5.84 IEC Extremely Inverse—C3

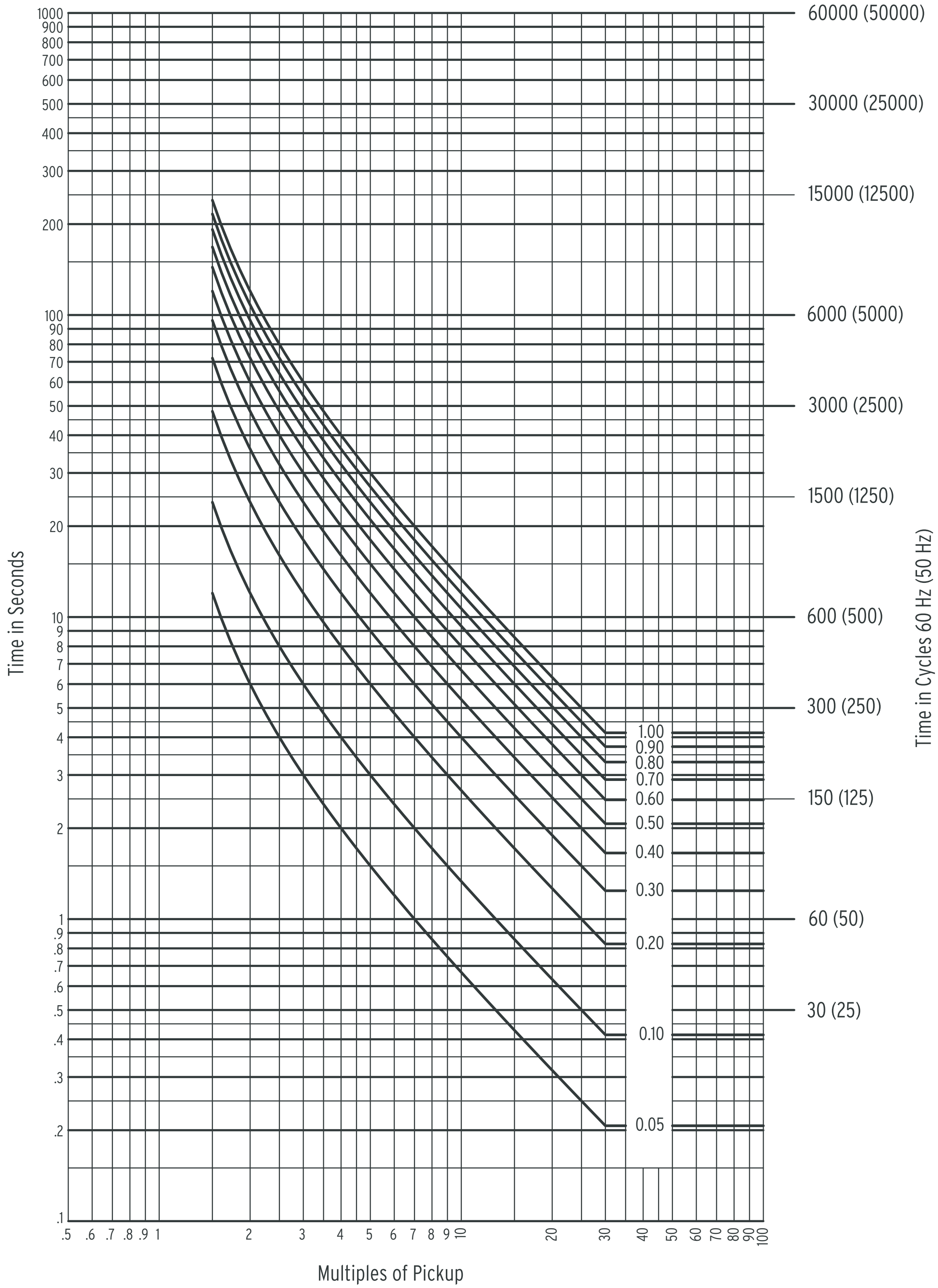


Figure 5.85 IEC Long-Time Inverse—C4

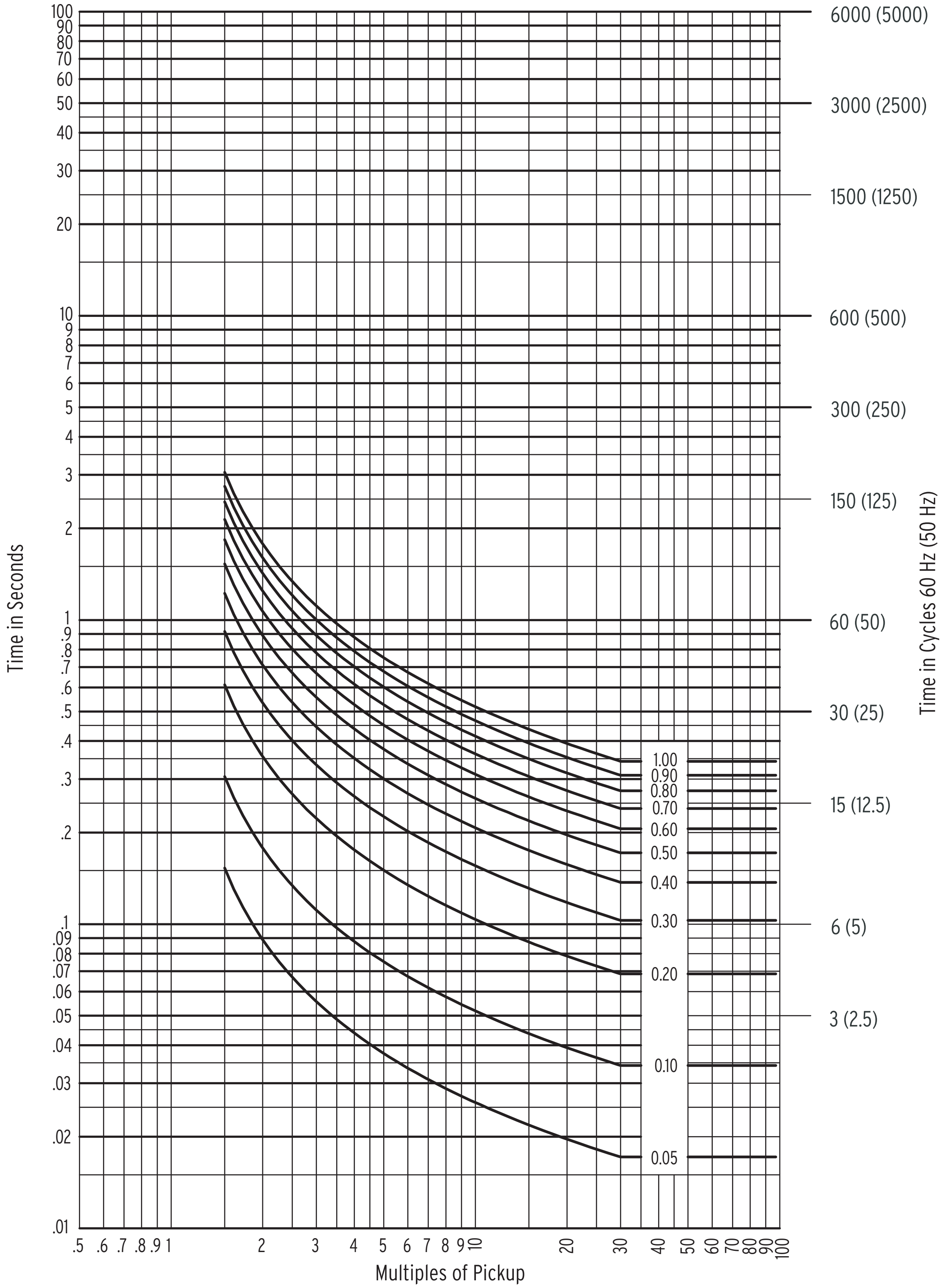


Figure 5.86 IEC Short-Time Inverse—C5

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

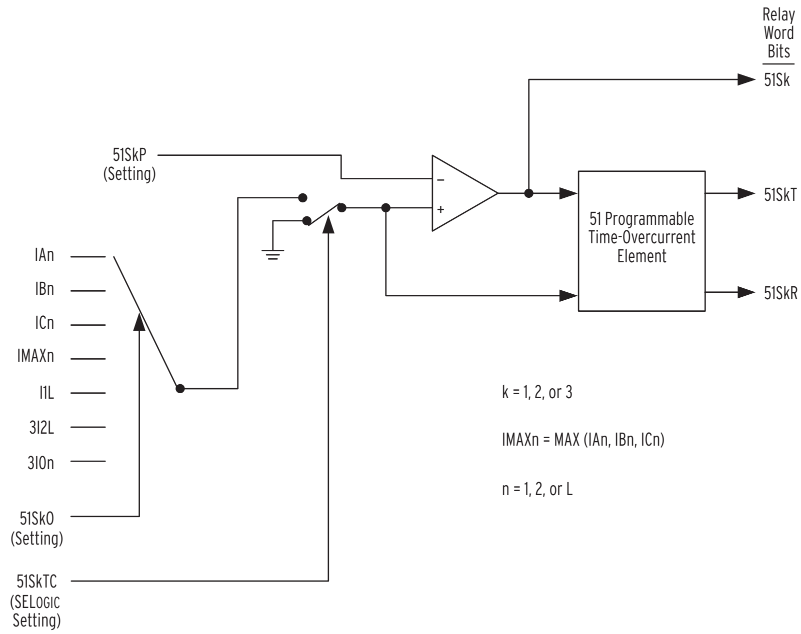


Figure 5.87 Selectable Inverse-Time Overcurrent Element Logic Diagram

Over- and Undervoltage Elements

Instead of having dedicated operating quantities for the undervoltage and overvoltage elements, the relay offers the flexibility of unassigned elements. Unassigned means that the undervoltage and overvoltage elements are not assigned to a specific input quantity, but they are available for assignment, as the application requires.

The relay offers as many as six undervoltage and six overvoltage elements. Each of these 12 elements has two levels, for a total of 24 over- and undervoltage elements. *Figure 5.88* shows the undervoltage element logic, and *Figure 5.89* shows the undervoltage element logic.

The relay supports two voltage terminals, Y and Z. Select any one of the voltage quantities from *Table 5.66* as an input quantity (27O*n* and 59O*n* settings). You can select the same quantity for an undervoltage element as for an overvoltage element.

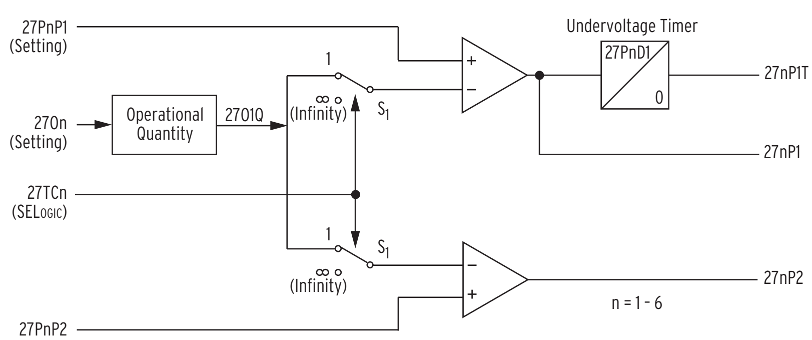


Figure 5.88 Undervoltage Elements

Although each under- and overvoltage element offers two levels, only Level 1 has a timer. If your application requires a time delay for the Level 2 elements, use a programmable timer to delay the output.

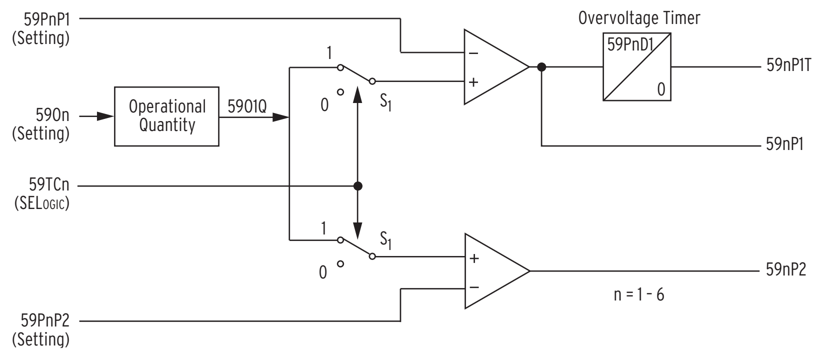


Figure 5.89 Overvoltage Elements

Select any one of the voltage elements from *Table 5.66* as an input quantity. You can select the same quantity for the undervoltage element as for an overvoltage element.

Table 5.66 Available Input Quantities

Voltage Quantity	Description
VAFIM	Filtered instantaneous A-Phase voltage magnitude
VBFIM	Filtered instantaneous B-Phase voltage magnitude
VCFIM	Filtered instantaneous C-Phase voltage magnitude
V1FIM	Filtered instantaneous positive-sequence voltage magnitude
VNMAXF	Maximum phase-to-neutral voltage magnitude
VNMINF	Minimum phase-to-neutral voltage magnitude
VPMAXF	Maximum phase-to-phase voltage magnitude
VPMINF	Minimum phase-to-phase voltage magnitude
3V2FIM[a]	Filtered instantaneous negative-sequence voltage magnitude
3V0FIM[a]	Filtered instantaneous zero-sequence voltage magnitude

[a] These quantities are only available for the overvoltage (59) elements.

Under- and Overvoltage Settings

E59 (Enable Overvoltage Elements)

Select the number of overvoltage elements (1–6) you require for your application.

Setting	Prompt	Range	Default	Category
E59	Enable Overvoltage Elements	N, 1–6	N	Group

E27 (Enable Undervoltage Elements)

Select the number of undervoltage elements (1–6) you require for your application.

Setting	Prompt	Range	Default	Category
E27	Enable Undervoltage Elements	N, 1–6	N	Group

27O*n* (Undervoltage Element Operating Quantity)

Select the desired operating quantity for each voltage terminal from *Table 5.66*.

Setting	Prompt	Range	Default	Category
27O*n*[a]	U/V Element *n* Operating Quantity	See *Table 5.66*	V1FIM	Group

[a] *n* = 1–6.

27P*n*P1 (Undervoltage Level 1 Pickup)

Set pickup values for the voltage values below that you want the Level 1 undervoltage elements to assert.

Setting	Prompt	Range	Default	Category
27P*n*P1[a]	U/V Element *n* Level 1 P/U	2.00 to 300 volts, sec.	20	Group

[a] *n* = 1–6.

27P*n*P2 (Undervoltage Level 2 Pickup)

Set pickup values for the voltage values below that you want the Level 2 undervoltage elements to assert.

Setting	Prompt	Range	Default	Category
27P*n*P2	U/V Element *n* Level 2 P/U	2.00 to 300 volts, sec.	15	Group

27TC*n* (Undervoltage Torque Control)

Use the torque-control setting to specify conditions under which the undervoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

Setting	Prompt	Range	Default	Category
27TC*n*[a]	U/V Element *n* Torque Control (SELOGIC Equation)	SELOGIC Equation	1	Group

[a] *n* = 1–6.

27P*n*D1 (Undervoltage Level 1 Time Delay)

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the output asserts.

Setting	Prompt	Range	Default	Category
27P*n*D1[a]	U/V Element *n* Level 1 Delay	0.00 to 16000 cyc.	10	Group

[a] *n* = 1–6.

59O*n* (Overvoltage Element Operating Quantity)

Select from Table 1.70 the desired operating quantity for each voltage terminal.

Setting	Prompt	Range	Default	Category
59O*n*[a]	O/V Element *n* Operating Quantity	See *Table 5.66*	V1FIM	Group

[a] *n* = 1–6.

59P*n*P1 (Overvoltage Level 1 Pickup)

Set pickup values for the voltage values above which you want the Level 1 overvoltage elements to assert.

Setting	Prompt	Range	Default	Category
59P*n*P1[a]	O/V Element *n* Level 1 P/U	2.00 to 300 volts, sec.	76	Group

[a] *n* = 1–6.

59P*n*P2 (Overvoltage Level 2 Pickup)

Set pickup values for the voltage value above which you want the Level 2 overvoltage elements to assert.

Setting	Prompt	Range	Default	Category
59P*n*P2[a]	O/V Element *n* Level 2 P/U	2.00 to 300 volts, sec.	80	Group

[a] *n* = 1–6.

59TC*n* (Overvoltage Torque Control)

Use the torque-control setting to specify conditions under which the overvoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

Setting	Prompt	Range	Default	Category
59TC*n*[a]	O/V Element *n* Torque Control (SELOGIC Equation)	SELOGIC Equation	1	Group

[a] *n* = 1–6.

59P*n*D1 (Overvoltage Level 1 Time Delay)

When the system voltage exceeds the overvoltage setting value, the overvoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the output asserts.

Setting	Prompt	Range	Default	Category
59P*n*D1[a]	O/V Element *n* Level 1 Delay	0.00 to 16000 cyc.	10	Group

[a] *n* = 1–6.

Switch-Onto-Fault Logic

The switch-onto-fault (SOTF) logic permits specified protection elements to trip for a settable time after the circuit breaker closes. Specify these elements in the SELOGIC control equation TRSOTF (switch-onto-fault trip). The SOTF logic works in two stages: validating a possible SOTF condition and initiating (enabling) the SOTF protection duration.

The relay validates an SOTF condition by sensing the following:

- *Upon circuit breaker opening*: detection of a pole-open condition (3PO or SPO) when setting 52AEND (52A Pole-Open Qualifying Time Delay) is other than OFF
- *Upon circuit breaker closing*: detection of a pole-open condition (3PO or SPO) when setting CLOEND (CLSMON or Single-Pole Open Delay) is other than OFF

Select either or both methods for the validating procedure.

The relay initiates SOTF protection at these corresponding instances:

- *Circuit breaker opening*: 52AEND timer timeout
- *Circuit breaker closing*: CLOEND time timeout and SELOGIC control equation CLSMON assertion

Circuit Breaker Opened SOTF Logic

Set ESOTF to Y and set 52AEND to other than OFF to enable the circuit breaker-opened SOTF logic. When the circuit breaker opens, the 52AEND timer operates when one or three poles open (SPO or 3PO assert). The logic includes the SPO condition if setting ESPSTF := Y (see *SOTF Options on page 5.118*). When the 3PO or SPO condition lasts longer than the 52AEND timer, the relay asserts Relay Word bit SOTFE (SOTF Enable).

When the circuit breaker closes, either Relay Word bit 3PO deasserts after the 3POD dropout time or Relay Word bit SPO deasserts after the SPOD dropout time. When 3PO or SPO deasserts, the relay continues to assert Relay Word bit SOTFE for dropout time SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options on page 5.118*).

Circuit Breaker Closed SOTF Logic

You can detect circuit breaker close bus assertion by monitoring the dc close bus. Connect a control input on the SEL-421 to the dc close bus. The control input energizes whenever a manual close or automatic reclosure occurs. Set SELOGIC control equation CLSMON (Close Signal Monitor) to monitor the control input (e.g., CLSMON := IN102) and consequently detect close bus assertion.

Set ESOTF to Y and set CLOEND to other than OFF to enable the circuit breaker-closed SOTF logic. The CLOEND timer operates when one or three poles open (SPO or 3PO asserts). If the 3PO or SPO condition continues longer than the CLOEND time and the close bus asserts (SELOGIC control equation CLSMON equals logical 1), Relay Word bit SOTFE asserts and remains asserted for dropout time setting SOTFD or until the logic detects a healthy voltage condition (if EVRST := Y, see *SOTF Options on page 5.118*).

SOTF Options

Set EVRST = Y to enable the Voltage Reset logic. If the system voltage is balanced (ratio of negative-sequence voltage to positive-sequence voltage is below 0.1), Relay Word bit SOTFE resets when the relay measures positive-sequence voltage at greater than VRSTPU times nominal voltage.

If setting ESPSTF (Single-Pole SOTF Enable) is enabled (ESPSTF := Y), the relay provides SOTF protection for an SPO condition.

Table 5.67 SOTF Settings

Setting	Prompt	Range	Default (5 A)
ESOTF	Switch-Onto-Fault	Y, N	Y
ESPSTF	Single-Pole Switch-Onto-Fault	Y, N	N
EVRST	Switch-Onto-Fault Voltage Reset	Y, N	N
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 Pu)	0.60–1.00 pu	0.8
52AEND	52a Pole Open Time Delay (cycles)	OFF, 0.000–16000	10.000
CLOEND	CLSMON or Single Pole Open Delay (cycles)	OFF, 0.000–16000	OFF
SOTFD	Switch-Onto-Fault Enable Duration (cycles)	0.500–16000	10.000
CLSMON	Close Signal Monitor	SELOGIC Equation	NA

Table 5.68 SOTF Relay Word Bits

Name	Description
SOTFE	Switch-Onto-Fault Trip Logic Enabled

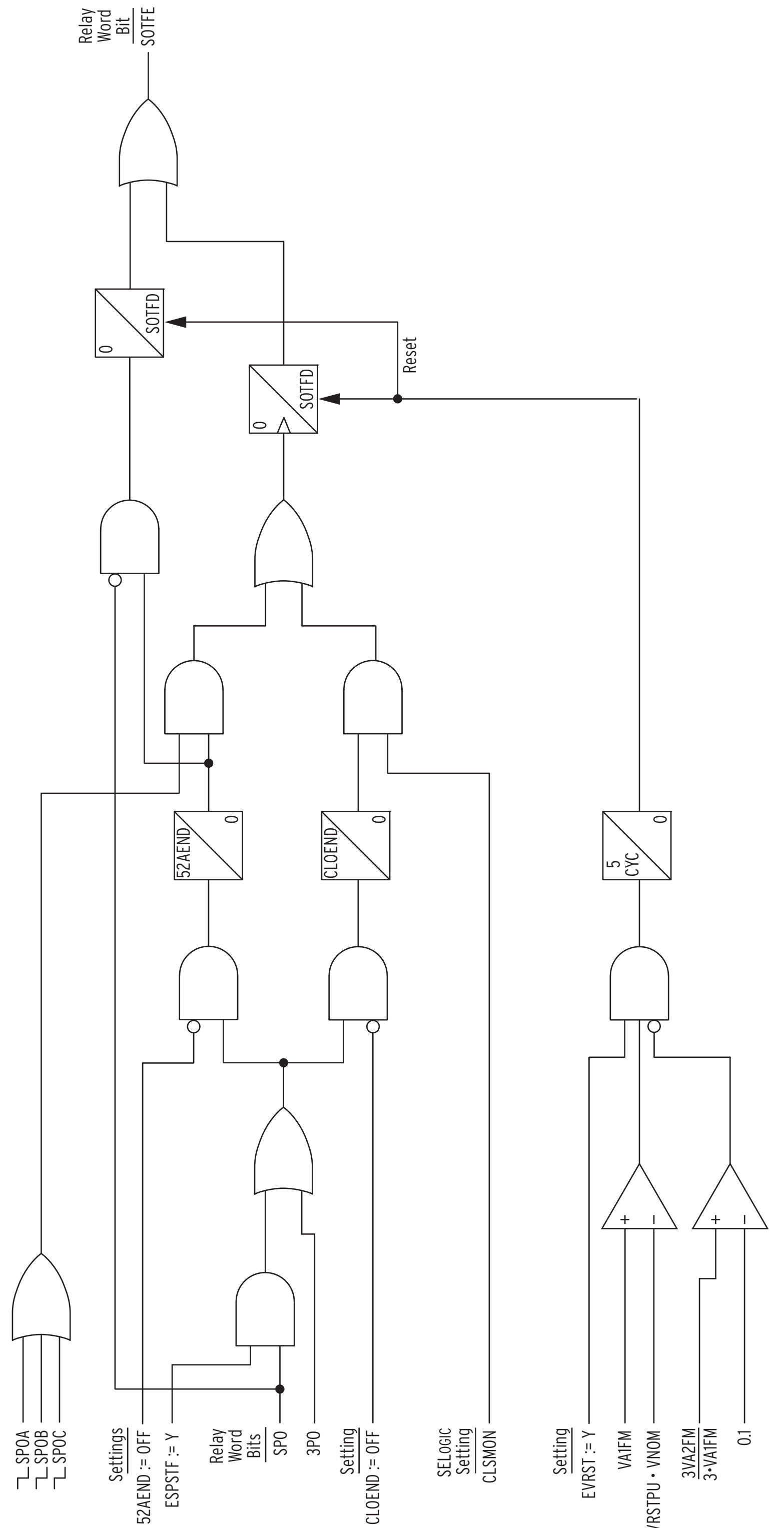


Figure 5.90 SOTF Logic Diagram

Communications-Assisted Tripping Logic

Communications-assisted tripping schemes provide unit protection for transmission lines without any need for external coordination devices. The relay includes the following five schemes.

- POTT—Permissive-Overreaching Transfer Trip
- POTT2—Two-Channel Permissive Overreaching Transfer Trip
- POTT3—Phase-Segregated Permissive Overreaching Transfer Trip
- DCUB—Directional Comparison Unblocking
- DCB—Directional Comparison Blocking

All of these schemes work in both two-terminal and three-terminal line applications. For the DCUB scheme, you have separate settings choices for these applications (ECOMM equals DCUB1 or DCUB2) because of unique DCUB logic considerations.

You must set Zone 3 reverse-looking (DIR3 equals R) for all three schemes.

Table 5.69 ECOMM Setting

Setting	Prompt	Range	Default (5 A)
ECOMM	Communications-Assisted Tripping	N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2	POTT

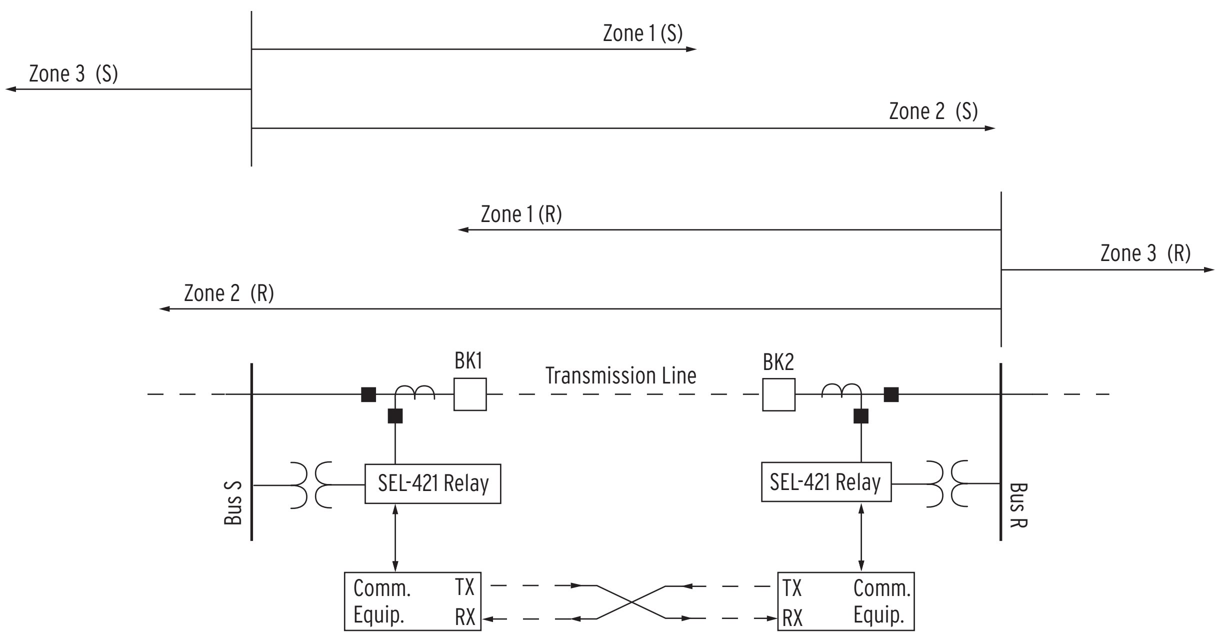


Figure 5.91 Required Zone Directional Settings

Directional Comparison Blocking Scheme

The Directional Comparison Blocking (DCB) trip scheme performs the following tasks:

- Provides carrier coordination timers that allow time for the block trip signal to arrive from the remote terminal. The 21SD timer is for the Zone 2 distance elements Z2P and Z2G. The 67SD timer is for the Level 2 overcurrent elements 67Q2 and 67G2.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time (Z3XD) following the dropout of all Zone 3 distance and Level 3 directional overcurrent elements.
- Latches block trip send condition by the phase-distance elements following a close-in zero voltage three-phase fault when the polarizing memory expires; return of polarizing memory voltage or interruption of fault current removes the latch.
- Extends the received block trip signal by a settable time (BTXD).

The DCB scheme consists of four sections:

- Coordination timers
- Starting elements
- Extension of the blocking signal
- Stopping elements

Coordination Timers

NOTE: The TRCOMM SELOGIC control equation determines which protection elements cause the relay to trip via the communications-assisted tripping scheme logic. In DCB schemes, set delayed Zone 2 mho phase and ground-distance protection (Z2PGS) plus delayed Level 2 negative-sequence residual ground directional overcurrent element (67QGS2) in the TRCOMM SELOGIC control equation. See *345 kV Tapped Overhead Transmission Line Example on page 6.53*.

Momentarily delaying the forward-looking Zone 2 and Level 2 elements that provide high-speed tripping at the local terminal ensures that the local circuit breaker does not trip for external faults behind the remote terminal. This delay provides time for the nondirectional and reverse-looking elements at the remote terminal to send a blocking signal to the local terminal during out-of-section faults. This particular time delay is the coordination time for the DCB scheme. There are separate coordination timers for Zone 2 distance elements (21SD) and Level 2 residual directional overcurrent elements (67SD).

The recommended setting for the 21SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Zone 3 distance protection maximum operating time
- Maximum communications channel time

The output of Zone 2 delay timer 21SD is Relay Word bit Z2PGS (Zone 2 Phase and Ground Short Delay).

The recommended setting for the 67SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Level 3 nondirectional low-set overcurrent element maximum operating time
- Maximum communications channel time

The output of Level 2 delay timer 67SD is Relay Word bit 67QG2S (Negative-Sequence and Residual Directional Overcurrent Short Delay).

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles.

Starting Elements

You can select nondirectional elements, directional elements, or both to detect external faults behind the local terminal. These elements send a blocking signal to the remote station to prevent unwanted high-speed tripping during out-of-section faults. Nondirectional elements do not process a directional decision, so nondirectional elements are always faster than directional elements.

Nondirectional Start

Relay Word bit NSTRT (Nondirectional Start) is assigned to a contact output to start transmitting the blocking signal. NSTRT asserts if either 50Q3 or 50G3 pickup.

Directional Start

Relay Word bit DSTRT (Directional Start) asserts if any of the following elements pick up:

- ➤ Zone 3 phase-distance elements
- ➤ Zone 3 ground-distance elements
- ➤ Level 3 negative-sequence directional overcurrent element
- ➤ Level 3 zero-sequence directional overcurrent element

Relay Word bit DSTRT is useful when a bolted close-in three-phase fault occurs behind the relay. Zone 3 phase-distance characteristics do not need a reverse offset. Should the polarizing voltage for the distance elements collapse to zero, the corresponding Zone 3 supervisory phase-to-phase current level detectors will cause the Zone 3 phase-distance elements to latch.

Use timer Z3XD (Zone 3 Reverse Time Delay on Dropout) to extend the blocking signal during current reversals. Use timer Z3XPU (Zone 3 Reverse Time Delay on Pickup) to prevent extension of the blocking signal resulting from Z3XD if a reverse-looking element picks up during a transient. This pickup delay ensures high-speed tripping for internal faults.

Extension of the Blocking Signal

The directional comparison blocking scheme typically uses an on/off carrier signal to block high-speed tripping at the remote terminal for out-of-section faults. Connect the carrier receive block signal output contact from the teleprotection equipment to a control input assigned to Relay Word bit BT (Block Trip Received). This input must remain asserted to block the forward-looking elements after the coordination timers expire. If the blocking signal drops out momentarily, the distance relay can trip for out-of-section faults.

Timer BTXD (Block Trip Extension) delays dropout of the control input assigned to Relay Word bit BT so that unwanted tripping does not occur during momentary lapses of the blocking signal (carrier holes). This timer maintains the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Three-Terminal Line

If you apply the DCB scheme to a three-terminal line, program SELOGIC control equation BT as follows:

BT := **IN105 OR IN106**. Block Trip Received (SELOGIC Equation)

Relay inputs IN105 or IN106 assert when the relay receives a blocking signal from either of the two other terminals. The relay cannot high-speed trip if either control input asserts. These two control inputs were chosen for this particular example. Use appropriate control inputs for your application.

Stopping Elements

Zone 2 distance and Level 2 directional overcurrent elements detect that the fault is in the tripping direction and stop the starting elements from transmitting the blocking signal to the remote terminal. Program an output contact to stop carrier by energizing an input of the communications equipment transmitter.

The stopping elements must have priority over the nondirectional starting elements; however, directional starting elements must have priority over the stopping elements. *Figure 5.92* shows that the directional starting elements have internal priority over the stopping elements. Use SELOGIC control equations to make sure that the stopping elements have priority over the nondirectional starting elements:

OUT101 := **NSTRT AND NOT STOP OR DSTRT**. Output (SELOGIC Equation)

Table 5.70 DCB Settings

Setting	Prompt	Range	Default (5 A)
Z3XPU	Zone 3 Reverse Pickup Delay (cycles)	0.000–16000	1.000
Z3XD	Zone 3 Reverse Dropout Time Delay (cycles)	0.000–16000	6.000
BTXD	Block Trip Receive Extension Time (cycles)	0.000–16000	1.000
21SD	Zone 2 Distance Short Delay (cycles)	0.000–16000	2.000
67SD	Level 2 Overcurrent Short Delay (cycles)	0.000–16000	2.000
BT	Block Trip Received	SELOGIC Equation	NA

Table 5.71 DCB Relay Word Bits

Name	Description
Z3XT	Current reversal guard timer
Z2PGS	Zone 2 phase and ground short delay element
67QG2S	Negative-sequence and residual directional overcurrent short delay element
DSTRT	Directional start element
NSTRT	Nondirectional start element
STOP	Stop element
BTX	Blocking signal extended

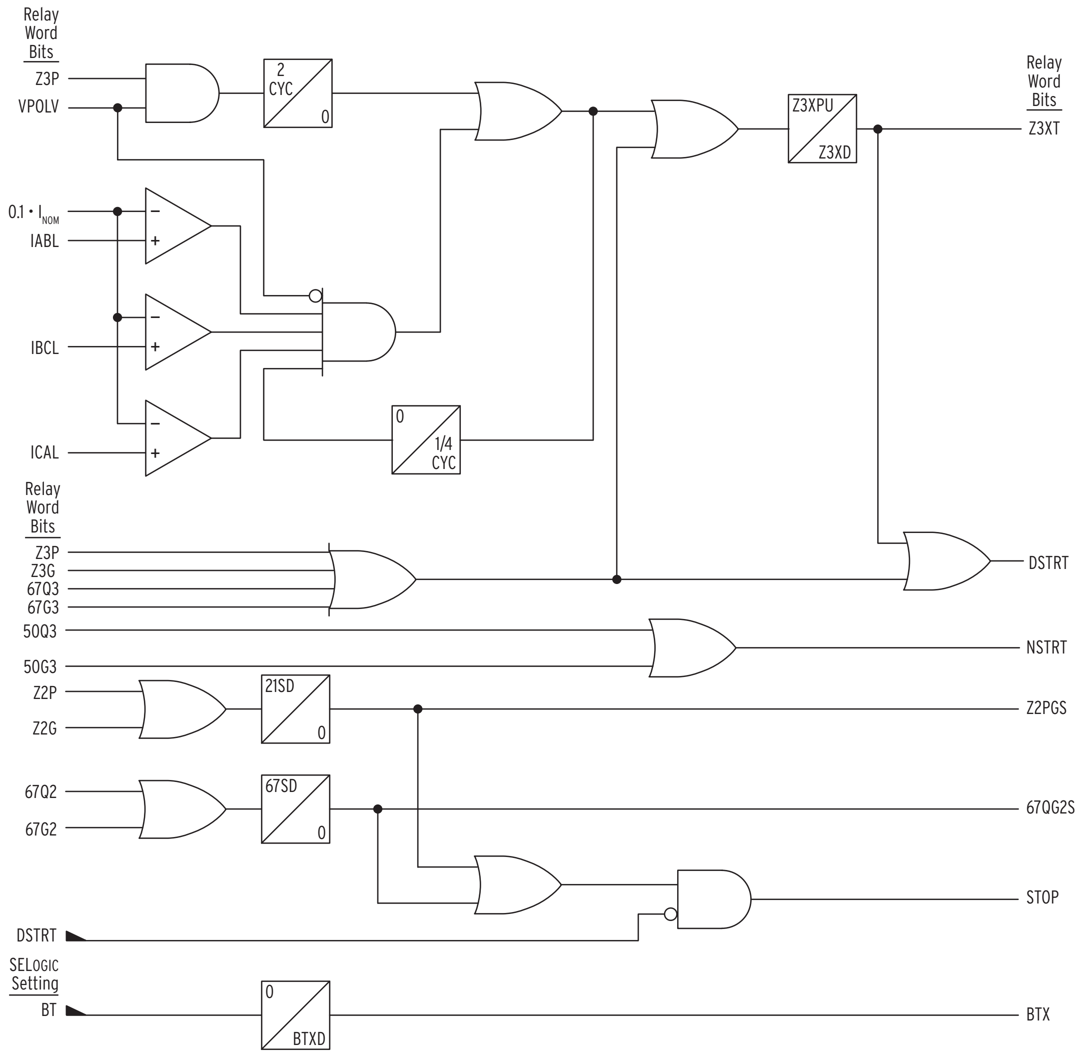


Figure 5.92 DCB Logic Diagram

Permissive Overreaching Transfer Tripping Scheme

Use MIRRORED BITS communications to implement a Permissive Overreaching Transfer Tripping (POTT) scheme efficiently and economically. MIRRORED BITS communications technology improves security and improves the overall operating speed. If the communications channel is reliable and noise-free (as with fiber-optic channels), then POTT provides both security and reliability. You can also implement a POTT scheme with other conventional communications channels such as leased telephone lines and microwave. The DCUB trip scheme is a better choice if the communications channel is less than perfect, but communications channel failures are unlikely to occur during external faults.

POTT Scheme Selection

The SEL-421 offers three POTT schemes: POTT, POTT2, and POTT3. The type of communications channel(s) in your application best determines which scheme to implement.

POTT

Use the conventional POTT scheme for an application with a single communications channel.

For details about implementing a conventional POTT scheme, see *POTT Trip Scheme on page 6.38*.

POTT2

Use the POTT2 scheme for applications with two communications channels, one for single-phase fault identification and one for multiphase fault identification. This scheme is useful in applications where there is a high likelihood of cross-country faults.

For details about implementing a POTT2 scheme, see *Cross-Country Fault Identification on page 6.43*.

POTT3

Use the POTT3 scheme for phase-segregated applications with three communications channels. In this scheme, each channel indicates permissive trip for single-phase. Multiphase fault detection results in all three channels transmitting a permissive trip.

For details about implementing a POTT3 scheme, see *Three-Channel POTT Scheme, POTT3 on page 6.46*.

POTT Scheme Logic

The POTT scheme logic performs the following tasks:

- Keys the communications equipment to send permissive trip (PT) when any element you include in the TRCOMM/TRCOMMD SELOGIC control equation asserts and the current reversal logic is not asserted
- Prevents keying and tripping by the POTT logic following a current reversal
- Echoes the received permissive signal to the remote terminal
- Prevents channel lockup during echo and test
- Provides a secure means of tripping for weak- and/or zero-infeed terminals
- Ensures proper tripping at both terminals during cross-country faults (via special logic implemented with SELOGIC control equations)

The POTT scheme logic consists of the following:

- Current reversal guard logic
- Echo
- Weak infeed logic

Current Reversal Guard Logic

Use current reversal guard for parallel line applications if the Zone 2 reach extends beyond the midpoint of the parallel transmission line. With current reversal guard, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when the reverse-looking protection sees an external fault. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two actions after a current reversal ceases and the reverse-looking elements drop out.

Echo

If the local circuit breaker is open, or a weak infeed condition exists, the remote relay permissive signal can echo back to itself and issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive signal back to the remote terminal after specific conditions are satisfied. This echo logic includes timers for qualifying the permissive signal and timers to block the echo logic during specific conditions.

Use the Echo Block Time Delay (EBLKD) to block the echo logic after dropout of local permissive elements. The recommended time setting for the EBLKD timer is the sum of the following:

➤ Remote terminal circuit breaker opening time
➤ Communications channel round-trip time
➤ Safety margin

An echo delay ensures that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. This delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults. Typically, these noise bursts coincide with faults external to the line section.

Because of the brief duration of noise bursts and the pickup for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The Echo Time Delay Pickup (ETDPU) timer specifies the time a permissive trip signal must be present.

The Echo Duration Time Delay (EDURD) limits the duration of the echoed permissive signal. Once the echo signal begins, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This cessation of the echo signal prevents the permissive trip signal from latching between the two terminals.

Weak-Infeed Logic

The SEL-421 provides weak-infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and allows the strong terminal to trip. After satisfaction of specific conditions, the weak terminal trips by converting the echoed permissive signal to a trip signal.

In some applications, one terminal might not contribute enough fault current to operate the protective elements, even with all sources in. It is important to trip the weak-infeed terminal to prevent low-level fault current from maintaining the fault arc (i.e., the fault will restrike following autoreclose at the strong terminal). Because the strong terminal is beyond the Zone 1 reach, it cannot trip for end-zone faults.

The faulted phase voltage(s) is depressed at the weak-infeed terminal, a condition that generates significant residual voltage during ground faults. The SEL-421 uses phase-to-phase undervoltage level detectors and a residual overvoltage level detector to qualify a weak-infeed condition. If setting EWFC equals Y, the relay enables the weak-infeed logic and settings 27PPW and 59NW are active. For single-pole tripping applications, set EWFC to SP and setting 27PWI is active.

The weak-infeed logic sets the Echo Conversion to Trip (ECTT) element upon satisfaction of the following.

- No reverse-looking elements have picked up (the reverse-looking elements override operation of the weak-infeed and echo logic for faults behind the relay location)
- LOP is deasserted when the setting ELOP equals Y1
- At least one phase-to-phase undervoltage element or the residual overvoltage element operates
- The local circuit breaker(s) is closed
- A permissive trip signal is received for ETDPU time period

The EWFC setting enables the weak-infeed feature of the relay. When the EWFC setting is Y, the ECTT logic is enabled. When the setting EWFC is SP, the relay can convert echo to a single-pole trip at the local terminal. ECTT logic is disabled when the setting is N.

Three-Terminal Lines

If you apply the POTT scheme to a three-terminal line, program SELOGIC control equation PT1 as follows:

PT1 := **IN105 AND IN106**. General Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 and IN106 assert when the relay receives a permissive signal from each of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

Cross-Country Faults

Refer to *500 kV Parallel Transmission Lines With Mutual Coupling Example on page 6.18* for a complete description of how to apply the SEL-421 using MIRRORED BITS communications. The SEL-421 POTT scheme logic (ECOMM = POTT2 or POTT3) includes additional logic that ensures proper single-pole tripping at both stations during cross-country faults. A cross-country fault consists of simultaneous single phase-to-ground faults on both of the parallel lines. If the simultaneous ground faults are beyond Zone 1 reach with respect to the local station, unwanted three-pole tripping could occur.

Table 5.72 POTT Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default (5 A)
Z3RBD	Zone 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000

Table 5.72 POTT Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default (5 A)
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N, SP	N
27PWI[a]	Weak Infeed Phase Undervoltage Pickup (V)	1.0–200	47.0
27PPW[b]	Weak Infeed Undervoltage Pickup (VFF)	0.1–300	80.0
59NW[b]	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0
PT1	General Permissive Trip Received (when ECOMM = POTT or POTT2)	SELOGIC Equation	IN102 AND PLT02
PT3	Three-Pole Permissive Trip Received (when ECOMM = POTT2)	SELOGIC Equation	NA
PTA	A-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA
PTB	B-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA
PTC	C-Phase Permissive Trip Received (when ECOMM = POTT3)	SELOGIC Equation	NA
EPTDIR	Enable Directional Element Permissive Trip	SELOGIC Equation	NA
PTDIR	Directional Element Permissive Trip Received	SELOGIC Equation	NA
COMZDTC	Directional Element Communications-assisted Trip Enable	SELOGIC Equation	NA

[a] Make setting when EWFC := SP.
[b] Make setting when EWFC := Y or SP.

Table 5.73 POTT Relay Word Bits (Sheet 1 of 2)

Name	Description
PT	Permission to trip received (ECOMM = POTT or POTT2)
PTA	A-Phase permissive trip received (ECOMM = POTT3)
PTB	B-Phase permissive trip received (ECOMM = POTT3)
PTC	C-Phase permissive trip received (ECOMM = POTT3)
EPTDIR	Directional element permissive trip enabled (ECOMM = POTT)
PTDIR	Directional element permissive trip received enabled (PTDIR = Y)
COMZDTC	Directional element communications-assisted trip torque equation asserted (PTDIR = Y)
Z3RB	Current reversal guard asserted (ECOMM = POTT or POTT2)
Z3RBA	A-Phase current reversal guard asserted (ECOMM = POTT3)
Z3RBB	B-Phase current reversal guard asserted (ECOMM = POTT3)
Z3RBC	C-Phase current reversal guard asserted (ECOMM = POTT3)
KEY	Transmit permission to trip (ECOMM = POTT or POTT2)
KEYA	Transmit A-Phase permissive trip (ECOMM = POTT3)
KEYB	Transmit B-Phase permissive trip (ECOMM = POTT3)
KEYC	Transmit C-Phase permissive trip (ECOMM = POTT3)
EKEY	Echo received permission to trip (ECOMM = POTT or POTT2)
EKEYA	A-Phase echo received permissive trip signal (ECOMM = POTT3)
EKEYB	B-Phase echo received permissive trip signal (ECOMM = POTT3)
EKEYC	C-Phase echo received permissive trip signal (ECOMM = POTT3)
ECTT	Echo conversion to trip (ECOMM = POTT or POTT2)
27AWI	A-Phase undervoltage condition
27BWI	B-Phase undervoltage condition

Table 5.73 POTT Relay Word Bits (Sheet 2 of 2)

Name	Description
27CWI	C-Phase undervoltage condition
WFC	Weak-infeed detected
KEY1	Transmit permission to single-pole trip
KEY3	Transmit permission to three-pole trip

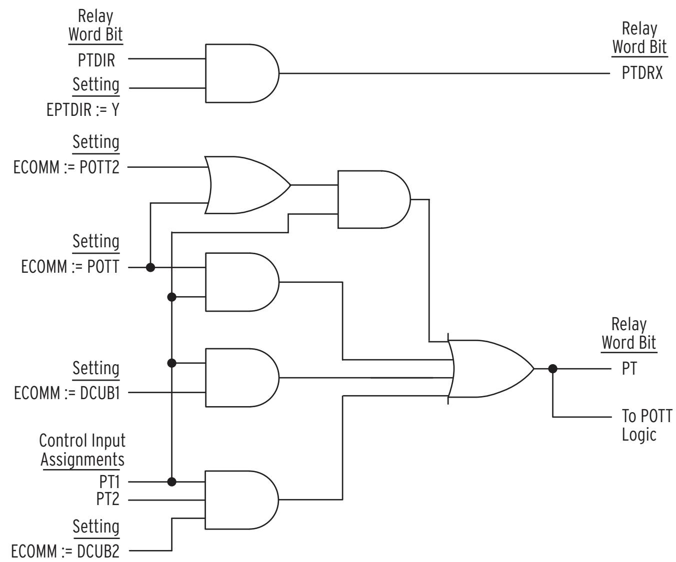


Figure 5.93 Permissive Trip Receiver Logic Diagram

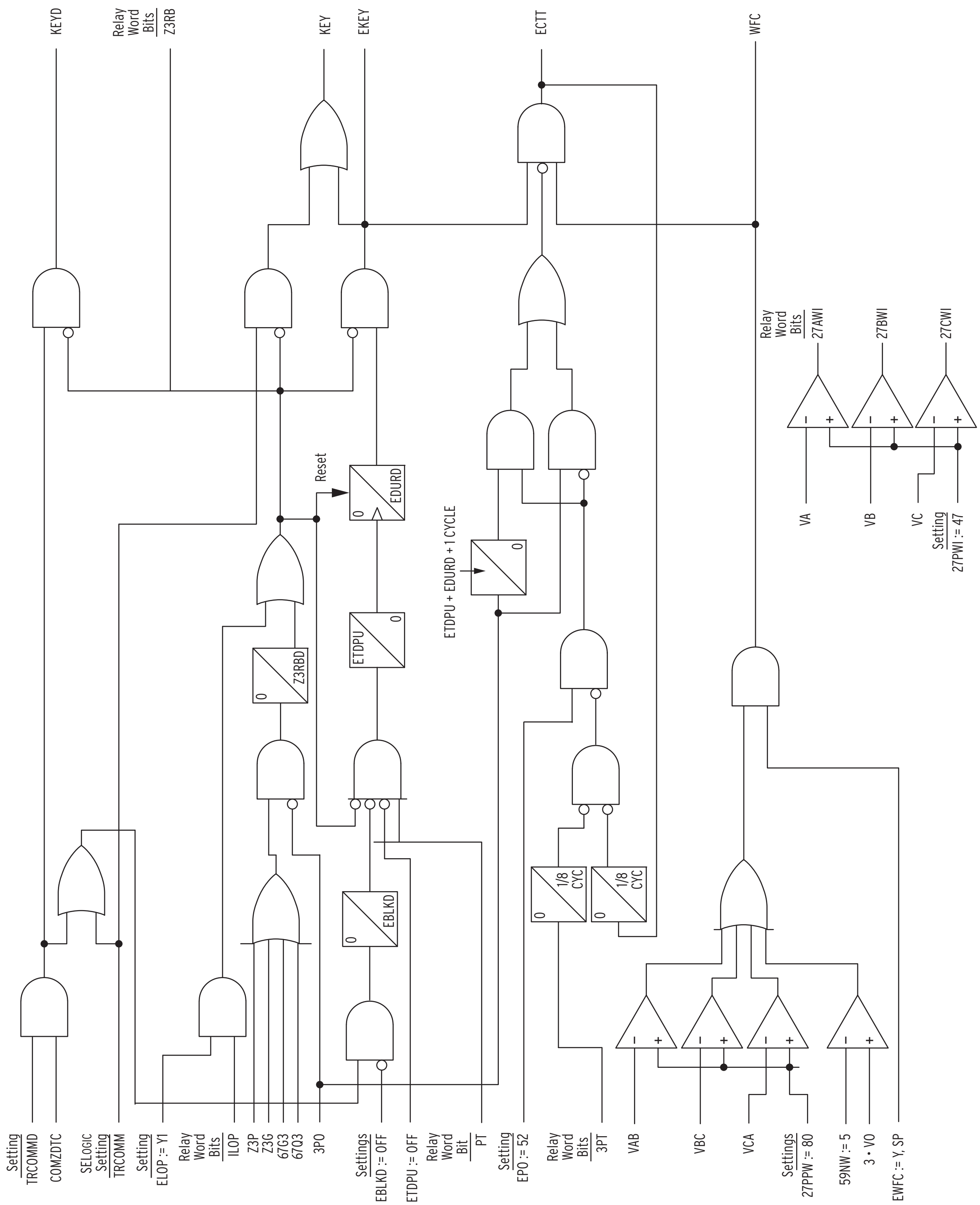


Figure 5.94 POTT Logic Diagram

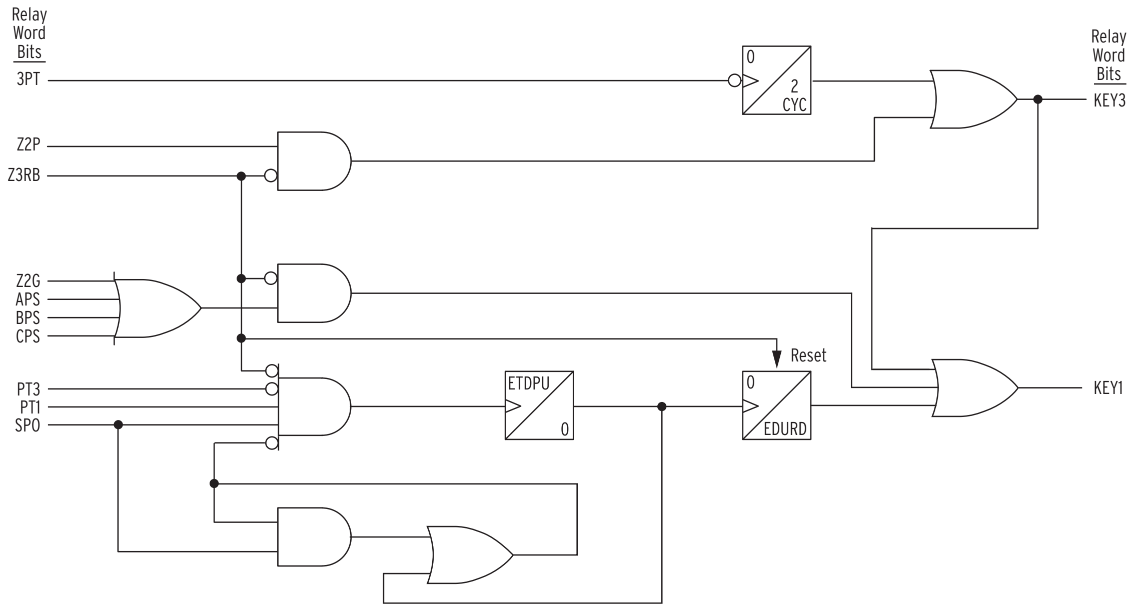


Figure 5.95 POTT Cross-Country Logic Diagram

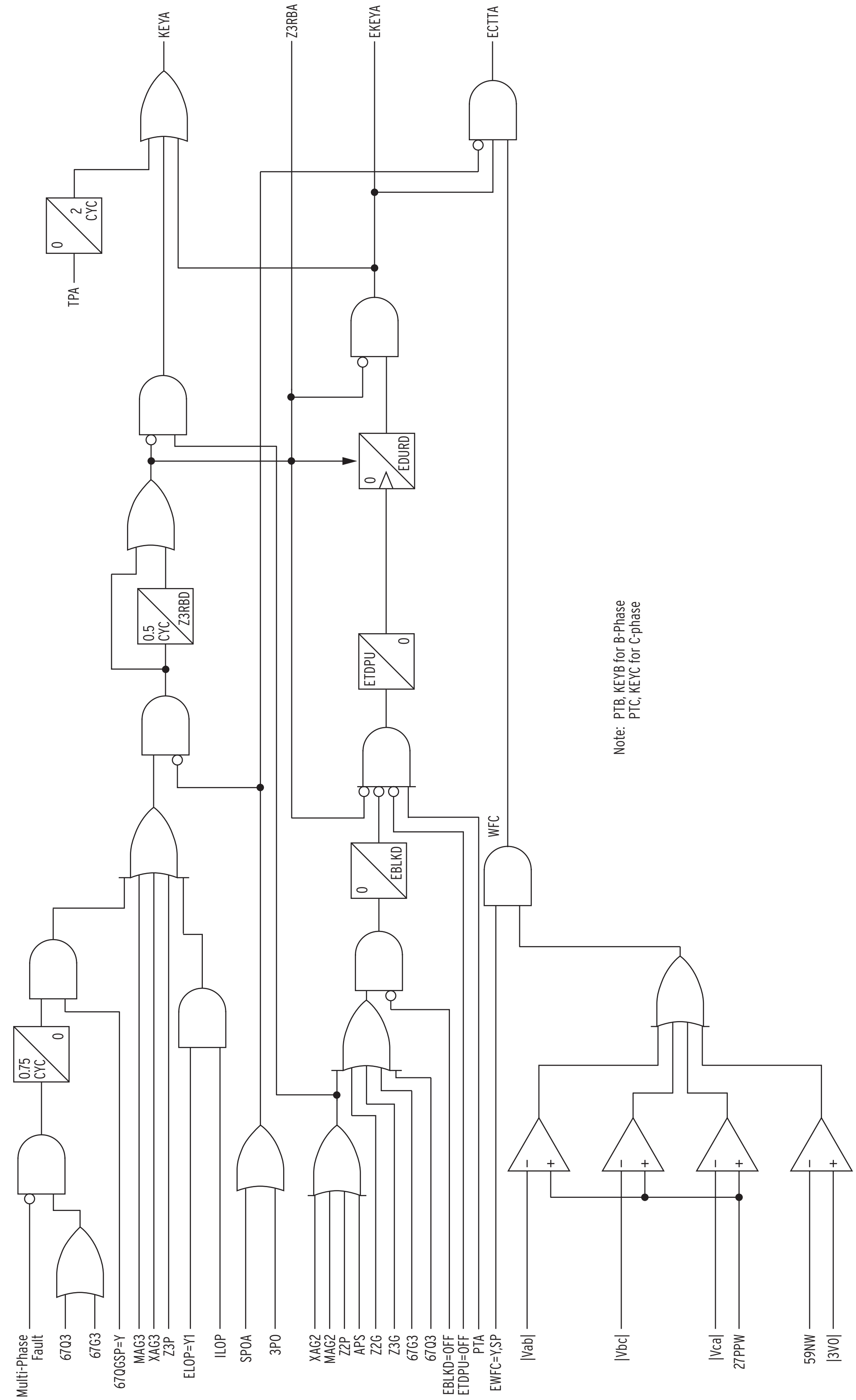


Figure 5.96 POTT Scheme Logic (ECOMM := POTT3) With Echo and Weak Infeed

Directional Comparison Unblocking Scheme Logic

The directional comparison unblocking (DCUB) tripping scheme in the SEL-421 provides a good combination of security and reliability, even when a communications channel is less than perfect. Communications channel failures are unlikely to occur during external faults. You can use the DCUB trip scheme with conventional communications channels such as power line carrier (PLC). Use improved methods such as MIRRORED BITS communications to implement the DCUB tripping scheme efficiently and economically. MIRRORED BITS communications and the DCUB tripping scheme give secure, high-speed operation.

Through a control input programmed to the loss-of-guard (LOG) function, the relay monitors the LOG output from the communications receiver. If LOG asserts, and no trip permission is received, the relay can high-speed trip during a short window using selected overreaching elements. The relay then asserts permissive trip blocking signal UBB and locks out permissive trip Relay Word bit PTRX. The typical DCUB application is a POTT scheme with the addition of a frequency shift-keying (FSK) carrier as the communications medium.

Enable the DCUB logic by setting ECOMM to DCUB1 or DCUB2. You must provide the relay all POTT settings plus the settings exclusive to the DCUB scheme. The following is an explanation of the differences between setting choices DCUB1 and DCUB2:

- DCUB1—directional comparison unblocking scheme for two-terminal lines (i.e., communication from **one** remote terminal)
- DCUB2—directional comparison unblocking scheme for three-terminal lines (i.e., communication from **two** remote terminals)

The DCUB logic takes the loss-of-guard and permissive trip outputs from the communications receivers and makes permissive trip (PTRX1 and PTRX2) outputs and permissive trip (unblock) blocking (UBB1 and UBB2) outputs.

PTRX1 asserts for loss of channel or for an actual received permissive trip in two-terminal line applications (e.g., setting ECOMM to DCUB1).

PTRX1 or PTRX2 assert for loss of channel or for an actual received permissive trip (for the respective Channel 1 or Channel 2) in three-terminal line applications (e.g., setting ECOMM to DCUB2).

Enable setting ECOMM (when set to DCUB1 and DCUB2) determines the routing of Relay Word bits PTRX1 and PTRX2 to control Relay Word bit PTRX. Relay Word bit PTRX is the permissive trip receive input into the trip logic.

Three-Terminal Lines

If you apply the DCUB scheme to a three-terminal line, program SELOGIC control equation PT1 and PT2 as follows:

PT1 := **IN105**. General Permissive Trip Received (SELOGIC Equation)

PT2 := **IN106**. Channel 2 Permissive Trip Received (SELOGIC Equation)

Relay control inputs IN105 or IN106 assert when the relay receives a permissive signal from one of the two other terminals. The relay cannot high-speed trip until both inputs assert. These two control inputs were chosen for this example. Use control inputs that are appropriate for your application.

In addition, for a three-terminal line, program SELOGIC control equations LOG1 and LOG2 as follows:

LOG1 := **IN205**. Channel 1 Loss-of-Guard

LOG2 := **IN206**. Channel 2 Loss-of-Guard

Relay control inputs IN205 or IN206 assert when the relay receives a loss-of-guard signal from either of the two other terminals. When SELOGIC control equation LOG1 (Channel 1 Loss-of-Guard) asserts, the relay asserts Relay Word bit UBB1 (Block Permissive Trip on Receiver 1) and removes the possibility that Relay Word bit PTRX1 (Permissive Trip on Receiver 1) will assert. These two control inputs were chosen for this particular example. Use control inputs that are appropriate for your application.

See *Table 5.74* for the DCUB settings. The first portion of the settings (from Z3RBD to PT1) are identical to the settings for the ECOMM := POTT scheme; (see *POTT Scheme Logic on page 5.125*).

Table 5.74 DCUB Settings

Setting	Prompt	Range	Default (5 A)
Z3RBD	Zone 3 Reverse Block Time Delay (cycles)	0.000–16000	5.000
EBLKD	Echo Block Time Delay (cycles)	0.000–16000	10.000
ETDPU	Echo Time Delay Pickup (cycles)	0.000–16000	2.000
EDURD	Echo Duration Time Delay (cycles)	0.000–16000	4.000
EWFC	Weak Infeed Trip	Y, N, SP	N
27PWI[a]	Weak Infeed Phase Undervoltage Pickup (V)	1.0–200	47.0
27PPW[b]	Weak Infeed Undervoltage Pickup ($V_{\phi\phi}$)	0.1–300	80.0
59NW[b]	Weak Infeed Zero-Sequence Overvoltage Pickup (V)	0.1–200	5.0
PT1	General Permissive Trip Received	SELOGIC Equation	IN101 AND PLT02
GARD1D	Guard Present Security Delay (cycles)	0.000–16000	120.000
UBDURD	Dcub Disabling Time Delay (cycles)	0.000–16000	180.000
UBEND	Dcub Duration Time Delay (cycles)	0.000–16000	20.000
PT2[c]	Channel 2 Permissive Trip Received	SELOGIC Equation	NA
LOG1	Channel 1 Loss-of-Guard	SELOGIC Equation	NA
LOG2[c]	Channel 2 Loss-of-Guard	SELOGIC Equation	NA

[a] Make setting when EWFC := SP.
[b] Make setting when EWFC := Y or SP.
[c] Make setting when ECOMM := DCUB2.

Timer Setting Recommendations

GARD1D: Guard-Present Delay

This timer determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBDURD: DCUB Disable Delay

This timer prevents high-speed tripping via the POTT scheme logic after a settable time following a loss-of-channel condition; a typical setting is nine cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

UBEND: DCUB Duration Delay

This timer determines the minimum time before the relay declares a loss-of-channel condition; a typical setting is 0.5 cycles. Channel 1 and Channel 2 logic use separate timers but have this same delay setting.

Table 5.75 DCUB Relay Word Bits

Name	Description
UBB1	Block permissive trip on Receiver 1
PTRX1	Permissive trip received on Channel 1
UBB2	Block permissive trip on Receiver 2
PTXR2	Permissive trip received on Channel 2
UBB	Block permissive trip received on Channel 1 or Channel 2
PTRX	Permissive trip received on Channel 1 and Channel 2

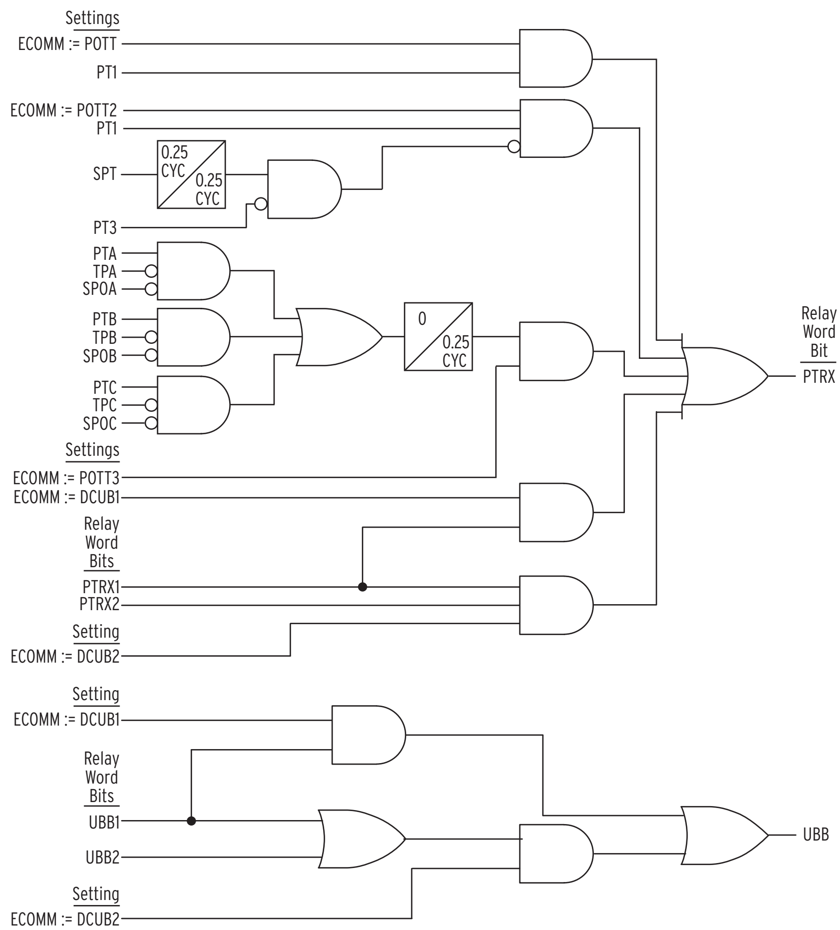


Figure 5.97 Permissive Trip Received Logic Diagram

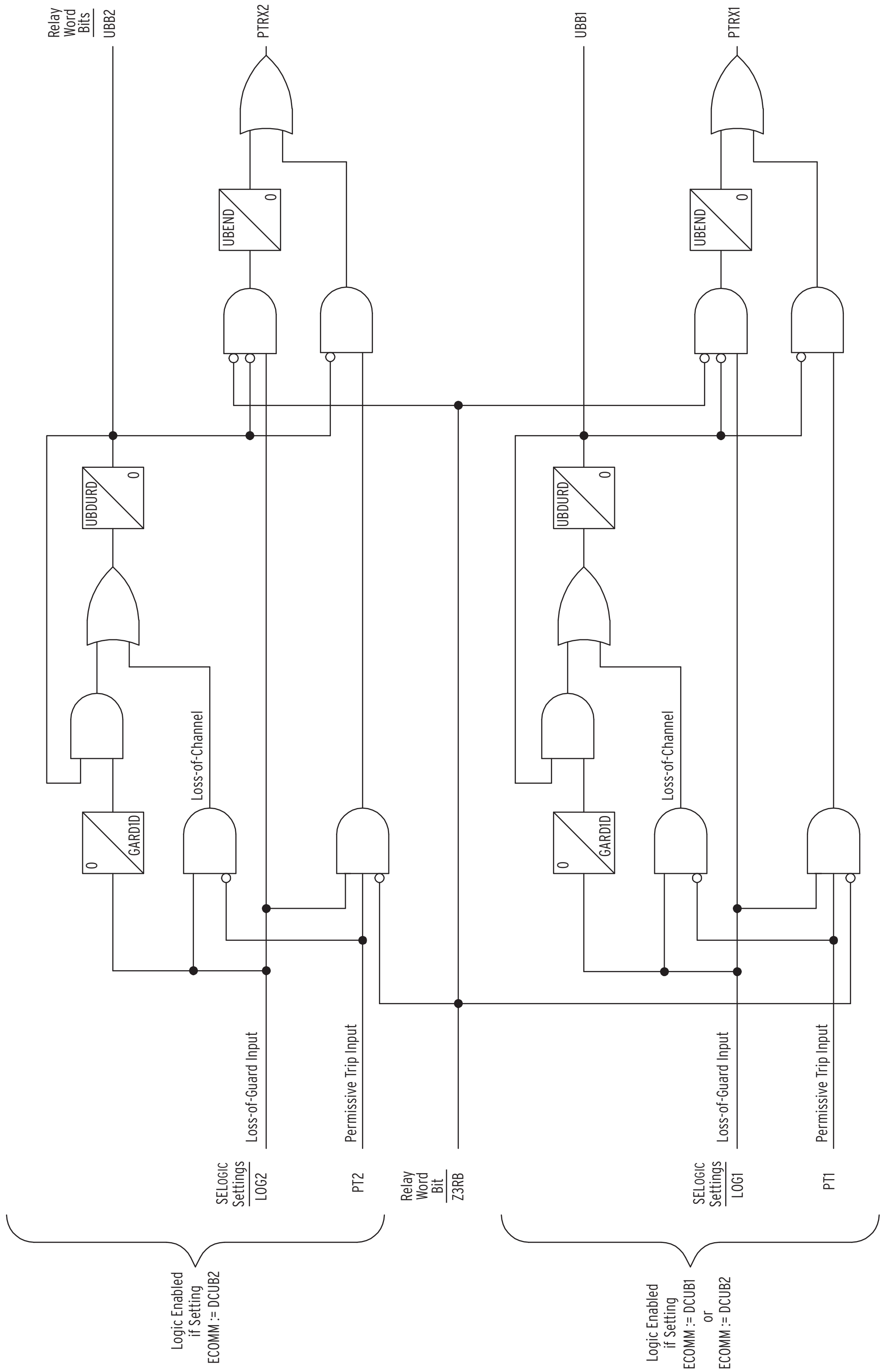


Figure 5.98 DCUB Logic Diagram

Trip Logic

Use the SEL-421 trip logic to configure the relay for tripping one or two circuit breakers. You can apply the SEL-421 in single-pole tripping applications, three-pole tripping applications, or both. Set the SEL-421 to trip unconditionally (as with step distance) or with the aid of a communications channel (as with the POTT, DCUB, DCB, and DTT schemes).

Three-Pole Tripping

The relay uses three-pole tripping logic if Relay Word bit E3PT (three-pole trip enable SELOGIC control equation) equals logical 1. You can set E3PT to 1 or assign a control input so that an external condition changes the state of this Relay Word bit.

There are separate three-pole tripping SELOGIC control equations for two circuit breakers, E3PT1 and E3PT2, respectively. When you set E3PT1 or E3PT2 to 1, the corresponding circuit breaker trips three pole only. For details on setting E3PT, E3PT1, and E3PT2, see *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.9* and *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.25 in the SEL-400 Series Relays Instruction Manual*.

Single-Pole Tripping

The relay uses single-pole tripping logic if Relay Word bit E3PT, three-pole trip enable SELOGIC control equation, equals logical 0. You can either set E3PT to 0 or assign a control input so that an external condition changes the state of this Relay Word bit.

The SEL-421 automatically single-pole trips for the following conditions when the single-pole tripping logic is active:

- Zone 1 ground-distance protection asserts for a single phase-to-ground fault
- Zone 2 ground-distance protection asserts for a single phase-to-ground fault and is permitted to trip via the communications-assisted tripping logic
- Any one of three SELOGIC control equations, DTA, DTB, or DTC, is assigned to an input and asserts (per-phase direct transfer trip)

You can also set the SEL-421 to single-pole trip through the following three options:

Table 5.76 Additional Settings for Single Pole Tripping (SPT)

Setting	Prompt	Selection
Z2GTSP	Zone 2 Ground Distance Time Delay Single-Pole Trip	Y
67QGSP	Zone 2 Directional Negative-Sequence/Residual Ground Overcurrent Single Pole Trip	Y
EWFC[a]	Weak-Infeed Trip	SP[b]

[a] In POTT and DCUB settings.
[b] SP = single pole.

Trip SELOGIC Control Equations

You select the appropriate relay elements for unconditional, direct transfer tripping, switch-onto-fault, and communications-assisted tripping. Set these SELOGIC control equations for tripping:

- ➤ TR—Unconditional tripping
- ➤ DTA, DTB, DTC—Direct transfer tripping
- ➤ TRSOTF—SOTF tripping
- ➤ TRCOMM/TRCOMMD—Communications-assisted tripping

Include the instantaneous and time-delayed tripping elements in the TR SELOGIC control equation. You would typically set instantaneous high-set current level detectors and Zone 2 distance protection in the TRSOTF SELOGIC control equation. You would also set instantaneous Zone 2 distance protection in the TRCOMM SELOGIC control equation.

TR

The TR SELOGIC control equation determines which elements trip unconditionally. You would typically set all instantaneous and time-delayed tripping elements (step-distance protection plus instantaneous and time-overcurrent protection) in the TR SELOGIC control equation.

DTA, DTB, and DTC

The DTA, DTB, and DTC SELOGIC control equations determine which elements directly trip the remote terminal. Each equation is phase selective. If you are applying three-pole tripping only, set DTA, DTB, and DTC to the same Relay Word bit expression.

TRSOTF

The TRSOTF control equation defines which elements trip while SOTF protection is active. These elements trip instantaneously if they assert during the SOTFD time.

TRCOMM

The TRCOMM and TRCOMMD SELOGIC control equation determines which elements trip via the communications-based scheme logic. You would typically set the overreaching Zone 2 distance elements or Level 2 directional overcurrent elements in the TRCOMM SELOGIC control equation. Normally, you need only one equation, but if you want to separate distance and directional elements, use both equations. For example, enter the distance elements in the TRCOMM equation and the direction elements in the TRCOMMD equation.

Trip Unlatch Options

Unlatch the trip contact output after the trip to remove dc voltage from the trip coil. The SEL-421 provides two settings to unlatch trip contact outputs after a protection trip has occurred:

- ➤ TULO—following a protection trip, phase selective
- ➤ ULTR—following a protection trip, all three poles

TULO

Table 5.77 shows the four trip unlatch options for setting TULO.

Table 5.77 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open and the Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

ULTR

Use ULTR, the unlatch trip SELOGIC control equation, to define the conditions that unlatch the trip contact outputs. This method always unlatches all three poles.

Timers

The SEL-421 provides dedicated timers (minimum trip duration, trip during open pole, etc.) for the trip logic.

Minimum Trip Duration

The minimum trip duration timer settings, TDUR1D and TDUR3D, determine the minimum length of time that Relay Word bits TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT assert. Use these timers for the designated trip control outputs. The trip output occurs for the TDURD time or the duration of the trip condition, whichever is greater.

TDUR1D is the minimum trip duration time following a single-pole trip. TDUR3D is the minimum trip duration time following a three-pole trip. If another trip occurs during the single-pole open dead time following a single-pole trip, TDUR3D replaces TDUR1D.

Trip During Open-Pole Time Delay

If another fault occurs, it is common to trip the two remaining phases for the following two periods:

- ➤ During the single-pole-open interval following the original single-pole trip.
- ➤ During the reclosing relay reclaim (reset) time state following a single-pole reclose.

To use the reclosing relay in the SEL-421 to reclose the breaker(s), see *Internal Recloser on page 6.9* and *Internal Recloser on page 6.25 in the SEL-400 Series Relays Instruction Manual*. This section describes the E3PT, E3PT1, and E3PT2 settings necessary for autoreclose logic control of the single-pole and three-pole tripping sequence. The TOPD (Trip during Open-Pole Time Delay) setting has no relevance in this situation.

If an external reclosing relay is being used, control signals from the reclosing relay will typically be used to control the SEL-421 single- and three-pole tripping sequence. Another method is to use the TOP (Trip during Open-Pole) Relay Word bit to select a three-pole trip after a single-pole trip in the SEL-421 by making an appropriate setting for TOPD (Trip during Open-Pole Time Delay), and then including the TOP Relay Word bit in the E3PT setting—see *Figure 5.102*. See *External Recloser on page 6.10* and *External Recloser on page 6.26 in the SEL-400 Series Relays Instruction Manual* for additional information. See *TOPD on page 6.41* for an application example using the TOP Relay Word bit.

Timer setting TOPD determines the period during which any subsequent single-pole trips are converted to a three-pole trip following the original single-pole trip. To use this feature, include the Relay Word bit TOP in the E3PT setting.

Trip Output Signals

There are seven Relay Word bits (TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT) that you can program to drive contact outputs to trip circuit breakers. Relay Word bits TPA*n*, TPB*n*, and TPC*n* are phase-selective tripping signals for controlling the individual poles of the circuit breakers for single-pole tripping schemes. Use Relay Word bit 3PT (Three-Pole Trip) to trip all three poles of both circuit breakers.

Manual Trip Logic

The SEL-421 also has additional logic for manually tripping the circuit breakers. Use SELOGIC control equations BK1MTR and BK2MTR to trip the circuit breakers manually. Use SELOGIC control equations ULMTR1 and ULMTR2 to unlatch manual trips for Circuit Breaker 1 and Circuit Breaker 2, respectively.

Trip Logic Settings and Relay Word Bits

The trip logic settings are shown in *Table 5.78*, and the Relay Word bits are shown in *Table 5.79*. Some of the settings are only required in certain situations, as noted.

Table 5.78 Trip Logic Settings (Sheet 1 of 2)

Setting	Prompt	Range	Default (5 A)
TR	Trip	SELOGIC Equation	Z1P OR Z1G OR M2PT OR Z2GT
TRCOMM[a]	Communications-Assisted Trip	SELOGIC Equation	(Z2P OR Z2G) AND PLT02
TRCOMMD	Communications-Assisted Trip	SELOGIC Equation	NA
TRSOTF[b]	Switch-Onto-Fault Trip	SELOGIC Equation	50P1 OR Z2P OR Z2G
DTA	Direct Transfer Trip A-Phase	SELOGIC Equation	NA
DTB	Direct Transfer Trip B-Phase	SELOGIC Equation	NA
DTC	Direct Transfer Trip C-Phase	SELOGIC Equation	NA
BK1MTR	Breaker 1 Manual Trip—BK1	SELOGIC Equation	OC1 OR PB8_PUL
BK2MTR[c]	Breaker 2 Manual Trip—BK2	SELOGIC Equation	NA
ULTR	Unlatch Trip	SELOGIC Equation	TRGTR
ULMTR1	Unlatch Manual Trip—BK1	SELOGIC Equation	NOT (52AA1 AND 52AB1 AND 52AC1)
ULMTR2[c]	Unlatch Manual Trip—BK2	SELOGIC Equation	1

Table 5.78 Trip Logic Settings (Sheet 2 of 2)

Setting	Prompt	Range	Default (5 A)
TOPD	Trip During Open Pole Time Delay (cycles)	2.000-8000	2.000
TULO	Trip Unlatch Option	1, 2, 3, 4	3
Z2GTSP	Zone 2 Ground Distance Time Delay	Y, N	N
67QGSP	Zone 2 Direct Negative Sequence/Residual Overcurrent SPT	Y, N	N
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (cycles)	2.000–8000	6.000
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (cycles)	2.000–8000	12.000
E3PT	Three-Pole Trip Enable	SELOGIC Equation	1
E3PT1	Breaker 1 Three-Pole Trip	SELOGIC Equation	1
E3PT2	Breaker 2 Three-Pole Trip	SELOGIC Equation	1
ER	Event Report Trigger Equation	SELOGIC Equation	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G

[a] Make setting when ECOMM := N.
[b] Make setting when ESOTF := Y.
[c] Make setting when NUMBK := 2.

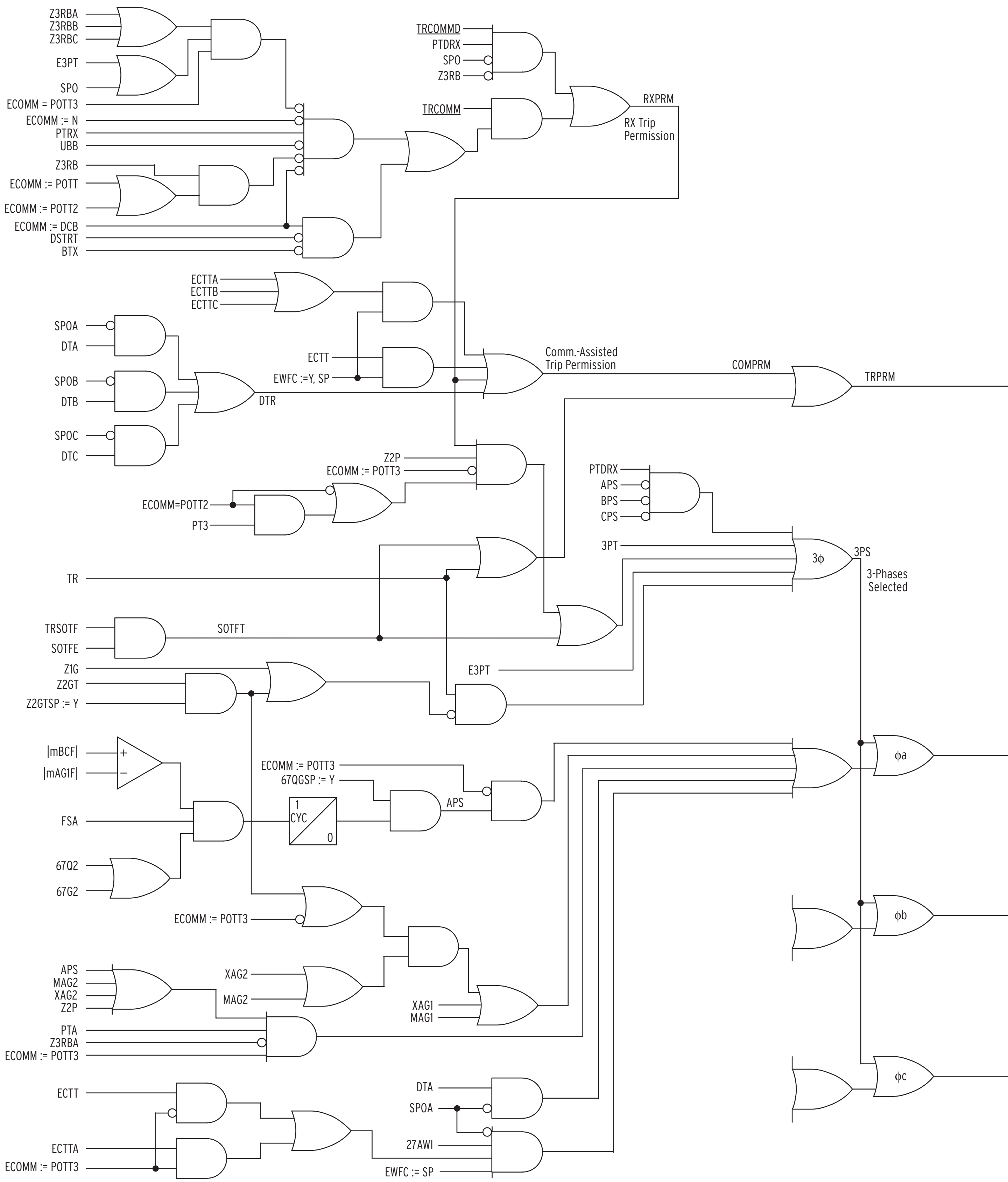


Figure 5.99 Trip Logic Diagram

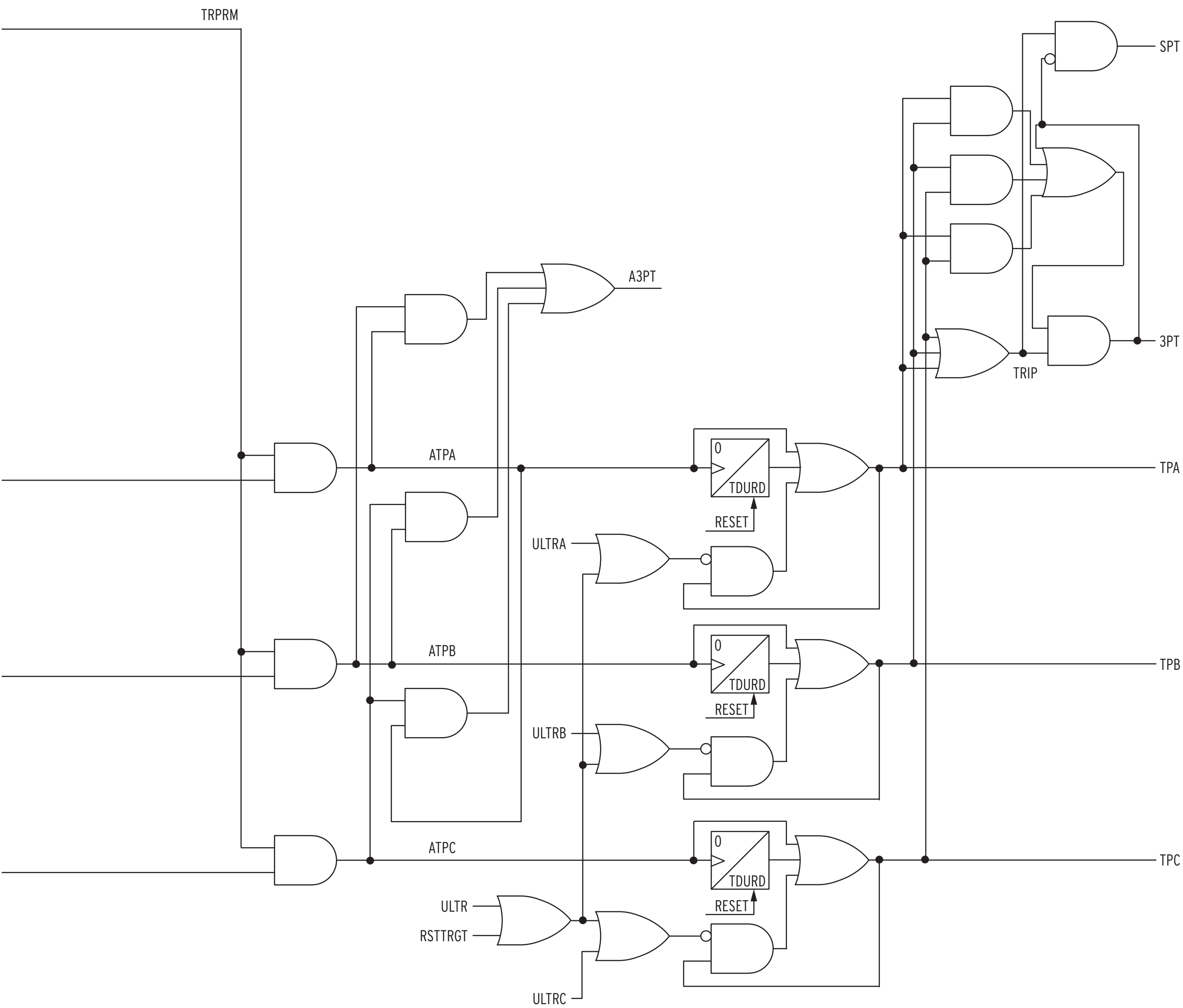


Figure 5.99 Trip Logic Diagram (Continued)

Table 5.79 Trip Logic Relay Word Bits

Name	Description
RXPRM	Receiver trip permission
COMPRM	Communications-assisted trip permission
TRPRM	Trip permission
DTR	Direct transfer trip
SOTFT	Switch-onto-fault trip
E3PT	Three-pole trip enable
E3PT1	Circuit Breaker 1 three-pole trip enable
E3PT2	Circuit Breaker 2 three-pole trip enable
APS	A-Phase selected
BPS	B-Phase selected
CPS	C-Phase selected
3PS	Three-phase selected
27AWI	Weak infeed A-Phase undervoltage
27BWI	Weak infeed B-Phase undervoltage
27CWI	Weak infeed C-Phase undervoltage
ULTRA	Unlatch A-Phase trip
ULTRB	Unlatch B-Phase trip
ULTRC	Unlatch C-Phase trip
ULTR	Unlatch all protection trips
ATPA	Assert A-Phase trip
ATPB	Assert B-Phase trip
ATPC	Assert C-Phase trip
A3PT	Assert three-pole trip
TPA	Trip A-Phase
TPB	Trip B-Phase
TPC	Trip C-Phase
TRIP	Trip A-Phase or B-Phase or C-Phase
3PT	Three-pole trip
SPT	Single-pole trip
TPA1	Circuit Breaker 1 trip A-Phase
TPB1	Circuit Breaker 1 trip B-Phase
TPC1	Circuit Breaker 1 trip C-Phase
TPA2	Circuit Breaker 2 trip A-Phase
TPB2	Circuit Breaker 2 trip B-Phase
TPC2	Circuit Breaker 2 trip C-Phase
TOP	Trip during open-pole timer is asserted
ULMTR1	Circuit Breaker 1 unlatch manual trip
ULMTR2	Circuit Breaker 2 unlatch manual trip

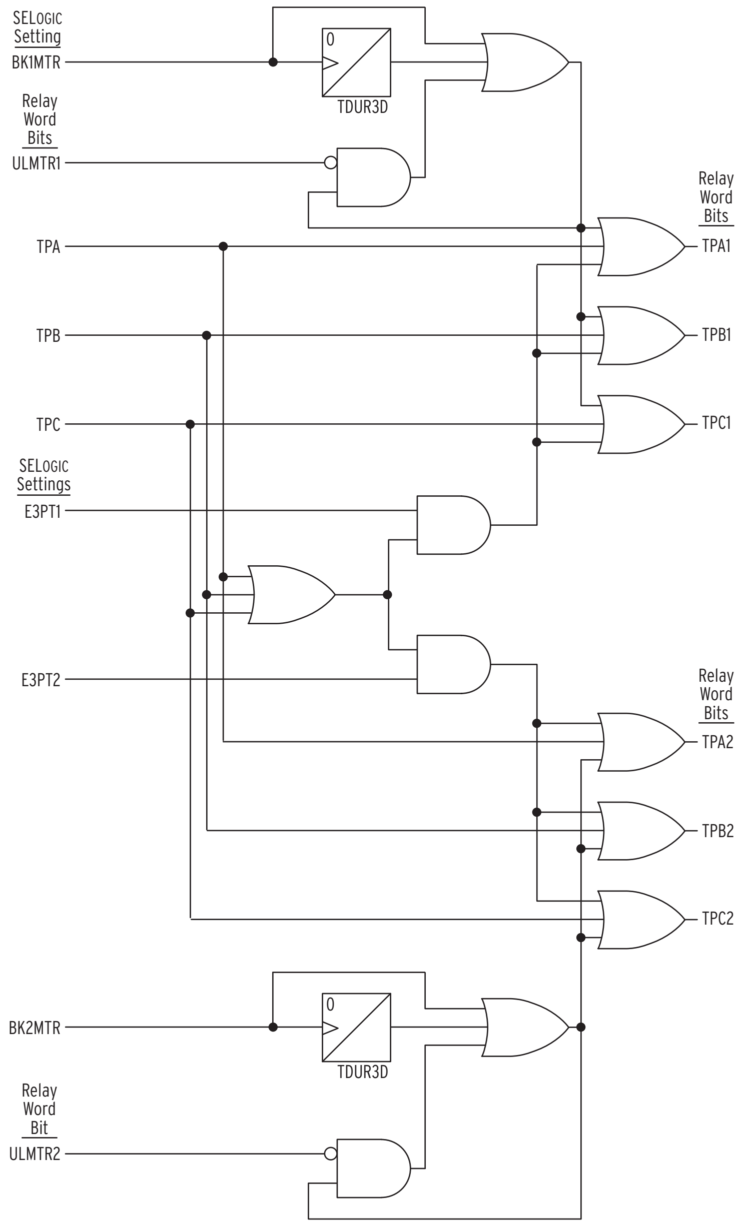


Figure 5.100 Two Circuit Breakers Trip Logic Diagram

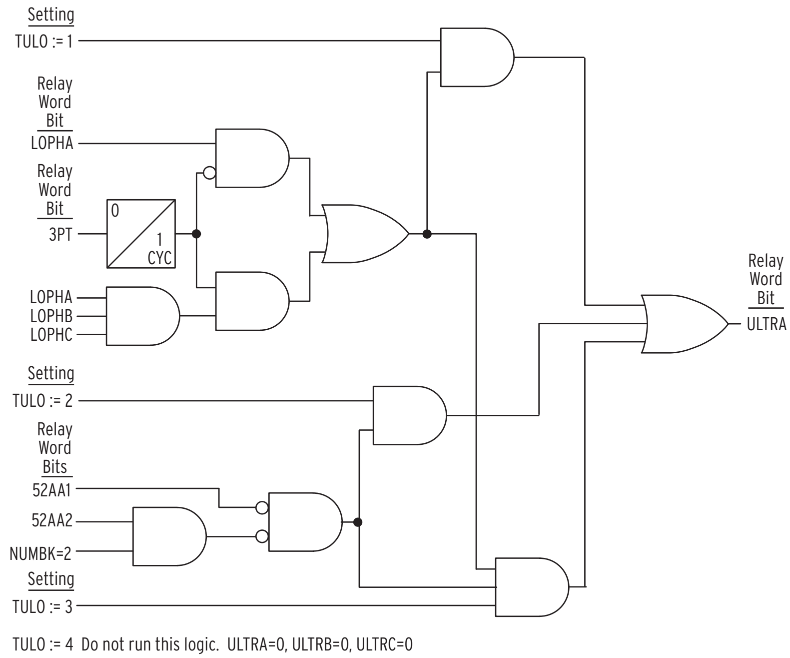


Figure 5.101 Trip A Unlatch Logic

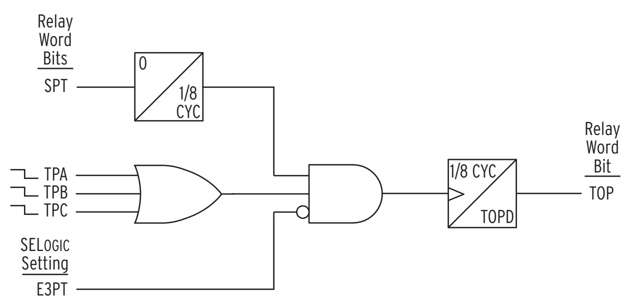


Figure 5.102 Trip During Open Pole

Circuit Breaker Failure Protection

Use the SEL-421 to provide circuit breaker failure protection for as many as two circuit breakers. The circuit breaker failure protection logic includes the following schemes:

- ➤ Failure to interrupt fault current for phase currents
- ➤ Failure to interrupt load current
- ➤ No current/residual current circuit breaker failure protection
- ➤ Flashover protection while the circuit breaker is open

All schemes can incorporate single-pole and three-pole retrip. Single-pole and three-pole initiations are available for circuit breaker failure, including extended breaker failure initiation. The circuit breaker failure logic also includes breaker failure trip latching logic.

The failure-to-interrupt-fault-current logic includes two schemes; both are suitable for three-pole or single-pole tripping applications. Scheme 1 is basic circuit breaker failure that is useful for most applications. Scheme 2 allows you to have different breaker failure times to differentiate between single-pole and three-pole tripping conditions. The failure-to-trip-load-current logic uses the circuit breaker failure initiation input for three-pole trips only. The flashover protection logic does not need voltage information.

Subsidence current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load. Subsidence current exponentially decays and delays resetting of instantaneous overcurrent elements. However, the open-phase detection logic causes the relay 50Fϕ*n* elements to reset in less than one cycle during subsidence current conditions (see *Figure 5.114*, *Figure 5.115*, and *Figure 5.116*). The open-phase detection logic output is B*n*OPHϕ (see *Table 5.23*).

Failure to Interrupt Fault Current: Scheme 1

Circuit Breaker Failure Protection Logic

The logic shown in *Figure 5.103* applies to single circuit breaker configurations (EBFL = 1). Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following fault inception and just prior to the assertion of Relay Word bit BFI3P1 (Breaker 1 Three-Pole Circuit Breaker Failure Initiation). At circuit breaker failure initiation, timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. If 50FA1 remains asserted when the BFPU1 timer expires, Relay Word bit FBF1 asserts. Use this Relay Word bit in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page 5.154*). If the protected circuit breaker opens successfully, 50FA1 drops out before the BFPU1 timer expires and FBF1 does not assert.

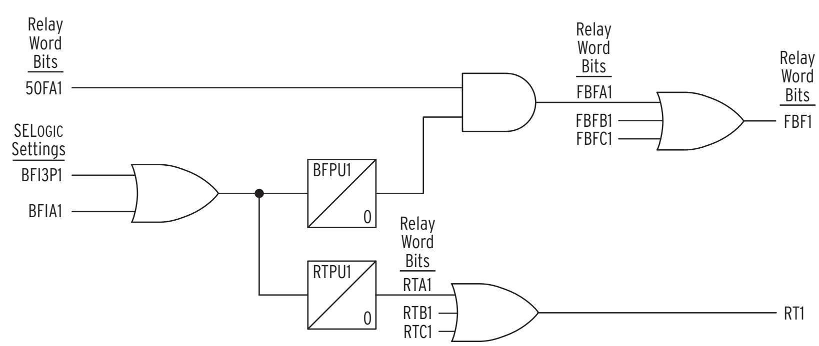


Figure 5.103 Scheme 1 Logic Diagram

Retrip Logic

Some three-pole circuit breakers have two separate trip coils. If one trip coil fails, the local protection can attempt to energize the second trip coil to prevent an impending circuit breaker failure operation. Configure your protection system to always attempt a local retrip using the second trip coil before the circuit breaker failure pickup time delay timer expires.

RTPU1 (Retrip Time Delay on Pickup Timer) begins timing when BFI3P1 asserts. Relay Word bit RT1 (Breaker 1 Retrip) asserts immediately after RTPU1 times out. Assign a control output to trip the circuit breaker when Relay Word bit RT1 asserts.

Failure to Interrupt Fault Current: Scheme Y1

Circuit Breaker Failure Protection Logic

The logic shown in *Figure 5.104* applies to single breaker configurations. Scheme Y1 is similar to Scheme 1, but the current check (50FA1) is now part of the Breaker Failure initiate timer (BFPU1) and Retrip Time delay (RTPU1) in addition to the Breaker Failure initiate settings (BFI3P1 or BFIA1).

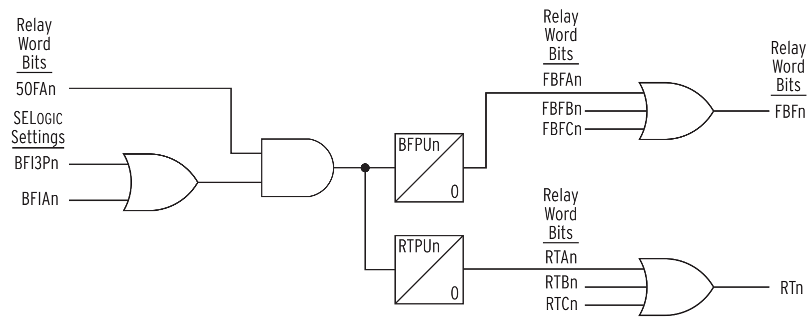


Figure 5.104 Scheme Y1 Circuit Breaker Failure Logic

Failure to Interrupt Fault Current: Scheme 2

Scheme 2 actually consists of two discrete circuit breaker failure protection schemes. The first scheme is applied for multiphase faults; apply a short time delay on pickup prior to asserting the circuit breaker failure trip because three-phase faults are the greatest threat to transient power system stability. The second scheme is applied for single phase-to-ground faults; an additional timer is provided so you can coordinate retripping and circuit breaker failure tripping for the different fault types.

Circuit Breaker Failure Protection Logic: Multiphase Faults

The logic diagram shown in *Figure 5.105* applies to three-pole tripping for one or two circuit breakers (EBFL = 2). Use this logic when the protected circuit breaker fails following a three-pole trip from the line-relaying scheme.

Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following fault inception and just prior to the assertion of Relay Word bit BFIA1 (Breaker 1 A-Phase Circuit Breaker Failure Initiation). At circuit breaker failure initiation, timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. If 50FA1 remains asserted when timer BFPU1 expires and at least two of the three initiation Relay Word bits BFIA1, BFIB1, or BFIC1 are asserted, Relay Word bit FBF1 (Breaker 1 Circuit Breaker Failure) asserts. (Two of three asserted initiation Relay Word bits indicate a multiphase fault.) Use FBF1 in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page 5.154*). If the protected circuit breaker opens successfully, 50FA1 drops out before timer BFPU1 expires and Relay Word bit FBF1 does not assert.

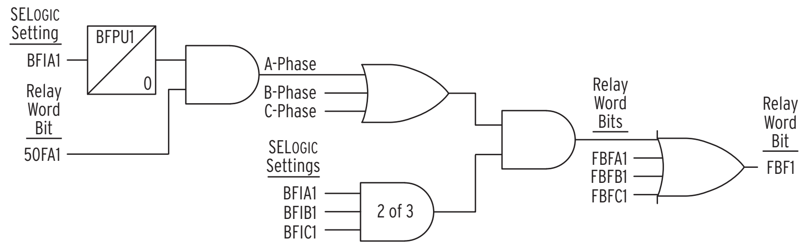


Figure 5.105 Scheme 2 Three-Pole Circuit Breaker Failure Protection Logic

Failure to Interrupt Fault Current: Scheme Y2 (Setting EBFL = Y2)

Three-Pole Circuit Breaker Failure Protection Logic

The logic shown in *Figure 5.106* applies to three-pole breaker configurations. Scheme Y2 is similar to Scheme 2, but the current check (50FA1) is now part of the Breaker Failure initiate timer (BFPU1) in addition to the Breaker Failure initiate settings (BFI3P1 or BFIA1).

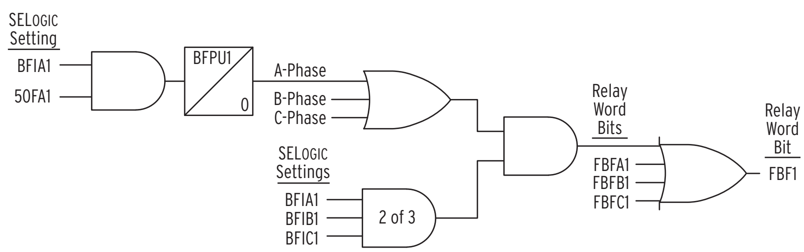


Figure 5.106 Scheme Y2 Three-Pole Circuit Breaker Failure Logic

Failure to Interrupt Fault Current: Scheme 2 (Setting EBFL = 2)

Circuit Breaker Failure Protection Logic: Single-Phase Faults

The logic diagram shown in *Figure 5.107* applies to single-pole tripping for one or two circuit breakers (EBFL = 2). A-Phase is discussed; B-Phase and C-Phase logic is similar. Use this logic when one pole of the circuit breaker fails following a single-pole trip from the line-relaying scheme.

Fault current causes 50FA1 (Breaker 1 A-Phase Instantaneous Overcurrent Element) to assert immediately following ground fault inception and just prior to the assertion of Relay Word bit BFIA1 (Breaker 1 A-Phase Circuit Breaker Failure Initiation). At circuit breaker failure initiation timer BFPU1 (Breaker 1 Circuit Breaker Failure Time Delay on Pickup Timer) starts timing. Timer BFPU1 cascades into timer SPBFPU1 (Breaker 1 Single-Pole Trip Breaker Failure Time Delay on Pickup Timer). Therefore, use this second timer, SPBFPU1, to coordinate circuit breaker failure operations for single-pole and three-pole trips.

If 50FA1 remains asserted when timer SPBFPU1 expires and neither of the two Relay Word bits BFIB1 and BFIC1 is asserted, Relay Word bit FBFA1 (A-Phase Breaker 1 Circuit Breaker Failure) asserts. Use FBFA1 in the circuit breaker failure tripping logic to cause a circuit breaker failure trip (see *Circuit Breaker Failure Trip Logic on page 5.154*). If the protected circuit breaker successfully opens, 50FA1 drops out before timer SPBFPU1 expires and Relay Word bit FBFA1 does not assert.

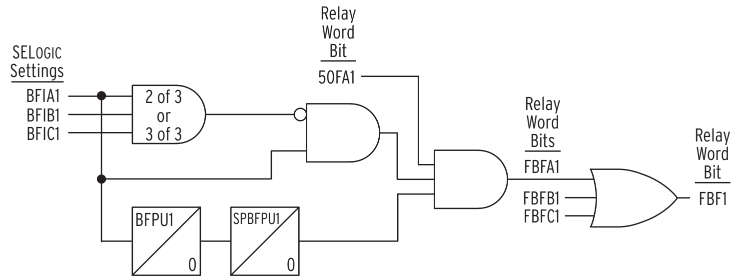


Figure 5.107 Scheme 2 Single-Pole Circuit Breaker Failure Protection Logic

Failure to Interrupt Fault Current: Scheme Y2 (Setting EBFL = Y2)

Single-Pole Circuit Breaker Failure Protection Logic

The logic shown in *Figure 5.108* applies to single-pole breaker configurations. Scheme Y2 is similar to Scheme 2, but the current check (50FA1) is now part of the Breaker Failure initiate timer (BFPU1) and Retrip Time delay (RTPU1) in addition to the Breaker Failure initiate settings (BFI3P1 or BFIA1).

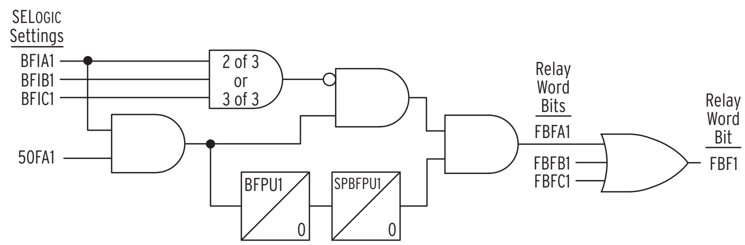


Figure 5.108 Scheme Y2 Single-Pole Circuit Breaker Failure Protection Logic

Retrip Logic

Some single-pole circuit breakers have two separate trip coils per pole. All three primary trip coils are energized if the line-relaying scheme asserts a three-pole trip. If one or more of the primary trip coils fail, the local protection should attempt a three-pole retrip.

Only one of the primary trip coils is energized if the line-relaying scheme asserts a single-pole trip. The corresponding primary trip coil can fail following the single-pole trip. You can decide whether to single-pole or three-pole retrip following the unsuccessful single-pole trip. Attempt all local retrips before the corresponding circuit breaker failure time delay (BFPU*n* and SPBFPU*n*) on pickup timer expires.

Retrip Scheme 2 Three Pole (Setting EBFL = 2)

Figure 5.109 illustrates the current-supervised three-pole retrip logic (EBFL = 2). Timer RT3PPU1 (Breaker 1 Three-Pole Retrip Time Delay on Pickup Timer) begins timing when at least two of the initiation Relay Word bits BFIA1, BFIB1, or BFIC1 assert. The relay asserts RT3P1 (Three-Pole Retrip) when timer RT3PPU1 times out. You can use just output RT3P1 for three-pole retrip without current supervision. Relay Word bit RTS3P1 (Breaker 1 Current Supervised Three-Pole Retrip) asserts immediately after timer RT3PPU1 expires, if one of the phase current level detectors is picked up.

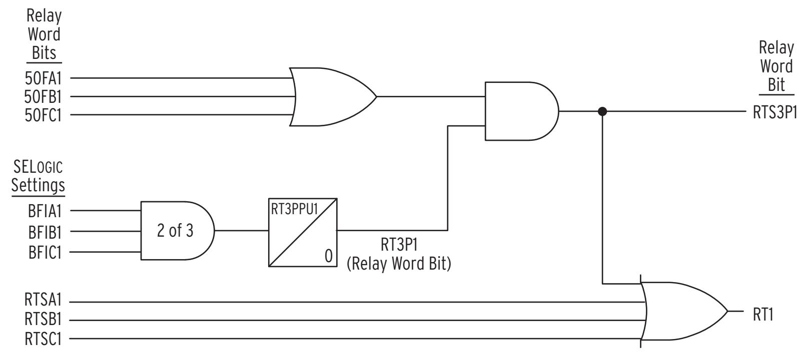


Figure 5.109 Scheme 2 Current-Supervised Three-Pole Retrip Logic

Retrip Scheme Y2 Three Pole (Setting EBFL = Y2)

The logic shown in *Figure 5.110* applies to three-pole breaker configurations. Scheme Y2 is similar to Scheme 2, but the current check (50FA1) is now part of the Retrip Time delay (RTPU1).

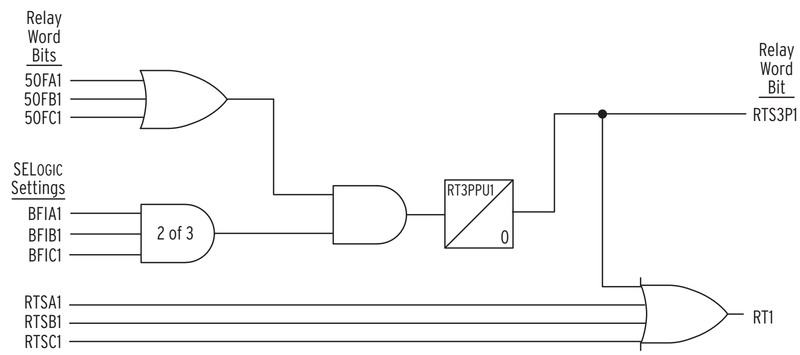


Figure 5.110 Scheme Y2 Current-Supervised Three-Pole Retrip Logic

Retrip Scheme 2 Single Pole (Setting EBFL = 2)

Figure 5.111 illustrates the current-supervised single-pole retrip logic (EBFL = 2). Timer RTPU1 (Breaker 1 Retrip Time Delay on Pickup Timer) begins timing when initiation Relay Word bit BFIA1 asserts. Relay Word bit RTA1 (Breaker 1 A-Phase Retrip) asserts immediately after timer RTPU1 expires. You can use just the RTA1 output for single-pole retrip without current supervision. Relay Word bit RTSA1 (Breaker 1 Current Supervised A-Phase Retrip) asserts if 50FA1 is picked up.

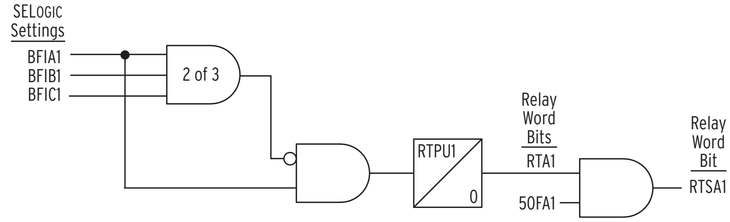


Figure 5.111 Scheme 2 Current-Supervised Single-Pole Retrip Logic

Retrip Scheme Y2 Single Pole (Setting EBFL = Y2)

The logic shown in *Figure 5.112* applies to three-pole breaker configurations. Scheme Y2 is similar to Scheme 2, but the current check (50FA1) is now part of the Retrip Time delay (RTPU1).

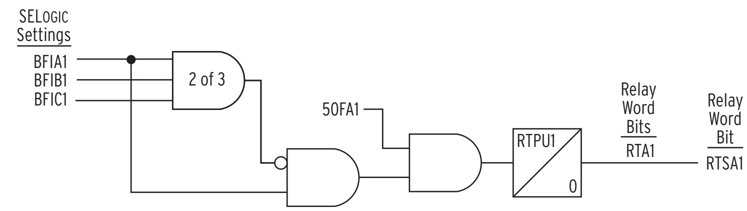


Figure 5.112 Scheme Y2 Current-Supervised Single-Pole Retrip Logic

Circuit Breaker Failure Initiation Dropout and Seal-In

The SEL-421 circuit breaker failure protection features breaker failure initiation extension and a breaker failure seal-in latch. The lower portion of *Figure 5.114* shows the dropout and seal-in logic.

Dropout Delay

Set timer BFIDO1 (Breaker Failure Initiate Dropout Delay—BK1) to stretch a short pulsed circuit breaker failure initiation. Use this feature for protecting dual circuit breakers when separate 86 BF lockout relays have differing energizing times.

Seal-In Delay

Set timer BFISP1 (Breaker Failure Initiate Seal-In Delay—BK1) to qualify extended circuit breaker failure initiation latch seal-in. When you set BFISP1 longer than BFIDO1 and the circuit breaker failure initiate is greater than the difference of the two timers, the relay seals in the circuit breaker failure extended initiation after the initiate signal deasserts until the BFIDO1 time expires and all 50Fϕn elements deassert.

No Current/Residual Current Circuit Breaker Failure Protection Logic

The SEL-421 has separate circuit breaker failure logic that operates on zero-sequence current rather than phase current. Use this logic to detect a circuit breaker failure and take appropriate action when a weak source drives the fault or if the protected circuit breaker fails to trip during a high-resistance ground fault. The residual current input to this logic is the 50R1 residual overcurrent element (see *Figure 5.113*). Setting 50RP1 (Residual Current Pickup—BK1) is the pickup threshold setting for the 50R1 element.

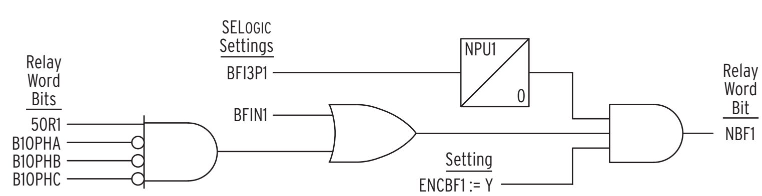


Figure 5.113 No Current/Residual Current Circuit Breaker Failure Protection Logic Diagram

Relay Word bit NBF1 (Breaker 1 Low Current Breaker Failure) asserts when timer NPU1 (Low Current Breaker Failure Time Delay on Pickup) expires and one of the following conditions exists:

- ➤ Circuit Breaker 1 residual overcurrent element 50R1 is asserted and the relay does not detect an open pole in any of the three phases for Circuit Breaker 1 (i.e., NOT B1OPHA, NOT B1OPHB, or NOT B1OPHC)
- ➤ Relay Word bit BFIN1 (No Current Breaker Failure Initiation) is asserted

For no current applications, such as a digital signal indicating a loss-of-field from a generator, use inputs BFI3P1 and BFIN*n*. Circuit breaker failure clearing can occur after timer NPU1 times out. For no current/residual current breaker failure trips, insert NBF1 in the circuit breaker failure trip SELOGIC control equation BFTR1 (see *Circuit Breaker Failure Trip Logic on page 5.154*).

Failure to Interrupt Load Current Protection Logic

The circuit breaker failure protection used during load conditions is independent from circuit breaker failure protection that you use during fault conditions. Use circuit breaker failure protection for load conditions either alone or in addition to circuit breaker failure protection for fault conditions as a second level of breaker failure protection. *Figure 5.115* shows that the output of the load current protection is Relay Word bit LCBF1 (Load Current Breaker Failure). Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Load Current Detection: 50LP1

This scheme detects failures of the circuit breaker to open when circuit breaker current is greater than the 50LP1 setting. The 50LP1 element should pick up when the protected circuit breaker is closed.

If the protected circuit breaker is in a ring-bus or circuit breaker-and-a-half arrangement, set 50LP1 to pick up for the line-charging current of the shortest line that circuit breaker services. Use the following equation to calculate the charging current for a given line:

$$I_c = V_g \bullet B_c \text{ A primary}$$

Equation 5.31

where:

V_g = Line-to-ground voltage
B_c = Total line capacitive susceptance

Time Delay on Pickup: LCPU1

The time delay setting for this protection scheme is typically longer than fault current conditions because of lower current duties associated with this type of circuit breaker failure operation. Extending the time delay allows more time for a slow but operative circuit breaker to clear a low-current fault. A disadvantage with the extended time delay is that a fault continues if the circuit breaker fails. Weigh these considerations when selecting time delays for this scheme. Please note that some circuit breakers take more time than other circuit breakers to break low amounts of current; consult the manufacturer of the protected circuit breaker for details.

The recommended setting for LCPU1 is the sum of the following:

- ➤ Nominal circuit breaker operate time
- ➤ 50LP1 dropout time
- ➤ Safety margin

Calculate the safety margin by subtracting all conditions required to isolate the fault during a circuit breaker failure condition from the maximum acceptable fault clearing time. The safety margin will be longer in this case than for the fault current logic because the total acceptable time to clear the fault at these lower fault duties is longer.

Load Current Circuit Breaker Failure Initiation: BFILC1

Program SELOGIC control equation BFILC1 (Load Current Breaker Failure Initiation) to initiate this scheme. For example, use the auxiliary contacts from the circuit breaker to detect when the circuit breaker is open. Relay Word bit LCBF1 asserts if Relay Word bit BFILC1 remains asserted for time LCPU1 and the relay detects load current.

Circuit Breaker Flashover Protection

Circuit breaker failure protection during flashover conditions is independent of the other circuit breaker protection functions. Use this protection either alone or in addition to the other protection.

Use current flow to detect when an open circuit breaker pole flashes over. Set BLKFOA1 to TPA or CLS1 to block flashover protection for 6 cycles if an A-phase single-pole trip occurs, or when circuit breaker BK1 closes.

Figure 5.116 shows the flashover circuit breaker failure logic. Flashover timer FOPU1 (Flashover Time Delay—BK1) starts timing if the circuit breaker is open and current exceeds setting 50FO1 (Flashover Current Pickup—BK1). The relay uses pole-open logic BnOPHϕ to determine whether the circuit breaker is open.

The output of the flashover protection is Relay Word bit FOBF1. Use this output to activate an external alarm, retrip the circuit breaker, or energize a lockout relay.

Circuit Breaker Failure Trip Logic

The SEL-421 has dedicated circuit breaker failure trip logic (see *Figure 5.117*). Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for circuit breaker failure trips from Relay Word bits FBF1, NBF1, LCBF1, and FOBF1.

When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 (Breaker Failure Trip for Circuit Breaker BK1) to logical 1 until BFTR1 deasserts, timer TDUR3D times out, and an unlatch or reset condition is active.

Unlatch Circuit Breaker Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1.

Table 5.80 Circuit Breaker Failure Relay Word Bits (Sheet 1 of 2)

Name[a]	Description
BFI3P1	Three-pole circuit breaker failure initiation
BFIA1	A-Phase circuit breaker failure initiation
BFIB1	B-Phase circuit breaker failure initiation
BFIC1	C-Phase circuit breaker failure initiation
BFIN1	No current circuit breaker failure initiation
BFILC1	Load current breaker failure initiation
BFI3PT1	Three-pole circuit breaker failure extended initiation
BFIAT1	A-Phase circuit breaker failure extended initiation
BFIBT1	B-Phase circuit breaker failure extended initiation
BFICT1	C-Phase circuit breaker failure extended initiation
FBFA1	A-Phase circuit breaker failure
FBFB1	B-Phase circuit breaker failure
FBFC1	C-Phase circuit breaker failure
FBF1	Circuit breaker failure
NBF1	No current/residual current circuit breaker failure
LCBF1	Load current circuit breaker failure
BLKFOA1	Block A-Phase flashover detection
BLKFOB1	Block B-Phase flashover detection
BLKFOC1	Block C-Phase flashover detection
FOA1	A-Phase flashover detected
FOB1	B-Phase flashover detected
FOC1	C-Phase flashover detected
FOBF1	Flashover detected
RT3P1	Three-pole retrip
RTA1	A-Phase retrip
RTB1	B-Phase retrip
RTC1	C-Phase retrip
RT1	Retrip
RTS3P1	Three-pole current supervised retrip
RTSA1	A-Phase current supervised retrip
RTSB1	B-Phase current supervised retrip
RTSC1	C-Phase current supervised retrip
50FA1	A-Phase current threshold
50FB1	B-Phase current threshold
50FC1	C-Phase current threshold
50R1	Residual current threshold
50LCA1	A-Phase load current threshold
50LCB1	B-Phase load current threshold
50LCC1	C-Phase load current threshold
50FOA1	A-Phase flashover current threshold
50FOB1	B-Phase flashover current threshold

Table 5.80 Circuit Breaker Failure Relay Word Bits (Sheet 2 of 2)

Name[a]	Description
50FOC1	C-Phase flashover current threshold
BFTRIP1	Breaker 1 circuit breaker failure trip

[a] For Circuit Breaker 2, replace 1 with 2 in the setting label.

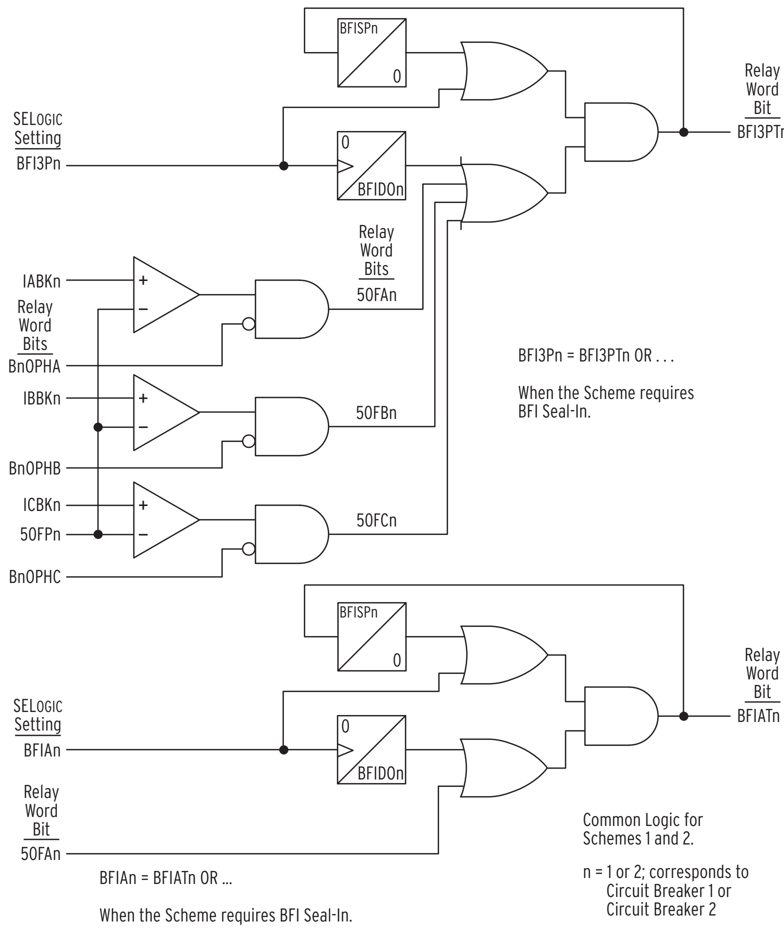


Figure 5.114 Circuit Breaker Failure Seal-In Logic Diagram

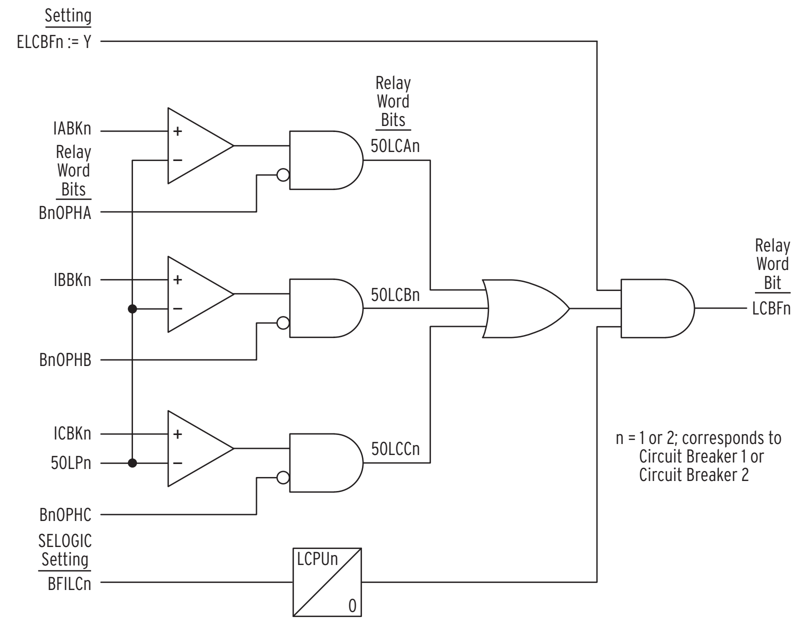


Figure 5.115 Failure to Interrupt Load Current Logic Diagram

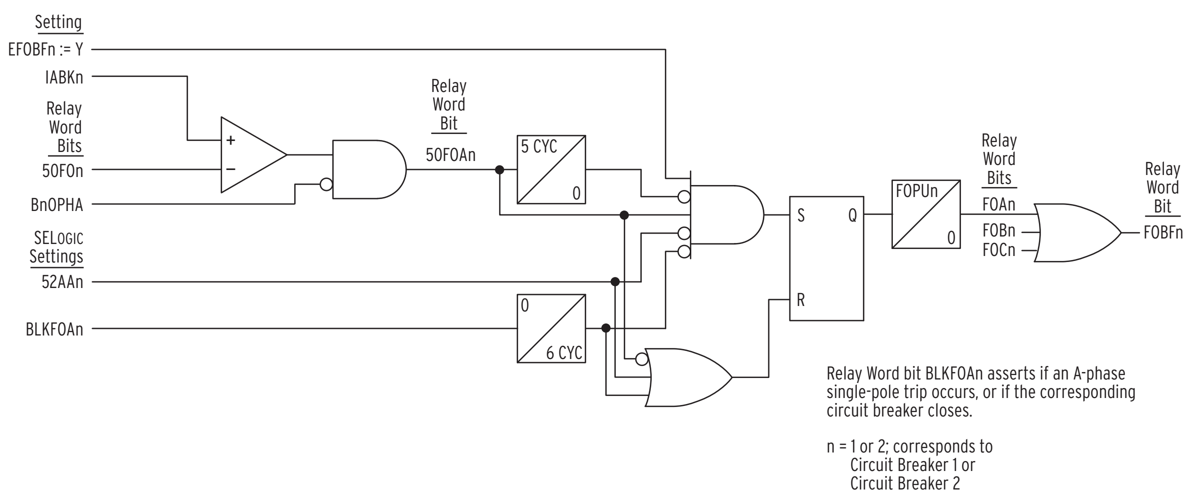


Figure 5.116 Flashover Protection Logic Diagram

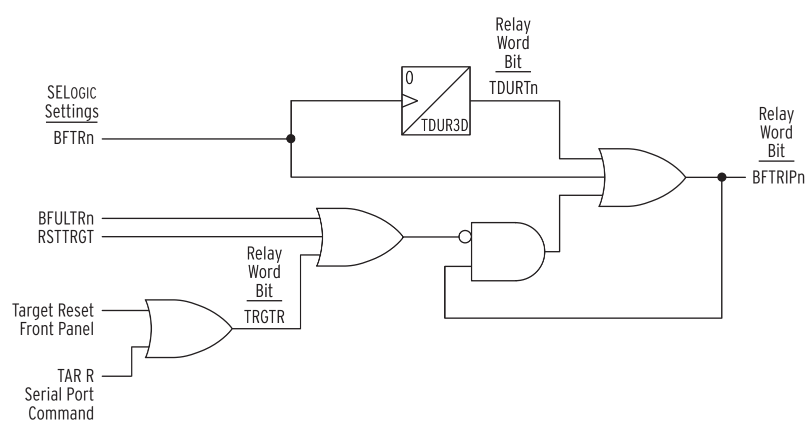


Figure 5.117 Circuit Breaker Failure Trip Logic Diagram

Synchronism Check

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay for synchronism check to account for this added delay.

Synchronism-check elements prevent circuit breakers from closing if the corresponding phases across the open circuit breaker are excessively out of phase. The synchronism-check elements selectively close circuit breaker poles under the following criteria:

The systems on both sides of the open circuit breaker are in phase (within a settable voltage angle difference), and one of the following is true:

- The voltages on both sides of the open circuit breaker are healthy (within a settable voltage magnitude window).
- The difference between the voltages on both sides of the open circuit breaker are less than a set limit.
- The voltages on both sides are healthy and the difference voltage is less than a set limit.

You can use synchronism-check elements to program the relay to supervise circuit breaker closing; include the synchronism-check element outputs in the close SELOGIC control equations. These element outputs are Relay Word bits 25W1BK1, 25A1BK1, 25W2BK1, 25A2BK1, 25W1BK2, 25A1BK2, 25W2BK2, and 25A2BK2 (see *Synchronism-Check Logic Outputs on page 5.160* and *Angle Checks and Synchronism-Check Element Outputs on page 5.168*).

An example best demonstrates the synchronism-check capability in the relay. This subsection presents a typical synchronism-check system.

Generalized System

The generalized system single-line drawing in *Figure 5.118* shows a partial circuit breaker-and-a-half or ring-bus substation arrangement. Presuming that both Circuit Breakers BK1 and BK2 are open, the system is split into three sections: Bus 1, Bus 2, and Line.

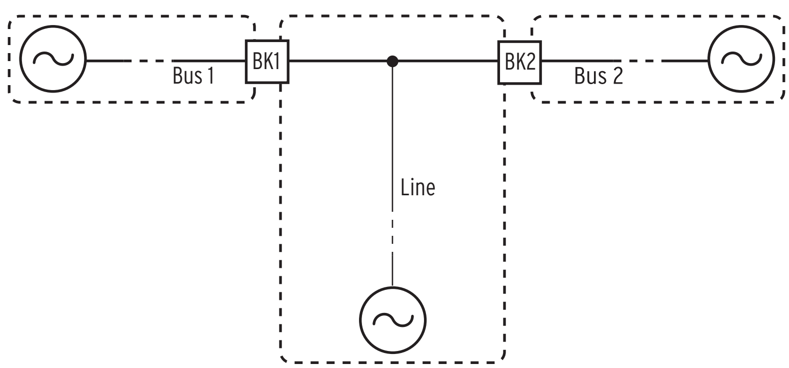


Figure 5.118 Partial Breaker-and-a-Half or Partial Ring-Bus Breaker Arrangement

Paralleled and Asynchronous Systems

Figure 5.118 shows remote sources for each section. Often, a portion of the power system is paralleled beyond the open Circuit Breakers BK1 and BK2; the remote sources are really the same aggregate source. If the aggregate source is much closer to one side of the open circuit breaker than the other, there is a noticeable voltage angle difference across the system (it is not simply zero degrees). The corresponding angular separation results from load flow and the impedance of the parallel system.

You must consider this angle difference when setting the synchronism-check element for a paralleled system. For example, if the expected angle because of load flow is 10 degrees, do not set the voltage angle difference setting to less than 15–20 degrees nominal. A paralleled system does not imply a zero degree voltage angle difference at every measuring point.

Single-Phase Voltage Inputs

Figure 5.119 shows single-phase voltage transformers (1 PT) on Bus 1 and Bus 2. Use these single-phase voltage sources to perform a synchronism check across the two circuit breakers.

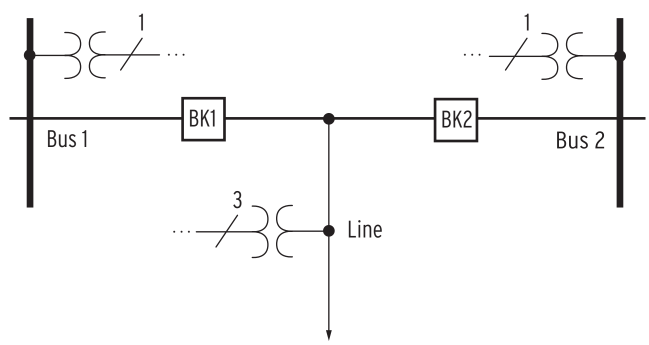


Figure 5.119 Synchronism-Check Voltages for Two Circuit Breakers

Synchronism check occurs on a single-phase voltage basis—see the single-phase potential transformers (1 PT) shown on each bus in *Figure 5.119*. The assumption is that if the monitored single-phase voltage inputs are in phase (within a settable voltage angle difference), and they meet the criteria of being healthy (within a settable voltage magnitude window) and/or the voltage difference is less than a set limit, the other phase-to-neutral voltages are likewise in phase and share the same voltage magnitude relationship. The line voltage source is three-phase, but you only need a single-phase bus voltage to perform a synchronism check across the corresponding circuit breaker. The relay uses the three-phase voltage from the line for other functions such as distance protection and metering.

Setting E25BK*n* := Y

If E25BK*n* is set to Y, where *n* = 1 or 2, the synchronizing logic verifies that both the reference voltage and synchronizing voltage are healthy (within a settable voltage magnitude window) before enabling the synchronism-check logic.

Setting E25BK*n* := Y1

If E25BK*n* is set to Y1, where *n* = 1 or 2, the synchronizing logic verifies that the difference voltage between the reference and synchronizing voltages is less than the 25VDIF setting before enabling the synchronism-check logic.

Setting E25BK*n* := Y2

If E25BK*n* is set to Y2, where *n* = 1 or 2, the synchronizing logic verifies that both the reference and synchronizing voltages are healthy and that the difference between them is less than the 25VDIF setting before enabling the synchronism-check logic. It combines the logic that is used when E25BK*n* is set to Y or Y1.

Synchronism-Check Settings Example

This example uses a two-circuit breaker arrangement (see *Figure 5.119*). Set the synchronism-check enable settings:

E25BK1 := **Y**. Synchronism Check for Circuit Breaker BK1 (Y, N, Y1, Y2)

E25BK2 := **Y**. Synchronism Check for Circuit Breaker BK2 (Y, N, Y1, Y2)

NOTE: If Global setting NUMBK = 1, the synchronism-check logic is not executed for Breaker 2.

If you are using the relay on a single circuit breaker, enable synchronism check for only one circuit breaker (E25BK1 := Y and E25BK2 := N).

Figure 5.120 shows the correspondence between the synchronism-check settings and the two-circuit breaker application example. All of these settings are listed in *Section 10: Settings*. The following subsections explain these settings and include an explanation of Alternative Synchronism-Check Voltage Source 2 settings (see *Figure 5.131*).

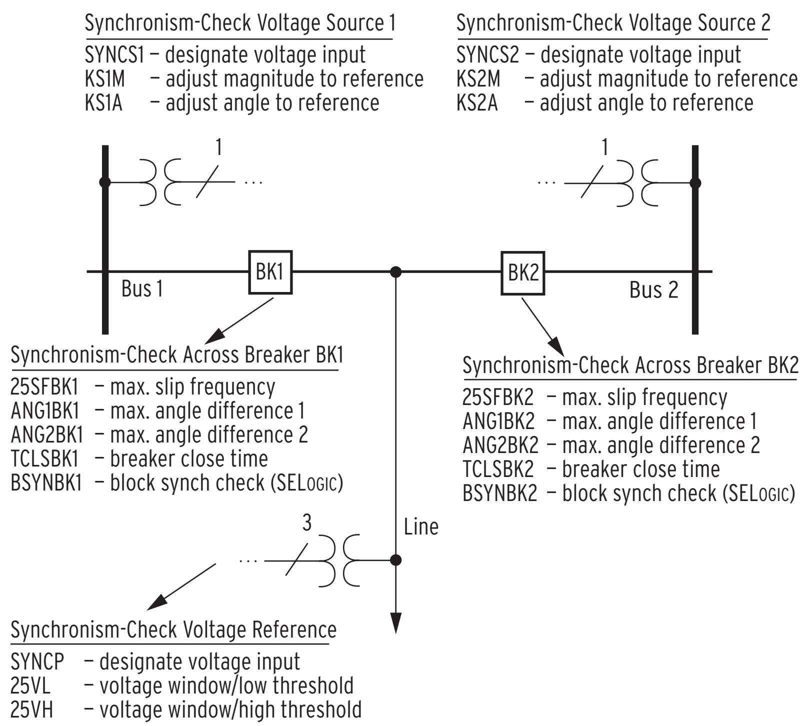


Figure 5.120 Synchronism-Check Settings

Synchronism-Check Logic Outputs

Figure 5.121 shows the correspondence between synchronism-check logic outputs (Relay Word bits) and the two-circuit breaker arrangement. These Relay Word bits assert to logical 1 (e.g., 59VP equals logical 1) if true and deassert to logical 0 (e.g., 59VS1 equals logical 0) if false. *Table 5.81* lists these Relay Word bits.

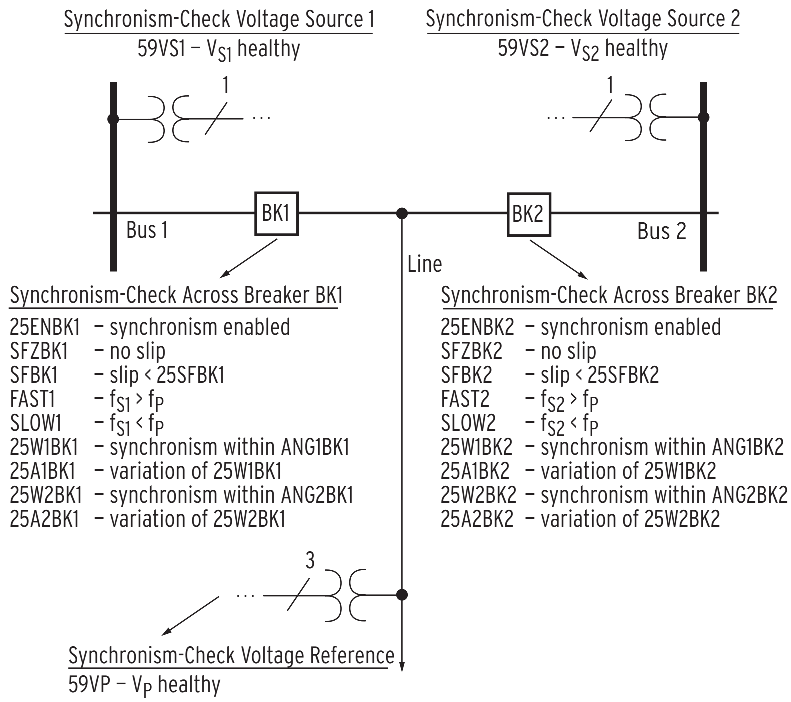


Figure 5.121 Synchronism-Check Relay Word Bits

Table 5.81 Synchronism-Check Relay Word Bits (Sheet 1 of 2)

Relay Word Bit	Description
59VP	V_P within healthy voltage window
59VS1	V_{S1} within healthy voltage window
59VDIF1	Circuit Breaker BK1 synchronizing voltage difference less than limit
25ENBK1	Circuit Breaker BK1 synchronism-check element enabled
SFZBK1	Circuit Breaker BK1 slip frequency less than 0.005 Hz ("no slip" condition)
SFBK1	0.005 Hz ≤ Circuit Breaker BK1 slip frequency < 25SFBK1
25W1BK1	Voltage angle across Circuit Breaker BK1 < ANG1BK1
25W2BK1	Voltage angle across Circuit Breaker BK1 < ANG2BK1
25A1BK1	Same operation as 25W1BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 5.130*)
25A2BK1	Same operation as 25W2BK1, except for the restrictive operation (0° closure attempt) when setting 25SFBK1 ≠ OFF and the system is slipping (see *Figure 5.130*)
FAST1	Bus 1 frequency greater than line frequency ($f_{S1} > f_P$)
SLOW1	Bus 1 frequency less than line frequency ($f_{S1} < f_P$)
59VS2	V_{S2} within healthy voltage window
59VDIF2	Circuit Breaker BK2 synchronizing voltage difference less than limit
25ENBK2	Circuit Breaker BK2 synchronism-check element enabled
SFZBK2	Circuit Breaker BK2 slip frequency less than 0.005 Hz ("no slip" condition)
SFBK2	0.005 Hz ≤ Circuit Breaker BK2 slip frequency < 25SFBK2
25W1BK2	Voltage angle across Circuit Breaker BK2 < ANG1BK2
25W2BK2	Voltage angle across Circuit Breaker BK2 < ANG2BK2

Table 5.81 Synchronism-Check Relay Word Bits (Sheet 2 of 2)

Relay Word Bit	Description
25A1BK2	Same operation as 25W1BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 5.130*)
25A2BK2	Same operation as 25W2BK2, except for the restrictive operation (0° closure attempt) when setting 25SFBK2 ≠ OFF and the system is slipping (see *Figure 5.130*)
FAST2	Bus 2 frequency greater than line frequency ($f_{S2} > f_P$)
SLOW2	Bus 2 frequency less than line frequency ($f_{S2} < f_P$)

Supervising Circuit Breaker Closing via Synchronism Check

Use the synchronism-check element outputs to control circuit breaker closing. Some examples follow (the ellipsis indicates other elements that you can add to these SELOGIC control equations).

Supervising Autoreclosing of Circuit Breaker BK1

3P1CLS := **25A1BK1 OR ...** Three-Pole BK1 Reclose Supervision (SELOGIC Equation)

Manual Closing of Circuit Breaker BK1

BK1MCL := **25W2BK1 OR ...** Circuit Breaker BK1 Manual Close (SELOGIC Equation)

PT Connections

Figure 5.122 is an example of connecting PTs to the relay for two circuit breakers. The Bus 1 and Bus 2 single-phase voltages are connected to relay voltage inputs VAZ and VBZ, respectively. They could just as easily have been connected to any of the other voltage inputs. The voltage connected to voltage input VAZ (setting SYNCS1 := VAZ; see *Figure 5.122*) is not necessarily from A-Phase on Bus 1. Likewise, the voltage connected to voltage input VBZ (setting SYNCS2 := VBZ; see *Figure 5.122*) is not necessarily from B-Phase on Bus 2. The connection can be from any phase-to-neutral or phase-to-phase voltage (as long as you do not exceed the relay voltage input ratings). Settings in the relay compensate for any steady-state magnitude or angle difference with respect to a synchronism-check voltage reference, as discussed next in this example.

Three-phase line voltages are connected to relay voltage inputs VAY, VBY, and VCY (these voltage inputs are also used for distance elements fault location, loss-of-potential, load encroachment, and directionality). Only one of these single-phase voltage inputs is designated for use in synchronism check. In this example, this voltage input is also designated the synchronism-check voltage reference (setting SYNCP := VAY; see *Figure 5.122*). As the synchronism-check voltage reference, the relay makes all steady-state magnitude and angle adjustments for the Bus 1 and Bus 2 synchronism check voltages (connected to voltage inputs FAZ and FBZ, respectively, as discussed in the preceding paragraph) with respect to this designated reference line voltage, VAY, as discussed later in this example.

For a single-circuit breaker application, you can use either bus-side potentials or line-side potentials for line relaying; connect the three-phase voltage source to potential inputs VAY, VBY, and VCY. If a single-phase voltage source is available on the other side of the circuit breaker for synchronism check, connect the source to potential input VAZ, VBZ, or VCZ.

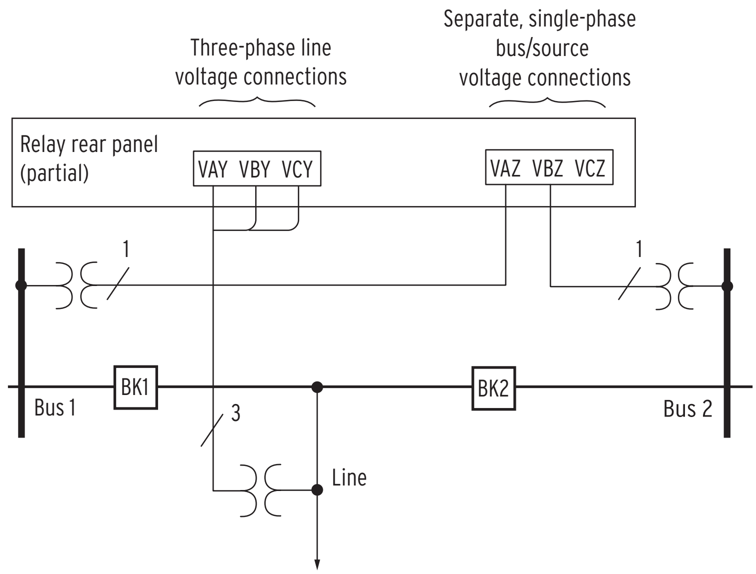


Figure 5.122 Example Synchronism-Check Voltage Connections to the SEL-421

Voltage Magnitude and Angle Compensation

The *Figure 5.122* example continues in *Figure 5.123*. The *Figure 5.123* example demonstrates possible voltage input connections (presuming ABC phase rotation). The synchronism-check voltage reference (V_P) is from the A-Phase voltage (V_A) of the line. You can connect phase-to-phase voltage V_{BC} originating from Bus 1, and connect phase-to-neutral voltage V_C from Bus 2. Thus, Bus 1 voltage V_{BC} lags synchronism-check voltage reference V_P by 90 degrees, and Bus 2 voltage V_C lags the synchronism-check voltage reference V_P by 240 degrees. To compensate for these steady-state angle differences, set KS1A for Bus 1 and KS2A for Bus 2.

KS1A := **90**. Synchronism Source 1 Angle Shift (0, 30, …, 330 degrees)

KS2A := **240**. Synchronism Source 2 Angle Shift (0, 30, …, 330 degrees)

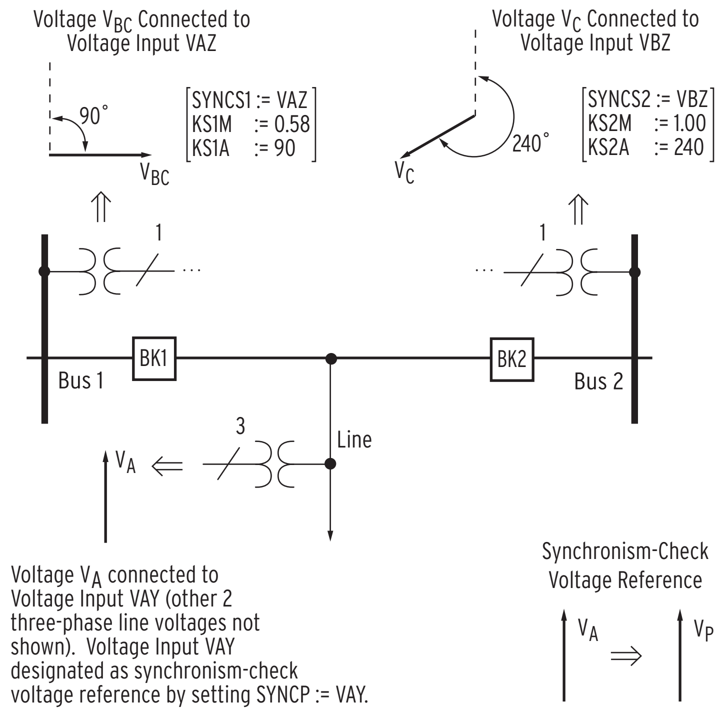


Figure 5.123 Synchronism-Check Voltage Reference

For a given secondary base voltage, phase-to-phase voltages are a factor of 1.73 (√3) times the magnitude of the phase-to-neutral voltages. In reverse, phase-to-neutral voltages are a factor of 0.58 (1/√3) times the magnitude of the phase-to-phase voltages. Therefore, you must compensate the Bus 1 voltage V_{BC} magnitude with setting KS1M to reference it to the synchronism-check voltage reference V_P magnitude.

KS1M := **0.58**. Synchronism Source 1 Ratio Factor (0.10–3)

You do not need special magnitude compensation for the Bus 2 voltage V_C to reference Synchronism Source 2 to the synchronism-check voltage reference V_P magnitude; these are both phase-to-neutral voltages with the same nominal rating (for example, 67 V secondary).

KS2M := **1.00**. Synchronism Source 1 Ratio Factor (0.10–3)

As another example of synchronism-source magnitude adjustment flexibility, suppose Bus 1 voltage V_{BC} is 201 V secondary (phase-to-phase), and the synchronism-check voltage reference V_P is 67 V secondary (phase-to-neutral). Then, the magnitude compensation setting would be as in *Equation 5.32*.

$$\text{KS1M} = \frac{67\ \text{V}}{201\ \text{V}} := 0.33$$

Equation 5.32

Normalized Synchronism-Check Voltage Sources VS1 and VS2

The *Figure 5.123* example continues in *Figure 5.124*, which graphically illustrates how the introduced settings adjust the Bus 1 and Bus 2 synchronism-check input voltages in angle and magnitude to reference to the synchronism-check voltage reference V_P. The resultant Bus 1 and Bus 2 voltages are the normalized synchronism-check voltage sources V_{S1} and V_{S2}, respectively.

Voltages V_P, V_{S1}, and V_{S2} are used in the logic in the balance of this section to check for healthy voltage and determine voltage phase angle for synchronism-check element operation.

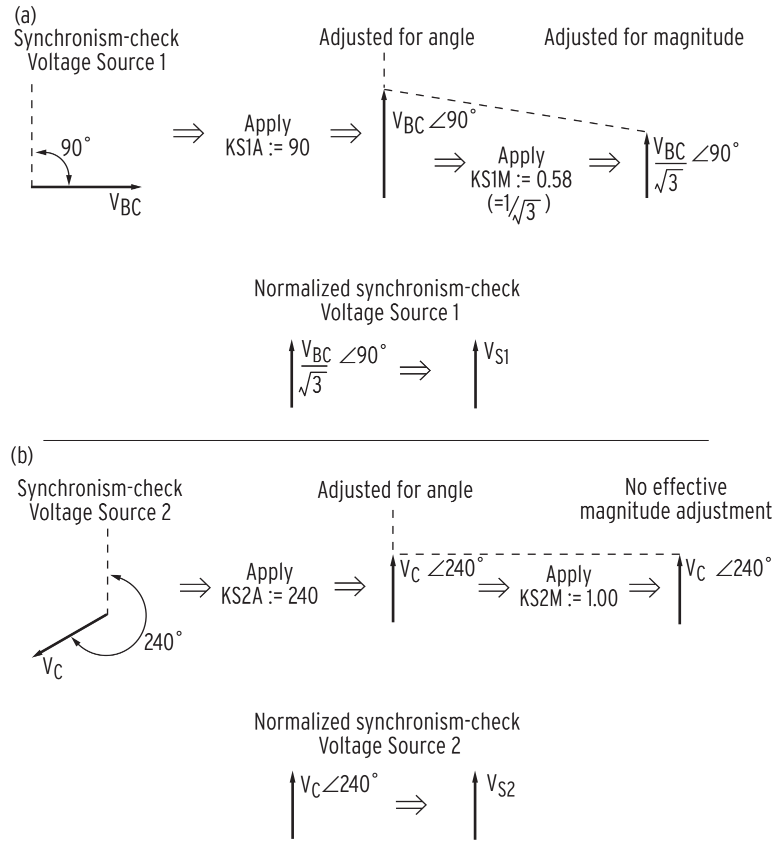


Figure 5.124 Normalized Synchronism-Check Voltage Sources VS1 and VS2

Voltage Checks and Blocking Logic

Two conditions can cause the synchronism-check function in the SEL-421 to abort. These conditions are out-of-range synchronism-check input voltages and block synchronism check configurations that you specify in SELOGIC control equations.

Voltage Magnitude Checks (Applicable When E25BK*n* = Y or Y2)

For synchronism check to proceed for a given circuit breaker (BK1 or BK2) when E25BK*n* = Y or Y2, the voltage magnitudes of the synchronism-check voltage reference V_P and the corresponding normalized synchronism-check voltage source on the other side of the circuit breaker (normalized voltage V_{S1} for Circuit Breaker BK1 and normalized voltage V_{S2} for Circuit Breaker BK2) must lie within a healthy voltage window, bounded by voltage threshold settings 25VH and 25VL (see *Figure 5.125*).

The relay asserts Relay Word bits 59VP, 59VS1, and 59VS2 to indicate healthy synchronism-check voltages V_P, V_{S1}, and V_{S2}, respectively (see *Figure 5.125*). If either of the voltage pairs (V_P and V_{S1} or V_P and V_{S2}) does not meet this healthy voltage criterion, synchronism check cannot proceed for the circuit breaker associated with the corresponding voltage pair.

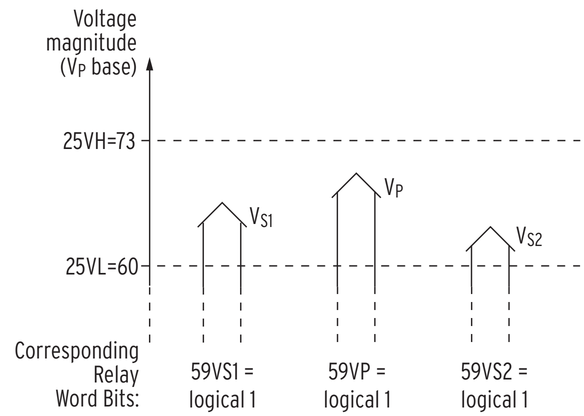


Figure 5.125 Healthy Voltage Window and Indication

Voltage Difference Checks (Applicable When E25BK*n* = Y1 or Y2)

For synchronism check to proceed for a given circuit breaker (BK1 or BK2) when E25BK*n* = Y1 or Y2, the absolute value of the difference between the synchronism-check reference voltage, V_P, and the corresponding normalized synchronism-check voltage source on the other side of the circuit breaker (normalized voltage V_{S1} for Circuit Breaker BK1 and normalized voltage V_{S2} for Circuit Breaker BK2) must be less than the 25VDIF setting (see *Figure 5.126*). The logic includes a 5-volt secondary check to ensure the relay does not operate on erroneous signals.

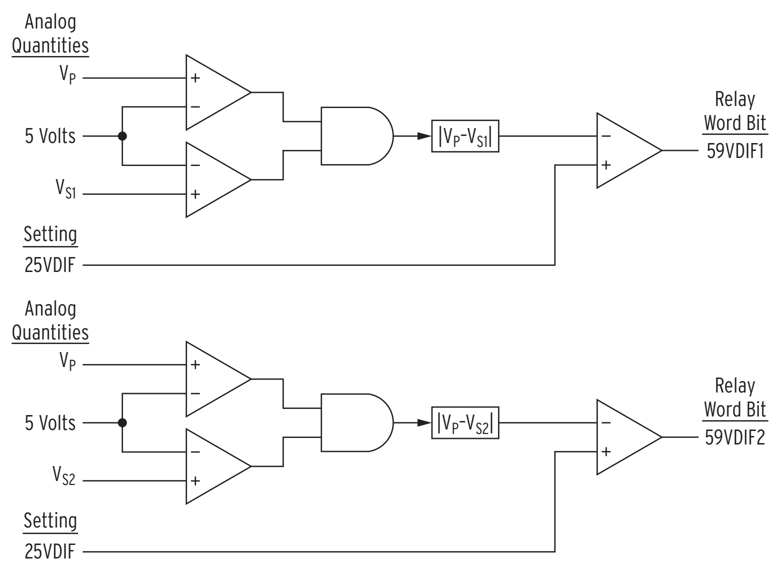


Figure 5.126 Synchronism-Check Voltage Difference Logic

Block Synchronism Check

If the block synchronism check BSYNBK*n* SELOGIC control equation (where *n* = 1 or 2 for Circuit Breaker BK1 or Circuit Breaker BK2, respectively) asserts, synchronism check cannot proceed for the corresponding circuit breaker. Following is an example for Circuit Breaker BK1:

BSYNBK1 := **52AA1 AND 52AB1 AND 52AC1**. Block Synchronism Check—BK1 (SELOGIC Equation)

If Circuit Breaker BK1 is closed, the three-pole indication back to the relay shows 52AA1 equals 52AB1 equals 52AC1 equals logical 1. Thus, BSYNBK1 equals logical 1, and synchronism check is blocked for Circuit Breaker BK1. There is no need to qualify or continue with the synchronism check for circuit breaker closing; the circuit breaker is already closed.

Synchronism-Check Enable Logic

The relay combines the voltage check elements and block synchronism check condition to create a synchronism-check enable condition for each circuit breaker, as shown in *Figure 5.127*. Settings E25BK1 and E25BK2 determine which enable logic is active.

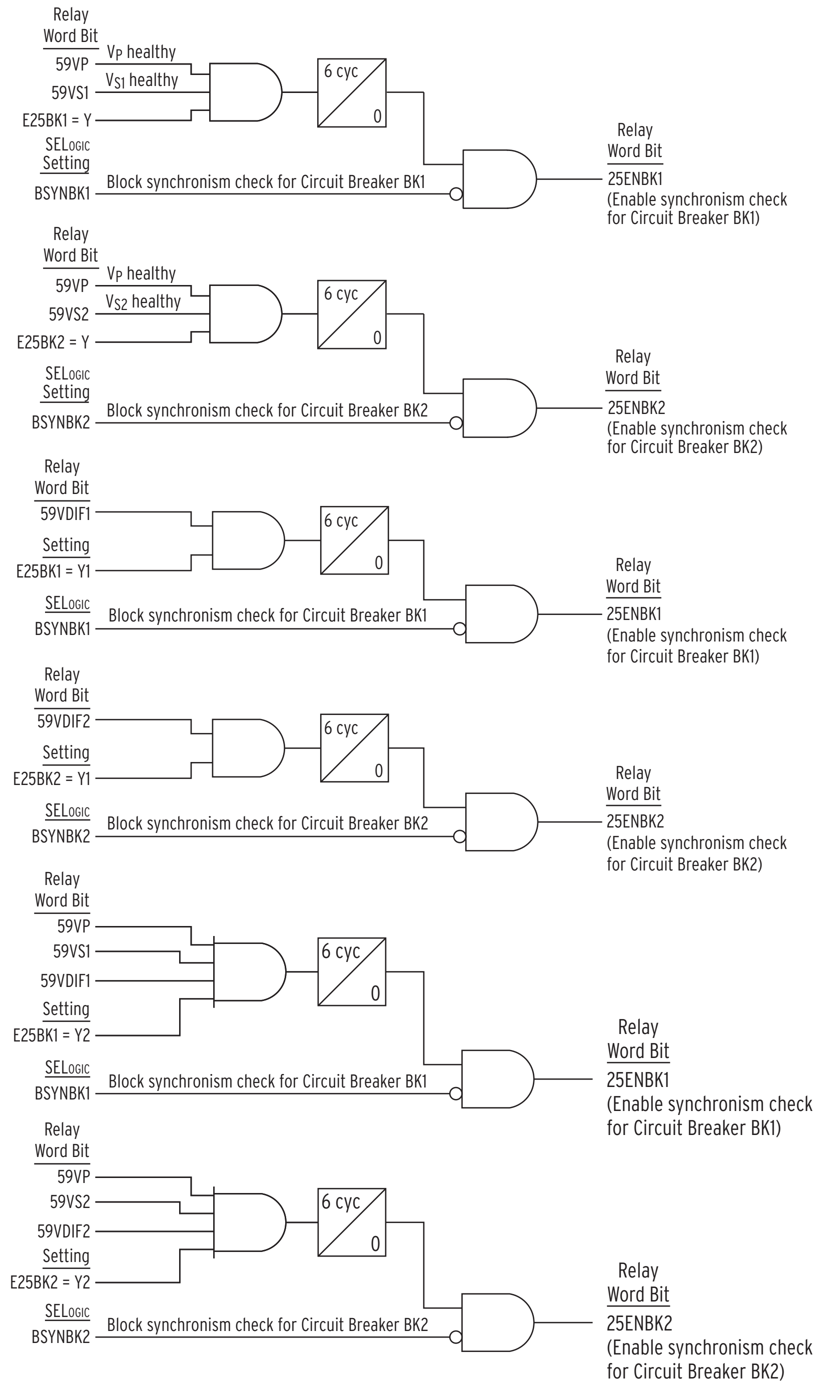


Figure 5.127 Synchronism-Check Enable Logic

Angle Checks and Synchronism-Check Element Outputs

After the relay determines that it is appropriate to enable synchronism-check logic as defined in *Figure 5.127*, the relay must check voltage phase angles across the circuit breakers before a final synchronism-check element output can be available for supervising circuit breaker closing.

The following discussion/examples use Circuit Breaker BK1. Synchronism-check element output operation for Circuit Breaker BK2 is similar (replace BK2 for BK1 in associated settings and Relay Word bits).

Angle Difference Settings ANG1BK1 and ANG2BK1

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay for synchronism check to account for this added delay.

Each circuit breaker has two angle difference windows. For Circuit Breaker BK1, the maximum angle difference settings are ANG1BK1 and ANG2BK1.

Often, a greater phase angle across the circuit breaker is tolerated for a manual close. Typically, you set angle setting ANG1BK1 for synchronism check in autoreclosing Circuit Breaker BK1 (e.g., ANG1BK1 := 20 degrees), and you set angle setting ANG2BK1 for synchronism check when manually closing Circuit Breaker BK1 (e.g., ANG2BK1 := 35 degrees).

Synchronism-Check Element Outputs 25W1BK1 and 25A1BK1

Angle difference setting ANG1BK1 affects synchronism-check element outputs 25W1BK1 and 25A1BK1. *Figure 5.128*, *Figure 5.129*, and *Figure 5.130* illustrate the operation of synchronism-check element outputs 25W1BK1 and 25A1BK1.

These outputs operate for a voltage phase angle within and without the angle difference setting ANG1BK1 for the following three conditions:

- no slip
- slip—no compensation
- slip—with compensation

The operational differences between synchronism-check element outputs 25W1BK1 and 25A1BK1 are apparent in the "slip—with compensation" example (*Figure 5.130*).

The second angle difference setting (ANG2BK1) for Circuit Breaker BK1 operates similarly to affect synchronism-check element outputs 25W2BK1 and 25A2BK1.

"No Slip" Synchronism Check

Refer to the paralleled system beyond the open circuit breaker in *Figure 5.119*. For such a system, there is essentially no slip across the open circuit breaker (the monitored voltage phasors on each side are not moving with respect to one another). In a "no slip" system, any voltage angle difference across the open circuit breaker remains relatively constant.

The four drawings shown in *Figure 5.128* are separate, independent cases for a "no slip" paralleled system. If the phase angle between the synchronism-check voltage reference V_P and the normalized synchronism-check voltage source V_{S1} is less than angle setting ANG1BK1, synchronism-check element outputs 25W1BK1 and 25A1BK1 both assert to logical 1. The relay declares that the per-phase voltages across Circuit Breaker BK1 are in synchronism. Otherwise, if the phase angle is greater than or equal to angle setting ANG1BK1, element outputs 25W1BK1 and 25A1BK1 both deassert to logical 0; the relay declares that the per-phase voltages across Circuit Breaker BK1 are out-of-synchronism.

The out-of-synchronism phase angles in *Figure 5.128* appear dramatic for a "no slip" paralleled system. This is for illustrative purposes; these angles are not usually this large in actual systems.

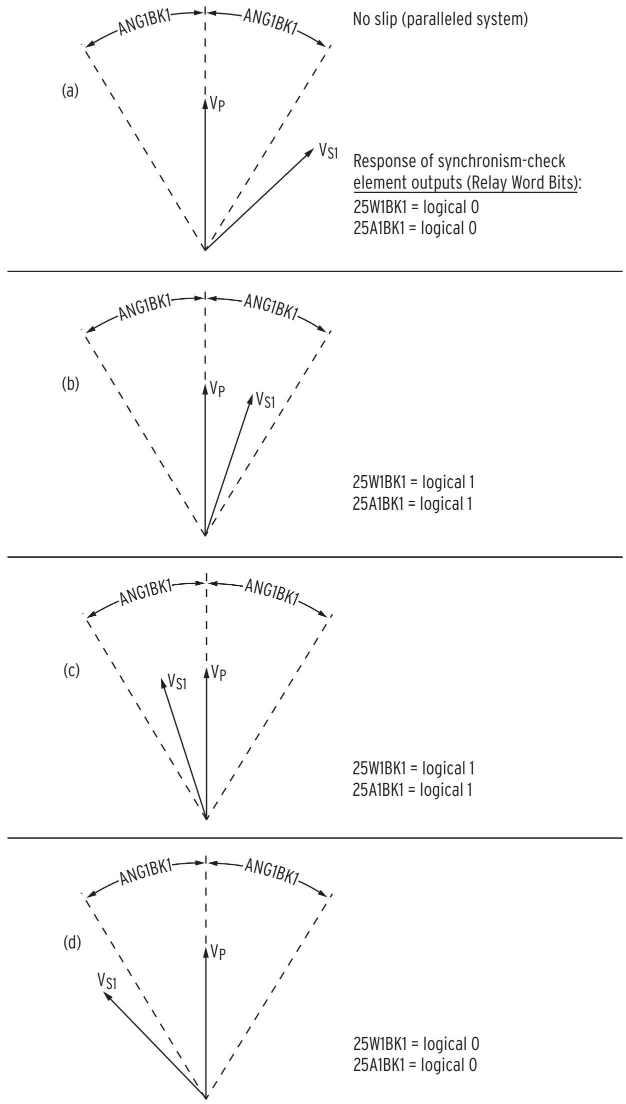


Figure 5.128 "No Slip" System Synchronism-Check Element Output Response

Slip Frequency and SFZBK1

Relay Word bit SFZBK1 (BK1 Slip Frequency less than 0.005 Hz) also asserts to logical 1, indicating a "no slip" condition across Circuit Breaker BK1. In other words, the slip frequency is less than 0.005 Hz ($|f_{S1}–f_P| < 0.005$ Hz).

Synchronism-Check Element Output Effects

Note that element outputs 25W1BK1 and 25A1BK1 operate identically in all of the "no slip" cases in *Figure 5.128* (both assert to logical 1 or deassert to logical 0).

"Slip—No Compensation" Synchronism Check

The four cases [(a), (b), (c), and (d)] shown in *Figure 5.129* are "slip—no compensation" cases for asynchronous systems (not paralleled). The cases progress in time from top to bottom. The normalized synchronism-check voltage source

V_{S1} slips with respect to synchronism-check voltage reference V_P. The indication of the rotation arrow on phasor V_{S1} (and the time progression down the page) shows that the system corresponding to V_{S1} has a higher system frequency f_{S1} than the system corresponding to reference V_P with system frequency f_P. The slip frequency across Circuit Breaker BK1 is f_{S1}–f_P.

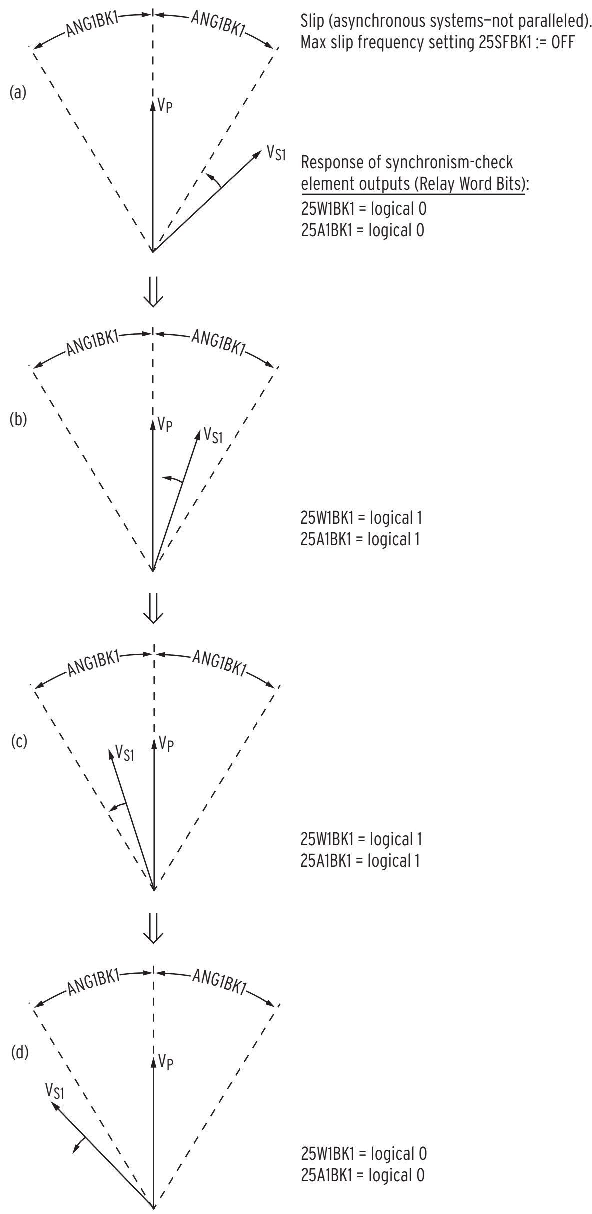


Figure 5.129 "Slip—No Compensation" Synchronism-Check Element Output Response

Positive Slip Frequency

If the slip frequency is positive, V_{S1} is slipping ahead of reference V_P (the system corresponding to V_{S1} has a higher system frequency than the system corresponding to V_P; $f_{S1} > f_P$). Positive slip frequency is the counter-clockwise rotation of V_{S1} with respect to reference V_P, as shown in *Figure 5.129*. Relay Word bit FAST1 asserts to logical 1 (and Relay Word bit SLOW1 deasserts to logical 0) to indicate this condition.

Negative Slip Frequency

If the slip frequency is negative, V_{S1} is slipping behind reference V_P (the system corresponding to V_{S1} has a lower system frequency than the system corresponding to V_P; $f_{S1} < f_P$). For such a case, V_{S1} rotates clockwise with respect to reference V_P. Relay Word bit SLOW1 asserts to logical 1 (and Relay Word bit FAST1 deasserts to logical 0) to indicate this condition.

"No-Slip" Condition

If the absolute value of the slip is less than 0.005 Hz ($|f_{S1}–f_P| < 0.005$ Hz; a "no-slip" condition), both Relay Word bits FAST1 and SLOW1 deassert to logical 0 and Relay Word bit SFZBK1 asserts to logical 1. A "no-slip" condition is confirmed when FAST1 and SLOW1 are deasserted, and SFZBK1 is asserted.

Synchronism-Check Element Output Effects

Compare the corresponding "slip—no compensation" cases in *Figure 5.129* to the previous "no-slip" cases in *Figure 5.128*. Note that synchronism-check element outputs 25W1BK1 and 25A1BK1 operate identically in all cases of the "slip—no compensation" examples in *Figure 5.129* (both assert to logical 1 or deassert to logical 0). The condition of "no slip" or "slip—no compensation" does not affect the operation of element outputs 25W1BK1 and 25A1BK1 in the scenarios depicted in *Figure 5.128* and *Figure 5.129*.

The similarity of element outputs 25W1BK1 and 25A1BK1 for the "no slip" condition (*Figure 5.128*) and the "slip—no compensation" (*Figure 5.129*) condition results from the maximum slip frequency setting 25SFBK1 := OFF. Setting 25SFBK1 has no effect in a "no slip" scenario (*Figure 5.128*), but the setting does affect the operation of synchronism-check element output 25A1BK1 (see the "slip—no compensation" scenario, *Figure 5.129*).

With setting 25SFBK1 := OFF, the relay does not compensate for the further angular travel of V_{S1} (with respect to reference V_P) during the Circuit Breaker BK1 close time setting TCLSBK1. The relay measures the phase angle directly with no compensation between reference V_P and V_{S1} for synchronism-check element output 25A1BK1.

The relay always measures the phase angle directly (without compensation) between reference V_P and V_{S1} for element output 25W1BK1. Setting 25SFBK1, time setting TCLSBK1, and whether system conditions are "no slip" (*Figure 5.128*) (see the "slip—no compensation" in *Figure 5.129*) have no effect on element output 25W1BK1.

"Slip—With Compensation" Synchronism Check

Figure 5.130 is derived from *Figure 5.129*, but with the maximum slip frequency setting 25SFBK1 set to some value other than OFF; thus the SEL-421 compensates for circuit breaker closing time with setting TCLSBK1. This results in a compensated normalized synchronism-check voltage source V'_{S1}.

Synchronism-check element output 25W1BK1 in *Figure 5.130* operates the same as in *Figure 5.129*. Element output 25W1BK1 is unaffected by relay settings 25SFBK1 and TCLSBK1, and by whether system conditions are slipping. Element 25W1BK1 follows normalized synchronism-check voltage source V_{S1}.

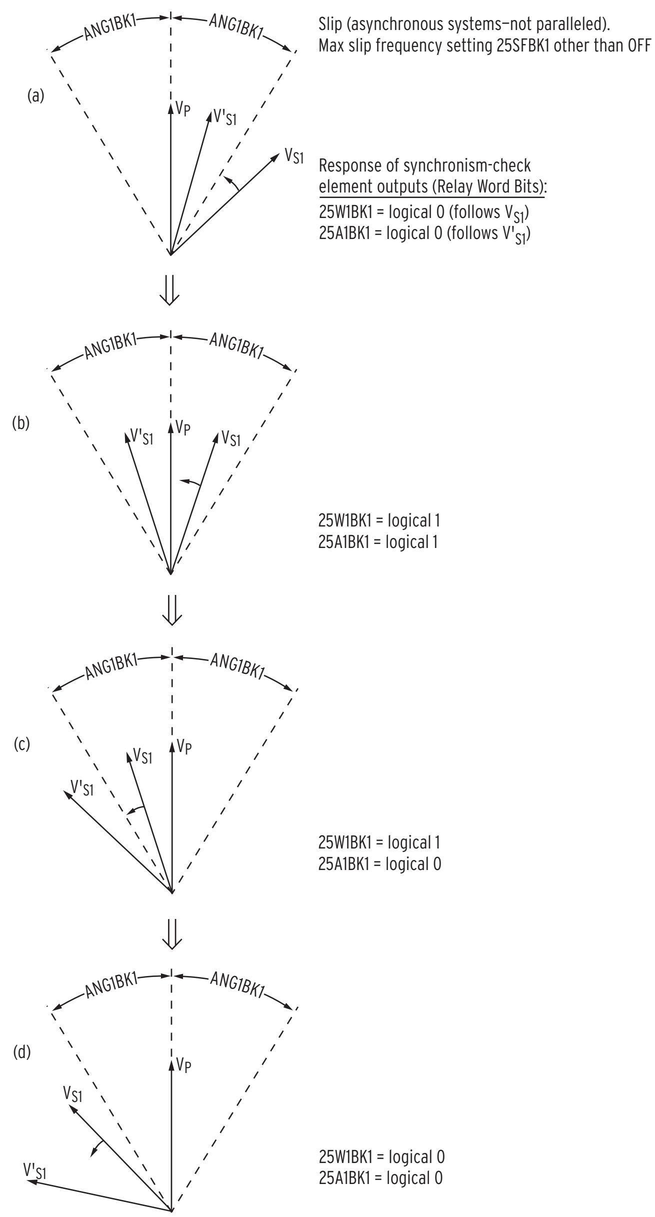


Figure 5.130 "Slip—With Compensation" Synchronism-Check Element Output Response

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay for synchronism check to account for this added delay.

Element 25A1BK1 follows V'_{S1}. With setting 25SFBK1 (maximum slip frequency) set to other than OFF, the relay calculates V'_{S1} derived from V_{S1}. Phasor V'_{S1} leads V_{S1} by an angle described by *Equation 5.33*:

$$\text{angle} = \frac{(f_{S1} - f_P)\ \text{slip cycle}}{s \bullet \dfrac{60\ \text{cyc}}{s}} \bullet \frac{360°}{\text{slip cycle}} \bullet \text{TCLSBK1 (cyc)}$$

Equation 5.33

From *Equation 5.33* note that the angle between V_{S1} and V'_{S1} increases for a greater slip between V_{S1} and V_P (f_{S1}–f_P), a greater Circuit Breaker BK1 close time setting TCLSBK1, or both in combination.

For any case [(a), (b), (c), or (d)] in *Figure 5.130*, the location of V'_{S1} is the location of V_{S1} a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Consider, for example, issuing a close command to Circuit Breaker BK1. If case (b) in *Figure 5.130* represents the time at which the close command occurs, then V_{S1} is the normalized synchronism-check voltage source position at the instant the close is issued and V'_{S1} is the position of V_{S1} when Circuit Breaker BK1 actually closes.

Slip Frequency

If the slip frequency exceeds setting 25SFBK1, synchronism check cannot proceed via element output 25A1BK1. Synchronism check stops because element output 25A1BK1 deasserts to logical 0 for an out-of-range slip frequency condition, regardless of other synchronism-check conditions such as healthy voltage magnitudes.

Synchronism check remains possible (although not necessarily advantageous) if you use element output 25W1BK1 and the slip frequency exceeds setting 25SFBK1. Synchronism-check element 25W1BK1 does not measure slip. In this instance, synchronism check occurs (25W1BK1 is logical 1) when the phase angle difference between reference V_P and V_{S1} is less than angle setting ANG1BK1.

Synchronism-Check Element Output Effects

A contradiction seems to result from analysis of case (a) in *Figure 5.130*; it appears that element output 25A1BK1 should assert to logical 1 because V'_{S1} is within angle setting ANG1BK1. Note in this case, however, that V'_{S1} is approaching synchronism-check reference VP. This is where element output 25A1BK1 behaves differently than element output 25W1BK1, for setting 25SFBK1 set to some value other than OFF. As V'_{S1} approaches V_P, 25A1BK1 remains deasserted (equals logical 0) until the phase angle difference between reference V_P and V'_{S1} equals zero degrees.

At this zero degrees difference between V_P and V'_{S1} point, element output 25A1BK1 asserts to logical 1. We know the systems will truly be in synchronism (0 degrees between reference V_P and V_{S1}) a period later (this period is setting TCLSBK1, Circuit Breaker BK1 Close Time). Thus, if a close command occurs right at the instant that element output 25A1BK1 asserts to logical 1, then there will be a zero degree phase angle difference across Circuit Breaker BK1 when Circuit Breaker BK1 actually closes. Closing Circuit Breaker BK1 at a phase angle difference of 0 degrees between reference V_P and V'_{S1} minimizes system shock when you bring two asynchronous systems together.

Element output 25A1BK1 remains asserted to logical 1 as V'_{S1} moves away from reference V_P. When the phase angle difference between reference V_P and V'_{S1} is again greater than angle setting ANG1BK1, element output 25A1BK1 deasserts to logical 0.

Alternative Synchronism-Check Source 2 Settings

You can program alternative input sources for the synchronism-check function in the SEL-421. Alternative inputs give you additional flexibility to synchronize other portions of your power system.

The SELogic control equation ALTS2 determines when the relay uses alternate Synchronism-Check Voltage Source 2 in place of regular Synchronism-Check Voltage Source 2. When ALTS2 is logical 1, the relay substitutes alternative Synchronism-Check Voltage Source 2 (ASYNCS2) and corresponding settings AKS2M and AKS2A for the regular Synchronism-Check Voltage Source 2 values SYNCS2, KS2M, and KS2A. The result is a normalized synchronism-check voltage source V_{S2} derived from the alternative source.

Example 5.1

Figure 5.131 shows an extra circuit breaker (BK3) and a generator position added to the existing example system of *Figure 5.119*. You can monitor the voltage at the generator position by connecting a single-phase voltage to remaining voltage input VCZ (see *Figure 5.122*). Make setting ASYNCS2 := VCZ to designate this relay voltage input as the alternate synchronism-check voltage source.

ASYNCS2 := **VCZ**. Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)

For this new synchronism source voltage connection, adjust the source-to-reference magnitude ratio with setting AKS2M and the source-to-reference angle compensation with setting AKS2A, considering the settings for *Voltage Magnitude and Angle Compensation on page 5.163*.

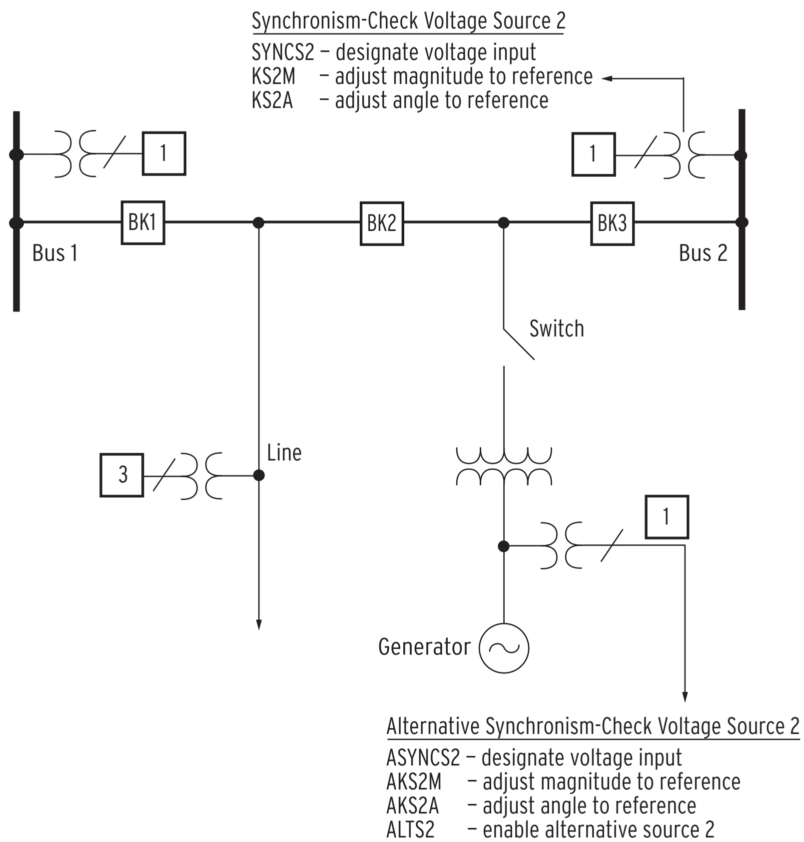


Figure 5.131 Alternative Synchronism-Check Source 2 Example and Settings

For example, in *Figure 5.131*, the Bus 2 voltage is the regular Synchronism-Check Voltage Source 2 for synchronism check across Circuit Breaker BK2. However, if Circuit Breaker BK3 is open and the generator switch is closed, the Synchronism-Check Voltage Source 2 transfers to the alternative Synchronism-Check Voltage Source 2 the voltage from the generator position.

Example 5.1

For circuit breaker status, make the following 52A auxiliary contact connections from the circuit breaker and switch to control inputs on the SEL-421:

- Circuit breaker BK3 to IN103
- Generator switch to IN104

These input connections are for this application example only; use relay inputs that are appropriate for your system.

Set the ALTS2 SELOGIC control equation to assert when Circuit Breaker BK3 is open and the generator switch is closed.

ALTS2 := **NOT IN103 AND IN104**. Alternative Synchronism Source 2 (SELOGIC Equation)

SECTION 6

Protection Applications Examples

This section provides detailed instructions for setting the SEL-421 Relay protection functions. Use these application examples to help familiarize yourself with the relay, and to assist you with your own protection settings calculations. The settings that are not mentioned in these examples do not apply.

Setting calculation guidelines are provided for the following applications:

- *230 kV Overhead Distribution Line Example on page 6.1*
- *500 kV Parallel Transmission Lines With Mutual Coupling Example on page 6.18*
- *345 kV Tapped Overhead Transmission Line Example on page 6.53*
- *EHV Parallel 230 kV Underground Cables Example on page 6.87*

Separate protection application examples are provided for the following functions:

- *Out-of-Step Logic Application Examples on page 6.119*
- *Autoreclose Example on page 6.137*
- *Autoreclose and Synchronism Check Example on page 6.141*
- *Circuit Breaker Failure Application Examples on page 6.151*
- *230 kV Tapped Transmission Line Application Example on page 6.170*

230 kV Overhead Distribution Line Example

Figure 6.1 shows a double-ended 230 kV line with SEL-421 protection at each end. This example explains how to calculate settings for the SEL-421 at Station S that protects the line between Stations S and R.

NOTE: The SEL-421-4 provides fast and secure tripping for the line segment but does not have the high-speed distance elements of the SEL-421-5.

This application example uses step-distance protection to provide high-speed tripping for faults in the first 80 percent of the line and time-delayed tripping for the last 20 percent.

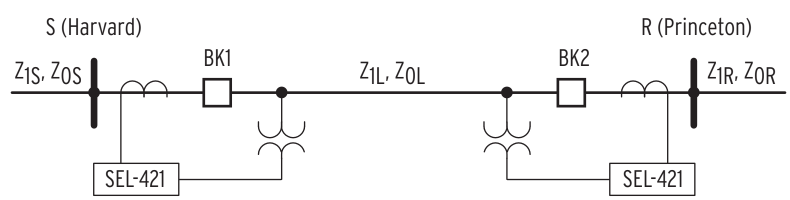


Figure 6.1 230 kV Overhead Transmission Line

Power System Data

Table 6.1 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay, using this example as a guide.

Table 6.1 System Data—230 kV Overhead Transmission Line

Parameter	Value
Nominal system line-to-line voltage	230 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line length	50 miles
Line impedances: Z_{1L}, Z_{0L}	39 Ω ∠84° primary, 124 Ω ∠81.5° primary
Source S impedances: $Z_{1S} = Z_{0S}$	50 Ω ∠86° primary
Source R impedances: $Z_{1R} = Z_{0R}$	50 Ω ∠86° primary
PTR (potential transformer ratio)	230 kV:115 V = 2000
CTR (current transformer ratio)	500:5 = 100
Phase rotation	ABC

Convert the power system impedances from primary to secondary, so you can later calculate protection settings. *Table 6.2* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{100}{2000} = 0.05$$

Equation 6.1

$$\begin{aligned} Z_{1L(secondary)} &= k \bullet Z_{1L(primary)} \\ &= (0.05 \bullet (39\ \Omega\ \angle 84°)) \\ &= 1.95\ \Omega\ \angle 84° \end{aligned}$$

Equation 6.2

Table 6.2 Secondary Impedances

Parameter	Value
Line impedances: Z_{1L}, Z_{0L}	1.95 Ω ∠84° secondary, 6.2 Ω ∠81.5° secondary
Source S impedances: $Z_{1S} = Z_{0S}$	2.5 Ω ∠86° secondary
Source R impedances: $Z_{1R} = Z_{0R}$	2.5 Ω ∠86° secondary

The maximum load current is 495 A primary.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- Two zones of mho distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, time-delayed tripping

- ➤ Inverse-time directional zero-sequence overcurrent backup protection
- ➤ Switch-onto-fault (SOTF) protection, fast tripping when the circuit breaker closes

Relay settings that are not mentioned in these examples do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- ➤ Station (SID)
- ➤ Relay (RID)
- ➤ Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **HARVARD — 230 kV**. Station Identifier (40 characters)

RID := SEL-421 **Relay**. Relay Identifier (40 characters)

Configure the SEL-421 for one circuit breaker.

NUMBK := **1**. Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1**. Breaker 1 Identifier (40 characters)

You can select both nominal frequency and phase rotation for the relay.

NFREQ := **60**. Nominal System Frequency (50, 60 Hz)

PHROT := **ABC**. System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N**. Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 6.2 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying; potential input VAZ is for synchronism check. *Synchronism Check on page 5.158* describes how to apply the synchronism-check function.

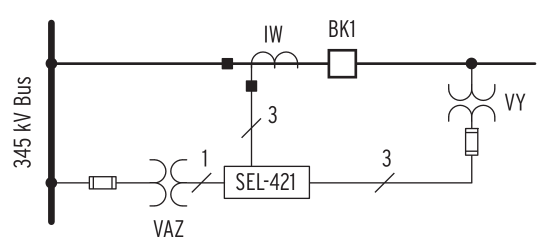


Figure 6.2 Circuit Breaker Arrangement at Station S

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that Circuit Breaker 1 is a three-pole trip circuit breaker.

BK1TYP := **3**. Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101**. A-Phase N/O Contact Input -BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX.

Use the Y potential input for line relaying and the Z potential input for synchronism check. Use the W current input for line relaying. The settings VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 6.2*).

CTRW := **100**. Current Transformer Ratio—Input W (1–50000)

PTRY := **2000**. Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115**. PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)

PTRZ := **2000**. Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **115**. PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)

Enter the secondary value of the positive-sequence impedance of the protected line. See *Table 6.2* for the secondary line impedances.

Z1MAG := **1.95**. Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **84.00**. Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line.

Z0MAG := **6.20**. Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **81.50**. Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y**. Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. For this example, set the length in miles.

LL := **50**. Line Length (0.10–999)

The fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase zones of mho phase (E21P), mho ground (E21MG), and quadrilateral ground (E21XG) distance protection. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use two zones of mho phase and ground-distance protection.

E21P := **2**. Mho Phase-Distance Zones (N, 1–5)

E21MG := **2**. Mho Ground-Distance Zones (N, 1–5)

E21XG := **N**. Quadrilateral Ground-Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault.

$$\begin{aligned} SIR &= \frac{|Z_{1S}|}{0.8 \bullet |Z_{1L}|} \\ &= \frac{2.5\ \Omega}{0.8 \bullet 1.95\ \Omega} \\ &= 1.603,\ SIR < 5 \end{aligned}$$

Equation 6.3

ECVT := **N**. CVT Transient Detection (Y, N)

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N**. Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground-distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y**. Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y**. Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N**. Out-of-Step (Y, N)

Do not enable the load-encroachment logic, as the minimum apparent load impedance is outside the mho phase-distance characteristics.

ELOAD := **N**. Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1**. Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N**. Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N**. Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if the step distance protection fails to operate.

E51S := **1**. Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO or AUTO2 and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO2**. Directional Control (Y, AUTO, AUTO2)

Communications-assisted tripping is not required.

ECOMM := **N**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential (LOP) to the distance relay, while unavoidable, is detectable. When the relay detects the loss-of-potential, the relay can block distance element operation, block or enable forward directional overcurrent elements, and issue an alarm for any true LOP condition.

NOTE: If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect an LOP when the circuit breaker(s) closes again.

Table 6.3 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward directional overcurrent elements. These forward directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1**. Loss-of-Potential (Y, Y1, N)

You do not need Advanced Settings for this application example.

EADVS := **N**. Advanced Settings (Y, N)

Phase-Distance Elements (21P)

Mho Phase-Distance Element Reach

Employ each zone of mho phase-distance protection as follows:

- ➤ Zone 1—Instantaneous underreaching tripping
- ➤ Zone 2—Time-delayed overreaching backup tripping

Zone 1 Phase-Distance Element Reach

Zone 1 phase-distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the transmission line. Errors in the current transformers and potential transformers, modeled transmission line data, and fault study data do not permit setting Zone 1 for 100 percent of the transmission line. If you set Zone 1 for 100 percent of the transmission line, unwanted tripping could occur for faults just beyond the remote end of the line.

Set Zone 1 phase-distance protection equal to 80 percent of the transmission line positive-sequence impedance.

Z1MP = 0.8 • Z1L = 1.56 Ω

Z1MP := **1.56**. Zone 1 Reach (OFF, 0.05-64 Ω secondary)

Zone 2 Phase-Distance Element Reach

Zone 2 phase-distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected line to make certain delayed tripping occurs for faults located in the last 20 percent of the line. Set Zone 2 phase-distance reach equal to 120 percent of the positive-sequence impedance of the transmission line.

Z2MP = 1.2 • Z1L = 2.34 Ω

Z2MP := **2.34**. Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Ground-Distance Elements (21MG)

Mho Ground-Distance Element Reach

Employ each zone of mho ground-distance protection as follows:

- ➤ Zone 1—Instantaneous underreaching tripping
- ➤ Zone 2—Time-delayed overreaching backup tripping

Zone 1 Mho Ground-Distance Element Reach

Zone 1 mho ground-distance reach must meet the same requirement as that for Zone 1 mho phase-distance protection; i.e., the reach setting can be no greater than 80 percent of the line.

Z1MG = 0.8 • Z1L = 1.56 Ω

Z1MG := **1.56**. Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground-Distance Element Reach

Zone 2 mho ground-distance reach must meet the same requirement as that for Zone 2 mho phase-distance protection; i.e., set the reach equal to 120 percent of the line.

Z2MG = 1.2Z1L = 2.34 Ω

Z2MG : = **2.34**. Zone 2 (OFF, 0.05–64 Ω secondary)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground-distance elements at the same reach if you set the reach equal per zone (for example, Z1MP = Z1MG). Ground-distance elements should measure fault impedance in terms of positive-sequence impedance only. The relay automatically calculates the setting for the Zone 1 zero-sequence current compensation factor when you set k0M1 to AUTO.

k0M1 := **AUTO**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

When you enter AUTO as the setting for k0M1, the relay calculates the zero-sequence current compensation as follows:

$$k01 = \frac{Z0MAG\angle Z0ANG - Z1MAG\angle Z1ANG}{3 \bullet Z1MAG\angle Z1ANG}$$

Equation 6.4

Zone 2 uses the same zero-sequence current compensation factor as that for Zone 1 because the Advanced Settings are disabled.

The relay displays the following values for k0M1 and k0A1:

k0M1 := **0.727**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **–3.65**. Zone 1 ZCS Factor Angle

Distance Element Common Time Delay

Set the appropriate timers Z1D and Z2D for both phase and ground-distance elements.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

You do not need to delay Zone 1 distance protection; it trips instantaneously.

Z1D := **0.000**. Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection, plus downstream circuit breaker operating time and a safety margin. A typical Zone 2 phase and ground-distance time delay setting is 20 cycles.

Z2D := **20.000**. Zone 2 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR, TRCOMM, and TRCOMMD) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground-distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

This is a three-pole tripping application example; confirm that the SOTF protection is for three-pole tripping.

ESPSTF := **N**. Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic such that the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period, the relay must sense that the positive-sequence voltage is greater than the VRSTPU setting multiplied by the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option, and leave the VRSTPU setting at default (0.8).

EVRST := **Y**. Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- ➤ A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- ➤ Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information, see *Switch-Onto-Fault Logic on page 5.117*.

Turn off 52AEND, 52A Pole-Open Time Delay.

52AEND := **OFF**. 52A Pole-Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000**. CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000**. Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command. Connect IN102 in parallel with the circuit breaker close coil.

CLSMON := **IN102**. Close Signal Monitor (SELOGIC Equation)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase-distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **13.29**. Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000**. Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1**. Level 1 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if the step distance protection fails to operate.

Select zero-sequence line current as the operating quantity.

NOTE: Use your company practices and philosophy when determining these settings.

51S1O := **3I0L**. 51S1 Operate Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The n in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

The relay measures 8.61 A secondary of $3I_0$ for a bolted single phase-to-ground fault at the remote terminal. Set the pickup to 20 percent of $3I_0$.

51S1P := **1.72**. 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (RF) is provided by 51S1P on a radial basis:

$$
\begin{aligned}
R_F &= \frac{PTR}{CTR} \bullet \frac{VNOMY/\sqrt{3}}{51S1P} \\
&= \left(\frac{2000}{100} \bullet \frac{115V/\sqrt{3}}{1.72A}\right) \\
&= 722\ \Omega
\end{aligned}
$$

Equation 6.5

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study. Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30-cycles for ground faults in front of the first downstream overcurrent element.

51S1C := **U3**. 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD := **1.96**. 51S1 Inverse-Time Overcurrent Time Dial (0.50–15)

Set the overcurrent element to emulate electromechanical reset, so the overcurrent element coordinates properly with electromechanical relays.

51S1RS := **Y**. 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC := **32GF**. 51S1 Torque Control (SELOGIC Equation)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground-distance elements and residual ground directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER equal to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground-distance elements and residual ground directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground-distance elements and residual ground directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV**. Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground-distance elements and residual ground directional overcurrent elements. Set E32IV equal to logical 1.

E32IV := **1**. Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Pole-Open Detection

The setting EPO offers two options for deciding what conditions signify an open pole, as listed in *Table 6.4*.

Table 6.4 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open-phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay can incorrectly declare LOP during a pole-open condition if there is charging current that exceeds the pole-open current threshold.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (e.g., 52AA1) from the circuit breaker deasserts and the open-phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52**. Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground-distance elements in case of pole scatter during closing of the circuit breaker.

3POD := **0.500**. Three-Pole Open Time Dropout Delay (0.000–60 cycles)

Trip Logic

This logic configures the relay for tripping. These settings consist of four categories:

- ➤ Trip equations
- ➤ Trip unlatch options
- ➤ Trip timers
- ➤ Three-pole tripping enable

Trip Equations

Set these two SELOGIC control equations for tripping:

- TR (unconditional)
- TRSOTF (SOTF)

TR

The TR SELOGIC control equation determines which protection elements cause the relay to trip unconditionally. You typically set all direct tripping and time-delayed protection elements in the SELOGIC control equation TR. Direct tripping and time-delayed protection elements include step distance protection elements, plus instantaneous and time-overcurrent protection elements.

Set TR equal to Zone 1 instantaneous protection (Z1T), time-delayed Zone 2 distance protection, and the inverse-time overcurrent element (51S1T). For information on setting 51S1T, see *Selectable Operating Quantity Time Overcurrent Element 1 on page 6.10*.

TR := **Z1T OR Z2T OR 51S1T**. Trip (SELOGIC Equation)

TRSOTF

The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Scheme on page 6.8*). Set instantaneous Zone 2 distance protection (Z2P and Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker 52A contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR

Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting, which asserts ULTR when you push the front-panel **TARGET RESET** pushbutton.

ULTR := **TRGTR**. Unlatch Trip (SELOGIC Equation)

TULO

Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 6.5* shows the four trip unlatch options for setting TULO.

Table 6.5 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole-Open Logic on page 5.25*.

TULO := **3**. Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration

The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000**. Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) equal to logical 1 to enable the SEL-421 for three-pole tripping only.

E3PT := **1**. Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker 1.

E3PT1 := **1**. Breaker 1 3PT (SELOGIC Equation)

Control Outputs

Main Board

OUT101 trips Circuit Breaker 1.

OUT101 := **3PT**.

Example Completed

This completes the application example describing configuration of the SEL-421 for step-distance protection of a 230 kV overhead transmission line. You can use this example as a guide when setting the relay for similar applications. Analyze your particular power system so you can properly determine your corresponding settings.

Relay Settings

Table 6.6 lists the protective relay settings for this example. Settings used in this example appear in boldface type.

Table 6.6 Settings for 230 kV Overhead TX Example (Sheet 1 of 4)

Setting	Prompt	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	HARVARD - 230 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR Z2P OR Z2G OR Z3P OR Z3G
Current and Voltage Source Selection (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration Settings (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	100
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000.0
VNOMY	Pt Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000.0
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	1.95
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.00
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	6.20
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	81.50

Table 6.6 Settings for 230 kV Overhead TX Example (Sheet 2 of 4)

Setting	Prompt	Entry
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	50
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	2
E21MG	Mho Ground Distance Zones (N, 1–5)	2
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N
ECVT	Cvt Transient Detection (Y, N)	N
ESERCMP	Series-compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-onto-fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y1, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./def.-time O/c Elements (N, 1–4)	1
E50G	Residual Ground Inst./def.-time O/c Elements (N, 1–4)	N
E50Q	Negative-sequence Inst./def.-time O/c Elements (N, 1–4)	N
E51S	Selectable Inverse-time O/c Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO, AUTO2)	AUTO2
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	N
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	N
Mho Phase-Distance Element Reach (Group)		
Z1MP	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	1.56
Z2MP	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	2.34
Mho Phase-Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Mho Ground-Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	1.56
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	2.34
Zero-Sequence Current Compensation Settings (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	AUTO
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)	–3.65
Ground Phase-Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF

Table 6.6 Settings for 230 kV Overhead TX Example (Sheet 3 of 4)

Setting	Prompt	Entry
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
SOTF Scheme Settings (Group)		
ESPSTF	Single Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 pu)	0.8
52AEND	52A Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
CLOEND	CLSMON or Single Pole Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Phase Instantaneous Overcurrent Pickup Settings (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	13.29
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Selectable Operating Quantity Time Overcurrent Element Settings (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	1.72
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15.00)	1.96
51S1RS	51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage And Current Enable (SELOGIC Equation)	1
Pole-Open Detection Settings (Group)		
EPO	Pole-Open Detection (52, V)	52
SPOD	Single-Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three-Pole Open Dropout Delay (0.000–60 cycles)	0.500
Trip Logic Settings (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	Z2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip – Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL

Table 6.6 Settings for 230 kV Overhead TX Example (Sheet 4 of 4)

Setting	Prompt	Entry
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip – Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Dir. Neg.-Seq./Residual O/C Single Pole Trip (Y, N)	N
TDUR1D	SPT Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	3PT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 3PT (SELOGIC Equation)	1
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	3PT

[a] Parameter *n* is 1 for BK1, 2 for BK2, and L for Line.

500 kV Parallel Transmission Lines With Mutual Coupling Example

Figure 6.3 shows double-ended overhead 500 kV parallel lines with SEL-421 protection at each end of the first circuit. These transmission lines have zero-sequence mutual coupling. This example explains how to calculate settings for the SEL-421 at Station S that protects Line 1 in *Figure 6.3* between Stations S and R.

This application example uses communications-assisted tripping with a digital communications channel to provide high-speed protection for faults along the 500 kV circuit. Distance protection is enabled.

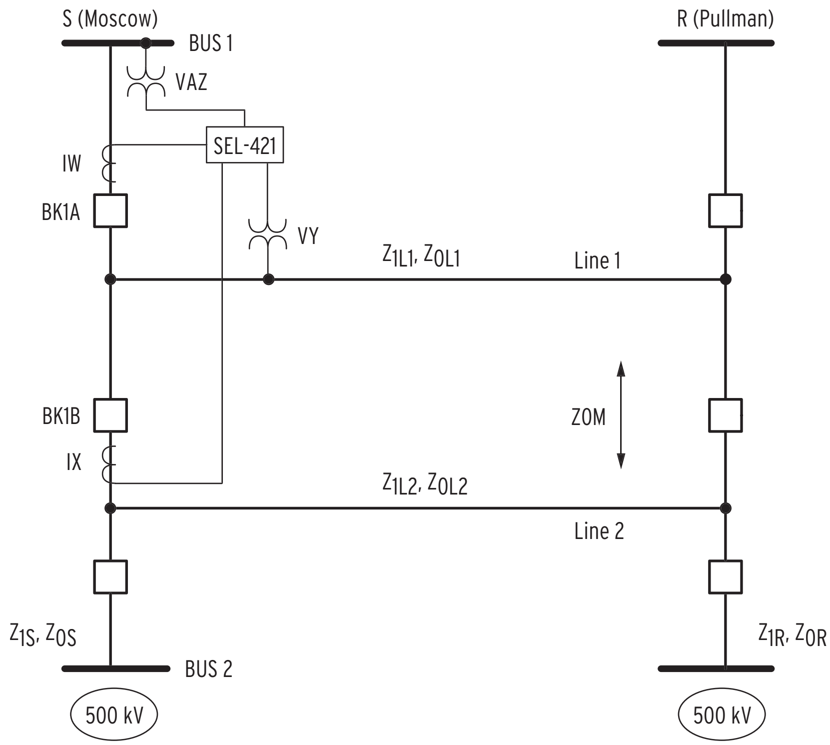


Figure 6.3 500 kV Parallel Overhead Transmission Lines

Power System Data

Table 6.7 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay using this example as a guide.

Table 6.7 System Data—500 kV Parallel Overhead Transmission Lines

Parameter	Value
Nominal system line-to-line voltage	500 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line length	75 miles
Line impedances: $Z_{1L1} = Z_{1L2}$ $Z_{0L1} = Z_{0L2}$	 44.78 Ω ∠87.6° primary 162.9 Ω ∠82.1° primary
Zero-sequence mutual coupling: Z_{0M}	 88.35 Ω ∠76.6° primary
Source S impedances: $Z_{1S} = Z_{0S}$	 50 Ω ∠88° primary
Source R impedances: $Z_{1R} = Z_{0R}$	 20 Ω ∠88° primary
PTR (Potential transformer ratio)	500 kV:111.11 V = 4500
CTR (Current transformer ratio)	2000:5 = 400
Phase rotation	ABC

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 6.8* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{400}{4500} = 0.089$$

Equation 6.6

$$\begin{aligned} Z_{1L1(\text{secondary})} &= k \bullet Z_{1L1(\text{primary})} \\ &= 0.089 \bullet (44.78\ \Omega\ \angle 87.6°) \\ &= 3.98\ \Omega\ \angle 87.6° \end{aligned}$$

Equation 6.7

Table 6.8 Secondary Impedances

Parameter	Value
Line impedances: $Z_{1L1} = Z_{1L2}$	3.98 Ω ∠87.6° secondary
$Z_{0L1} = Z_{0L2}$	14.48 Ω ∠82.1° secondary
Zero-sequence mutual coupling: Z_{0M}	7.86 Ω ∠76.6° secondary
Source S impedances: $Z_{1S} = Z_{0S}$	4.45 Ω ∠88° secondary
Source R impedances: $Z_{1R} = Z_{0R}$	1.78 Ω ∠88° secondary

The maximum load current is 1302 A primary and occurs when the parallel line is out of service.

Application Summary

This application is for two circuit breakers, single-pole tripping application with the following functions:

- POTT (permissive overreaching transfer tripping) scheme
- Three zones of phase (mho) and ground (mho and quadrilateral) distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, communications-assisted and time-delayed tripping
  - Zone 3, reverse-looking, prevents unwanted tripping during current reversals
- Inverse-time directional zero-sequence overcurrent backup protection
- SOTF protection, fast tripping when the circuit breaker closes

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)
- Circuit Breaker 2 (BID2)

You can enter as many as 40 characters per identification setting.

SID := **MOSCOW — 500 kV**. Station Identifier (40 characters)

RID := **SEL-421 Relay**. Relay Identifier (40 characters)

Configure the SEL-421 for two circuit breakers. This particular application uses two circuit breakers because the terminal is a circuit breaker-and-a-half configuration.

NUMBK := **2**. Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1**. Breaker 1 Identifier (40 characters)

BID2 := **Circuit Breaker 2**. Breaker 2 Identifier (40 characters)

You can select both the nominal frequency and phase rotation.

NFREQ := **60**. Nominal System Frequency (50, 60 Hz)

PHROT := **ABC**. System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for two circuit breakers in a circuit breaker-and-a-half configuration. Set ESS to 3.

ESS := **3**. Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

After you select 3 for setting ESS, the relay automatically sets LINEI, BK1I, and BK2I as follows:

LINEI := **COMB**. Line Current Source (IW, COMB)

BK1I := **IW**. Breaker 1 Current Source (IW, IX, NA)

BK2I := **IX**. Breaker 2 Current Source (IW, IX, NA)

In this application example Circuit Breaker BK1A is Breaker 1 in the relay settings and BK1B is Breaker 2 in the relay settings.

Figure 6.4 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and the combination of current inputs IW and IX for line relaying; potential input VAZ is for synchronism check. *Autoreclose and Synchronism Check Example on page 6.141* describes how to apply the synchronism-check function.

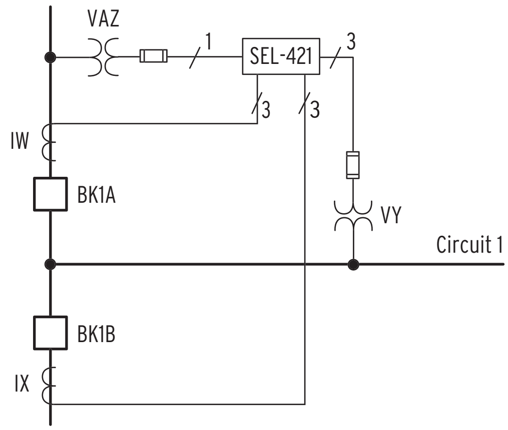


Figure 6.4 Circuit Breaker-and-a-Half Arrangement: Station S, Line 1

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that both circuit breakers are single-pole trip type.

BK1TYP := **1**. Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

BK2TYP := **1**. Breaker 2 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses normally open auxiliary contacts from the circuit breakers to determine whether each pole is opened or closed.

52AA1 := **IN101**. A-Phase N/O Contact Input—BK1 (SELOGIC Equation)

52AB1 := **IN102**. B-Phase N/O Contact Input—BK1 (SELOGIC Equation)

52AC1 := **IN103**. C-Phase N/O Contact Input—BK1 (SELOGIC Equation)

Circuit Breaker 2 Inputs

52AA2 := **IN104**. A-Phase N/O Contact Input—BK2 (SELOGIC Equation)

52AB2 := **IN105**. B-Phase N/O Contact Input—BK2 (SELOGIC Equation)

52AC2 := **IN106**. C-Phase N/O Contact Input—BK2 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX. Use the Y potential input for line relaying and the Z potential input for synchronism checks. Enable the voltage and current source selection so you can combine W and X current inputs for the line current. VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 6.4*).

CTRW := **400**. Current Transformer Ratio—Input W (1–50000)

CTRX := **400**. Current Transformer Ratio—Input X (1–50000)

PTRY := **4500**. Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **111**. PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

PTRZ := **4500**. Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **111**. PT Nominal Voltage (L–L)—Input Z (60–300 V secondary)

Enter the secondary value of the positive-sequence impedance of the protected line. See *Table 6.8* for the secondary line impedances.

Z1MAG := **3.98**. Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **87.6**. Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line.

Z0MAG := **14.48**. Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **82.1**. Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y**. Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **75.00**. Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance zones. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use three zones of phase and ground-distance protection.

E21P := **3**. Mho Phase-Distance Zones (N, 1–5)

E21MG := **3**. Mho Ground-Distance Zones (N, 1–5)

E21XG := **3**. Quadrilateral Ground-Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault. Double the source impedance magnitude because the relay measures half the total fault current when the parallel line is in service and the fault is located at the remote bus.

$$\begin{aligned} SIR &= \frac{2 \bullet |Z_{1S}|}{0.8 \bullet |Z_{1L}|} \\ &= \frac{2 \bullet 4.45\ \Omega}{0.8 \bullet 3.98\ \Omega} \\ &= 2.76,\ SIR < 5 \end{aligned}$$

Equation 6.8

ECVT := **N**. CVT Transient Detection (Y, N)

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N**. Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground-distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y**. Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y**. Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N**. Out-of-Step (Y, N)

Do not enable the load-encroachment logic, as the minimum apparent load impedance is outside the mho phase-distance characteristics.

ELOAD := **N**. Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1**. Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N**. Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N**. Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1**. Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO or AUTO2 and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO2**. Directional Control (Y, AUTO, AUTO2)

Use the two-channel POTT trip scheme (POTT2) to quickly clear faults internal to the protected line.

ECOMM := **POTT2**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page 5.28* for more information.

Table 6.9 lists the three choices for enabling LOP.

Table 6.9 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1**. Loss-of-Potential (Y, Y1, N)

Enable the Advanced Settings so you can properly set the zero-sequence compensation factors for the zero-sequence mutual coupling between the parallel transmission lines.

EADVS := **Y**. Advanced Settings (Y, N)

Phase-Distance Elements (21P)

Mho Phase-Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching direct tripping
- Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Phase-Distance Element Reach

Zone 1 phase-distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the transmission line. Errors in the current transformers, potential transformers, modeled transmission line data, and fault study data do not permit setting of Zone 1 for 100 percent of the transmission line. Unwanted tripping could occur for faults just beyond the remote end of the line if you set Zone 1 for 100 percent of the transmission line.

Set Zone 1 phase-distance protection equal to 80 percent of the transmission line positive-sequence impedance.

$$Z1MP = 0.8 \bullet Z1L1 = 3.18\ \Omega$$

Z1MP := **3.18**. Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase-Distance Element Reach

Zone 2 phase-distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected line. Set Zone 2 phase-distance reach to 120 percent of the positive-sequence impedance of the transmission line. This setting provides high-speed tripping via the communications channel for faults located in the last 20 percent of the line.

$$Z2MP = 1.2 \bullet Z1L1 = 4.78\ \Omega$$

Z2MP := **4.78**. Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase-Distance Element Reach

Zone 3 phase-distance protection must have adequate reach to prevent unwanted tripping during current reversals (this application example uses a permissive overreaching transfer tripping (POTT) scheme). Set the Zone 3 reach equal to Zone 2 and rely on the length of the protected transmission line for the safety margin. This setting makes the Zone 3 fault coverage greater than the Zone 2 fault coverage at the remote terminal.

$$Z3MP = Z2MP = 4.78\ \Omega$$

Z3MP := **4.78**. Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground-Distance Elements (21MG and 21XG)

Mho Ground-Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching direct tripping
- Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Mho Ground-Distance Element Reach

Zone 1 mho ground-distance reach must meet the same requirement as that for Zone 1 mho phase-distance protection; the reach setting should be no greater than 80 percent of the line.

$$Z1MG = 0.8 \bullet Z_{1L1} = 3.18\ \Omega$$

Z1MG := **3.18**. Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground-Distance Element Reach

Zone 2 mho and ground-distance reach must meet the same requirement as that for Zone 2 mho phase-distance protection; the reach setting is 120 percent of the line.

$$Z2MG = 1.2 \bullet Z1L1 = 4.78\ \Omega$$

Z2MG := **4.78**. Zone 2 (OFF, 0.05–64 Ω secondary)

Zone 3 Mho Ground-Distance Element Reach

Zone 3 mho ground-distance reach must meet the same requirement as that for Zone 3 mho phase-distance protection; it equals the Zone 2 reach.

$$Z3MG = Z2MG = 4.78\ \Omega$$

Z3MG := **4.78**. Zone 3 (OFF, 0.05–64 Ω secondary)

Quadrilateral Ground-Distance Element Reach

The reactive reach for each zone of quadrilateral ground-distance protection lies on the relay characteristic angle (Z1ANG), rather than on the ordinate (reactance) of the impedance plane (see *Figure 6.5*).

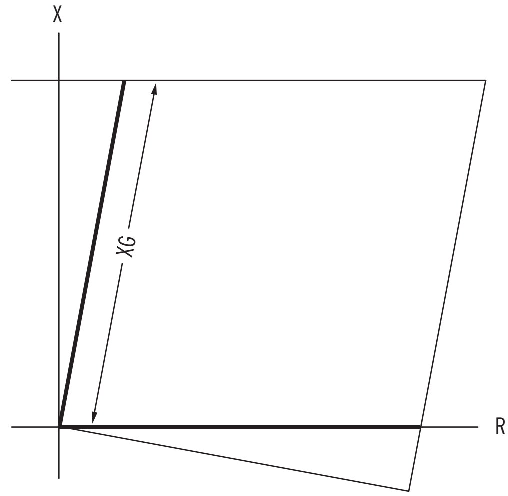


Figure 6.5 Quadrilateral Ground-Distance Element Reactive Reach Setting

Zone 1 Reactance

Zone 1 quadrilateral ground-distance reactance reach must meet the same requirement as that for Zone 1 mho phase-distance protection; the reach setting should be no greater than 80 percent of the line.

$XG1 = 0.8 \bullet Z_{1L1} = 3.18\ \Omega$

XG1 := **3.18**. Zone 1 Reactance (OFF, 0.05–64 Ω secondary)

Zone 1 Resistance

Find RG1 (Zone1 resistance) from the per-unit reach *m* of the Zone 1 reactance. Use *Equation 6.9*, which is *Equation 3* in *Appendix A—Quadrilateral Reactive Reach Versus Resistive Reach Setting Guideline* from the paper *Digital Communications for Power System Protection: Security, Availability, and Speed*. You can find a copy of this paper on the SEL website at selinc.com.

$$m = 1 - \frac{R}{X_{1L1} \bullet 20}$$

Equation 6.9

where:

m = per-unit reach of XG1

R = RG1, the Zone 1 resistance

X_{1L1} = positive-sequence transmission line reactance

XG1 is set at 80 percent of the transmission line (i.e., m = 0.8 per-unit); the positive-sequence reactance of the overhead transmission line X_{1L1} is 3.977 Ω secondary (from the rectangular form of Z_{1L1} in *Table 6.8*).

$$\begin{aligned} Z_{1L1} &= 3.98\Omega\ \angle 87.6^{\circ} \\ &= R_{1L1} + jX_{1L1} \\ &= 0.167 + j3.977 \end{aligned}$$

Equation 6.10

Rearrange *Equation 6.9* as follows to calculate RG1:

$$\begin{aligned} RG1 &= (1 - m) \cdot 20 \cdot X_{1L1} \\ &= (1 - 0.8) \cdot 20 \cdot 3.977\ \Omega \\ &= 15.9\ \Omega \end{aligned}$$

Equation 6.11

SEL recommends that you apply a safety margin of 50 percent because single pole tripping is enabled for this particular application.

$RG1 = 0.5 \cdot 15.9\ \Omega = 7.96\ \Omega$

RG1 := **7.96**. Zone 1 Resistance (0.05–50 Ω secondary)

Zone 2 Reactance

Zone 2 quadrilateral ground-distance reach must meet the same requirement as that for Zone 2 mho phase-distance protection; the reach setting is 120 percent of the line.

$XG2 = 1.2 \cdot Z_{1L1} = 1.2 \cdot 3.98 = 4.78\ \Omega$

XG2 := **4.78**. Zone 2 Reactance (OFF, 0.05–64 Ω secondary)

Zone 2 Resistance

Set Zone 2 quadrilateral resistive reach as follows:

$$\begin{aligned} RG2 &= XG2 \cdot \frac{RG1}{XG1} \\ &= 4.78\ \Omega \cdot \frac{7.96\ \Omega}{3.18\ \Omega} \\ &= 11.97\ \Omega \end{aligned}$$

Equation 6.12

RG2 := **12.00**. Zone 2 Resistance (0.05–50 Ω secondary)

Zone 3 Reactance

Zone 3 quadrilateral ground-distance reach must meet the same requirement as that for Zone 3 mho phase-distance protection; it equals Zone 2 reach.

$XG3 = XG2 = 4.78\ \Omega$

XG3 := **4.78**. Zone 3 Reactance (OFF, 0.05–64 Ω secondary)

Zone 3 Resistance

The Zone 3 quadrilateral resistive reach is also scaled by an additional factor of 125 percent to ensure that it has greater coverage than the remote Zone 2 during external resistive ground faults behind the local terminal.

$RG3 = 1.25 \cdot RG2 = 1.25 \cdot 12.00 = 15\ \Omega$

RG3 := **15.00**. Zone 3 Resistance (0.05–50 Ω secondary)

Quadrilateral Ground Polarizing Quantity

You must enter two final settings for quadrilateral ground-distance protection because Advanced Settings are enabled. These settings are XGPOL and TANGG.

XGPOL allows you to choose the polarizing quantity for the quadrilateral ground-distance protection. You can choose either negative- or zero-sequence current. Choose appropriately to reduce overreach and underreach of the reactance line. The reactance line can underreach or overreach during high-resistance single phase-to-ground faults. Nonhomogeneous negative- or zero-sequence networks can cause this underreach or overreach.

Figure 6.6 defines whether the negative- or zero-sequence network is homogeneous.

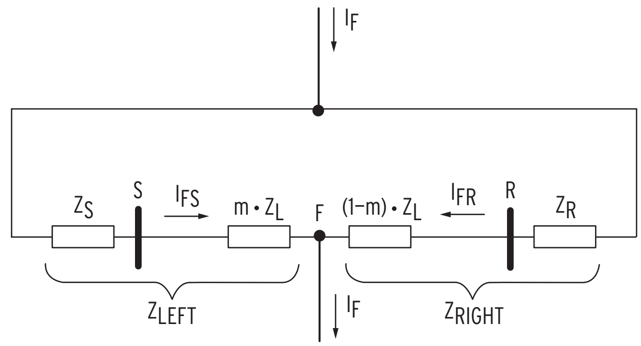


Figure 6.6 Definition of Homogeneous Network

Z_{LEFT} is the total impedance up to the fault (F) on the left-hand side, while Z_{RIGHT} is the total impedance up to the fault on the right-hand side. A network is homogeneous with respect to the particular fault location if *Equation 6.12* is satisfied:

$$\frac{X_{LEFT}}{R_{LEFT}} = \frac{X_{RIGHT}}{R_{RIGHT}}$$

Equation 6.13

Use *Equation 6.14* and *Equation 6.15* to determine the zero-sequence and negative-sequence homogeneity:

$$T_0 = \arg\left(\frac{Z_{0S} + Z_{0L} + Z_{0R}}{(1 - m) \cdot Z_{0L} + Z_{0R}}\right)$$

Equation 6.14

$$T_2 = \arg\left(\frac{Z_{1S} + Z_{1L} + Z_{1R}}{(1 - m) \cdot Z_{1L} + Z_{1R}}\right)$$

Equation 6.15

The values T_0 and T_2 represent how much the apparent fault impedance (Z_F) measured by relay tilts up or down (electrical degrees) because of the nonhomogeneity of the corresponding network for a fault at location *m* (see *Figure 6.7*).

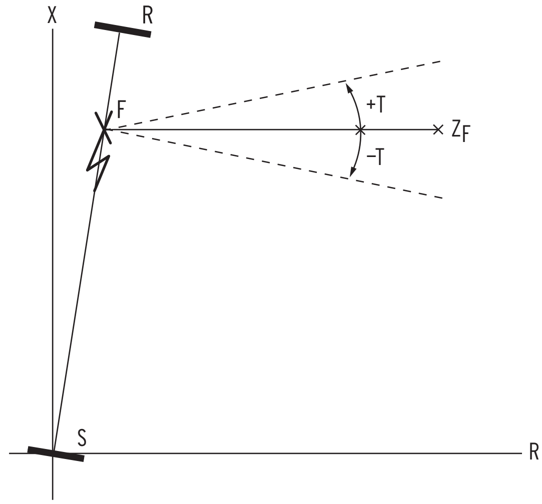


Figure 6.7 Tilt in Apparent Fault Impedance Resulting From Nonhomogeneity

Calculate T_0 and T_2 for a ground fault at the remote bus (i.e., *m* equals one per unit). The magnitude of whichever angle is greater indicates that the corresponding network is less homogeneous for a ground fault at the remote bus. The remote bus is selected for the fault location to prevent Zone 1 ground-distance overreach.

Table 6.15 provides the results of *Equation 6.14* and *Equation 6.15* for both the negative-sequence and zero-sequence networks. The negative-sequence network is more homogeneous than the zero-sequence network because the magnitude of T_2 is less than the magnitude of T_0.

Table 6.10 Tilt Resulting From Nonhomogeneity

Calculation	Angle
T_2	–0.2°
T_0	–4.1°

Select negative-sequence current flowing in the line as the polarizing quantity for the ground-distance quadrilateral reactance measurement.

XGPOL := **I2**. Quadrilateral Ground Polarizing Quantity (I2, IG)

Nonhomogeneous Correction Angle

TANGG is the nonhomogeneous angle setting that also helps prevent overreach or underreach by compensating the angle of the reactance line.

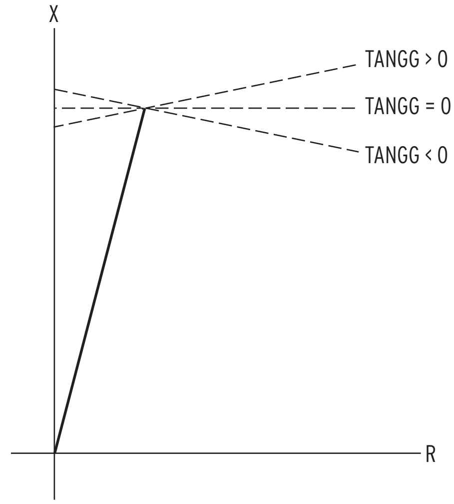


Figure 6.8 Nonhomogeneous Angle Setting

Set TANGG to prevent the Zone 1 quadrilateral ground-distance reactance measurement from overreaching for ground faults located at the remote bus. *Equation 6.15* (T_2) from Quadrilateral Ground Polarizing Quantity was approximately zero. Therefore, set TANGG equal to zero.

TANGG := **0**. Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground-distance elements at the same reach if you set the reach equal per zone (for example, Z1MP = Z1MG). Ground-distance elements should measure fault impedance in terms of positive-sequence impedance only.

The relay has three zero-sequence current compensation factors (k01, k0, and k0R). The Zone 1 ground-distance element has a dedicated zero-sequence current compensation factor (k01). Advanced Settings are enabled for this particular example; set two independent zero-sequence current compensation factors, one for forward-looking (k0) zones and one for reverse-looking (k0R) zones.

The SEL-421 ground-distance elements do not employ zero-sequence mutual coupling compensation. Zero-sequence mutual coupling can cause under/overreaching problems on both the faulted line and the nonfaulted line relaying terminals for parallel line applications employing ground-distance elements. Set the residual current compensation factors k0 and k0R appropriately to compensate for the effect of mutual coupling on parallel lines.

Apply the following expression for the Zone 1 zero-sequence current compensation factor.

$$\begin{aligned} k01 &= \frac{Z_{0L1} - Z_{1L1}}{3 \cdot Z_{1L1}} \\ &= \frac{14.48\ \Omega\ \angle 82.1° - 3.98\ \Omega\ \angle 87.6°}{3 \cdot 3.98\ \Omega\ \angle 87.6°} \\ &= 0.88\ \angle{-7.6°} \end{aligned}$$

Equation 6.16

k0M1 := **0.880**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **-7.60**. Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)

Zone 2 ground-distance elements tend to underreach for faults at the remote bus because residual current flows in the same direction for both parallel lines. Apply the following expression for the forward compensation factor so that Zone 2 ground-distance elements see ground faults at the remote bus when zero-sequence mutual coupling is a concern.

$$
\begin{aligned}
k0 &= \frac{Z_{0L1} - Z_{1L1} + Z_{0M}}{3 \cdot Z_{1L1}} \\
&= \frac{14.48\ \Omega\ \angle 82.1° - 3.98\ \Omega\ \angle 87.6° + 7.86\ \Omega\ \angle 76.6°}{3 \cdot 3.98\ \Omega\ \angle 87.6°} \\
&= 1.54\ \angle{-9°}
\end{aligned}
$$

Equation 6.17

k0M := **1.540**. Forward Zones ZSC Factor Magnitude (0.000–10)

k0A := **–9.0**. Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Set the reverse compensation factor equal to the forward compensation factor so that Zone 3 ground-distance protection has the same reach for external faults as the remote Zone 2 ground-distance protection.

K0MR := **1.540**. Reverse Zones ZSC Factor Magnitude (0.000–10)

k0AR := **–9.0**. Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Parallel Line Out-of-Service

When the parallel line is out-of-service, Zone 2 and 3 ground-distance elements overreach; these elements still coordinate properly during external faults because the elements overreach by the same amount. Consider using an alternate settings group if Zone 2 ground-distance protection provides time-delayed backup protection; Zone 2 ground-distance protection and downstream Zone 1 ground-distance protection could coordinate poorly.

Distance Element Common Time Delay

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Set the appropriate timers Z1D, Z2, and Z3D for both phase and ground-distance elements.

There is no need to delay Zone 1 distance protection since it trips instantaneously.

Z1D = **0.000**. Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection, downstream circuit breaker operating time, and a safety margin. A typical Zone 2 phase and ground-distance time delay setting is 20 cycles.

Z2D := **20.000**. Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Set Zone 3 for zero time delay.

Z3D := **0.000**. Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR, TRCOMM, and TRCOMMD) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground-distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

Single-pole tripping is applied for this particular example. The ability to single-pole trip when SOTF is enabled helps improve transient power system stability. The setting ESPSTF enables single-pole switch-onto-fault protection; the SOTF is armed following a single-pole reclose attempt. Enable this option.

ESPSTF := **Y**. Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period, the relay must sense that the positive-sequence voltage is greater than the VRSTPU setting multiplied by the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option, and leave VRSTPU = 0.8.

EVRST := **Y**. Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- ➤ A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- ➤ Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information, see *Switch-Onto-Fault Logic on page 5.117*.

Select the 52A option for this application and set the delay (52AEND) shorter than the shortest reclose open interval.

52AEND := **10.000**. 52A Pole-Open Time Delay (OFF, 0.000–16000 cycles)

Turn off CLOEND (CLSMON Delay) because this method is not used.

CLOEND := **OFF**. CLSMON or Single Pole-Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000**. Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase-distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **7.21**. Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000**. Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; place no conditions on torque control.

67P1TC := **1**. Level 1 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select zero-sequence line current as the operating quantity.

51S1O := **3I0L**. 51S1 Operate Quantity (Ia*n*, Ib*n*, Ic*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The *n* in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

The fault current ($3I_0$) measured by the relay for a bolted single phase-to-ground fault at the remote station with both lines in-service is 2.25 A secondary. (A remote end fault for the downstream relay gives a fault current of 1.22 A secondary.) Set the pickup to 30 to 50 percent of $3I_0$.

51S1P = **0.50**. 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) is provided by 51S1P on a radial basis:

$$R_F = \frac{PTR}{CTR} \cdot \frac{VNOMY / \sqrt{3}}{51S1P} = \frac{4500}{400} \cdot \frac{111.11\ V / \sqrt{3}}{0.50\ A} = 1443\ \Omega\ \text{primary}$$

Equation 6.18

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study.

Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30 cycles for ground faults in front of the first downstream overcurrent element.

51S1C = **U3**. 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD = **1.68**. 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset.

51S1RS = **Y**. 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC = **32GF**. 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F), or reverse-looking (R). Set Zone 3 distance elements reverse-looking, because these are blocking elements for the POTT trip scheme.

DIR3 := **R**. Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground-distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground-distance elements and residual ground directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground-distance elements and residual ground directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV**. Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground-distance elements and residual ground directional overcurrent elements. Set E32IV to logical 1.

E32IV := **1**. Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Pole-Open Detection

The setting EPO offers two options for deciding what conditions signify an open pole, as listed in *Table 6.11*.

Table 6.11 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open-phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied, because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay can incorrectly declare LOP during a pole-open condition if there is charging current that exceeds the pole-open current threshold.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (52AA1, for example) from the circuit breaker deasserts and the open-phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52**. Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

SPOD is the time delay on dropout after the Relay Word bit SPO deasserts. This time delay allows power system transients to settle after the open pole recloses, thereby stabilizing the ground-distance elements corresponding to that phase. If a three-pole open condition (3PO) asserts, SPOD resets immediately.

SPOD := **0.500**. Single-Pole Open Dropout Delay (0.000–60 cycles)

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground-distance elements in case of pole scatter during closing of the circuit breaker(s).

3POD := **0.500**. Three-Pole Open Dropout Delay (0.000–60 cycles)

POTT Trip Scheme

The permissive overreaching transfer trip (POTT) scheme is selected to provide high-speed tripping for faults along the protected line.

The POTT scheme logic consists of four sections:

- Current reversal guard logic
- Echo
- Weak infeed logic
- Permission to Trip Received

Current Reversal Guard Logic

You need current reversal guard for this parallel line application. When a reverse-looking element detects an external fault, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two conditions after a current reversal occurs and the reverse-looking elements drop out.

Set Z3RBD timer to accommodate for the following:

- Remote terminal R circuit breaker maximum opening time
- Maximum communications channel reset time
- Remote terminal R Zone 2 relay maximum reset time

Assume a circuit breaker opening time of 3 cycles, a communications channel reset time of 1 cycle, and remote Zone 2 relay reset time of 1 cycle. The sum of these times gives a conservative setting of 5 cycles for a three-cycle circuit breaker.

Z3RBD := **5.000**. Zone 3 Reverse Block Time Delay (0.000–16000 cycles)

Echo

If the local circuit breaker is open, or a weak infeed condition exists at the local terminal, the received permissive signal can echo back to the remote relay and cause it to issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive signal back to the remote terminal after specific conditions are satisfied. The echo logic includes timers for qualifying the permissive signal as well as timers for blocking the echo logic during specific conditions.

Use setting EBLKD (Echo Block Time Delay) to block the echo logic after dropout of local permissive elements. The recommended setting for the EBLKD timer is the sum of the following:

- Remote terminal R circuit breaker opening time
- Communications channel round trip time
- Safety margin

Assume a circuit breaker opening time of 3 cycles, a communications channel round trip time of 2 cycles, and a safety margin of 5 cycles. The sum of these three times gives a conservative setting of 10 cycles for a 3-cycle circuit breaker.

EBLKD := **10.000**. Echo Block Time Delay (OFF, 0.000–16000 cycles)

The echo time delay, setting ETDPU, makes certain that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. The delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults.

Because of the brief duration of noise bursts and the pickup time for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The echo time delay pickup (ETDPU) timer specifies the time a permissive trip signal must be present. The ETDPU setting depends upon your communications equipment, but a conservative setting for this timer is 2 cycles.

ETDPU := **2.000**. Echo Time Delay Pickup (OFF, 0.000–16000 cycles)

The setting EDURD (Echo Duration Time-Delay) limits the duration of the echoed permissive signal. Once an echo signal initiates, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This termination of the echo signal prevents the permissive trip signal from latching between the two terminals. Assume a 3-cycle circuit breaker at the remote terminal and a 1-cycle channel delay. The sum of these two is a setting of 4 cycles.

EDURD := **4.000**. Echo Duration Time Delay (0.000–16000 cycles)

Weak Infeed

The SEL-421 provides weak infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and causes the strong terminal to trip. The weak terminal trips by converting the echoed permissive signal to a trip signal after satisfaction of specific conditions.

This application does not require use of the weak-infeed feature.

EWFC := **N**. Weak Infeed Trip (Y, N, SP)

Permission to Trip Received

Two Relay Word bits identify receipt of permission to trip:

- **PT1**—General permission to trip received
- **PT3**—Three-pole permission to trip received

Refer to *Cross-Country Fault Identification on page 6.43* for a detailed explanation of this particular communications-assisted tripping scheme logic.

If PT1 is asserted, the relay can high-speed single-pole trip via the communications channel. However, if PT3 is asserted, the relay high-speed three-pole trips via the communications channel. This logic prevents the SEL-421 at Station S from three-pole tripping for cross-country faults (for example, A-Phase-to-ground fault on Line 1 and B-Phase-to-ground fault simultaneously on Line 2) beyond the reach of local Zone 1 ground-distance protection.

Direct tripping is also implemented for reliability and to decrease the overall tripping time of the SEL-421 at Station S for cross-country faults beyond the reach of local Zone 1 ground-distance protection. The logic PT1 and PT3 requires that the circuit breakers at Station R single-pole trip the external fault on line 2 first before the SEL-421 at Station S can single-pole trip for the case of cross-country faults beyond the reach of Zone 1 ground-distance protection at Station S. Direct tripping for cross-country faults is faster since the SEL-421 at Station S do not have to wait for the remote circuit breakers to single-pole trip.

PT1 := **RMB1A**. General Permissive Trip Received (SELOGIC Equation)

PT3 := **RMB2A**. Three-Pole Permissive Trip Received (SELOGIC Equation)

Trip Logic

Trip logic configures the relay for tripping. These settings consists of the following:

- Trip equations
- Trip unlatch options
- Single-pole trip options
- Trip timers
- Enable single-pole tripping

Trip Equations

Set these six SELOGIC control equations for tripping:

- TR (unconditional)
- TRCOMM/TRCOMMD (communications-assisted)
- TRSOTF (SOTF)
- DTA, DTB, and DTC (direct tripping)

The TR SELOGIC control equation determines which protection elements trip unconditionally. Set TR to Zone 1 instantaneous distance protection, Zone 2 time-delayed distance protection, and inverse time overcurrent protection for backup.

TR := **Z1T OR Z2T OR 51S1T**. Trip (SELOGIC Equation)

The TRCOMM/TRCOMMD SELOGIC control equation determines which elements trip via the communication-based scheme logic. In this example, only use the TRCOMM setting (i.e., set TRCOMMD = NA). Set instantaneous Zone 2 distance protection in the TRCOMM logic equation.

TRCOMM := **Z2P OR Z2G**. Communications-Assisted Trip (SELOGIC Equation)

The TRSOTF SELOGIC control equation defines which elements trip when SOTF protection is active. Set instantaneous overcurrent element 50P1 and Zone 2 distance protection in the TRSOTF SELOGIC control equation.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

The DTA, DTB, and DTC SELOGIC control equations receive single-pole direct transfer trips from the remote terminal whenever the remote SEL-421 single-pole trips. Use this tripping logic for reliability and to decrease SEL-421 operating time during cross-country faults beyond the reach of local Zone 1 ground-distance protection.

DTA := **RMB3A**. Direct Transfer Trip A-Phase (SELOGIC Equation)

DTB := **RMB4A**. Direct Transfer Trip B-Phase (SELOGIC Equation)

DTC := **RMB5A**. Direct Transfer Trip C-Phase (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output programmed for tripping after the circuit breaker auxiliary a contacts break the dc current. The SEL-421 provides three methods for unlatching control outputs programmed for tripping after occurrence of a protection trip:

- ULTR—following a protection trip, all three poles
- TOPD—Unlatch single-pole trip if another protection trip occurs during single-pole dead time
- TULO—following a protection trip, phase selective

ULTR

Use ULTR, the unlatch trip SELOGIC control equation, to unlatch all three poles. Use the default setting, to assert ULTR when you push the front-panel **TARGET RESET** pushbutton.

ULTR := **TRGTR**. Unlatch Trip (SELOGIC Equation)

TOPD

It is common practice to trip the two remaining phases after the single-pole open dead time, or if the single-pole autoreclose cycle does not reset, following the original single-pole trip. If the SEL-421 internal reclosing relay is being used, the E3PT, E3PT1, and E3PT2 settings in the trip logic should be set as shown in *Internal Recloser on page 6.9* and *Internal Recloser on page 6.25 in the SEL-400 Series Relays Instruction Manual*. See *Autoreclose Example on page 6.137* for information on using the SEL-421 reclosing relay.

To illustrate another way of using an external reclosing relay, this example will not use the SEL-421 Relay's autoreclose logic, rather, it uses the TOP (Trip During Open Pole) Relay Word bit to control the trip logic.

The timer setting TOPD determines the length of time for converting any subsequent single-pole trips to a three-pole trip following the original single-pole trip. Set this timer to the single-pole open dead time (30 cycles) and the reset time (three seconds) for the recloser plus a 5-cycle safety margin. See *Trip During Open-Pole Time Delay on page 5.139* in this manual and *External Recloser on page 6.10* and *External Recloser on page 6.26 in the SEL-400 Series Relays Instruction Manual* for additional information.

TOPD := **215.00**. Trip During Open Pole Time Delay (2.000–8000 cycles)

TULO

Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. You can select from among the four trip unlatch options in *Table 6.12*.

Table 6.12 Trip Unlatch Options

Option	Description
1	Unlatch the trip when the relay has detected that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay has detected that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay has detected that the conditions for the first two options are satisfied.
4	Do not run this logic.

Select the third option if a 52A contact is available because the relay uses both open-phase detection and status information from the circuit breaker(s). For information on the pole-open logic, see *Switch-Onto-Fault Logic on page 5.117*.

TULO := **3**. Trip Unlatch Option (1, 2, 3, 4)

Single-Pole Trip Options

You can program the SEL-421 to single-pole trip for Zone 2 ground-distance operations. Employ this method if you want single-pole tripping during ground faults within the last 20 percent of the protected line when the communications channel is not available. Do not enable this option.

Z2GTSP := **N**. Zone 2 Ground-Distance Time Delay SPT (Y, N)

The SEL-421 can assert a single-pole trip during high resistance ground faults such that the fault impedance lies outside of the ground-distance protection characteristics; the FIDS logic selects the faulted phase when residual directional overcurrent elements provide communications-assisted tripping. Do not enable this option.

67QGSP := **N**. Zone 2 Dir. Negative-Sequence/Residual Ground Overcurrent SPT (Y, N)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip durations and open-pole time delays.

Minimum Trip Duration

The minimum trip duration timer settings, TDUR1D and TDUR3D, determine the minimum length of time that Relay Word bits TPA1, TPA2, TPB1, TPB2, TPC1, TPC2, and 3PT assert. Use these timers to control the designated trip control outputs. The control outputs programmed for tripping close for the greater of the TDUR*n*D time, or the duration of the trip condition.

TDUR1D is the minimum trip duration following a single-pole trip. TDUR3D is the minimum trip duration following a three-pole trip. If another trip occurs during the single-pole open dead time following a single-pole trip, TDUR3D replaces TDUR1D.

A typical setting for both of these timers is 9 cycles.

TDUR1D := **9.000**. SPT Min Trip Duration Time Delay (2.000–8000 cycles)

TDUR3D := **9.000**. 3PT Min Trip Duration Time Delay (2.000–8000 cycles)

Enable Single-Pole Tripping

The relay contains both three-pole and single-pole tripping logic. The relay uses single-pole tripping logic if the setting for E3PT, Three-Pole Trip Enable SELOGIC control equation, equals logical 0. For this example, an external reclosing relay is present. Use the TOP (Trip During Open Pole) Relay Word bit and the IN107 control input, to enable single-pole tripping. If E3PT equals logical 0 (assigned control input is deasserted), single-pole tripping is enabled.

E3PT := **IN107 OR TOP**. Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1 and Circuit Breaker BK2. In this example, the same three-phase trip selection input is used for both breakers. See *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.9* and *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.25 in the SEL-400 Series Relays Instruction Manual* for details on the three-pole trip enable settings.

E3PT1 := **IN107**. Breaker 1 3PT (SELOGIC Equation)

E3PT2 := **IN107**. Breaker 2 3PT (SELOGIC Equation)

Control Outputs

Main Board

Use SELOGIC control equations to assign the control outputs for tripping.

Use the main board control outputs for tripping. The first three control outputs trip Circuit Breaker BK1A and the next three trip circuit breaker BK1B.

OUT101 := **TPA1**.

OUT102 := **TPB1**.

OUT103 := **TPC1**.

OUT104 := **TPA2**.

OUT105 := **TPB2**.

OUT106 := **TPC2**.

Cross-Country Fault Identification

Fault Identification

The SEL-421 provides two means of implementing simultaneous ground fault tripping logic for single-pole tripping applications in double-circuit tower applications. This particular example is based upon the POTT2 scheme, a 2-channel POTT scheme. The implementation of this logic uses the simplicity and flexibility of SELOGIC control equations and MIRRORED BITS communications.

For this particular example, when a cross-country fault occurs close in to Station R, the local line protection correctly identifies the faults as single phase-to-ground; Line 1 protection identifies a Zone 1 A Phase-to-ground fault, while Line 2 protection identifies a Zone 1 B Phase-to-ground fault. Tripping for both lines at Station R is instantaneous and independent from the communications channel. *Figure 6.9* illustrates a cross-country fault close in to Station R (that is, beyond Zone 1 reach with respect to Station S).

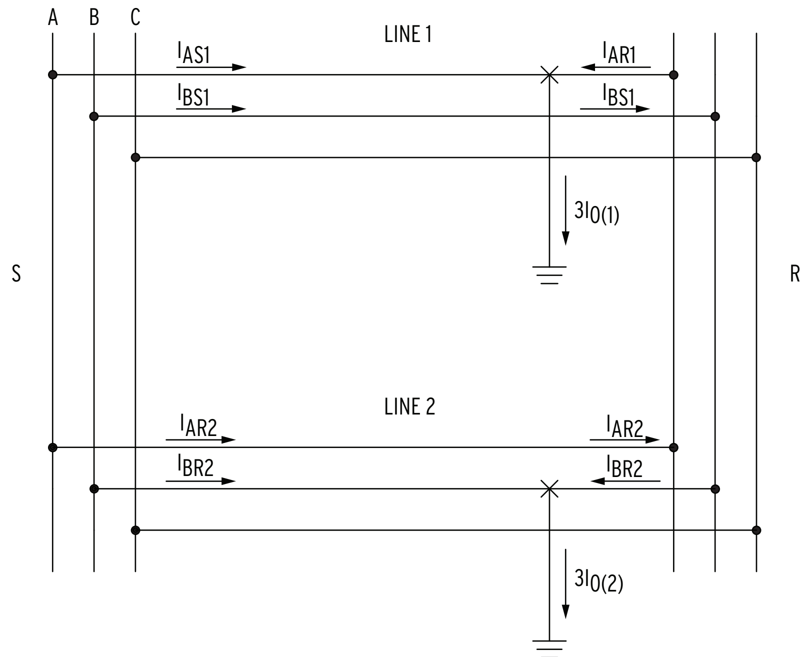


Figure 6.9 Current Distribution During Cross-Country Fault

The difficulty arises with the line protection at Station S prior to a circuit breaker opening at Station R (after the circuit breakers open at Station R, the line protection at Station S identifies each fault as single phase-to-ground). This difficulty diminishes as the fault location moves closer to Station S. At Station S, the relays for Lines 1 and 2 misidentify the fault as ABG. If the permissive trip signal from Station R arrives while an overreaching Zone 2 phase-to-phase distance element at Station S is picked up, an undesirable three-pole trip results for both lines at Station S. (An ABG fault involves more than one phase, so protection for this fault must use three-pole tripping.)

To avoid this, you must make provisions for identifying the mismatch in fault type identification between the line protection at both ends of the line. In doing so, you avoid three-pole tripping both lines at Station S while single-pole tripping both lines at Station R.

Transmit Equations

Overcoming this mismatch requires at least two communications channels, one for transmitting three-pole trip permission (KEY3) and another for transmitting all permissive trips (KEY1). The relay at Station S must receive both permissive signals before three-pole tripping via the communications scheme. Thus, the POTT2 scheme determines if there is agreement at both line ends on fault type declaration. The relay checks fault type agreement by comparing the local fault identification with the type of received permissive trip signal.

The Zone 2 phase-distance (Z2P) element asserts KEY1 and KEY3. The Zone 2 ground-distance (Z2G) element asserts KEY1 only. Use two separate signals, rather than one, to send permission:

- KEY1—Transmit General Permissive Trip
- KEY3—Transmit Three-Phase Permissive Trip

Assign these two permissive signals to the first two Transmit MIRRORED BITS signals.

TMB1A := **KEY1 OR EKEY AND RMB1A**. Transmit MIRRORED BITS 1A (SELOGIC Equation)

TMB2A := **KEY3 OR EKEY AND RMB2A**. Transmit MIRRORED BITS 2A(SELOGIC Equation)

Receive Equations

Any type of fault detected within Zone 2 at Station R transmit KEY1, which is converted to PT1 at Station S through the MIRRORED BITS pair, TMB1A and RMB1A. The SEL-421 at Station S can high-speed single-pole trip via the communications channel if the fault type is identified as single-phase and single-pole tripping is enabled, regardless of fault selection at the remote terminal.

Figure 6.10 is a simplified logic diagram for the communications-assisted tripping logic.

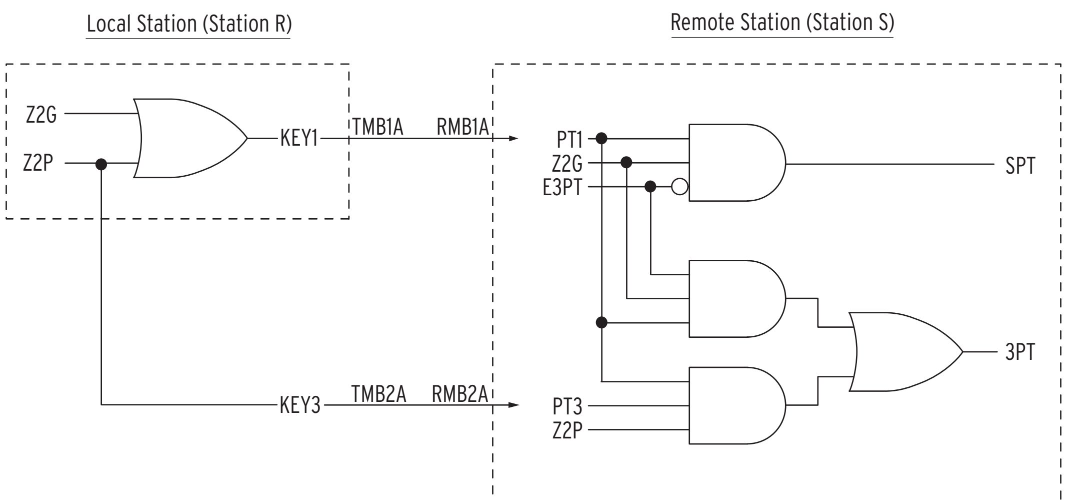


Figure 6.10 Simplified POTT Scheme KEY1/KEY3 Logic

If the SEL-421 at Station S detects a multiphase fault in Zone 2, it can high-speed three-pole trip only if both PT1 and PT3 assert. PT3 confirms that the remote terminal (Station R) has also identified the fault type as multiphase. If the SEL-421 detects a multiphase fault in Zone 2 and receives only PT1, like in the cross-country fault situation on a parallel-line system, the relay delays a trip until the permissive signal received agrees with the fault type detected locally. The fault type detected by the SEL-421 at Station S changes from a multiphase to a single-phase ground fault after Station R clears the external fault on line 2. The relay can then single-pole trip via the received PT1. Note that a desired single-pole trip at Station S occurs only after Station R clears the external fault on line 2. To avoid a delayed trip in a cross-country fault situation, you may choose the three-channel POTT scheme (POTT3), as described below.

Two Relay Word bits identify receipt of trip permission:

- PT1—General permission to trip received
- PT3—Three-pole permission to trip received

Assign PT1 to the corresponding Received MIRRORED BITS signals.

PT1 := **RMB1A**. General Permissive Trip Received (SELOGIC Equation)

PT3 := **RMB2A**. Three-Pole Permissive Trip Received (SELOGIC Equation)

Three-Channel POTT Scheme, POTT3

In a cross-country fault situation of a mutually coupled parallel-line system, a relay using the one-channel POTT scheme will trip all three poles at the remote-to-fault terminal. This is because the relay at the remote terminal sees a multi-phase fault and receives the only permissive trip signal. Both transmission lines will be out of service if even a single-phase ground fault occurs on each circuit.

The two-channel POTT scheme retains the much-desired single-pole tripping in the event of cross-country faults. However, the relay at the remote terminal has to delay a single-pole trip until the external fault is cleared at the close-in terminal. This application example uses direct transfer trips described below to compliment the two-channel POTT scheme and reduce the single-pole trip delay to a minimum.

As an alternative to the two-channel POTT scheme with direct transfer trips, you may use the phase-segregate three-channel POTT scheme (POTT3) to correctly single-pole trip without a delay in the event of cross-country faults. In the previous cross-country fault example, the SEL-421 on line 1 at Station R will transmit KEYA to the relay at Station S, which converts it to PTA, a permissive A-Phase trip signal. The relay then combines a locally detected Zone 2 phase-distance element with the received PTA and trips A-Phase only without a time delay. Because the direct transfer trips are not necessary in the three-channel POTT scheme, the total communications channels used would be three.

For three-channel POTT applications, the following equations apply:

ECOMM := **POTT3**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

TMB1A := **KEYA**. Transmit MIRRORED BITS 1A (SELOGIC Equation)

TMB2A := **KEYB**. Transmit MIRRORED BITS 2A (SELOGIC Equation)

TMB3A := **KEYC**. Transmit MIRRORED BITS 3A (SELOGIC Equation)

PTA := **RMB1A**. A-Phase Permissive Trip Received (SELOGIC Equation)

PTB := **RMB2A**. B-Phase Permissive Trip Received (SELOGIC Equation)

PTC := **RMB3A**. C-Phase Permissive Trip Received (SELOGIC Equation)

Relay Word bit KEY is general permission to trip.

Single-Line Applications

For single-line applications, the following equations apply:

ECOMM := **POTT**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

TMB1A := **KEY**. Transmit MIRRORED BITS 1A (SELOGIC Equation)

PT1 := **RMB1A**. General Permissive Trip Received (SELOGIC Equation)

Relay Word bit KEY is general permission to trip.

Direct Tripping

Direct tripping is faster because the SEL-421 Relays at Station S do not have to wait for the circuit breakers at Station R to single-pole trip first; that is, the SEL-421 Relays at Station R single-pole direct transfer trip the SEL-421 Relays at Station S during crossing country faults beyond the reach of Zone 1 ground-distance protection at Station S.

Transmit Equations

TMB3A := **TPA AND NOT 3PT**. Transmit MIRRORED BITS 3A (SELOGIC Equation)

TMB4A := **TPB AND NOT 3PT**. Transmit MIRRORED BITS 4A (SELOGIC Equation)

TMB5A := **TPC AND NOT 3PT**. Transmit MIRRORED BITS 5A (SELOGIC Equation)

Receive Equations

DTA := **RMB3A**. Direct Transfer Trip A-Phase (SELOGIC Equation)

DTB := **RMB4A**. Direct Transfer Trip B-Phase (SELOGIC Equation)

DTC := **RMB5A**. Direct Transfer Trip C-Phase (SELOGIC Equation)

Example Completed

This completes the application example that describes how to set the SEL-421 for communications-assisted protection of 500 kV parallel overhead transmission lines with zero-sequence mutual coupling. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.13 lists all protective relay settings for this example. Settings used in this example appear in boldface type.

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 1 of 7)

Setting	Prompt	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	MOSCOW - 500 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	2
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
BID2	Breaker 2 Identifier (40 characters)	Circuit Breaker 2
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition (SELOGIC Equation)	50P1 OR 51S1 OR Z2P OR Z2G OR Z3P OR Z3G

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 2 of 7)

Setting	Prompt	Entry
Current and Voltage Source Selection (Global)		
ESS	Current And Voltage Source Selection (Y, N, 1, 2, 3, 4)	3
LINEI	Line Current Source (IW, COMB)	COMB
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW
BK2I	Breaker 2 Current Source (IX, COMB, NA)	IX
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
EB2MON	Breaker 2 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	1
BK2TYP	Breaker 2 Trip Type (Single Pole = 1, Three Pole = 3)	1
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
52AB1	B-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN102
52AC1	C-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN103
Breaker 2 Inputs (Breaker Monitoring)		
52AA2	A-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN104
52AB2	B-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN105
52AC2	C-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN106
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	400
CTRX	Current Transformer Ratio—Input X (1–50000)	400
PTRY	Potential Transformer Ratio—Input Y (1–10000)	4500.0
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	111
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	4500.0
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	111
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	3.98
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	87.6
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	14.48
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	82.1
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	75

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 3 of 7)

Setting	Prompt	Entry
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	3
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	3
ECVT	Cvt Transient Detection (Y, N)	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-Of-Step (Y, Y1, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Residual Ground Inst./Def.-Time O/C Elements (N, 1–4)	N
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	N
E51S	Selectable Inverse-Time O/C Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO, AUTO2)	AUTO2
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB2, DCUB2)	POTT2
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	N
EBFL2	Breaker 2 Failure Logic (N, 1, 2, Y1, Y2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N, Y1, Y2)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	Y
VMEMC	Memory Voltage Control (SELOGIC equation)	0
EFID	Enable FID Logic (Y, N)	Y
Z50P1	Zone 1 Phase Fault Detector (0.50–170.00 A, secondary)	0.5
Z50G1	Zone 1 Ground Fault Detector (0.50–100.00 A, secondary)	0.5
Mho Phase-Distance Element Reach (Group)		
Z1MP	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	3.18
Z2MP	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	4.78
Z3MP	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	4.78
Mho Phase-Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 4 of 7)

Setting	Prompt	Entry
Mho Ground-Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	3.18
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	4.78
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary)	4.78
Quadrilateral Ground-Distance Element Reach (Group)		
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary)	3.18
RG1	Zone 1 Resistance (0.05–50 Ω secondary)	7.96
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary)	4.78
RG2	Zone 2 Resistance (0.05–50 Ω secondary)	12.00
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary)	4.78
RG3	Zone 3 Resistance (0.05–50 Ω secondary)	15.00
XGPOL	Quadrilateral Ground Polarizing Quantity (I2, IG)	I2
TANGG	Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)	0.0
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.880
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)	–7.6
k0M	Forward Zones ZSC Factor Magnitude (0.000–10)	1.540
k0A	Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)	–9.0
k0MR	Reverse Zones ZSC Factor Magnitude (0.000–10)	1.540
k0AR	Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)	–9.0
Ground-Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000
SOTF Scheme Settings		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	Y
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 pu)	0.60–1.00 pu
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	10.000
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	OFF
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	NA

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 5 of 7)

Setting	Prompt	Entry
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	7.21
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	0.50
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15)	1.68
51S1RS	51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Direction Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage And Current Enable (SELOGIC Equation)	1
Pole-Open Detection (Group)		
EPO	Pole-Open Detection (52, V)	52
SPOD	Single-Pole Open Dropout Delay (cycles)	0.500
3POD	Three-Pole Open Dropout Delay (cycles)	0.500
POTT Trip Scheme (Group)		
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N, SP)	N
27PWI	Weak Infeed Phase Undervoltage Pickup (1.0–200 V secondary)	47.0
27PPW	Weak Infeed Phase-to-Phase Undervoltage Pickup (1.0–300 V secondary)	80.0
59NW	Weak Infeed Zero-Sequence Overvoltage Pickup (1.0–200 V secondary)	5.0
PT1	General Permissive Trip Received (SELOGIC Equation)	RMB1A
PT3	Three-Pole Permissive Trip Received (SELOGIC Equation)	RMB2A

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 6 of 7)

Setting	Prompt	Entry
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	Z2G OR Z2P
TRCOMMD	Dir. Element Comms.-Assisted Trip (SELOGIC Equation)	NA
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	Z2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	RMB3A
DTB	Direct Transfer Trip B-Phase (SELOGIC control equation)	RMB4A
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	RMB5A
BK1MTR	Manual Trip—Breaker 1 (SELOGIC Equation)	OC1 OR PB7_PUL
BK2MTR	Manual Trip—Breaker 2 (SELOGIC Equation)	OC2 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip—Breaker 1 (SELOGIC Equation)	NOT (52AA1AND 52AB1 AND 52AC1)
ULMTR2	Unlatch Manual Trip—Breaker 2 (SELOGIC Equation)	NOT (52AA2 AND 52AB2 AND 52AC2)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	215.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Directional Neg.-Seq./Residual Ground Overcurrent SPT (Y, N)	N
TDUR1D	SPT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
TDUR3D	3PT Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	IN107 OR TOP
E3PT1	Breaker 1 3PT (SELOGIC Equation)	IN107
E3PT2	Breaker 2 3PT (SELOGIC Equation)	IN107
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	TPA1
OUT102	(SELOGIC Equation)	TPB1
OUT103	(SELOGIC Equation)	TPC1
OUT104	(SELOGIC Equation)	TPA2
OUT105	(SELOGIC Equation)	TPB2
OUT106	(SELOGIC Equation)	TPC2

Table 6.13 Settings for 500 kV Parallel TX Example (Sheet 7 of 7)

Setting	Prompt	Entry
MIRRORED BITS Transmit Equations (Outputs)		
TMB1A	(SELOGIC Equation)	KEY1 OR EKEY AND RMB1A
TMB2A	(SELOGIC Equation)	KEY3 OR EKEY AND RMB2A
TMB3A	(SELOGIC Equation)	TPA AND NOT 3PT
TMB4A	(SELOGIC Equation)	TPB AND NOT 3PT
TMB5A	(SELOGIC Equation)	TPC AND NOT 3PT
TMB6A	(SELOGIC Equation)	NA
TMB7A	(SELOGIC Equation)	NA
TMB8A	(SELOGIC Equation)	NA
TMB1B	(SELOGIC Equation)	NA
TMB2B	(SELOGIC Equation)	NA
TMB3B	(SELOGIC Equation)	NA
TMB4B	(SELOGIC Equation)	NA
TMB5B	(SELOGIC Equation)	NA
TMB6B	(SELOGIC Equation)	NA
TMB7B	(SELOGIC Equation)	NA
TMB8B	(SELOGIC Equation)	NA

[a] Parameter *n* is 1 for BK1, 2 for BK2, and L for Line.

345 kV Tapped Overhead Transmission Line Example

Figure 6.11 shows a three-ended 345 kV transmission line with SEL-421 protection at Stations S and R. A tap midway between Stations S and R feeds an autotransformer. This example explains how to calculate settings for the SEL-421 at Station S that protects the 345 kV circuit between Substation S, Substation R, and the autotransformer. The 345 kV and 138 kV windings of the autotransformer are wye-connected and solidly grounded. The tertiary voltage windings are delta-connected and lag the other windings by 30 degrees.

This application example uses communications-assisted tripping with PLC (power line carrier) communication to provide high-speed protection for faults along the 345 kV circuit. The relay uses distance elements and residual ground directional overcurrent elements in this protection scheme.

Another SEL-421 located on the 138 kV side of the autotransformer blocks high-speed tripping at Stations S and R for faults on the 138 kV side of the autotransformer.

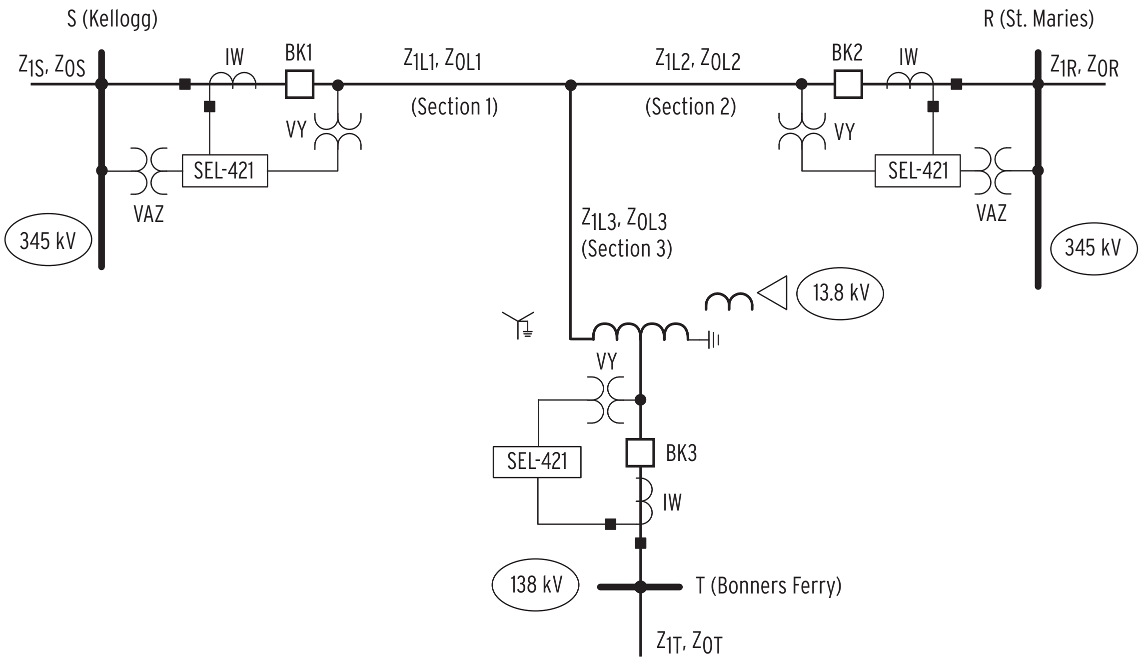


Figure 6.11 345 kV Tapped Overhead Transmission Line

Power System Data

Table 6.14 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay using this example as a guide.

Table 6.14 System Data—345 kV Tapped Overhead Transmission Line (Sheet 1 of 2)

Parameter	Value
EHV nominal system line-to-line voltage (transformer primary)	345 kV
HV line-to-line voltage (transformer secondary)	138 kV
MV line-to-line voltage (transformer tertiary)	13.8 kV
Nominal relay current	5 A secondary
Nominal frequency	60 Hz
Line lengths[a] S–t (Section 1) t–R (Section 2) t–T (Section 3)	 50 miles 50 miles 75 miles
Line impedances: $Z_{1L1} = Z_{1L2}$ $Z_{0L1} = Z_{0L2}$ Z_{1L3} Z_{0L3}	 29.67 Ω ∠84.7° primary 96.65 Ω ∠73° primary 44.5 Ω ∠84.7° primary 144.98 Ω ∠73° primary
Transformer impedances: X_{HM} X_{ML} X_{HL}	 8% on 500 MVA; 1.6% on 100 MVA 10% on 25 MVA; 40% on 100 MVA 15% on 25 MVA; 60% on 100 MVA
Source S impedances: $Z_{1S} = Z_{0S}$	10 Ω ∠87° primary
Source R impedances: $Z_{1R} = Z_{0R}$	35 Ω ∠87° primary

Table 6.14 System Data—345 kV Tapped Overhead Transmission Line (Sheet 2 of 2)

Parameter	Value
Source T impedances: $Z_{1T} = Z_{0T}$	0.656 Ω ∠87° per unit
PTR (potential transformer ratio)	345 kV:115 V = 3000.0
CTR (current transformer ratio)	1000:5 = 200
Phase rotation	ABC

[a] Parameter *t* is the tap point on the 345 kV line; S and R are terminals at the ends of the 345 kV line (see *Figure 6.11*).

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 6.15* lists the corresponding secondary impedances. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{200}{3000} = 0.067$$

Equation 6.19

$$\begin{aligned} Z_{1L1(\text{secondary})} &= k \bullet Z_{1L1(\text{primary})} \\ &= (0.067 \bullet (29.67\Omega \angle 84.7°)) \\ &= 2\Omega \angle 84.7° \end{aligned}$$

Equation 6.20

Table 6.15 Secondary Impedances

Parameter	Value
Line impedances: $Z_{1L1} = Z_{1L2}$ $Z_{0L1} = Z_{0L2}$ Z_{1L3} Z_{0L3}	 2 Ω ∠84.7° secondary 6.44 Ω ∠73° secondary 3 Ω ∠84.7° secondary 9.65 Ω ∠73° secondary
Transformer impedances: X_{HM} X_{ML} X_{HL}	 8% @ 500 MVA; 1.6% on 100 MVA 10% @ 25 MVA; 40% on 100 MVA 15% @ 25 MVA; 60% on 100 MVA
Source S impedances: $Z_{1S} = Z_{0S}$	 0.67 Ω ∠87° secondary
Source R impedances: $Z_{1R} = Z_{0R}$	 2.33 Ω ∠87° secondary
Source T impedances: $Z_{1T} = Z_{0T}$	 0.656 Ω ∠87° per unit

The tapped autotransformer is rated at 500 MVA; the corresponding maximum load current is 837 A primary at 354 kV.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- DCB (directional comparison blocking) trip scheme
- Three zones of mho phase and ground-distance protection
  - Zone 1, forward-looking, instantaneous underreaching protection
  - Zone 2, forward-looking, communications-assisted high-speed tripping and time-delayed tripping
  - Zone 3, reverse-looking, starting element
- Two levels of zero-sequence directional overcurrent protection
  - Level 2, forward-looking, communications-assisted high-speed tripping
  - Level 3, reverse-looking, starting element
- Inverse-time directional zero-sequence overcurrent backup protection
- Load-encroachment logic: prevents unwanted tripping during heavy load conditions
- SOTF protection: fast tripping when the circuit breaker closes

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **KELLOG - 345 kV**. Station Identifier (40 characters)

RID := **SEL-421 Relay**. Relay Identifier (40 characters)

Configure the SEL-421 for one circuit breaker.

NUMBK := **1**. Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1**. Breaker 1 Identifier (40 characters)

You can select both nominal frequency and phase rotation for the relay.

NFREQ := **60**. Nominal System Frequency (50, 60 Hz)

PHROT := **ABC**. System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N**. Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 6.12 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying; potential input VAZ is for synchronism check. *Synchronism Check on page 5.158* describes how to apply the synchronism check function.

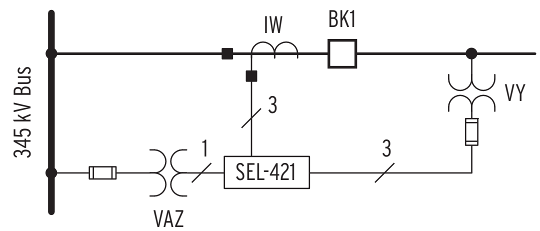


Figure 6.12 Circuit Breaker Arrangement at Station S

Breaker Monitor

Circuit Breaker Configuration

Set the relay to indicate that Circuit Breaker 1 is a three-pole trip circuit breaker.

BK1TYP := **3**. Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101**. A-Phase N/O Contact Input -BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and currents that the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios PTRY, PTRZ, CTRW, and CTRX. Use the Y potential input for line relaying and the Z potential input for synchronism checks. Use the W current input for line relaying. The settings VNOMY and VNOMZ specify the nominal secondary line-to-line voltage of the potential transformers (see *Figure 6.12*).

CTRW := **200**. Current Transformer Ratio—Input W (1–50000)

PTRY := **3000**. Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115**. PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

PTRZ := **3000**. Potential Transformer Ratio—Input Z (1–10000)

VNOMZ := **115**. PT Nominal Voltage (L–L)—Input Z (60–300 V secondary)

Set Z1MAG equal to Z1L1 plus Z1L2 so the fault locator provides correct results for internal faults not located on the tap (i.e., source T is extremely weak and provides practically no infeed). See *Table 6.15* for the secondary line impedances.

Z1MAG := **4.00**. Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **84.7**. Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary value of the zero-sequence impedance of the protected line from Station S to Station R, ignoring the tap.

Z0MAG := **12.88**. Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **73.0**. Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y**. Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **100.00**. Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase zones of phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance protection. You can independently select the number of zones per type of distance protection. Select only the number of zones needed. For this application example, use three zones of mho phase and ground-distance protection.

E21P := **3**. Mho Phase-Distance Zones (N, 1–5)

E21MG := **3**. Mho Ground-Distance Zones (N, 1–5)

E21XG := **N**. Quadrilateral Ground-Distance Zones (N, 1–5)

Now enable the other logic you will need for this application example.

You do not need CVT transient detection if the SIR (Source Impedance Ratio) is less than five. SIR is equal to the ratio of the local source impedance to the relay reach. Calculate the ratio based on the Zone 1 reach because you do not want Zone 1 distance protection to overreach during an external fault.

$$\begin{aligned} SIR &= \frac{|Z_{1S}|}{0.8 \bullet |Z_{1L1} + Z_{1L2}|} \\ &= \frac{0.67\ \Omega}{0.8 \bullet (2\ \Omega + 2\ \Omega)} \\ &= 0.209,\ SIR<5 \end{aligned}$$

Equation 6.21

ECVT := **N**. CVT Transient Detection (Y, N)

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

The transmission line is not series compensated.

ESERCMP := **N**. Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground-distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y**. Distance Element Common Time Delay (Y, N)

The SOTF logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y**. Switch-Onto-Fault (Y, N)

Do not enable the Out-of-Step logic for this application example.

EOOS : = **N**. Out-of-Step (Y, N)

The relay has a load-encroachment feature that prevents operation of the phase-distance elements during heavy load. This unique feature permits the load to enter a predefined area of the phase-distance characteristics without causing unwanted tripping.

ELOAD := **Y**. Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1**. Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use residual ground overcurrent elements for the DCB trip scheme. The Level 2 residual ground overcurrent element (67G2) is forward-looking and provides communications-assisted tripping. The Level 3 residual overcurrent element (67G3) is reverse-looking and blocks the tripping at Station R during out-of-section faults behind Station S. Enable three levels of residual ground overcurrent protection.

E50G := **3**. Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require negative-sequence overcurrent protection.

E50Q := **N**. Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1**. Selectable Inverse-Time Overcurrent Element (N, 1–3)

Set E32 to AUTO or AUTO2 and the relay automatically calculates the settings corresponding to the ground directional element (32G).

E32 := **AUTO2**. Directional Control (Y, AUTO, AUTO2)

Use the DCB tripping scheme.

ECOMM := **DCB**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect an LOP condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page 5.28* for more information.

Table 6.16 lists the three choices for enabling LOP.

Table 6.16 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during an LOP condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1**. Loss-of-Potential (Y, Y1, N)

You do not need Advanced Settings for this application example.

EADVS := **N**. Advanced Settings (Y, N)

Phase-Distance Elements (21P)

Mho Phase-Distance Element Reach

Employ each zone of mho phase-distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—DCB scheme tripping
- Zone 3—DCB scheme blocking

Zone 1 Phase-Distance Element Reach

Zone 1 phase-distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults for 80 percent of the distance from Station S to Station R because this is the shortest line segment from one terminal to another. Errors in the current transformers, potential transformers, modeled transmission line data, and fault study data do not permit Zone 1 to be set equal to 100 percent of the distance to Station R. Otherwise, unwanted tripping could occur for faults just beyond the remote terminal.

Set Zone 1 phase-distance protection equal to 80 percent of the positive-sequence impedance from Station S to Station R.

$$\begin{aligned} Z1MP &= 0.8 \bullet (Z_{1L1} + Z_{1L2}) \\ &= (0.8 \bullet (2 + 2)\ \Omega) \\ &= 3.2\ \Omega \end{aligned}$$

Equation 6.22

Z1MP := **3.2**. Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase-Distance Element Reach

Set Zone 2 phase-distance reach to include the tapped autotransformer.

Perform the following fault study to determine the apparent fault impedance the SEL-421 distance elements measure for faults at the 138 kV terminals of the autotransformer. Use these measurements to set the distance reach settings. Station R should be in service to account for infeed. Place an AG and ABC fault at the 138 kV terminals of the autotransformer and record the secondary voltage and current the relay measures at Station S. Apply these quantities in *Equation 6.23* and *Equation 6.26*, to determine the fault impedance the relay measures for the two fault types shown in *Table 6.17*. Use *Equation 6.23* for an A-Phase-to-ground fault and *Equation 6.26* for the three-phase fault.

$$|Z_{AG}| = \left|\frac{V_A}{I_A + k_0 \bullet 3I_0}\right|$$

Equation 6.23

where:

V_A = A-Phase-to-neutral voltage
I_A = A-Phase current
k_0 = zero-sequence compensation factor
$3I_0$ = zero-sequence current

The relay uses the zero-sequence compensation factor to measure zero-sequence quantities in terms of positive-sequence quantities.

$$k_0 = \frac{Z_{0L1} - Z_{1L1}}{3 \bullet Z_{1L1}}$$

Equation 6.24

The zero-sequence current is the sum of the phase currents.

$$3I_0 = I_A + I_B + I_C$$

Equation 6.25

The magnitude of the impedance for B-Phase-to-C-Phase, B-Phase-to-C-Phase-to-ground, and three-phase faults is $|Z_{BC}|$.

$$|Z_{BC}| = \left|\frac{V_{BC}}{I_{BC}}\right|$$

Equation 6.26

where:

V_{BC} = B-Phase-to-C-Phase voltage
I_{BC} = B-Phase-to-C-Phase current

Table 6.17 lists the results of the Z_{AG} and Z_{BC} calculations.

Table 6.17 Local Zone 2 Fault Impedance Measurements

Fault Type	$\lvert Z_{AG} \rvert$	$\lvert Z_{BC} \rvert$
AG	7.77 Ω	NA
ABC	NA	8.8 Ω

Select the phase-to-phase measurement from *Table 6.17*. Multiply this value by a safety factor of 125 percent to obtain Zone 2 phase-distance element reach.

$$\begin{aligned} Z2MP &= 1.25 \bullet 8.8\ \Omega \\ &= 11.00\ \Omega \end{aligned}$$

Equation 6.27

Z2MP := **11.00**. Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase-Distance Element Reach

Zone 3 phase-distance protection is reverse-looking. Zone 3 at Station S must have adequate reach to prevent unwanted tripping by the SEL-421 Relays at Stations R or T during external faults behind the local terminal. The Zone 3 reach at Station S must cover overreach from the furthest reaching remote Zone 2 for reverse faults when there is no infeed from the other remote terminal.

Figure 6.13 illustrates this coordination issue. You must set the Zone 2 reach at Station T to account for infeed during faults beyond the tap on the 345 kV system. However, when one 345 kV station is out of service, the Zone 2 at Station T overreaches for faults on the other side of the tap on the 345 kV system.

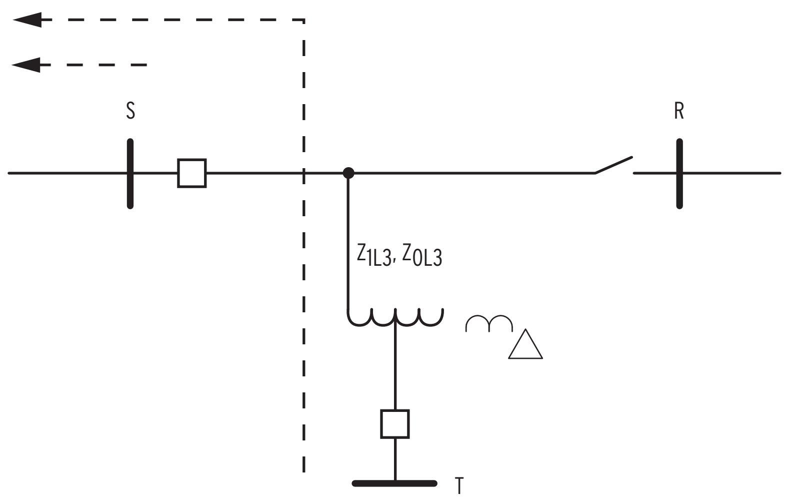


Figure 6.13 Reverse Zone 3 Coordination

Place AG and ABC faults at Station T and use *Equation 6.23* and *Equation 6.26* with respect to Station R to record the results in primary. Next place AG and ABC faults at Station R and use *Equation 6.23* and *Equation 6.26* with respect to Station T to record the results in primary. *Table 6.18* lists the results in primary and per unit.

Table 6.18 Apparent Impedance Measurement for Remote Faults

Station	|ZAG|	|ZBC|
Relay at Station R, Fault at Station T	152.7 Ω (0.128 per unit)	196.65 Ω (0.165 per unit)
Relay at Station T, Fault at Station S	79.605 Ω (0.418 per unit)	76.845 Ω (0.404 per unit)
Relay at Station T, Fault at Station R	103.86 Ω (0.545 per unit)	115.86 Ω (0.608 per unit)

The SEL-421 at Station T measures the largest apparent fault impedance for faults at Station R because the source at Station S is stronger than the source at Station R. Therefore, Zone 2 at Station T must be set to 115.86 Ω primary (plus a safety margin) so that the relay can detect faults at Station R when the source at Station S is in-service; this is the largest Zone 2 reach.

Figure 6.14 is an impedance diagram of the 345 kV tapped overhead transmission line; only the reactances (per unit) are shown.

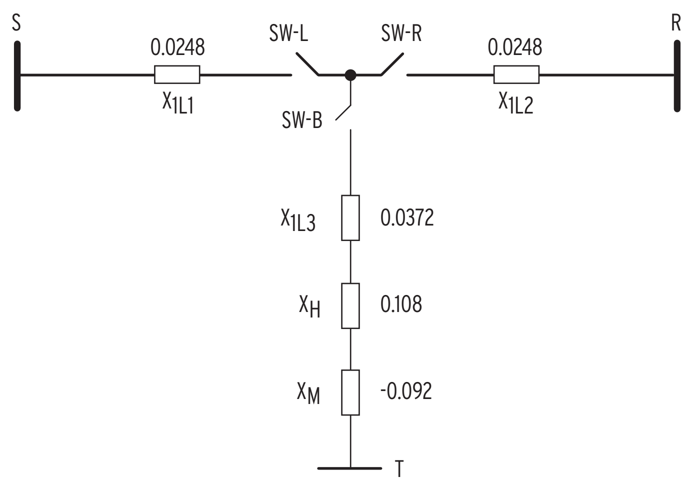


Figure 6.14 Impedance Diagram

To determine the greatest amount of overreach from a remote terminal during reverse faults with respect to Station S, subtract the fault impedance from the corresponding apparent impedance measurement from *Table 6.18*.

Calculate the overreach at Station R (SW-B open; SW-L and SW-R closed).

$$\begin{aligned}\text{Overreach} &= |Z_{APP}| - X_{1L1} - X_{1L2}\\ &= 0.165 - 0.0248 - 0.0248\\ &= 0.115 \text{ per-unit}\end{aligned}$$

Equation 6.28

Calculate the overreach at Station T (SW-R open; SW-L and SW-B closed).

$$\begin{aligned}\text{Overreach} &= |Z_{APP}| - X_M - X_H - X_{1L3} - X_{1L1}\\ &= 0.608 - (-0.092) - 0.108 - 0.0372 - 0.0248\\ &= 0.53 \text{ per-unit}\end{aligned}$$

Equation 6.29

Station T has the greatest overreach. Use *Equation 6.30* to set Zone 3 phase-distance element reach.

$$
\begin{aligned}
Z3MP &= \frac{CTR}{PTR}\% \ Z(\text{per-unit}) \cdot Z_{base} \cdot 120\% \\
&= \frac{200}{3000} \cdot 0.53 \cdot 1190.25 \cdot 1.2 \\
&= 50.5\ \Omega
\end{aligned}
$$

Equation 6.30

where:

$$
\begin{aligned}
Z_{base} &= \frac{(345\text{kV})^2}{100\ \text{MVA}} \\
&= 1190.25\ \Omega
\end{aligned}
$$

Equation 6.31

Z3MP := **50.50**. Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground-Distance Elements (21MG and 21XG)

Mho Ground-Distance Element Reach

Employ each zone of mho ground-distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—DCB scheme tripping
- Zone 3—DCB scheme blocking

Zone 1 Mho Ground-Distance Element Reach

Zone 1 mho ground-distance element reach must meet the same requirement as that for Zone 1 mho phase-distance protection; the reach setting can be no greater than 80 percent of the protected line.

Z1MG = Z1MP = 3.2 Ω

Z1MG := **3.20**. Zone 1 (OFF, 0.05–64 Ω secondary)

Zone 2 Mho Ground-Distance Element Reach

Set Zone 2 ground-distance element reach equal to Zone 2 phase-distance element reach; this ensures that Zone 2 ground-distance elements can see faults internal to the tapped autotransformer. Zone 2 phase-distance element reach was set to see the largest apparent fault impedance for faults at the 138 kV terminal of the tapped autotransformer.

Z2MG = Z2MP = 11 Ω

Z2MG := **11.00**. Zone 2 (OFF, 0.05–64 Ω secondary)

Zone 3 Mho Ground-Distance Element Reach

Set Zone 3 ground-distance element reach equal to Zone 3 phase-distance element reach; this ensures that Zone 3 ground-distance elements coordinate with the remote Zone 2 ground-distance elements at Station R and Station T for out-of-section faults behind the local terminal. Zone 3 phase-distance element reach was set to coordinate with the largest remote Zone 2 phase-distance element reach.

Z3MG = Z3MP = 50.50 Ω

Z3MG := **50.50**. Zone 3 (OFF, 0.05–64 Ω secondary)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps to keep the phase and ground-distance elements at the same reach if you set the reach equal per zone (for example, Z1MP = Z1MG). Ground-distance elements should measure fault impedance in terms of positive-sequence impedance only. The relay automatically calculates the setting for the Zone 1 zero-sequence current compensation factor when you set k0M1 to AUTO.

k0M1 := **AUTO**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

When you enter AUTO as the setting for k0M1, the relay calculates the zero-sequence current compensation as follows:

$$k01 = \frac{Z0MAG\angle Z0ANG - Z1MAG\angle Z1ANG}{3 \cdot Z1MAG\angle Z1ANG}$$

Equation 6.32

Zone 2 and Zone 3 use the same zero-sequence current compensation factor as that for Zone 1 because Advanced Settings are disabled.

The relay displays the following values for k0M1 and k0MA:

k0M1 := **0.750**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0MA := **-16.87**. Zone 1 ZCS Factor Angle (–180.0 to +180.0 degrees)

Distance Element Common Time Delay

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Set the appropriate timers Z1D, Z2D, and Z3D for both phase and ground-distance elements.

You do not need to delay Zone 1 distance protection; it trips instantaneously.

Z1D := **0.000**. Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2 distance protection provides time-delayed tripping as a backup function. Set this delay to 20 cycles.

Z2D := **20.000**. Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Zone 3 distance protection is reverse-looking and you do not need to apply it for tripping in this application. Set Zone 3 for zero time delay.

Z3D := **0.000**. Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Scheme

SOTF logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR, TRCOMM, and TRCOMMD) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Apply SOTF when using line-side potentials for relaying. Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground-distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Single-Pole SOTF

This is a three-pole tripping application example; confirm that the SOTF protection is for three-pole tripping.

ESPSTF := **N**. Single-Pole Switch-Onto-Fault (Y, N)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted, but before the SOTFD timer expires. To quickly reset the SOTF period, the relay must sense that the positive-sequence voltage is greater than the VRSTPU setting times the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option, and leave VRSTPU = 0.8.

EVRST := **Y**. Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- ➤ A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- ➤ Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, the close bus method only enables SOTF protection immediately following the close command to the circuit breaker. For more information, see *Switch-Onto-Fault Logic on page 5.117*.

Turn off 52AEND, 52A Pole-Open Time Delay, because the 52A method is not used.

52AEND := **OFF**. 52A Pole-Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000**. CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000**. Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command.

CLSMON := **IN102**. Close Signal Monitor (SELOGIC Equation)

Load Encroachment

The relay uses a load-encroachment feature that prevents operation of the phase-distance elements during heavy load. This unique feature permits the load to enter a predefined area of the phase-distance characteristics without causing unwanted tripping. *Figure 6.15* illustrates the load-encroachment function superimposed on the mho phase-distance protection characteristics.

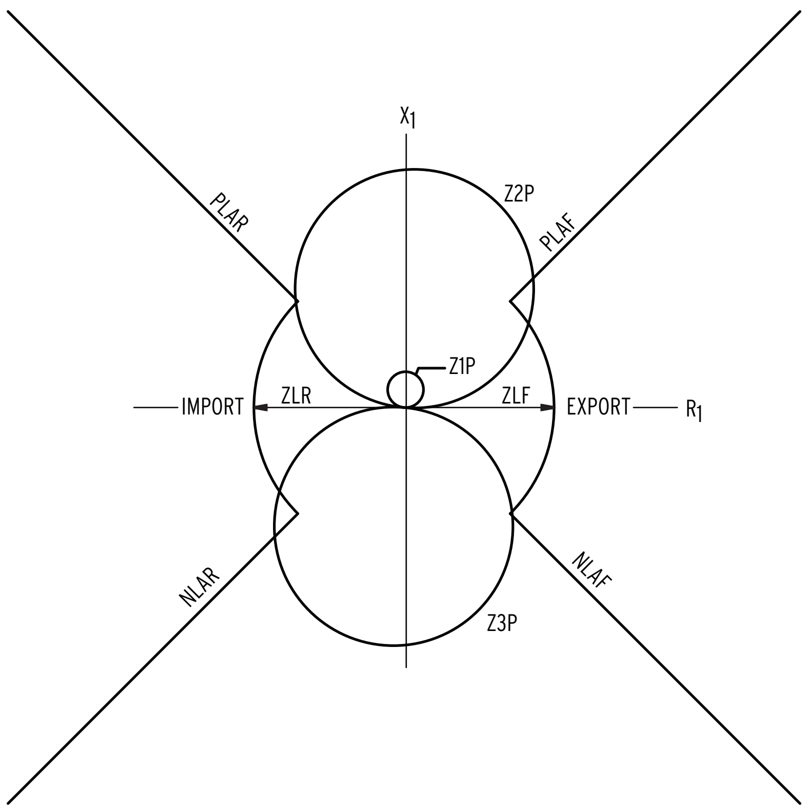


Figure 6.15 Load-Encroachment Function

Define the load-encroachment characteristic with load impedance settings in the forward (ZLF) and reverse (ZLR) directions. Define the two load sectors, export and import, with angle settings PLAF, NLAF, PLAR, and NLAR in the forward and reverse directions.

The transformer MVA rating is the maximum load. Assume that Station S can supply the total load the autotransformer draws. Set load encroachment according to maximum load for the protected line (4.2 A secondary). The bus voltage at Station S is 65.7 V line-to-neutral during maximum load.

$V_{LN} = 65.7$ V

$I_{\phi} = 4.2$ A

Therefore, the minimum load impedance the relay measures is as follows:

$$\begin{aligned} Z_{load} &= \frac{V_{LN}}{I_{\phi}} \\ &= \frac{65.7\ \text{V}}{4.2\ \text{A}} \\ &= 15.6\ \Omega \end{aligned}$$

Equation 6.33

Note that this load impedance is well inside the Zone 3 mho ground-distance element reach, Z3MG, or 50.5 Ω.

Multiply Z_{load} by a safety factor of 80 percent to account for overload conditions.

$$\begin{aligned} Z_{load} &= 0.8 \bullet 15.6\ \Omega \\ &= 12.5\ \Omega \end{aligned}$$

Equation 6.34

Set the forward and reverse load impedance thresholds (ZLF and ZLR, respectively) according to the minimum load impedance.

ZLF := **12.5**. Forward Load Impedance (0.05–64 Ω secondary)

ZLR := **12.5**. Reverse Load Impedance (0.05–64 Ω secondary)

To be conservative, assume a load angle range of ±45°. Assume both forward (export) and reverse (import) load ranges to be the same.

PLAF := **45.0**. Forward Load Positive Angle (–90.0 to +90.0 degrees)

NLAF := **–45.0**. Forward Load Negative Angle (–90.0 to +90.0 degrees)

PLAR := **135.0**. Reverse Load Positive Angle (+90.0 to +270.0 degrees)

NLAR := **225.0**. Reverse Load Negative Angle (+90.0 to +270.0 degrees)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use 50P1, Level 1 phase instantaneous overcurrent element, as a nondirectional high-set phase overcurrent element for SOTF protection. If the local circuit breaker closes into a close-in three-phase bolted fault with line-side potential transformers, the polarizing voltage for the phase-distance elements is zero. Therefore, the distance protection does not operate. In this case, the 50P1 element quickly trips the circuit breaker because this overcurrent element does not rely on the polarizing voltage.

To rapidly clear faults, set 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions to ensure the relay operates for low-level fault current.

50P1P := **49.80**. Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000**. Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1**. Level 1 Torque Control (SELOGIC Equation)

Residual Ground Instantaneous/Definite-Time Overcurrent Elements

This application example has three levels of residual ground overcurrent elements. You will use these overcurrent elements later in the DCB scheme. The Level 2 residual ground overcurrent element is set forward-looking to serve as a tripping element. The Level 3 residual ground overcurrent element is set as both a nondirectional (50G3) and reverse-looking (67G3) starting element. Be sure to set residual ground elements above any loading unbalance.

Disable Level 1 residual ground overcurrent element; this particular application does not use this element.

50G1P := **OFF**. Level 1 Pickup (OFF, 0.25–100 A secondary)

Enable Level 2 residual ground overcurrent element for DCB tripping. Ground-distance elements measure fault resistance consisting of arcing resistance and ground return resistance. Ground return resistance can consist of tower footing resistance and tree resistance. The total ground fault resistance can lie outside of the ground-distance characteristics. Residual overcurrent protection is the best method available for detecting high-resistance ground faults because this method of protection provides the greatest sensitivity. Set the pickup to 20 percent of the nominal current (5 A).

50G2P := **1.00**. Level 2 Pickup (OFF, 0.25–100 A secondary)

Enable Level 3 residual ground overcurrent element to send the blocking signal for out-of-section faults. Set the pickup of Level 3 residual ground overcurrent element (50G3) at Station S to half the remote forward-looking residual ground overcurrent element (50G2) at Station R.

$$50G3P_S = \frac{50G2P_R}{2}$$

Equation 6.35

This measure provides security during out-of-section faults, because the blocking elements are twice as sensitive as the tripping elements.

50G3P := **0.50**. Level 3 Pickup (OFF, 0.25–100 A secondary)

You do not need to add intentional time delays for Level 2 and Level 3 pickups.

67G2D := **0.000**. Level 2 Time Delay (0.000–16000 cycles)

67G3D := **0.000**. Level 3 Time Delay (0.000–16000 cycles)

Set Level 2 torque control equation to the forward decision from the ground directional element, 32GF.

67G2TC := **32GF**. Level 2 Torque Control (SELOGIC Equation)

Set Level 3 torque control equation to the reverse decision from the ground directional element, 32GR.

67G3TC := 32GR. Level 3 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select zero-sequence line current as the operating quantity.

51S1O := **3I0L**. 51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The *n* in the 51S1O setting is L for line, 1 for BK1, and 2 for BK2.

The relay measures 4.8 A secondary of $3I_0$ for a bolted single-phase-to-ground fault at the 345 kV terminals of the autotransformer. Set the pickup to 20 percent of $3I_0$.

51S1P := **0.96**. 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) is provided by 51S1P on a radial basis:

$$\begin{aligned} R_F &= \frac{PTR}{CTR} \bullet \frac{VNOMY/\sqrt{3}}{51S1P} \\ &= \left(\frac{3000}{200} \bullet \frac{115V/\sqrt{3}}{0.96A}\right) \\ &= 1037\ \Omega \text{ primary} \end{aligned}$$

Equation 6.36

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study.

Set the local overcurrent element to coordinate with the downstream overcurrent element such that there is an 18-cycle (60 Hz nominal) safety margin for ground faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for a close-in ground fault. Therefore, set the local time-overcurrent element to operate approximately 30 cycles for ground faults in front of the first downstream overcurrent element.

51S1C := **U3**. 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD := **2.0**. 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset, so the overcurrent element coordinates properly with electromechanical overcurrent relays.

51S1RS := **Y**. 51S1 Inverse-Time Overcurrent Electromechanical Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC := **32GF**. 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F) or reverse-looking (R). Set Zone 3 distance elements reverse-looking because these are blocking elements for the DCB trip scheme.

DIR3 := **R**. Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground-distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide the ground directional element. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to QV. The first listed directional element choice, Q, is the first priority directional element to provide directional control for the ground-distance elements and residual directional overcurrent elements. If Q is not operable, the second listed directional element choice, V, provides directional control for the ground-distance elements and residual directional overcurrent elements. A polarizing quantity was not available for choice I, so I is not selected for this particular application example.

ORDER := **QV**. Ground Directional Element Priority (combine Q, V, I)

SELOGIC control equation E32IV must assert to logical 1 to enable V or I for directional control of the ground-distance elements and residual directional overcurrent elements. Set E32IV to logical 1.

E32IV := **1**. Zero-Sequence Voltage and Current Enable (SELOGIC Equation)

Reverse Ground Directional Checks

32QG and 32V makes forward and reverse directional decisions during unbalanced faults based upon the following four settings:

- Z2F—Forward Directional Z2 Threshold
- Z2R—Reverse Directional Z2 Threshold
- Z0F—Forward Directional Z0 Threshold
- Z0R—Reverse Directional Z0 Threshold

For 32QG, if the apparent negative-sequence impedance measured by the relay (z2) is less than Z2F, the unbalanced fault is declared forward. If z2 is greater than Z2R, the unbalanced fault is declared reverse.

For 32V, if the apparent zero-sequence impedance measured by the relay (z0) is less than Z0F, the unbalanced fault is declared forward. If z0 is greater than Z0R, the unbalanced fault is declared reverse.

The SEL-421 automatically calculates these four settings as follows when Advanced Settings are disabled and setting E32 is AUTO:

$$\begin{aligned} \text{Z2F} &= 0.5 \bullet \text{Z1MAG} \\ &= (0.5 \bullet 4.00\ \Omega) \\ &= 2.00\ \Omega \end{aligned}$$

Equation 6.37

$$\begin{aligned} \text{Z2R} &= \text{Z2F} + \frac{0.5}{\text{I}_{\text{NOM}}} \\ &= 2.00\ \Omega + 0.10\ \Omega \\ &= 2.10\ \Omega \end{aligned}$$

Equation 6.38

$$\begin{aligned} \text{Z0F} &= 0.5 \bullet \text{Z0MAG} \\ &= (0.5 \bullet 12.88\ \Omega) \\ &= 6.44\ \Omega \end{aligned}$$

Equation 6.39

$$\begin{aligned} \text{Z0R} &= \text{Z0F} + \frac{0.5}{\text{I}_{\text{NOM}}} \\ &= 6.44\ \Omega + 0.10\ \Omega \\ &= 6.54\ \Omega \end{aligned}$$

Equation 6.40

Perform the following two checks to make sure the ground directional element does not incorrectly make a forward decision during a reverse unbalanced fault.

32QG Reverse Directional Check

You set Z1MAG equal to Z_{1L1} plus Z_{1L2} so the fault locator provides correct results for internal faults not located on the tap (i.e., source T is extremely weak and provides practically no infeed).

Figure 6.16 is the negative-sequence network for the 345 kV tapped overhead transmission line. Assume that the negative-sequence impedances are equal to the positive-sequence impedances.

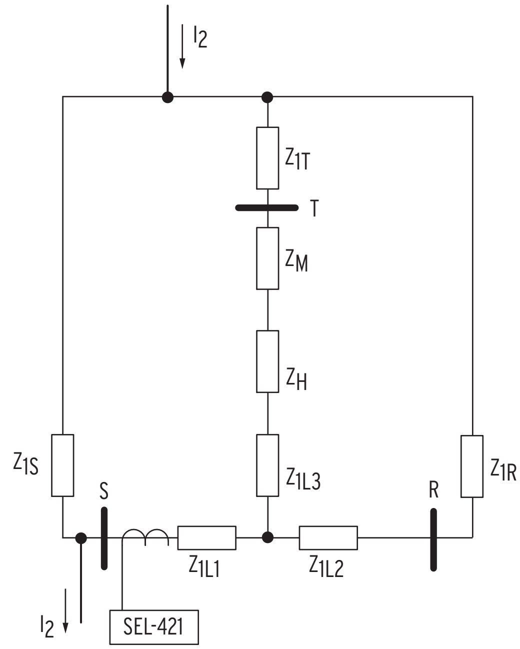


Figure 6.16 345 kV Tapped Line Negative-Sequence Network

Zn is an approximation of the impedance calculation for the n-sequence voltage-polarized directional statement for a reverse fault.

If z2 is less than Z2F during a reverse unbalanced fault, 32QG incorrectly declares that the fault is forward with respect to the relay location (CT shown in *Figure 6.16*). The relay automatically sets Z2F equal to one-half Z1MAG. *Equation 6.41* is the apparent negative-sequence impedance z2 measured by the 32QG element during a reverse unbalanced fault.

$$z_0 = Z_{0L1} + Z_{0P}$$

Equation 6.41

where:

Z_{2P} = parallel combination of the Line 3 impedance, transformer reactances (neglect resistance), and the Bus T impedance with Line 2 and the Bus R impedance

X_H = transformer high-side winding reactance

X_M = transformer low-side winding reactance

X_L = transformer tertiary winding reactance

The downstream parallel impedance, Z_{2P}, is the Line 3 impedance, the transformer reactances, and the Bus R impedance.

$$Z_{2P} = (Z_{1L3} + jX_H + jX_M + jX_{1T}) \parallel (Z_{1L2} + Z_{1R})$$

Equation 6.42

Use the following two assumptions to simplify the calculations:

1. Assume the power system is purely reactive
2. Ignore source impedances Z_{1R} and Z_{1T} (a conservative assumption)

Calculate the transformer reactances.

$$\begin{aligned} X_H &= 0.5 \bullet (X_{HM} + X_{HL} - X_{ML}) \\ &= (0.5 \bullet (0.016 + 0.6 - 0.4)) \\ &= 0.108 \text{ per-unit} \end{aligned}$$

$$\begin{aligned} X_M &= 0.5 \bullet (X_{HM} + X_{ML} - X_{HL}) \\ &= (0.5 \bullet (0.016 + 0.4 - 0.6)) \\ &= -0.092 \text{ per-unit} \end{aligned}$$

$$\begin{aligned} X_L &= 0.5 \bullet (X_{HL} + X_{ML} - X_{HM}) \\ &= (0.5 \bullet (0.6 + 0.4 - 0.016)) \\ &= 0.492 \text{ per-unit} \end{aligned}$$

Equation 6.43

Use these assumptions from *Equation 6.42* to create a simplified form of the downstream parallel impedance.

$$\begin{aligned} Z_{2P} &= j([X_{1L3} + X_H + X_M] \parallel [X_{1L2}]) \\ &= j\left(\frac{(X_{1L3} + X_H + X_M) \bullet X_{1L2}}{(X_{1L3} + X_H + X_M) + X_{IL2}}\right) \\ &= j\left(\frac{(0.038 + 0.108 - 0.092) \bullet 0.025}{(0.038 + 0.108 - 0.092) + 0.025}\right) \\ &= j0.017 \text{ per-unit primary} \end{aligned}$$

Equation 6.44

The secondary base impedance is calculated as follows:

$$\begin{aligned} Z_{base} &= \frac{CTR \bullet (345 \text{ kV})^2}{PTR \bullet 100 \text{ MVA}} \\ &= \frac{200 \bullet (345 \text{ kV})^2}{3000 \bullet 100 \text{ MVA}} \\ &= 79.35\ \Omega \end{aligned}$$

Equation 6.45

Calculate the parallel impedance in secondary ohms.

$$\begin{aligned} Z_{2P(secondary)} &= Z_{2P(primary)} \bullet Z_{base} \\ &= (J0.017 \bullet 79.35\ \Omega) \\ &= 1.35\ \Omega \text{ secondary} \end{aligned}$$

Equation 6.46

To determine whether the 32QG element always operates correctly during reverse unbalanced faults, check the following condition:

$Z2F < |Z_{1L1}| + |Z_{2P}|$

$2\ \Omega < 2\ \Omega + 1.35\ \Omega$

$2\ \Omega < 3.35\ \Omega$

The condition is satisfied; the reverse negative-sequence voltage-polarized directional element decision is correct during reverse unbalanced faults.

32V Reverse Directional Check

You set Z0MAG equal to Z_{0L1} plus Z_{0L2} so the fault locator provides correct results for internal faults not located on the tap (that is, source T is extremely weak and provides practically no infeed).

Figure 6.17 is the zero-sequence network for the 345 kV tapped overhead transmission line.

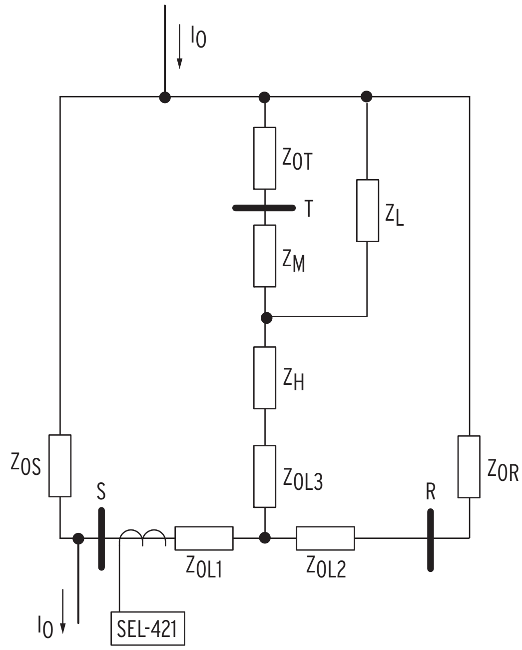


Figure 6.17 345 kV Tapped Line Zero-Sequence Network

If z0 is less than Z0F during a reverse unbalanced fault, 32V incorrectly declares that the fault is forward with respect to the relay location (CT shown in *Figure 6.17*). The relay automatically sets Z0F equal to one-half Z0MAG. *Equation 6.47* is the apparent zero-sequence impedance measured by 32V during reverse unbalanced faults:

$$z_0 = Z_{0L1} + Z_{0P}$$

Equation 6.47

where:

Z_{0P} = parallel combination of the Line 3 impedance, transformer high-side reactance (neglect resistance), and the parallel combination of the transformer low-side and Bus T impedance in parallel with the transformer tertiary impedance, in parallel with Line 2 and the Bus R impedance (see *Figure 6.17*).

$$Z_{0P} = (Z_{0L3} + jX_H + Z_{0PP}) \parallel (Z_{0L2} + Z_{0R})$$

Equation 6.48

where:

Z_{0PP} = the parallel combination of the transformer low-side and Bus T impedance in parallel with the transformer tertiary impedance

Use the following two assumptions to simplify the calculations:

1. Assume the power system is purely reactive
2. Ignore source impedances Z_{0R} and Z_{0T} (a conservative assumption)

Calculate the effect of transformer low side and transformer tertiary impedances.

$$
\begin{aligned}
Z_{0PP} &= (Z_M + Z_{0T}) \parallel Z_L \\
&= \frac{j^2 X_M \bullet X_L}{j \bullet (X_M + X_L)} \\
&= \frac{-j \bullet -1 \bullet -0.092 \bullet 0.492}{-0.092 + 0.492} \\
X_{0PP} &= -j0.113 \text{ per-unit, } X_{0PP}
\end{aligned}
$$

Equation 6.49

Use these assumptions to create a simplified form of the downstream parallel impedance (from *Equation 6.48*).

$$
\begin{aligned}
Z_{0P} &= (X_{0L3} + X_H + X_{0PP}) \parallel (X_{0L2}) \\
&= j\left(\frac{(X_{0L3} + X_H + X_{0PP}) \bullet X_{0L2}}{(X_{0L3} + X_H + X_{0PP}) + X_{0L2}}\right) \\
&= j\left(\frac{(0.122 + 0.108 - 0.113) \bullet 0.081}{(0.122 + 0.108 - 0.113) + 0.081}\right) \\
&= j0.048 \text{ per unit}
\end{aligned}
$$

Equation 6.50

Calculate the parallel impedance using Z_{base} from *Equation 6.45*.

$$
\begin{aligned}
Z_{0P} &= Z_{0P} \bullet Z_{base} \\
&= j(0.048 \bullet 79.35\ \Omega) \\
&= 3.8\ \Omega \text{ secondary}
\end{aligned}
$$

Equation 6.51

To determine whether the zero-sequence voltage-polarized 32V element always operates correctly during reverse unbalanced faults, check the following condition:

$Z0F < |Z_{0L1}| + |Z_{0P}|$

$6.44\ \Omega < 6.44\ \Omega + 3.8\ \Omega$

$6.44\ \Omega < 10.24\ \Omega$

The condition is satisfied; the reverse zero-sequence voltage-polarized directional element decision is correct during reverse unbalanced faults.

Pole-Open Detection

The setting EPO offers two options for deciding what conditions signify an open pole, as listed in *Table 6.19*.

Table 6.19 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open-phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay can incorrectly declare LOP during a pole-open condition if there is charging current that exceeds the pole-open current threshold.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (e.g., 52AA1) from the circuit breaker deasserts and the open-phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52**. Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD establishes the time delay on dropout after the Relay Word bit 3PO deasserts. This delay is important when you use line-side potential transformers for relaying. Use the 3POD setting to stabilize the ground-distance elements in case of pole scatter during closing of the circuit breaker(s).

3POD := **0.500**. Three-Pole Open Time Dropout Delay (0.000–60 cycles)

DCB Trip Scheme

This application example uses DCB trip scheme. In this scheme high-speed tripping occurs during internal autotransformer faults when the communications channel is not available.

The DCB trip scheme consists of the following three sections:

- Starting elements
- Coordination timers
- Extension of the blocking signal

Starting Elements

You can select nondirectional elements (NSTRT), directional elements (DSTRT), or both to detect out-of-section faults behind the local terminal. These elements send a blocking signal to Station R to prevent unwanted tripping during out-of-section faults. Nondirectional elements are always faster than directional elements, because directional elements need additional time to process the directional decision. Select both types of elements for this application.

Assign Relay Word bit NSTRT (Nondirectional Start) to OUT102 to start transmission of the blocking signal. NSTRT asserts if Level 3 residual ground overcurrent element (50G3) picks up. However, Relay Word bit STOP has priority over Relay Word bit NSTRT. If a Z2P, Z2G, or 67G2 assert, the relay halts transmission of the blocking signal that nondirectional overcurrent elements started.

You have enabled three levels of residual ground overcurrent elements. The Level 2 residual ground directional overcurrent element provides communications-assisted tripping for internal unbalanced faults. The Level 3 residual ground overcurrent element provides nondirectional start (50G3) and directional start (67G3).

The Relay Word bit DSTRT asserts if any of the following elements pick up:

- Zone 3 phase-distance elements (Z3P)
- Zone 3 ground-distance elements (Z3MG)
- Level 3 residual ground directional overcurrent element (67G3)

Relay Word bit DSTRT is useful when a bolted close-in three-phase fault occurs behind the relay. If the polarizing voltage for the distance elements collapses to zero, the corresponding Zone 3 supervisory phase-to-phase current level detectors latch the Zone 3 phase-distance elements. Therefore, the Zone 3 phase-distance characteristics do not need a reverse offset for this particular situation.

Assign Relay Word bit DSTRT (Directional Start) to OUT102 to start transmission of the blocking signal.

OUT102 := **NSTRT AND NOT STOP OR DSTRT**.

OUT103 stops the local transmitter from sending the blocking signal to the remote terminal.

OUT103 := **STOP OR 3PT**.

Time delay on pickup prevents transmission of the blocking signal if a transient causes a reverse-looking element to pick up momentarily. Set the corresponding timer to 1 cycle.

Z3XPU := **1.000**. Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)

You can also extend the blocking signal during current reversals. Set the corresponding dropout timer to 5 cycles.

Z3XD := **5.000**. Zone 3 Reverse Dropout Delay (0.000–16000 cycles)

Coordination Timers

The forward-looking elements that provide high-speed tripping at Station S must be delayed momentarily so the local circuit breaker does not trip for external faults behind Station R. This time delay provides time for the nondirectional and reverse-looking blocking elements at Station R to send a signal to Station S during out-of-section faults. This particular time delay is the coordination time for the DCB trip scheme. There are separate coordination timers for Zone 2 distance elements (21SD) and Level 2 residual directional overcurrent elements (67SD).

The recommended setting for the 21SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Zone 3 distance protection maximum operating time
- Maximum communications channel time

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles. Assume a remote Zone 3 distance protection pickup time of one cycle; the remote Zone 3 distance protection should operate faster than the local Zone 2 distance protection because the apparent fault impedance is deeper inside the remote Zone 3 distance protection characteristic. Finally, assume a communications channel time of 0.5 cycle. The sum of these times provides a conservative setting of 1.63 cycles.

21SD := **1.625**. Zone 2 Distance Short Delay (0.000–16000 cycles)

The recommended setting for the 67SD timer is the sum of the following three times:

- Control input recognition time (including debounce timer)
- Remote Level 3 nondirectional low-set overcurrent element maximum operating time
- Maximum communications channel time

If the control input time delay on pickup debounce timer is zero, the maximum recognition time for the control input is 0.125 cycles. Assume a 1-cycle pickup for remote Level 3 nondirectional blocking elements; the remote Level 3 current level detectors operate faster than the local Level 2 current level detectors because the remote Level 3 current level detectors pickup is lower. Finally, assume a communications channel time of 0.5 cycle. The sum of these times provides a conservative setting of 1.63 cycles.

67SD := **1.625**. Level 2 Overcurrent Short Delay (0.000–16000 cycles)

Blocking Signal Extension

Assign a control input to recognize when the local terminal receives a blocking signal from the remote terminal during external faults.

BT := **IN103**. Block Trip Received (SELOGIC Equation)

The DCB trip scheme uses an on/off carrier signal to block high-speed tripping at Stations S and R for out-of-section faults. Connect the carrier receive block signal output from the teleprotection equipment to a control input assigned to the SELOGIC control equation BT. This control input must remain asserted to block the forward-looking tripping elements after the coordination timers expire. If the blocking signal drops out momentarily, the distance relay can trip for out-of-section faults.

A built-in timer, BTXD, delays dropout of the control input assigned to BT. This timer maintains the blocking signal at the receiving relay by delaying the dropout of BT. However, delayed tripping can occur for internal faults because this DCB protection scheme employs nondirectional elements; the relay always sends a blocking signal regardless of fault location. Therefore, set this timer to zero so that high-speed tripping occurs when the nondirectional starting elements assert for an internal autotransformer fault.

BTXD := **0.000**. Block Trip Received Extension Time (0.000–16000 cycles)

Figure 6.18 illustrates the dc schematic for the DCB trip scheme.

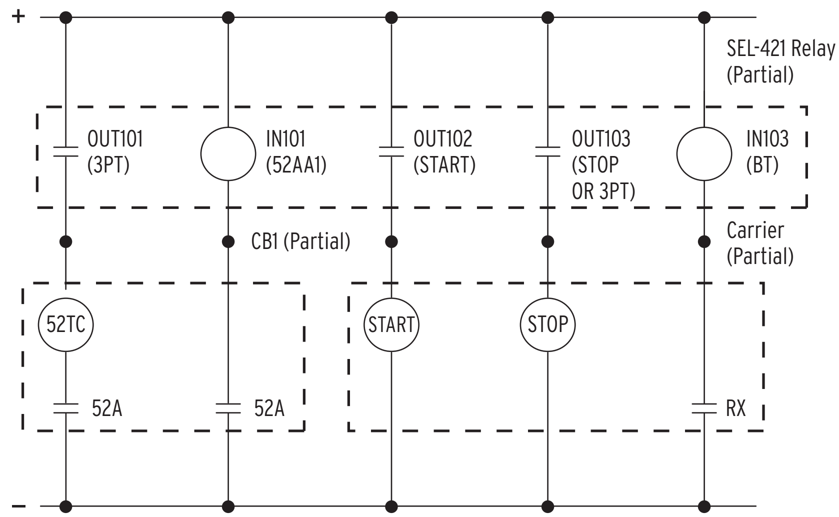


Figure 6.18 DC Schematic for DCB Trip Scheme

Trip Logic

Trip logic configures the relay for tripping. There are four trip logic settings:

- ➤ Trip equations
- ➤ Trip unlatch options
- ➤ Trip timers
- ➤ Three-pole tripping enable

Trip Equations

Set these three SELOGIC control equations for tripping:

- ➤ TR (unconditional)
- ➤ TRCOMM/TRCOMMD (communications-assisted; in this example, use only TRCOMM)
- ➤ TRSOTF (Switch-Onto-Fault)

TR

The TR SELOGIC control equation determines which protection elements cause the relay to trip unconditionally. Set TR to the Zone 1 instantaneous distance protection (Z1T), Zone 2 time-delayed distance protection, and the inverse-time overcurrent element (51S1) for backup protection. For information on setting 51S1, see *Selectable Operating Quantity Time Overcurrent Element 1 on page 6.10*.

TR := **Z1T OR Z2T OR 51S1T**. Trip (SELOGIC Equation)

TRCOMM

The TRCOMM SELOGIC control equation determines which protection elements cause the relay to trip via the communications-assisted tripping scheme logic. Set delayed Zone 2 mho phase and ground-distance protection (Z2PGS) plus delayed

Level 2 negative-sequence residual ground directional overcurrent element (67QGS2) in the TRCOMM SELOGIC control equation. See *Directional Comparison Blocking Scheme on page 5.121* for more information.

TRCOMM := **Z2PGS OR 67QG2S**. Communications-Assisted Trip (SELOGIC Equation)

TRSOFT

The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Scheme on page 6.8*). Set instantaneous Zone 2 distance protection (Z2P and Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker auxiliary “a” contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR

Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting, which asserts ULTR when you push the front-panel target reset button.

ULTR := **TRGTR**. Unlatch Trip (SELOGIC Equation)

TULO

Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 6.20* shows the four trip unlatch options for setting TULO.

Table 6.20 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (e.g., 52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole-Open Logic on page 5.25*.

TULO := **3**. Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration

The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000**. Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) to logical 1 to enable three-pole tripping only.

E3PT := **1**. Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1.

E3PT1 := **1**. Breaker 1 3PT (SELOGIC Equation)

Control Outputs

Main Board

OUT101 trips Circuit Breaker 1.

OUT101 := **3PT**.

OUT102 keys the local transmitter to send the blocking signal to the remote terminal during out-of-section faults behind Station S.

OUT102 := **NSTRT AND NOT STOP OR DSTRT**.

OUT103 stops the local transmitter from sending the blocking signal to the remote terminal.

OUT103 := **STOP OR 3PT**.

Example Completed

This completes the application example that describes setting of the SEL-421 for communications-assisted protection of a 345 kV tapped overhead transmission line. Analyze your particular power system to determine the appropriate settings.

Relay Settings

Table 6.21 lists all protective relay settings for this example.

Table 6.21 Settings for 345 kV Tapped TX Example (Sheet 1 of 4)

Setting	Prompt	Entry
General Global (Global)		
SID	Station Identifier (40 characters)	KELLOG --345 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR Z2P OR Z2G OR Z3P OR Z3G
Current and Voltage Source Selection Settings (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	200
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	3000.0
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	3000.0
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	4.00
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.7
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	12.88
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	73.0
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	100.00
Relay Configuration (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	3
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N
ECVT	CVT Transient Detection	N
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y1, N)	N
ELOAD	Load Encroachment (Y, N)	Y
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1

Table 6.21 Settings for 345 kV Tapped TX Example (Sheet 2 of 4)

Setting	Prompt	Entry
E50G	Residual Ground Inst./Def.-Time O/C Elements (N, 1–4)	3
E50Q	Negative-Sequence Inst./Def.-Time O/C Elements (N, 1–4)	N
E51S	Selectable Inverse-Time O/C Elements (N, 1–3)	1
E32	Directional Control (Y, AUTO, AUTO2)	AUTO2
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	DCB
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	N
Mho Phase-Distance Element Reach (Group)		
Z1MP	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	3.20
Z2MP	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	11.00
Z3MP	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	50.5
Mho Phase-Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Mho Ground-Distance Element Reach (Group)		
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary)	3.20
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary)	11.00
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary)	50.5
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.750
k0A1	Zone 1 ZSC Factor Angle (–180.00 to +180 degrees)	–16.87
Ground-Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000
SOTF Scheme (Group)		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 pu)	0.60–1.00 pu
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	OFF

Table 6.21 Settings for 345 kV Tapped TX Example (Sheet 3 of 4)

Setting	Prompt	Entry
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Load Encroachment (Group)		
ZLF	Forward Load Impedance (0.05–64 Ω secondary)	12.50
ZLR	Reverse Load Impedance (0.05–64 Ω secondary)	12.50
PLAF	Forward Load Positive Angle (–90.0 to +90 degrees)	45.0
NLAF	Forward Load Negative Angle (–90.0 to +90 degrees)	–45.0
PLAR	Reverse Load Positive Angle (+90.0 to +270 degrees)	135.0
NLAR	Reverse Load Negative Angle (+90.0 to +270 degrees)	225.0
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	49.80
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Residual Ground Instantaneous Overcurrent Pickup (Group)		
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	OFF
50G2P	Level 2 Pickup (OFF, 0.25–100 A secondary)	1.00
50G3P	Level 3 Pickup (OFF, 0.25–100 A secondary)	0.50
Residual Ground Overcurrent Definite-Time Delay (Group)		
67G2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67G3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
Residual Ground Overcurrent Torque Control (Group)		
67G2TC	Level 2 Torque Control (SELOGIC Equation)	32GF
67G3TC	Level 3 Torque Control (SELOGIC Equation)	32GR
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary)	0.96
51S1C	51S1 Inverse Time Overcurrent Curve (U1–U5)	U3
51S1TD	51S1 Inverse Time Overcurrent Time Dial (0.50–15.00)	2.0
51S1RS	51S1 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Directional Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV
E32IV	Zero-Sequence Voltage And Current Enable (SELOGIC Equation)	1

Table 6.21 Settings for 345 kV Tapped TX Example (Sheet 4 of 4)

Setting	Prompt	Entry
Pole-Open Detection (Group)		
EPO	Pole Open Detection (52, V)	52
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500
DCB Trip Scheme (Group)		
Z3XPU	Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)	1.000
Z3XD	Zone 3 Reverse Dropout Delay (0.000–16000 cycles)	5.000
21SD	Zone 2 Distance Short Delay (0.000–16000 cycles)	1.625
67SD	Level 2 Overcurrent Short Delay (0.000–16000 cycles)	1.625
BT	Block Trip Received (SELOGIC Equation)	IN103
BTXD	Block Trip Receive Extension Time (0.000–16000 cycles)	0.000
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	Z2PGS OR 67QG2S
TRCOMMD	Dir. Element Comms.-Assisted Trip (SELOGIC Equation)	NA
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	Z2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip–Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip–Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3
Z2GTSP	Zone 2 Ground Distance Time Delay For Single-Pole Tripping (Y, N)	N
67QGSP	Zone 2 Directional Negative-Sequence/Residual Overcurrent Single-Pole Trip (Y, N)	N
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 Three-Pole Trip (SELOGIC Equation)	1
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	3PT
OUT102	(SELOGIC Equation)	NSTRT AND NOT STOP OR DSTRT
OUT103	(SELOGIC Equation)	STOP OR 3PT

[a] Parameter *n* is 1 for BK1, 2 for BK2, and L for Line.

EHV Parallel 230 kV Underground Cables Example

This application example presents an underground cable system with double-ended 230 kV parallel cables (see *Figure 6.19*). SEL-421 Relays protect each end of the first circuit. This example explains settings calculations for the SEL-421 at Station S that protects Cable 1 between Station S and Station R.

The SEL-421 uses communications-assisted high-speed tripping to provide protection for faults along the 230 kV underground cable.

The two 230 kV underground cables run from Station S to Station R. Each circuit consists of three single-phase cables, each having an oil-filled copper conductor (hollow core). The cables are insulated with impregnated paper and have a lead sheath to prevent intrusion of moisture and to withstand fluid pressure. The cables are also grounded at both ends. Depending on the nature of a ground fault, ground fault current can return via the sheath, the ground, or both the sheath and ground.

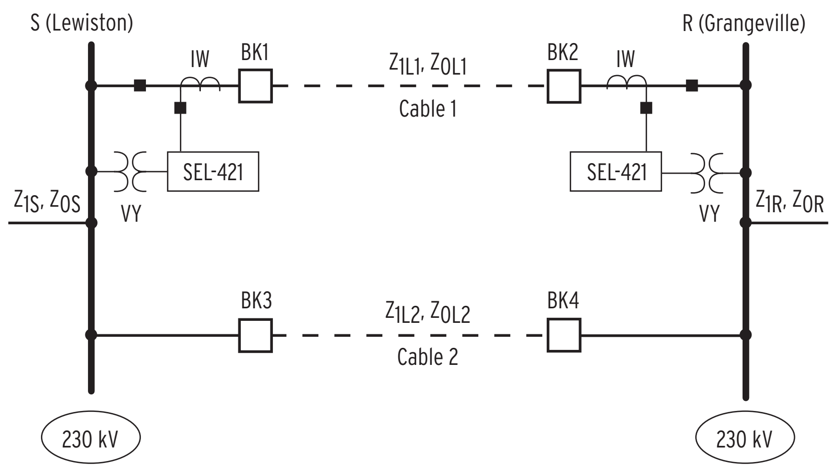


Figure 6.19 230 kV Parallel Underground Cables

Power System Data

Table 6.22 lists the power system data for this application example. Substitute the values and parameters that correspond to your system when you set the relay, using this example as a guide.

Table 6.22 System Data—230 kV Parallel Underground Cables (Sheet 1 of 2)

Parameter	Value
Nominal System Line-to-Line Voltage	230 kV
Nominal Relay Current	5 A secondary
Nominal Frequency	60 Hz
Cable Length	25 miles
Cable Impedances: $Z_{1L1} = Z_{1L2}$ Z_{0L1} (sheath return) = Z_{0L2} (sheath return) Z_{0L1} (ground return) = Z_{0L2} (ground return) Z_{0L1} (sheath and ground return) = Z_{0L2} (sheath and ground return)	 4.78 Ω ∠42.5° primary 9.45 Ω ∠17.4° primary 91.4 Ω ∠84.9° primary 9.58 Ω ∠21.7° primary

Table 6.22 System Data—230 kV Parallel Underground Cables (Sheet 2 of 2)

Parameter	Value
Cable Admittances: $Y_{1L1} = Y_{1L2}$ $Y_{0L1} = Y_{0L2}$	 $j6.71 \bullet 10^{-6}$ S primary (susceptance) $j6.71 \bullet 10^{-6}$ S primary (susceptance)
Source S Impedances: $Z_{1S} = Z_{0S}$	 50 Ω ∠87° primary
Source R Impedances: $Z_{1R} = Z_{0R}$	 35 Ω ∠87° primary
PTR (potential transformer ratio)	230 kV:115 V = 2000
CTR (current transformer ratio)	1000:5 = 200
Phase Rotation	ABC

Convert the power system impedances from primary to secondary so you can later calculate protection settings. *Table 6.23* lists the corresponding secondary quantities. Convert the impedances to secondary ohms as follows:

$$k = \frac{CTR}{PTR} = \frac{200}{2000} = 0.1$$

Equation 6.52

$$\begin{aligned} Z_{1L1(secondary)} &= k \bullet Z_{1L1(primary)} \\ &= (0.10 \bullet 4.78\ \Omega\ \angle 42.5°) \\ &= 0.48\ \Omega\ \angle 42.5° \end{aligned}$$

Equation 6.53

Table 6.23 Secondary Impedances

Parameter	Value
Cable Impedances: $Z_{1L1} = Z_{1L2}$ $Z_{0L1\ (sheath\ return\ only)} = Z_{0L2\ (sheath\ return\ only)}$ $Z_{0L1\ (ground\ return\ only)} = Z_{0L2\ (ground\ return\ only)}$ $Z_{0L1\ (sheath\ and\ ground\ return)} = Z_{0L2\ (sheath\ and\ ground\ return)}$	 0.48 Ω ∠42.5° secondary 0.95 Ω ∠17.4° secondary 9.14 Ω ∠84.9° secondary 0.96 Ω ∠21.7° secondary
Cable Admittance: $Y_{1L1} = Y_{1L2}$ $Y_{0L1} = Y_{0L2}$	 $6.71 \bullet 10^{-5}$ S ∠90° secondary $6.71 \bullet 10^{-5}$ S ∠90° secondary
Source S Impedances: $Z_{1S} = Z_{0S}$	 5.0 Ω ∠87° secondary
Source R Impedances: $Z_{1R} = Z_{0R}$	 3.5 Ω ∠87° secondary

The maximum load current of 777 A primary occurs when the parallel cable is out of service.

Application Summary

This particular example is for a single circuit breaker, three-pole tripping application with the following functions:

- POTT (permissive overreaching transfer trip) scheme
- Three zones of phase (mho) and ground (quadrilateral) distance protection
  - Zone 1—forward-looking, provides instantaneous underreaching protection
  - Zone 2—forward-looking, provides communications-assisted and time-delayed tripping
  - Zone 3—reverse-looking, prevents unwanted tripping during current reversals
- Two levels of negative-sequence directional overcurrent protection
  - Level 2—forward-looking, provides communications-assisted high-speed tripping
  - Level 3—reverse-looking, prevents unwanted tripping during current reversals
- Inverse-time directional negative-sequence overcurrent backup protection
- SOTF protection (fast tripping when the circuit breaker closes)

Relay settings that are not mentioned in this example do not apply to this application example.

Global Settings

General Global Settings

The SEL-421 has settings for identification. These settings allow you to identify the following:

- Station (SID)
- Relay (RID)
- Circuit Breaker 1 (BID1)

You can enter as many as 40 characters per identification setting.

SID := **LEWISTON -- 230 kV**. Station Identifier (40 characters)

RID := **SEL-421 Relay**. Relay Identifier (40 characters)

Configure the SEL-421 for the one circuit breaker that this particular application uses:

NUMBK := **1**. Number of Breakers in Scheme (1, 2)

BID1 := **Circuit Breaker 1**. Breaker 1 Identifier (40 characters)

Set the relay for nominal frequency and phase rotation.

NFREQ := **60**. Nominal System Frequency (50, 60 Hz)

PHROT := **ABC**. System Phase Rotation (ABC, ACB)

Current and Voltage Source Selection

The voltage and current source selection is for one circuit breaker. The relay derives the line current source from current input IW when you set ESS to N.

ESS := **N**. Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)

Figure 6.20 illustrates the current and voltage sources for this particular application. The relay uses potential input VY and current input IW for line relaying.

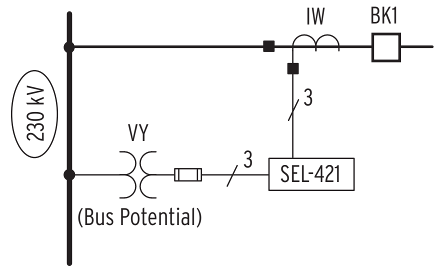


Figure 6.20 Circuit Breaker Arrangement at Station S, Cable 1

Breaker Monitor

Circuit Breaker Configuration

Set the Circuit Breaker BK1 type for a three-pole trip circuit breaker.

BK1TYP := **3**. Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)

Circuit Breaker 1 Inputs

The SEL-421 uses a normally open auxiliary contact (52A) from the circuit breaker to determine whether the circuit breaker is open or closed.

52AA1 := **IN101**. N/O Contact Input—BK1 (SELOGIC Equation)

Group Settings

Line Configuration

The SEL-421 has four transformer turns ratio settings that convert the secondary potentials and current s the relay measures to the corresponding primary values. These settings are the potential transformer and current transformer ratios (PTRY, PTRZ, CTRW, and CTRX). Use the VY potential input for line relaying; these come from the bus potentials (see *Figure 6.20*). Use the IW current input for line current. Relay setting VNOMY is the nominal secondary line-to-line voltage of the potential transformers.

PTRY := **2000**. Potential Transformer Ratio—Input Y (1–10000)

VNOMY := **115**. PT Nominal Voltage (L–L)—Input Y (60–300 V secondary)

CTRW := **200**. Current Transformer Ratio—Input W (1–50000)

Enter the secondary values of the positive-sequence impedance of the protected cable. See *Table 6.23* for the secondary cable impedances.

Z1MAG := **0.48**. Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z1ANG := **42.5**. Positive-Sequence Line Impedance Angle (5.00–90 degrees)

Enter the secondary values of the zero-sequence impedance of the protected cable. The zero-sequence impedance should correspond to the parallel sheath and ground fault return path (see $Z0_{L1(\text{sheath and ground})}$ in *Table 6.23*).

$$Z0MAG = k \bullet \left|Z0_{L1(\text{sheath and ground})}\right|$$

Equation 6.54

where:

k = the result of *Equation 6.52*

$$Z0MAG = 0.1 \bullet |Z0_{L1(\text{sheath and ground})}| = 0.1 \bullet |9.58\ \Omega\ \angle 21.7°| = 0.96\ \Omega$$

Z0MAG := **0.96**. Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)

Z0ANG := **21.7**. Zero-Sequence Line Impedance Angle (5.00–90 degrees)

Enable the fault locator.

EFLOC := **Y**. Fault Location (Y, N)

The LL setting is the line length. This value has no defined unit; you can set the line length in miles, kilometers, ohms, etc. Set the length in miles.

LL := **25.00**. Line Length (0.10–999)

The relay fault locator uses the values you enter for Z1MAG, Z1ANG, Z0MAG, Z0ANG, and LL.

Relay Configuration

You can select from zero to five phase mho (E21P), ground mho (E21MG), and ground quadrilateral (E21XG) distance zones. The number of zones per type of distance protection is independently selectable. Select only the number of zones you need. For this application example, use three zones of mho phase-distance protection and three zones of quadrilateral ground-distance protection.

E21P := **3**. Mho Phase-Distance Zones (N, 1–5)

E21MG := **N**. Mho Ground-Distance Zones (N, 1–5)

E21XG := **3**. Quadrilateral Ground-Distance Zones (N, 1–5)

You do not need CVT (capacitive voltage transformer) transient detection because PTs with wound windings are used for this particular application example.

ECVT := **N**. CVT Transient Detection (Y, N)

NOTE: The SEL-421-4 does not provide series-compensated line protection logic.

The underground cable is not series-compensated.

ESERCMP := **N**. Series-Compensated Line Logic (Y, N)

You can select a common time delay or an independent time delay per zone for phase and ground-distance protection. If you choose independent timing, evolving faults (such as those changing from single phase to multiphase) cause the timer to reset and result in additional delay. Select common time delay for this application.

ECDTD := **Y**. Distance Element Common Time Delay (Y, N)

The SOTF (switch-onto-fault) protection logic permits tripping by specified protection elements for a settable time after the circuit breaker closes.

ESOTF := **Y**. Switch-Onto-Fault (Y, N)

Do not enable the out-of-step logic for this application example.

EOOS := **N**. Out-of-Step (Y, N)

Do not enable the load-encroachment logic; the minimum apparent load impedance is outside the mho phase-distance characteristics.

ELOAD := **N**. Load Encroachment (Y, N)

Use Level 1 high-set instantaneous phase overcurrent element for SOTF protection.

E50P := **1**. Phase Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

This application does not require residual ground overcurrent protection.

E50G := **N**. Residual Ground Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Enable three levels of negative-sequence overcurrent protection. Use these negative-sequence current level detectors in conjunction with the communications-assisted tripping scheme.

E50Q := **3**. Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Use inverse-time overcurrent protection to provide backup protection for high-resistance ground faults. The 51S1 element provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

E51S := **1**. Selectable Operating Quantity Inverse-Time Overcurrent Element (N, 1–3)

The relay automatically calculates all of the ground directional elements settings when you select AUTO or AUTO2.

E32 := **AUTO2**. Directional Control (Y, AUTO, AUTO2)

Use the POTT trip scheme to quickly clear faults internal to the protected line.

ECOMM := **POTT**. Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)

Fuses or molded case circuit breakers often protect potential transformers. Operation of one or more fuses, or molded case circuit breakers, results in a loss of polarizing potential inputs to the relay. Loss of one or more phase voltages prevents the relay from properly determining fault distance or direction.

Occasional loss-of-potential to the distance relay, while unavoidable, is detectable. When the relay detects a loss-of-potential condition, the relay can block distance element operation, block or enable forward-looking directional overcurrent elements, and issue an alarm for any true loss-of-potential condition.

If line-side PTs are used, the circuit breaker(s) must be closed for the LOP logic to detect a loss-of-potential condition. Therefore, if three-phase potential to the relay is lost while the circuit breaker(s) is open (e.g., the PT fuses are removed while the line is de-energized), the relay cannot detect a loss-of-potential condition when the circuit breaker(s) closes again. At circuit breaker closing, the relay can detect one or two missing potentials that occurred while the circuit breaker was open. See *Loss-of-Potential Logic on page 5.28* for more information.

Table 6.24 lists the three choices for enabling LOP protection.

Table 6.24 LOP Enable Options

Option	Description
N	The LOP logic operates but does not disable voltage-polarized directional elements, distance elements, and forward-looking directional overcurrent elements. Use LOP in this case for alarm only.
Y	The relay disables all voltage-polarized directional elements and distance elements, but enables forward-looking directional overcurrent elements. These forward-looking directional overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.
Y1	The relay disables all voltage-polarized directional elements and distance elements. The relay also disables the overcurrent elements controlled by the voltage-polarized directional elements.

Set ELOP to Y1 for this application example. This choice reduces the chances of false tripping because of a loss-of-potential condition.

ELOP := **Y1**. Loss-of-Potential (Y, Y1, N)

Enable the Advanced Settings so you can properly set the zero-sequence compensation factors.

EADVS := **Y**. Advanced Settings (Y, N)

Phase-Distance Elements (21P)

Mho Phase-Distance Element Reach

Employ each zone of distance protection as follows:

- Zone 1—Instantaneous underreaching tripping
- Zone 2—Forward-looking fault detector for the POTT scheme and backup time delayed tripping
- Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Phase-Distance Element Reach

Zone 1 phase-distance protection provides instantaneous protection for phase-to-phase, phase-to-phase-to-ground, and three-phase faults in the first 80 percent of the cable. Errors in the current transformers, potential transformers, modeled cable data, and fault study data do not permit a Zone 1 setting for 100 percent of the cable; unwanted tripping could occur for faults just beyond the remote end of the cable.

Set Zone 1 phase-distance protection to 80 percent of the cable positive-sequence impedance.

$$Z1MP = 0.8 \bullet Z_{1L1} = 0.8 \bullet 0.48\ \Omega = 0.38\ \Omega$$

Z1MP := **0.38**. Zone 1 Reach (OFF, 0.05–64 Ω secondary)

Zone 2 Phase-Distance Element Reach

Zone 2 phase-distance protection must have adequate reach to detect all phase-to-phase, phase-to-phase-to-ground, and three-phase faults along the protected cable. Set Zone 2 phase-distance protection to 120 percent of the cable positive-sequence impedance. With this reach, high-speed tripping occurs via the communications channel for faults located in the last 20 percent of the cable.

$$Z2MP = 1.2 \bullet Z_{1L1} = 1.2 \bullet 0.48\ \Omega = 0.58\ \Omega$$

Z2MP := **0.58**. Zone 2 Reach (OFF, 0.05–64 Ω secondary)

Zone 3 Phase-Distance Element Reach

Zone 3 phase-distance protection must have adequate reach to prevent unwanted tripping during current reversals when the parallel line is in service because this example uses a POTT scheme. So that Zone 3 has greater fault coverage than Zone 2 at the remote terminal, set the reach to remote Zone 2 and rely upon the length of the protected cable as the safety margin.

$$Z3MP = Z2P = 0.58\ \Omega$$

Z3MP := **0.58**. Zone 3 Reach (OFF, 0.05–64 Ω secondary)

Ground-Distance Elements (21XG)

Quadrilateral Ground-Distance Element Reach

The main advantage of ground-distance protection is that Zone 1 provides instantaneous protection independent of the communications channel. Typically cable faults have little fault resistance; it is advantageous to conservatively set the resistance reach for quadrilateral ground-distance protection. Supplement quadrilateral ground-distance protection with directional negative-sequence overcurrent elements. The directional negative-sequence overcurrent elements employed in the communications-assisted tripping scheme provide excellent resistive coverage for high-resistance ground faults (e.g., a contaminated pothead flashes over).

The reactive reach for each zone of quadrilateral ground-distance protection lies on the relay characteristic angle (Z1ANG), rather than on the ordinate (reactance) of the impedance plane (see *Figure 6.21*).

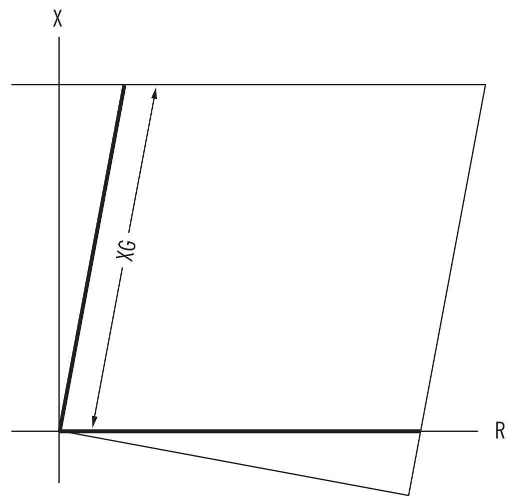


Figure 6.21 Quadrilateral Ground-Distance Element Reactive Reach Setting

Employ each zone of distance protection as follows:

- ➤ Zone 1—Instantaneous underreaching direct tripping
- ➤ Zone 2—Forward-looking tripping elements for the POTT scheme and backup tripping
- ➤ Zone 3—Current reversal guard for the POTT scheme, echo tripping, and weak infeed logic

Zone 1 Reactance

The reach of the Zone 1 reactance measurement of the quadrilateral ground-distance elements must meet the same requirement as that for Zone 1 mho phase-distance protection; the reach setting can be no greater than 80 percent of the cable.

$XG1 = 0.8 \bullet |Z_{1L1}| = 0.8 \bullet 0.48\ \Omega = 0.38\ \Omega$

XG1 := **0.38**. Zone 1 Reactance (OFF, 0.05–64 Ω secondary)

Zone 1 Resistance

Find RG1 (Zone 1 Resistance) from the per-unit reach m of the Zone 1 reactance. Use *Equation 6.55*, which is *Equation 3* in Appendix *A—Quadrilateral Reactive Reach Versus Resistive Reach Setting Guideline* from the paper *Digital Communications for Power System Protection: Security, Availability, and Speed* (go to selinc.com for a copy of this paper):

$$m = 1 - \frac{R}{X_{1L1} \bullet 20}$$

Equation 6.55

where:

m = per-unit reach of XG1
R = RG1 (the Zone 1 resistance)
X_{1L1} = positive-sequence transmission line reactance

XG1 is set at 80 percent of the underground cable (i.e., $m = 0.8$ per-unit); the positive-sequence reactance of the cable, X_{1L1}, is 0.323 Ω secondary (from the rectangular form of Z_{1L1} in *Table 6.23*).

$$\begin{aligned} Z_{1L1} &= R_{1L1} + jX_{1L1} \\ &= 0.48\ \Omega\ \angle 42.5° \\ &= 0.354 + j0.323\ \Omega \end{aligned}$$

Rearrange *Equation 6.55* to calculate RG1:

$$\begin{aligned} RG1 &= (1 - m) \bullet 20 \bullet X_{1L1} \\ &= (1 - 0.8) \bullet 20 \bullet 0.323\ \Omega \\ &= 1.29\ \Omega \end{aligned}$$

Equation 6.56

RG1 := **1.29**. Zone 1 Resistance (0.05–50 Ω secondary)

Zone 2 Reactance

Zone 2 quadrilateral ground-distance reach must meet the same requirement as that for Zone 2 mho phase-distance protection; the reach setting is 120 percent of the cable.

$XG2 = 1.2 \bullet |Z_{1L1}| = 1.2 \bullet 0.48 = 0.58\ \Omega$

XG2 := **0.58**. Zone 2 Reactance (OFF, 0.05–64 Ω secondary)

Zone 2 Resistance

Use the following formula to set RG2:

$$\begin{aligned} RG2 &= XG2 \bullet \frac{RG1}{XG1} \\ &= \left(0.58\ \Omega \bullet \frac{1.29\ \Omega}{0.38\ \Omega}\right) \\ &= (0.58\ \Omega \bullet 3.4) \\ &= 1.97\ \Omega \end{aligned}$$

Equation 6.57

RG2 := **1.97**. Zone 2 Resistance (0.05–50 Ω secondary)

Zone 3 Reactance

Zone 3 quadrilateral ground-distance reach must meet the same requirement as that for Zone 3 mho phase-distance protection; it equals Zone 2 reach.

$XG3 = XG2 = 0.58\ \Omega$

XG3 := **0.58**. Zone 3 Reactance (OFF, 0.05–64 Ω secondary)

Zone 3 Resistance

Set the Zone 3 resistance reach equal to Zone 2 resistance reach and multiply the reach by 125 percent for a safety margin to account for external resistive ground faults.

$RG3 = 1.25 \bullet RG2 = 1.25 \bullet 1.97 = 2.46\ \Omega$

RG3 := **2.46**. Zone 3 Resistance (0.05–50 Ω secondary)

Quadrilateral Ground Polarizing Quantity

Advanced Settings are enabled, so you must enter two final settings for the quadrilateral ground-distance protection. With setting XGPOL, you can choose the polarizing quantity for the quadrilateral ground-distance protection. You can choose either negative-sequence current (I2) or zero-sequence current (IG). Choose the appropriate quantity to reduce overreach and underreach of the reactance line. The reactance line can underreach or overreach during high-resistance single phase-to-ground faults because of nonhomogeneous negative-sequence or zero-sequence networks, and prefault load flow.

Figure 6.22 shows the network to determine negative-sequence or zero-sequence homogeneity.

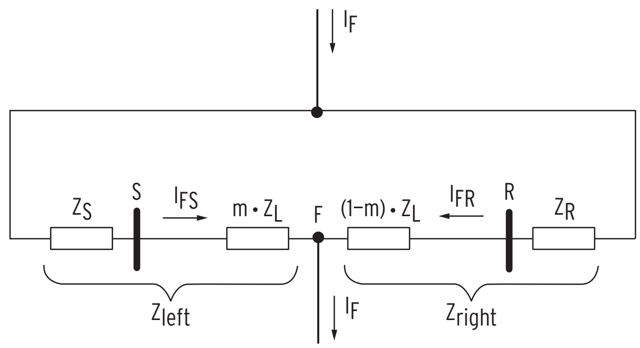


Figure 6.22 Circuit to Determine Network Homogeneity

Z_{left} is the total impedance up to the fault (F) on the left side of the fault location, while Z_{right} is the total impedance up to the fault on the right side of the network. A network is homogeneous with respect to the particular fault location if *Equation 6.58* is satisfied:

$$\frac{X_{left}}{R_{left}} = \frac{X_{right}}{R_{right}}$$

Equation 6.58

Use *Equation 6.59* and *Equation 6.60* to determine the zero-sequence and negative-sequence homogeneity:

$$T_0 = ARG\left(\frac{Z_{0S} + Z_{0L} + Z_{0R}}{(1 - m) \bullet Z_{0L} + Z_{0R}}\right)$$

Equation 6.59

$$T_2 = ARG\left(\frac{Z_{1S} + Z_{1L} + Z_{1R}}{(1 - m) \bullet Z_{1L} + Z_{1R}}\right)$$

Equation 6.60

The values T_0 and T_2 represent how much the apparent fault impedance measured by XAG tilts up or down (electrical degrees) because of the nonhomogeneity of the corresponding network. *Figure 6.23* illustrates the possible tilt situations caused by a nonhomogeneous network.

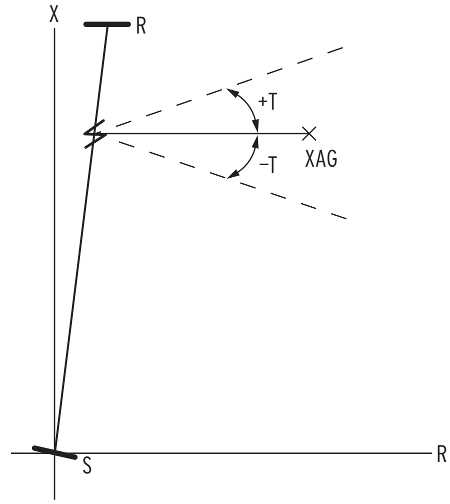


Figure 6.23 Apparent Fault Impedance Resulting From Nonhomogeneity

Table 6.25 provides the results of *Equation 6.59* and *Equation 6.60* for both the negative-sequence and zero-sequence networks. Remember that T0 depends on the return path of the ground fault; i.e., sheath, ground, or a parallel combination of both. The distance to fault is assumed to be 100 percent (*m* equals 1).

Table 6.25 Tilt Resulting From Nonhomogeneity

Angle	T_2	T_0 (sheath)	T_0 (ground)	T_0 (ground and sheath)
Negative-Sequence Network	–2.2°			
Zero-Sequence Network		–5.8°	–1.1°	–5.6°

The negative-sequence network is more homogeneous than the zero-sequence network when compared with two of the three corresponding cable zero-sequence impedances. Choose negative-sequence current for polarizing the quadrilateral ground-distance protection.

XGPOL := **I2**. Quadrilateral Ground Polarizing Quantity (I2, IG)

Selection I2 indicates that the negative-sequence current flowing in the cable is the polarizing quantity for the reactance line.

Nonhomogeneous Correction Angle

TANGG, the nonhomogeneous angle setting, also helps prevent overreach or underreach for ground faults at a specific fault location by compensating the angle of the reactance line.

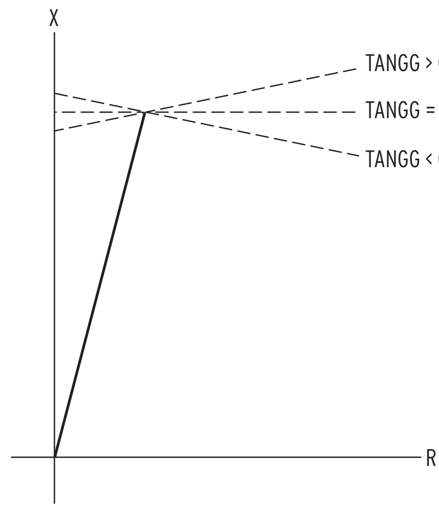


Figure 6.24 Nonhomogeneous Angle Setting

Set TANGG to prevent the Zone 1 quadrilateral ground-distance reactance measurement from overreaching for ground faults located at the remote bus. Use the result from *Equation 6.60* (T2 in *Quadrilateral Ground Polarizing Quantity on page 6.29*).

TANGG := **–2.2**. Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)

Zero-Sequence Current Compensation Factors

Zero-sequence current compensation helps keep the phase and ground-distance elements at the same reach if you set the phase reach and the ground reach equal per zone (e.g., Z1MP = XG1). Ground-distance elements should measure fault impedance in terms of positive-sequence impedance only.

The relay has three zero-sequence current compensation factors (k01, k0, and k0R). The Zone 1 ground-distance element has a dedicated zero-sequence current compensation factor (k01). Advanced Settings are enabled for this particular example (EADVS := Y), so you must set two additional independent zero-sequence current compensation factors, one for forward-looking zones (k0) and one for reverse-looking zones (k0R).

The zero-sequence cable impedance depends on the return path of the ground fault current during ground faults. The zero-sequence current compensation factors must be set so the Zone 1 ground-distance elements do not see ground faults external to the protected cable, while Zone 2 and Zone 3 ground-distance elements must see all internal ground faults.

The SEL-421 uses *Equation 6.61* to calculate the A-Phase-to-ground distance reactance measurement.

$$XAG = \frac{Im[V_A \bullet (I_{POL} \bullet e^{j \bullet TANGG})^*]}{Im[z1 \bullet (I_A + k01 \bullet 3I_0) \bullet (I_{POL} \bullet e^{j \bullet TANGG})^*]}$$

Equation 6.61

where:

V_A = A-Phase-to-ground voltage measured at Station S

I_A = A-Phase current measured through Cable 1 at Station S

$3I_0$ = zero-sequence current measured through Cable 1 at Station S

I_{POL} = negative-sequence or zero-sequence current measured through Cable 1 at Station S (based on the XGPOL setting, see *Quadrilateral Ground Polarizing Quantity on page 6.29*)

TANGG = nonhomogeneous correction angle

Im[ ] = imaginary part

* = complex conjugate

$$z1 = \frac{Z_1}{|Z_1|}$$

Equation 6.62

where:

Z_1 = Cable 1 positive-sequence impedance

$$k01 = \frac{Z_{0L1} - Z_{1L1}}{3 \cdot Z_{1L1}}$$

Equation 6.63

k01

You can set k01 based on three values for the zero-sequence cable impedance: $Z_{0L1(sheath)}$, $Z_{0L1(ground)}$, or $Z_{0L1(sheath\ and\ ground)}$. Select the zero-sequence cable impedance that prevents Zone 1 ground-distance element overreach.

To determine the best setting for k01, place an A-Phase-to-ground fault at Station R with the parallel cable out of service. Find the ground-distance reactance measurement XAG that does not overreach for this fault. Perform this evaluation using $Z_{0L1(sheath\ and\ ground)}$ and $Z_{0L1(sheath)}$ for the zero-sequence cable impedance. There is no need to determine the XAG measurement for ground faults at the remote terminal when k01 is set based on $Z_{0L1(ground)}$ because severe overreach occurs in all cases for the ground-only path.

Sheath and Ground Return Path

First apply *Equation 6.61* with k01 based on $Z_{0L1(sheath\ and\ ground)}$ (k01 equal to 0.374 ∠–39.2°). This is the most common ground fault return path. Set TANGG equal to zero and assume that IPOL is equal to negative-sequence current (i.e., XGPOL is equal to I2).

Table 6.26 lists the corresponding XAG (reactance of the phase-to-ground fault) calculations for the remote single phase-to-ground fault for each of the three possible zero-sequence cable impedances when the k01 calculation is based on the parallel return path. Use *Equation 6.64* to determine the amount of overreach/underreach:

$$\text{Overreach/Underreach} = \frac{XAG}{|Z_{1L1}|} \cdot 100\%$$

Equation 6.64

Table 6.26 XAG Measurement for Remote AG Fault (k01 = 0.374 ∠–39.2°, Sheath and Ground Return Path)

Calculation	Z0L1(sheath)	Z0L1(ground)	Z0L1(sheath and ground)
XAG (secondary ohms)	0.45 Ω	3.04 Ω	0.48 Ω
Overreach/Underreach[a]	93.8% (O)	633% (U)	100%

[a] O indicates overreach, U indicates underreach.

The results in *Table 6.26* show that the XAG calculation overreaches by 6.2 percent (i.e., 100% – 93.8% = 6.2%) if the sheath is the return path for the ground fault; therefore, you should not set k01 based on the sheath and ground (parallel) return path.

Sheath Return Path

Table 6.27 lists the corresponding XAG (reactance of the phase-to-ground fault) calculations for the remote single phase-to-ground fault for each of the three possible zero-sequence cable impedances when the k01 calculation is based on the sheath return path.

Table 6.27 XAG Measurement for Remote AG Fault (k01 = 0.385 ∠–46.7°, Sheath Return Path)

Calculation	Z0L1(sheath)	Z0L1(ground)	Z0L1(sheath and ground)
XAG (secondary ohms)	0.48 Ω	3.17 Ω	0.51 Ω
Overreach/Underreach[a]	100%	660% (U)	106% (U)

[a] O indicates overreach, U indicates underreach.

The results in *Table 6.27* show that there is no Zone 1 ground-distance overreach. Therefore, set k01 based on $Z_{0L1(sheath)}$.

k0M1 := **0.385**. Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)

k0A1 := **–46.7**. Zone 1 ZSC Factor Angle (–180.0 to +180.0 degrees)

k0 and k0R

Set the forward (k0) and reverse (k0R) zero-sequence current compensation factors so that the overreaching zones of ground-distance protection do not underreach for any internal ground fault. Put both parallel cables in service. *Table 6.28* lists the corresponding XAG calculations for a remote (Station R) ground fault for each of the three possible zero-sequence cable impedances when the k0 calculation is based on $Z_{0L1(ground)}$. (Replace k01 with k0 or replace k01 with k0R in *Equation 6.61* and *Equation 6.63*.)

Table 6.28 XAG Measurement for Remote AG Fault (k0 = 6.105 ∠44.5°, Ground Return Path)

Calculation	Z0L1(sheath)	Z0L1(ground)	Z0L1(sheath and ground)
XAG (secondary ohms)	0.04 Ω	0.48 Ω	0.05 Ω
Overreach/Underreach[a]	8.33% (O)	100%	10.4% (O)

[a] O indicates overreach, U indicates underreach

The results of *Table 6.28* show that the XAG calculation does not underreach when you set k0 based on the ground return path. Set k0 and k0R based on $Z_{0L1(ground)}$.

k0M := **6.105**. Forward Zones ZSC Factor Magnitude (0.000–10)

k0A := **44.5**. Forward Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

k0MR := **6.105**. Reverse Zones ZSC Factor Magnitude (0.000–10)

k0AR := **44.5**. Reverse Zones ZSC Factor Angle (–180.0 to +180.0 degrees)

Distance Element Common Time Delay

Set the operation time delay of both the phase and ground-distance elements.

Zone 1

There is no need to delay Zone 1 distance protection; the relay trips instantaneously for faults in Zone 1.

Z1D = **0.000**. Zone 1 Time Delay (OFF, 0.000–16000 cycles)

Zone 2

Zone 2 distance protection must coordinate with downstream Zone 1 distance protection plus the downstream circuit breaker operating time and a safety margin. A typical Zone 2 phase and ground-distance time delay setting is 20 cycles.

Z2D := **20.000**. Zone 2 Time Delay (OFF, 0.000–16000 cycles)

Short Adjacent Lines

You do not need to consider the following fault current return path scenario for this application example; this information is provided here for applications with short adjacent lines. *Figure 6.25* illustrates an important consideration if you apply time-delayed Zone 2 ground-distance protection to backup downstream Zone 1 ground-distance protection.

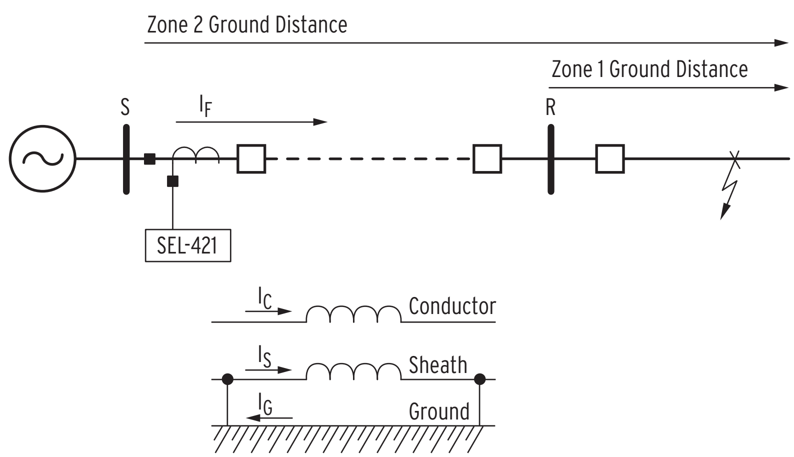


Figure 6.25 External Ground Fault

Fault current flows through the sheath and ground with respect to the cable because the sheath is grounded at each end during external ground faults. However, because you must make sure that Zone 2 ground-distance elements see all ground faults at remote Station R, the k0 setting was for the ground path only. Therefore, Zone 2 ground-distance protection may overreach for external ground faults, especially for the case of a short adjacent line. The solution is to increase Zone 2 time delay.

Zone 3

Zone 3 has reverse-looking distance protection that you do not need to apply for tripping in this application. Set Zone 3 for zero time delay.

Z3D := **0.000**. Zone 3 Time Delay (OFF, 0.000–16000 cycles)

SOTF Protection

SOTF logic is enabled when the circuit breaker closes. This logic provides protection for a short duration (setting SOTFD) until other protection (such as tripping from SELOGIC control equations TR, TRCOMM, and TRCOMMD) is available. The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of the protection elements assigned to TRSOTF during the SOTFD time causes the relay to trip instantaneously.

Use nondirectional overcurrent protection to clear close-in faults. Also use instantaneous overreaching distance protection to clear faults along the line. Assign instantaneous Zone 2 mho phase and ground-distance protection plus Level 1 phase overcurrent element to TRSOTF.

TRSOTF := **Z2P OR Z2G OR 50P1**. Switch-Onto-Fault Trip (SELOGIC Equation)

Voltage Reset

You can configure the logic so the SOTF enable duration resets within at least 5 cycles after it first asserted but before the SOTFD timer expires. To quickly reset the SOTF period before this time, the relay must sense that the positive-sequence voltage V_1 is greater than setting VRSTPU times the nominal voltage.

Use setting EVRST (Switch-Onto-Fault Voltage Reset) to enable fast reset. The advantage of resetting SOTF protection quickly is that unwanted tripping does not occur for subsequent faults external to the remote terminals during the SOTF period; these trips can occur if you set instantaneous Zone 2 distance protection elements in the TRSOTF SELOGIC control equation. Enable the voltage reset option.

EVRST := **Y**. Switch-Onto-Fault Voltage Reset (Y, N)

SOTF Initiation

The SOTF logic asserts via one or both of the following methods:

- A change in the normally open auxiliary contact 52A status showing that the circuit breaker has just opened
- Assertion of the relay control input assigned to the circuit breaker close bus

The 52A method initiation works well for both single and multiple circuit breaker applications and does not require an input from the close bus. However, close bus only initiation enables SOTF protection immediately following the close command to the circuit breaker. For more information see *Switch-Onto-Fault Logic on page 5.117*.

Turn off 52AEND (52A Pole-Open Time Delay).

52AEND := **OFF**. 52A Pole-Open Time Delay (OFF, 0.000–16000 cycles)

Select the close bus option for this application and set the close enable delay (CLOEND) shorter than the shortest reclose open interval.

CLOEND := **10.000**. CLSMON or Single-Pole Open Delay (OFF, 0.000–16000 cycles)

SOTF Duration

Setting SOTFD determines the longest period the SOTF logic can assert after the circuit breaker closes.

SOTFD := **10.000**. Switch-Onto-Fault Enable Duration (0.500–16000 cycles)

Close Signal Monitor

Assign the Relay Word bit CLSMON to a control input, so the relay can detect execution of the close command.

CLSMON := **IN102**. Close Signal Monitor (SELOGIC Equation)

Phase Instantaneous/Definite-Time Overcurrent Elements

Use Level 1 instantaneous phase overcurrent element (50P1) as a nondirectional high-set phase overcurrent element for SOTF protection. To rapidly clear faults, set pickup threshold 50P1P equal to 50 percent of the fault current measured at the local terminal for a close-in three-phase fault; use weak source conditions so that the relay operates for low-level fault current.

50P1P := **9.57**. Level 1 Pickup (OFF, 0.25–100 A secondary)

This application uses 50P1 as an instantaneous overcurrent element; you do not need time delay.

67P1D := **0.000**. Level 1 Time Delay (0.000–16000 cycles)

This application uses 50P1 as a nondirectional overcurrent element; you do not need torque control.

67P1TC := **1**. Level 1 Torque Control (SELOGIC Equation)

Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements

Negative-sequence directional overcurrent protection is an excellent choice for underground cable. The cable zero-sequence impedance depends on the current return paths, but the cable negative-sequence impedance does not. Negative-sequence directional overcurrent protection provides reliable and sensitive protection for cables against all unbalanced faults. Be sure to set negative-sequence overcurrent elements above system unbalances.

Negative-Sequence Overcurrent Elements

Enable three levels of negative-sequence overcurrent elements.

E50Q := **3**. Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (N, 1–4)

Disable Level 1 negative-sequence overcurrent element. This application does not use 50Q1.

50Q1P := **OFF**. Level 1 Pickup (OFF, 0.25–100 A secondary)

The Level 2 negative-sequence directional overcurrent element (67Q2) provides communications-assisted tripping for internal unbalanced faults. This element detects unbalanced faults in the forward direction and trips via the communications channel. The 50Q2P setting is the pickup for the directional overcurrent element 67Q2. Apply a setting equal to the default for the pickup of 32QG (Negative-Sequence Voltage Polarized Directional Element), which is 50FP (Forward Supervisory Overcurrent Pickup)

$$50Q2P = 50FP = 0.12 \bullet I_{NOM} = 0.12 \bullet 5\ A = 0.6\ A$$

50Q2P := **0.60**. Level 2 Pickup (OFF, 0.25–100 A secondary)

The Level 3 negative-sequence directional overcurrent element (67Q3) provides current reversal guard during unbalanced faults on the parallel cable to prevent unwanted tripping. The 50Q3P setting is the pickup for directional overcurrent element 67Q3. Set the pickup of Level 3 negative-sequence overcurrent element equal to the default for the pickup of 32QG (Negative-Sequence Voltage Polarized Directional Element), which is 50RP (Reverse Supervisory Overcurrent Pickup). The reverse-looking element is 150 percent more sensitive than the forward-looking element.

$$50Q3P = 50RP = 0.08 \bullet I_{NOM} = 0.08 \bullet 5\ A = 0.4\ A$$

50Q3P := **0.40**. Level 3 Pickup (OFF, 0.25–100 A secondary)

Negative-Sequence Overcurrent Pickup Coordination Check

Figure 6.26 illustrates why you need to check the sensitivity of the forward (50Q2P) and reverse (50Q3P) negative-sequence overcurrent pickup settings.

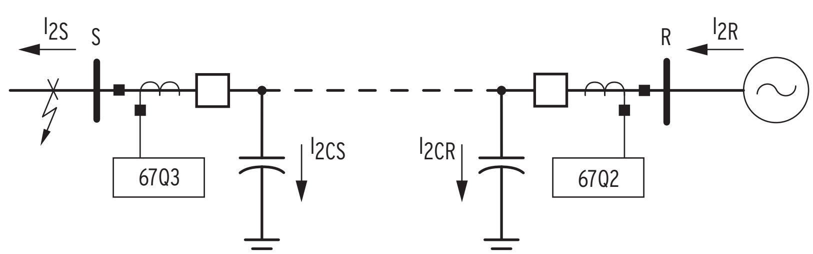


Figure 6.26 Negative-Sequence Fault Current Distribution-External Ground Fault

The shunt capacitance of the 230 kV cable causes the SEL-421 at Station S to measure less negative-sequence fault current for a reverse out-of-section ground fault than at Station R.

$$I_{2S} = I_{2R} - I_{2CR} - I_{2CS}$$

Equation 6.65

where:

I_{2R} = negative-sequence fault current supplied from Source R

I_{2S} = negative-sequence fault current flowing through the line terminal at Station S

I_{2CR} = negative-sequence shunt current at Station R

I_{2CS} = negative-sequence shunt current at Station S

Therefore, if the reverse-looking directional element at the local station is not more sensitive than the forward-looking directional element at the remote station, unwanted tripping can occur during external ground faults; the local 67Q3 element can fail to detect a reverse unbalanced fault that the remote 67Q2 element sees.

Use a short-circuit study to determine I_{2S} for a close-in reverse single phase-to-ground fault with respect to Station S; make sure to perform the fault calculations for the parallel cable both in service and out of service. The results of the study for this particular application show that the maximum difference between I_{2S} and I_{2R} for any close-in reverse unbalanced fault at Station S is 8.5 mA secondary. Therefore, the existing settings provided for 50Q2P and 50Q3P maintain coordination for external unbalanced faults.

There is no need to add any intentional time delay on pickup for Level 2 or 3 negative-sequence overcurrent elements.

67Q2D := **0.000**. Level 2 Time Delay (0.000–16000 cycles)

67Q3D := **0.000**. Level 3 Time Delay (0.000–16000 cycles)

Set the Level 2 torque control equation to the forward decision from the ground directional element.

67Q2TC := **32GF**. Level 2 Torque Control (SELOGIC Equation)

Set the Level 3 torque control equation to the reverse decision from the ground directional element.

67Q3TC := **32GR**. Level 3 Torque Control (SELOGIC Equation)

Selectable Operating Quantity Time Overcurrent Element 1

Use inverse-time overcurrent protection to provide backup protection for unbalanced faults including high-resistance ground faults. Selectable Operating Quantity Time Overcurrent Element 1 51S1 provides backup protection for unbalanced faults if both the communications-assisted and step distance protection fail to operate.

NOTE: Use your company practices and philosophy when determining these settings.

Select negative-sequence line current 3I2L as the operating quantity rather than 3I0L because ground current return paths vary.

51S1O := **3I2L**. 51S1 Operating Quantity
(IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)

The fault current ($3I_2$) that the relay measures for a bolted single phase-to-ground fault at the end of the longest line from the remote station with the parallel cable in service at minimum generation is 3.0 A secondary (this is the minimum of minimums). Set the pickup between 30 to 50 percent of this current.

$$51S1P = 1/3 \cdot 3I_{2FAULT} = 1/3 \cdot 3.00\text{ A} = 1.00\text{ A}$$

51S1P = **1.00**. 51S1 Overcurrent Pickup (0.25–16 A secondary)

Use the following formula to determine approximately how much primary fault resistance coverage (R_F) that 51S1P provides on a radial basis:

$$R_F = \frac{PTR}{CTR} \bullet \frac{\left|\frac{VNOMY}{\sqrt{3}}\right|}{51S1P}$$
$$= \left(\frac{2000}{200} \bullet \frac{\frac{115\ V}{\sqrt{3}}}{1.00\ A}\right)$$
$$= 664\ \Omega \text{ primary}$$

Equation 6.66

Use the following as a guide to set the curve and time dial; for secure backup protection, perform a coordination study. Set the local overcurrent element to coordinate with the downstream overcurrent element so there is a 12-cycle (60 Hz nominal) safety margin for phase-to-phase (high current) faults in front of the first downstream overcurrent element. Assume the operating time of the downstream overcurrent element is 12 cycles for close-in phase-to-phase faults. Therefore, set the local time-overcurrent element to operate at approximately 24 cycles for phase-to-phase faults in front of the first downstream overcurrent element.

The fault current ($3I_2$) that the relay measures for a bolted close-in phase-to-phase fault at the remote station with the parallel cable out of service is 18.67 A secondary. The pickup multiple is shown in *Equation 6.67*.

$$M = \frac{I_{2FAULT}}{51S1P}$$
$$= \frac{18.67\ A}{1.00\ A}$$
$$= 18.67$$

Equation 6.67

Use the parameters of 24 cycles operating time and M = 18.67 to choose the curve and time dial settings for the 51S1 element. For curve and timing information, see *Inverse-Time Overcurrent Elements on page 5.99*.

51S1C = **U3**. 51S1 Inverse-Time Overcurrent Curve (U1–U5)

51S1TD = **3.72**. 51S1 Inverse-Time Overcurrent Time Dial (0.50–15.0)

Set the overcurrent element to emulate electromechanical reset.

51S1RS = **Y**. 51S1 Inverse-Time Overcurrent EM Reset (Y, N)

Torque control the overcurrent element with the forward decision from the ground directional element.

51S1TC = **32GF**. 51S1 Torque Control (SELOGIC Equation)

Zone/Level Direction

Zone 1 and Zone 2 distance element directions are fixed in the forward direction. You can select the other zones independently as forward-looking (F), or reverse-looking (R). Set Zone 3 distance elements reverse-looking; these are blocking elements for the POTT scheme.

DIR3 := **R**. Zone/Level 3 Directional Control (F, R)

Directional Control

The SEL-421 uses an array of directional elements to supervise the ground-distance elements and residual directional overcurrent elements during ground fault conditions. Internal logic automatically selects the best choice for the ground directional element (32G) from among the negative-sequence voltage-polarized directional element (32QG), zero-sequence voltage-polarized directional element (32V), and the zero-sequence current-polarized directional element (32I).

The relay setting ORDER determines the order in which the relay selects directional elements to provide the ground directional decisions. You can set ORDER with any combination of Q, V, and I. The listed order of these directional elements determines the priority in which these elements operate to provide ground directional decisions. Only one specific directional element operates at any one time. Directional element classification is as follows:

- Q—Negative-sequence voltage-polarized directional element
- V—Zero-sequence voltage-polarized directional element
- I—Zero-sequence current-polarized directional element

Set ORDER to Q. This setting selects only the negative-sequence voltage-polarized directional element. You rely on 32QG to provide high-speed reliable and sensitive protection during unbalanced faults via the communications channel. Cable zero-sequence impedance depends on the fault current return path; the negative-sequence impedance of the cable does not.

ORDER := **Q**. Ground Directional Element Priority (combine Q, V, I)

The relay hides the Z0F, Z0R, a0, and E32IV settings because ORDER does not contain V or I.

Negative-Sequence Voltage-Polarized Directional Element Reverse Decision (R32QG) Check

The setting Z2R is the reverse threshold for the negative-sequence voltage-polarized directional element. If the apparent negative-sequence impedance (z2) that the relay measures is greater than Z2R, the relay declares that an unbalanced fault is reverse. For overhead transmission lines, ignore the shunt admittance that represents the charging capacitance. The shunt negative-sequence admittance of the underground cable is significant and modifies the z2 measurement during reverse faults. You must include this admittance in the cable model to verify proper operation of the default setting.

Figure 6.27 illustrates the effect of the shunt admittance at both ends of the circuit for a reverse unbalanced fault.

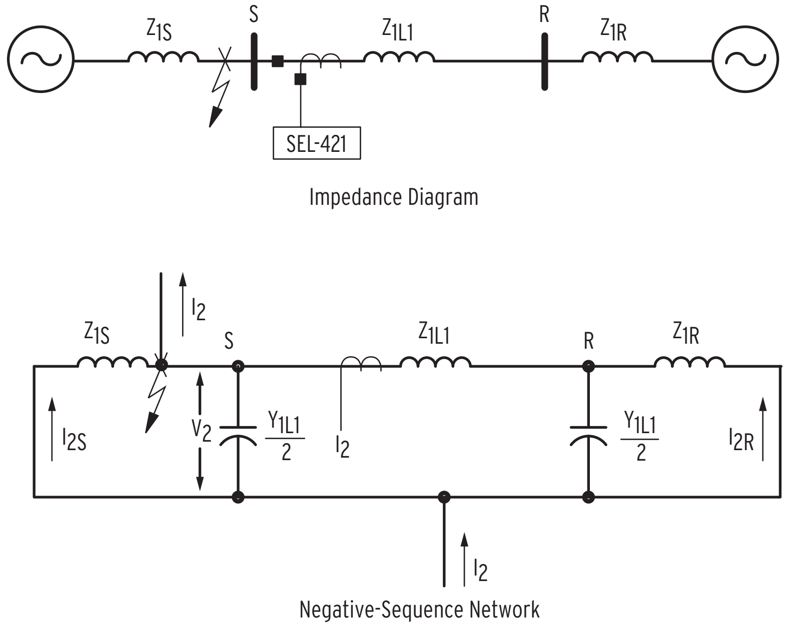


Figure 6.27 Reverse Unbalanced Fault on Cable Circuit (Shunt Admittance)

The technical paper *Underground/Submarine Cable Protection Using a Sequence Directional Comparison Scheme* (see selinc.com for a copy of this paper) provides an equation that allows you to express the apparent negative-sequence impedance at the relay terminal for a reverse unbalanced fault when accounting for charging capacitance:

$$|Z_{2S}| = \left|\frac{-V_{2S}}{I_{2S}}\right|$$
$$= \frac{4 \bullet Z_{1L1} + 2 \bullet Y_{1L1} \bullet Z_{1L1} \bullet Z_{1R} + 4 \bullet Z_{1R}}{4 + 4 \bullet Y_{1L1} \bullet Z_{1R} + 2 \bullet Y_{1L1} \bullet Z_{1L1} + Y^2{}_{1L1} \bullet Z_{1L1} \bullet Z_{1R}}$$
$$= 3.86\ \Omega$$

Equation 6.68

The SEL-421 uses *Equation 6.69* to calculate the apparent negative-sequence impedance during unbalanced faults:

$$z2 = \frac{\mathrm{Re}[V_2 \bullet (I_2 \bullet \angle Z1ANG)^*]}{|I_2|^2}$$

Equation 6.69

Equation 6.69 yields a more conservative result for the negative-sequence impedance when the parallel cable is out of service:

|Z2S| = 2.97 Ω

The result of *Equation 6.69* is greater than the default setting for Z2R; Z2R = (Z2F + 1/(2 • I_{NOM}). (See *Ground Directional Elements on page 1.18* for more information.)

Pole-Open Detection

The setting EPO offers two options for deciding what conditions signify an open pole, as listed in *Table 6.29*.

Table 6.29 Options for Enabling Pole-Open Logic

Option	Description
EPO := V	The logic declares a single-pole open if the corresponding phase undervoltage element asserts and the open-phase detection logic declares the pole is open. Select this option only if you use line-side potential transformers for relaying purposes. A typical setting for the 27PO, pole-open undervoltage threshold, is 60 percent of the nominal line-to-neutral voltage. Do not select this option when shunt reactors are applied because the voltage slowly decays after the circuit breaker opens. With this option selected, the relay can incorrectly declare LOP during a pole-open condition if there is charging current that exceeds the pole-open current threshold.
EPO := 52	The logic declares a single-pole open if the corresponding 52A contact (52AA1) from the circuit breaker deasserts and the open-phase detection logic declares that the pole is open.

Select the second option because a 52A contact is available. The relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision.

EPO := **52**. Pole-Open Detection (52, V)

Pole-Open Time Delay on Dropout

The setting 3POD is the time delay on dropout after the Relay Word bit 3PO deasserts. The setting 3POD stabilizes the ground-distance elements during pole scatter when the circuit breaker closes.

3POD := **0.500**. Three-Pole Open Dropout Delay (0.000–60 cycles)

POTT Trip Scheme

This application example presents the permissive overreaching transfer trip (POTT) scheme to high-speed trip for faults along the protected cable.

The POTT scheme logic consists of the following sections:

- Current reversal guard logic
- Echo
- Weak infeed logic
- Permission to trip received

Current Reversal Guard Logic

This is a parallel cable application, so you must use current reversal guard. When the reverse-looking elements detect an external fault, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal. The Zone 3 Reverse Block Delay (Z3RBD) timer extends these two operations after a current reversal occurs and the reverse-looking elements drop out.

Set the Z3RBD timer to accommodate the following:

- Remote Station R circuit breaker maximum opening time
- Maximum communications channel reset time
- Remote Station R Zone 2 relay maximum reset time

Assume a circuit breaker opening time of 3 cycles, a communications channel reset time of 1 cycle, and remote Zone 2 relay reset time of 1 cycle. The sum of these times gives a conservative setting of 5 cycles for a three-cycle circuit breaker.

Z3RBD := **5.000**. Zone 3 Reverse Block Time Delay (0.000–16000 cycles)

Echo

If the circuit breaker is open, or a weak infeed condition exists at the local terminal, the received permissive signal can echo back to the remote relay and cause it to issue a high-speed trip for faults beyond the remote relay Zone 1 reach. The SEL-421 includes logic that echoes the received permissive trip signal back to the remote terminal after specific conditions are satisfied. The echo logic includes timers for blocking the echo logic as well as timers for qualifying the permissive signal.

Use Echo Block Time Delay (EBLKD) to block the echo logic after dropout of local permissive elements. The recommended setting for the EBLKD timer is the sum of the following:

- Remote Station R circuit breaker opening time
- Communications channel round trip time
- Safety margin

Assume a circuit breaker opening time of 3 cycles, a communications channel round trip time of 2 cycles, and a safety margin of 5 cycles. The sum of these times gives a conservative setting of 10 cycles for a three-cycle circuit breaker.

EBLKD := **10.000**. Echo Block Time Delay (OFF, 0.000–16000 cycles)

The echo time delay, setting ETDPU, makes certain that the reverse-looking elements at the receiving end have sufficient time to operate and block the received echo signal for external faults behind the remote terminal. The delay also guards the echo and weak infeed logic against noise bursts that can occur on the communications channel during close-in external faults.

Because of the brief duration of noise bursts and the pickup time for the reverse-looking elements, a received signal must be present for a short time to allow the POTT scheme to echo the permissive signal back to the remote terminal. The ETDPU timer specifies the time a permissive trip signal must be present. The ETDPU setting depends upon your communications equipment, but a conservative setting for this timer is 2 cycles.

ETDPU := **2.000**. Echo Time Delay Pickup (OFF, 0.000–16000 cycles)

The setting EDURD (Echo Duration Time Delay) limits the duration of the echoed permissive signal. Once an echo signal initiates, it should remain for a minimum period of time and then stop, even if a terminal receives a continuous permissive signal. This cessation of the echo signal prevents the permissive trip signal from latching between the two terminals. Assume a 3-cycle circuit breaker at the remote terminal and a 1-cycle channel delay. The sum of these two is a setting of 4 cycles.

EDURD := **4.000**. Echo Duration Time Delay (0.000–16000 cycles)

Weak Infeed

The SEL-421 provides weak-infeed logic to high-speed trip both line terminals for internal faults near the weak terminal. The weak terminal echoes the permissive signal back to the strong terminal and causes the strong terminal to trip. The weak terminal trips by converting the echoed permissive signal to a trip signal if specific conditions are satisfied.

This application example does not use the weak-infeed feature.

EWFC := **N**. Weak Infeed Trip (Y, N, SP)

Permission to Trip Received

Assign a control input to receive trip permission from the remote terminal.

PT1 := **IN103**. General Permissive Trip Received (SELOGIC Equation)

Trip Logic

Trip logic configures the relay for tripping. There are four trip logic settings components:

- Trip equations
- Trip unlatch options
- Trip timers
- Three-pole tripping enable

Trip Equations

Set these three SELOGIC control equations for tripping:

- TR (unconditional)
- TRCOMM/TRCOMMD (communications-assisted; in this example we use only TRCOMM)
- TRSOTF (SOTF)

TR

The TR SELOGIC control equation determines which protection elements cause the relay to trip unconditionally. Set TR to the Zone 1 instantaneous distance protection (Z1T), Zone 2 time-delayed distance protection, and the inverse-time overcurrent element (51S1) for backup protection. For information on setting 51S1, see *Selectable Operating Quantity Time Overcurrent Element 1 on page 6.10*.

TR := **Z1T OR Z2T OR 51S1T**. Trip (SELOGIC Equation)

TRCOMM

The TRCOMM SELOGIC control equation determines which elements trip via the communication-assisted tripping logic. In the TRCOMM SELOGIC control equation, set Zone 2 mho phase-distance protection for phase faults, and Level 2 negative-sequence directional overcurrent element (67Q2) for ground faults.

TRCOMM := **Z2P OR 67Q2**. Communications-Assisted Trip (SELOGIC Equation)

TRSOTF

The TRSOTF SELOGIC control equation defines which protection elements cause the relay to trip when the SOTF scheme is active. Assertion of these protection elements during the SOTFD time causes the relay to trip instantaneously (see *SOTF Protection on page 6.103*). Set instantaneous Zone 2 distance protection (Z2G) and Level 1 phase instantaneous overcurrent element (50P1) in the TRSOTF SELOGIC control equation.

TRSOTF := Z2P OR Z2G OR 50P1. Switch-Onto-Fault Trip (SELOGIC Equation)

Trip Unlatch Options

Unlatch the control output you programmed for tripping (OUT101) after the circuit breaker auxiliary a contacts break the dc current. The SEL-421 provides two methods for unlatching control outputs following a protection trip:

- ULTR—all three poles
- TULO—phase selective

ULTR

Use ULTR, the Unlatch Trip SELOGIC control equation, to unlatch all three poles. Use the default setting to assert ULTR when you push the front-panel target reset button.

ULTR := **TRGTR**. Unlatch Trip (SELOGIC Equation)

TULO

Use TULO (Trip Unlatch Option) to select the conditions that cause the SEL-421 to unlatch the control outputs that you programmed for tripping. *Table 6.30* shows the four trip unlatch options for setting TULO.

Table 6.30 Setting TULO Unlatch Trip Options

Option	Description
1	Unlatch the trip when the relay detects that one or more poles of the line terminal are open, and Relay Word bit 3PT has deasserted.
2	Unlatch the trip when the relay detects that the corresponding 52A contact(s) from both circuit breakers (52AA1 and 52AA2) are deasserted.
3	Unlatch the trip when the relay detects that the conditions for Options 1 and 2 are satisfied.
4	Do not run this logic.

Select Option 3 because a 52A contact is available; the relay uses both open-phase detection and status information from the circuit breaker to make the most secure decision. For information on the pole-open logic, see *Pole-Open Logic on page 5.25*.

TULO := **3**. Trip Unlatch Option (1, 2, 3, 4)

Trip Timers

The SEL-421 provides dedicated timers for minimum trip duration.

Minimum Trip Duration

The minimum trip duration timer setting, TDUR3D, determines the minimum time that Relay Word bit 3PT asserts. For this application example, Relay Word bit 3PT is assigned to OUT101. The corresponding control output closes for TDUR3D time or the duration of the trip condition, whichever is longer.

A typical setting for this timer is 9 cycles.

TDUR3D := **9.000**. Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)

Three-Pole Tripping Enable

The relay contains both three-pole and single-pole tripping logic. Set E3PT (Three-Pole Trip Enable) to logical 1 to enable the SEL-421 for three-pole tripping only.

E3PT := **1**. Three-Pole Trip Enable (SELOGIC Equation)

Also set the appropriate three-pole tripping SELOGIC control equation for Circuit Breaker BK1.

E3PT1 := **1**. Breaker 1 3PT (SELOGIC Equation)

Control Outputs

Main Board

Use SELOGIC control equations to assign the control output for tripping.

Use the main board control outputs for tripping and keying the transmitter of the external teleprotection equipment.

OUT101 := **3PT**. (SELOGIC Equation)

OUT102 := **KEY**. (SELOGIC Equation)

Example Completed

This completes the application example that describes setting of the SEL-421 for communications-assisted protection of 230 kV underground cables. You can use this example as a guide when setting the relay for similar applications. Analyze your particular power system to determine the proper settings for your application.

Relay Settings

Table 6.31 lists the protective relay settings available for this example.

Table 6.31 Settings for 230 kV Parallel Cables Example (Sheet 1 of 5)

Setting	Prompt	Entry
General Global Settings (Global)		
SID	Station Identifier (40 characters)	LEWISTON -- 230 kV
RID	Relay Identifier (40 characters)	SEL-421 Relay
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Circuit Breaker 1
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
DATE_F	Date Format (MDY, YMD, DMY)	MDY
FAULT	Fault Condition Equation (SELOGIC Equation)	50P1 OR 51S1 OR Z2P OR Z2G OR Z3P OR Z3G
Current and Voltage Source Selection (Global)		
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
Breaker Configuration (Breaker Monitoring)		
EB1MON	Breaker 1 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
Breaker 1 Inputs (Breaker Monitoring)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Line Configuration (Group)		
CTRW	Current Transformer Ratio—Input W (1–50000)	200
CTRX	Current Transformer Ratio—Input X (1–50000)	200
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000.0
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000.0
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	0.48
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	42.5
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 Ω secondary)	0.96
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	21.7
EFLOC	Fault Location (Y, N)	Y
LL	Line Length (0.10–999)	25
Relay Configuration Settings (Group)		
E21P	Mho Phase Distance Zones (N, 1–5)	3
E21MG	Mho Ground Distance Zones (N, 1–5)	N
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	3
ECVT	CVT Transient Detection (Y, N)	N

Table 6.31 Settings for 230 kV Parallel Cables Example (Sheet 2 of 5)

Setting	Prompt	Entry
ESERCMP	Series-Compensated Line Logic (Y, N)	N
ECDTD	Distance Element Common Time Delay (Y, N)	Y
ESOTF	Switch-Onto-Fault (Y, N)	Y
EOOS	Out-of-Step (Y, Y1, N)	N
ELOAD	Load Encroachment (Y, N)	N
E50P	Phase Inst./Def.-Time O/C Elements (N, 1–4)	1
E50G	Res. Ground Inst./Def. Time O/C Elements (N, 1–4)	N
E50Q	Negative-Sequence Inst./Def. Time O/C Elements (N, 1–4)	3
E51S	Selectable Inverse Time O/C Element (N, 1–3)	1
E32	Directional Control (Y, AUTO, AUTO2)	AUTO2
ECOMM	Comm.-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	POTT
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	N
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N
E79	Reclosing (Y, Y1, N)	N
EMANCL	Manual Closing (Y, N)	N
ELOP	Loss-of-Potential (Y, Y1, N)	Y1
EDEM	Demand Metering (N, THM, ROL)	N
EADVS	Advanced Settings (Y, N)	Y
Mho Phase-Distance Element Reach (Group)		
Z1MP	Zone 1 Reach (OFF, 0.05–64 Ω secondary)	0.38
Z2MP	Zone 2 Reach (OFF, 0.05–64 Ω secondary)	0.58
Z3MP	Zone 3 Reach (OFF, 0.05–64 Ω secondary)	0.58
Mho Phase-Distance Element Time Delay (Group)		
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Quadrilateral Ground-Distance Element Reach (Group)		
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary)	0.38
RG1	Zone 1 Resistance (0.05–50 Ω secondary)	1.29
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary)	0.58
RG2	Zone 2 Resistance (0.05–50 Ω secondary)	1.97
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary)	0.58
RG3	Zone 3 Resistance (0.05–50 Ω secondary)	2.46
XGPOL	Quad Ground Polarizing Quantity (I2, IG)	I2
TANGG	Nonhomogeneous Correction Angle (–40.0 to +40 degrees)	–2.2
Zero-Sequence Current Compensation Factor (Group)		
k0M1	Zone 1 ZSC Factor Magnitude (AUTO, 0.000–10)	0.385
k0A1	Zone 1 ZSC Factor Angle (–180.0 to +180 degrees)	–46.7

Table 6.31 Settings for 230 kV Parallel Cables Example (Sheet 3 of 5)

Setting	Prompt	Entry
k0M	Forward Zones ZSC Factor Magnitude (0.000–10)	6.105
k0A	Forward Zones ZSC Factor Angle (–180.0 to +180 degrees)	44.5
k0MR	Reverse Zones ZSC Factor Magnitude (0.000–10)	6.105
k0AR	Reverse Zones ZSC Factor Angle (–180.0 to +180 degrees)	44.5
Ground-Distance Element Time Delay (Group)		
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	OFF
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	OFF
Distance Element Common Time Delay (Group)		
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	0.000
SOTF Scheme (Group)		
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	Y
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 pu)	0.60–1.00 pu
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	OFF
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	10.000
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000
CLSMON	Close Signal Monitor (SELOGIC Equation)	IN102
Phase Instantaneous Overcurrent Pickup (Group)		
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	9.57
Phase Overcurrent Definite-Time Delay (Group)		
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
Phase Overcurrent Torque Control (Group)		
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
Negative-Sequence Instantaneous Overcurrent Pickup (Group)		
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	OFF
50Q2P	Level 2 Pickup (OFF, 0.25–100 A secondary)	0.60
50Q3P	Level 3 Pickup (OFF, 0.25–100 A secondary)	0.40
Negative-Sequence Overcurrent Definite-Time Delay (Group)		
67Q2D	Level 2 Time Delay (0.000–16000 cycles)	0.000
67Q3D	Level 3 Time Delay (0.000–16000 cycles)	0.000
Negative-Sequence Overcurrent Torque Control (Group)		
67Q2TC	Level 2 Torque Control (SELOGIC Equation)	32GF
67Q3TC	Level 3 Torque Control (SELOGIC Equation)	32GR

Table 6.31 Settings for 230 kV Parallel Cables Example (Sheet 4 of 5)

Setting	Prompt	Entry
Selectable Operating Quantity Inverse-Time Overcurrent Element 1 (Group)		
51S1O	51S1 Op. Qty (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I2L
51S1P	51S1 O/C Pickup (0.25–16 A secondary)	1.00
51S1C	51S1 Inverse Time O/C Curve (U1–U5)	U3
51S1TD	51S1 Inverse Time O/C Time Dial (0.50–15)	3.72
51S1RS	51S1 Inverse Time O/C EM Reset (Y, N)	Y
51S1TC	51S1 Torque Control (SELOGIC Equation)	32GF
Zone/Level Direction (Group)		
DIR3	Zone/Level 3 Directional Control (F, R)	R
Directional Control (Group)		
ORDER	Ground Dir. Element Priority (combine Q, V, I)	Q
Pole-Open Detection (Group)		
EPO	Pole Open Detection (52, V)	52
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500
POTT Trip Scheme (Group)		
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000
EWFC	Weak Infeed Trip (Y, N, SP)	N
PT1	General Permissive Trip Received (SELOGIC Equation)	IN103
Trip Logic (Group)		
TR	Trip (SELOGIC Equation)	Z1T OR Z2T OR 51S1T
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	Z2P OR 67Q2
TRCOMMD	Dir. Element Comms.-Assisted Trip (SELOGIC Equation)	NA
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	Z2P OR Z2G OR 50P1
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA
BK1MTR	Manual Trip–Breaker 1 (SELOGIC Equation)	OC1 OR PB8_PUL
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR
ULMTR1	Unlatch Manual Trip–Breaker 1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000
TULO	Trip Unlatch Option (1, 2, 3, 4)	3

Table 6.31 Settings for 230 kV Parallel Cables Example (Sheet 5 of 5)

Setting	Prompt	Entry
Z2GTSP	Zone 2 Ground Distance Time Delay SPT (Y, N)	N
67QGSP	Zone 2 Dir. Negative-Sequence/Residual Overcurrent Single Pole Trip (Y, N)	N
TDUR1D	SPT Min Trip Duration Time Delay (2.000–8000 cycles)	6.000
TDUR3D	3PT Min Trip Duration Time Delay (2.000–8000 cycles)	9.000
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1
E3PT1	Breaker 1 3PT (SELOGIC Equation)	1
ER	Event Report Trigger (SELOGIC Equation)	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G
Main Board (Outputs)		
OUT101	(SELOGIC Equation)	3PT
OUT102	(SELOGIC Equation)	KEY

[a] Parameter *n* is 1 for BK1, 2 for BK2, and L for Line.

Out-of-Step Logic Application Examples

The SEL-421 features OOS (out-of-step) logic for the following two functions:

- OSB (out-of-step blocking) logic blocks phase-distance elements and Zone 1 ground-distance elements during power swings.
- OST (out-of-step tripping) logic trips the circuit breaker(s) during unstable swings.

There are two application examples that explain how to apply OOS logic: an out-of-step blocking scheme and an out-of-step tripping and blocking scheme. The examples provide detailed setting procedures for a 5 A relay.

These examples are for three-pole tripping in a 500 kV power system. Applications for single-pole tripping are similar. Refer to *Figure 6.28* for a one-line diagram of the 500 kV system.

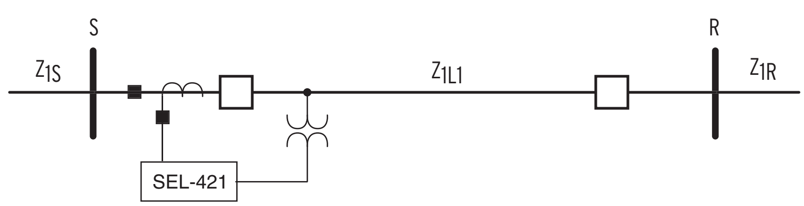


Figure 6.28 500 kV Power System

Power System Parameters

Table 6.32 lists the power system parameters.

Table 6.32 Positive-Sequence Impedances (Secondary)

Parameter	Value
Line impedances: Z_{1L1}	8.00 Ω ∠87.6° secondary (Z1MAG W ÐZ1ANG°)
Zone 2 Phase-Distance Reach: Z_{2MP}	9.60 Ω secondary
Source S impedances: Z_{1S}	8.8 Ω ∠88° secondary
Source R impedances: Z_{1R}	3.52 Ω ∠88° secondary
Nominal frequency (f_{NOM})	60 Hz
Nominal current (I_{NOM})	5 A secondary
Line Length	100 miles

Out-of-Step Blocking

This example demonstrates setting OSB function. Use this logic to discriminate between power swings and faults to prevent unwanted distance element trips. This application example assumes that you have set the phase-to-phase mho distance element Zone 2 reach. First, enable the OOS logic. Next, calculate the impedance reach settings for Zone 6 and Zone 7 (R1R6, R1R7, X1T6, and X1T7), and then calculate OSBD (out-of-step block time delay). All of the OOS settings appear in *Table 6.33* and *Table 6.34* at the end of this example.

Enable OOS Logic

NOTE: The relay automatically calculates and hides settings when you set EADVS to N and EOOST to N. *Table 6.33* lists these settings.

Access Group settings to enable the out-of-step logic.

EOOS := **Y**. Out-of-Step (Y, N)

You do not need to enable the Advanced Settings for this application example.

EADVS := **N**. Advanced Settings (Y, N)

Out-of-Step Tripping

Disable the OST logic for this particular application example.

EOOST := **N**. Out-of-Step Tripping (N, I, O)

Phase-Distance Element Blocking

OSB logic blocks phase-distance protection during a swing when the measured positive-sequence impedance enters the operating characteristics of the phase-distance elements (see Zone 1 and Zone 2 in *Figure 6.29*). In practice, it is not necessary to block all zones. In this application example, the OSB logic blocks zones that generate instantaneous tripping. The OSB logic blocks instantaneous Zone 1 and Zone 2 (Zone 2 is part of the communications-assisted tripping scheme).

The OSB logic typically supervises forward-looking Zone 1 and Zone 2 because the operation time of these two zones is ordinarily shorter than the time period during which the impedance of a power swing resides in these protection zones. For example, if the period of a swing is 1.5 seconds, OSB logic should supervise instantaneous Zone 1 and communications-assisted Zone 2.

During a power swing, the relay typically does not block overreaching zones of protection that provide time-delayed tripping. Do not block reverse-looking Zone 3 when this zone serves as a starting element for the DCB (directional comparison blocking) scheme or when this zone provides current reversal guard for the POTT (permissive overreaching transfer tripping) scheme. For example, if the OSB logic inhibits the DCB blocking signal during swings that pass behind the local relay, over-tripping can occur at the remote terminal. If a power swing enters both the local reverse-looking Zone 3 and the remote overreaching Zone 2, high-speed tripping occurs at the remote terminal because OSB logic removes the local Zone 3 element DCB scheme block.

Set the relay to block Zone 1 and Zone 2.

OOSB1 := **Y**. Block Zone 1 (Y, N)

OOSB2 := **Y**. Block Zone 2 (Y, N)

OOSB3 := **N**. Block Zone 3 (Y, N)

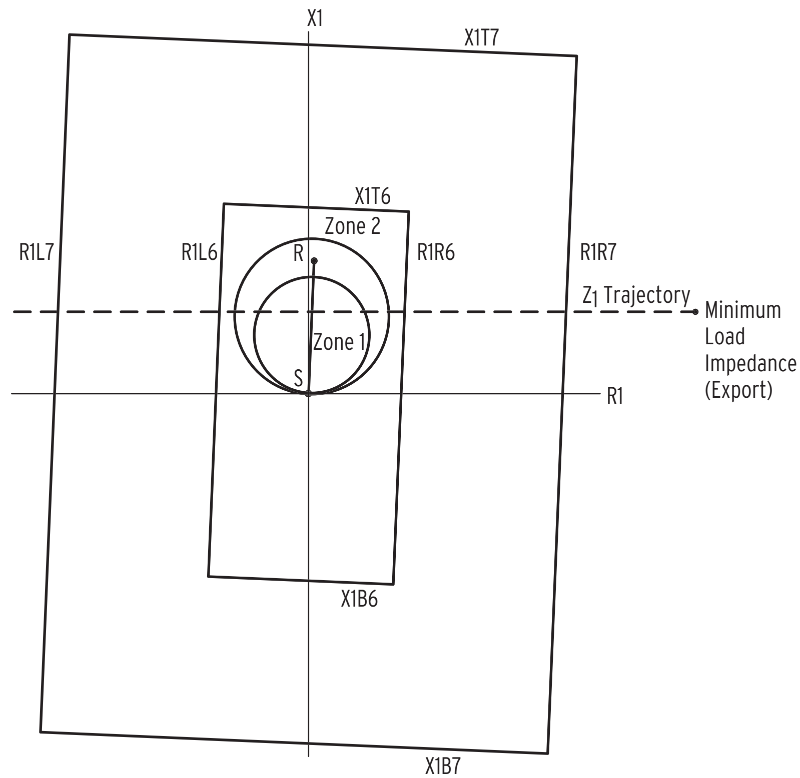


Figure 6.29 OOS Characteristic Settings Parameters

Zone 6 and Zone 7 Impedance Settings

The OOS logic uses two zones of concentric polygons, outer Zone 7 and inner Zone 6 (see *Figure 6.29*). The relay uses Zone 6 and Zone 7 for OOS logic timing to differentiate between power swings and faults. The relay measures a traveling positive-sequence impedance locus (Z_1) in Zone 6 and Zone 7 when a power swing or fault occurs. Two factors affect the Zone 6 and Zone 7 impedance settings:

- ➤ The outermost overreaching zone of phase-distance protection that you want to block.
- ➤ The load impedance that the relay measures during maximum load (minimum load impedance locus).

NOTE: This settings philosophy provides the most time for the relay to decide whether a fault or a power swing has occurred.

Set inner Zone 6 (X1T6, R1R6, X1B6, and R1L6) to encompass the outermost zone of phase-distance protection that you have selected for out-of-step blocking. Set Zone 7 so that the closest minimum load impedance locus is outside the Zone 7 characteristic for all loading conditions.

Resistance Blinders

Zone 2 is the outermost characteristic for this particular example. Include a safety margin (20 percent for this example).

When you set Zone 6, SEL recommends that you assume that Z1ANG is at 90 degrees. This allows the user to set the resistive reach of the zone along the x-axis. Internally, the relay will adjust the setting by the line angle Z1ANG when the zone setting is applied. Adjusting the setting by Z1ANG allows the resistive reach to be parallel with the line angle, as shown in *Figure 6.29*. Use *Equation 6.70* to set the reach of Zone 6 along the x-axis.

$$\begin{aligned} \text{R1R6} &= 1.2 \bullet \frac{\text{Z2MP}}{2} \\ &= \left(1.2 \bullet \frac{9.60\ \Omega}{2}\right) \\ &= 5.77\ \Omega \end{aligned}$$

Equation 6.70

where:

Z2MP = Zone 2 mho phase-distance element reach (see *Table 6.32*).

R1R6 := **5.77**. Zone 6 Resistance—Right (0.05–140 Ω secondary)

Set Zone 7 outer resistance blinders according to maximum load. In other words, set the Zone 7 outer right-hand resistance blinder just inside the corresponding minimum export load impedance locus (maximum load locus). The maximum load current is 2.41 A secondary, determined from load studies. The corresponding line-to-neutral voltage during maximum load at Station S is 61.44 V secondary.

$I_{L(max)}$ =2.41 A
VLN =61.44 V

Determine the minimum load impedance that the relay measures:

$$\begin{aligned} Z_{L_{min}} &= \frac{V_{LN}}{I_{L(MAX)}} \\ &= \frac{61.44\ \text{V}}{2.41\ \text{A}} \\ &= 25.49\ \Omega \end{aligned}$$

Equation 6.71

Assume that the maximum load angle is ±45°. Use trigonometry to calculate R1R7, which is the distance from the origin to the right-hand resistance blinder along line OP, the c side of the right triangle (see *Table 6.30*). The resistance blinders are parallel to the line characteristic impedance Z1L1, for which the angle is setting Z1ANG.

$$\cos(A) = \frac{c}{b}$$

Equation 6.72

where:

$A = 45° + (90° - \angle Z1ANG)$
$b = Z_{L(min)}$
$c =$ setting R1R7

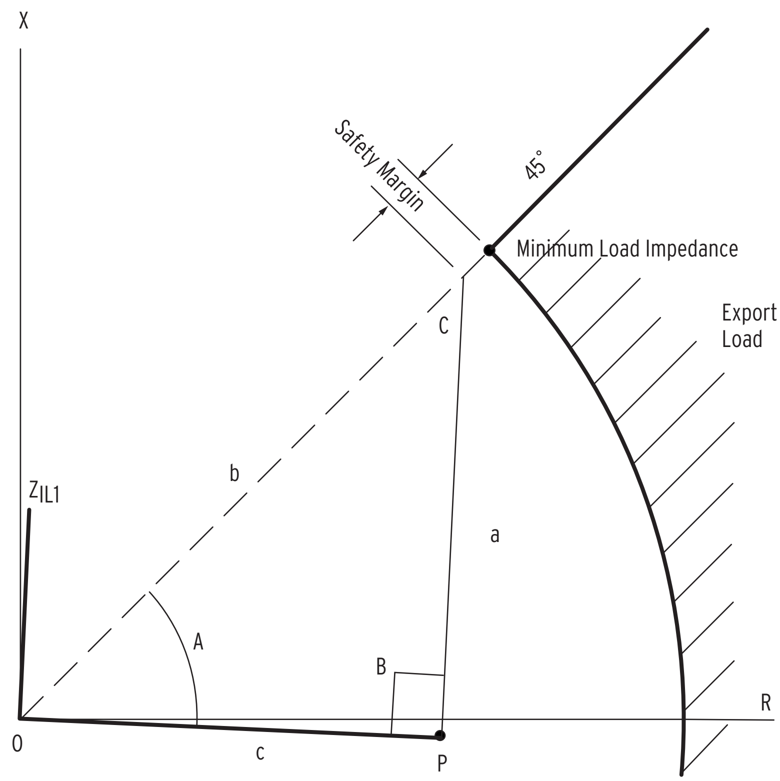


Figure 6.30 Calculating Setting R1R7

Rearrange *Equation 6.72* and multiply by a safety factor of 90 percent to calculate R1R7.

$$\begin{aligned} R1R7 &= 0.9\% \cdot Z_{L(min)} \cdot \cos(A) \\ &= 0.9 \cdot Z_{L(min)} \cdot \cos[45° + (90° - Z1ANG)] \\ &= 0.9 \cdot 25.49 \cdot \cos[45° + (90° - 87.6°)] \\ &= 0.9 \cdot 25.49 \cdot \cos(47.4°) \\ &= 15.53\ \Omega \end{aligned}$$

Equation 6.73

R1R7 := **15.53**. Zone 7 Resistance—Right (0.05–140 Ω secondary)

Reactance Lines

Zone 6 inner reactance lines X1T6 and X1B6 should completely encompass the outermost zone of phase-distance protection that you want to block from tripping during a power swing. Include a safety margin (20 percent).

$$\begin{aligned} X1T6 &= 1.2 \cdot Z2MP \\ &= (1.2 \cdot 9.60\ \Omega) \\ &= 11.52\ \Omega \end{aligned}$$

Equation 6.74

where:

Z2MP = Zone 2 mho phase-distance element reach

X1T6 := **11.52**. Zone 6 Reactance—Top (0.05–140 Ω secondary)

The distance between Zones 6 and 7 top reactance lines should equal the distance between Zones 6 and 7 right-hand resistance blinders.

NOTE: The value for X1T7 must be at least 0.1 Ω greater than that for X1T6.

$$\begin{aligned} X1T7 &= X1T6 + (R1R7 - R1R6) \\ &= 11.52\ \Omega + (15.53\ \Omega - 5.76\ \Omega) \\ &= 21.29\ \Omega \end{aligned}$$

Equation 6.75

X1T7 := **21.29**. Zone 7 Reactance—Top (0.05–140 Ω secondary)

Out-of-Step Block Time Delay

When the Z_1 impedance locus initially moves inside Zone 7, the relay starts the OSBD (out-of-step block time delay) timer. The Z_1 impedance trajectory is shown in *Figure 6.31* for the case of $|E_A| = |E_B|$ (E_A is the voltage at Node A and E_B is the voltage at Node B). The OSBD timer detects slow swings. If the OSBD timer expires before the Z_1 trajectory enters Zone 6, the relay detects a power swing blocking condition.

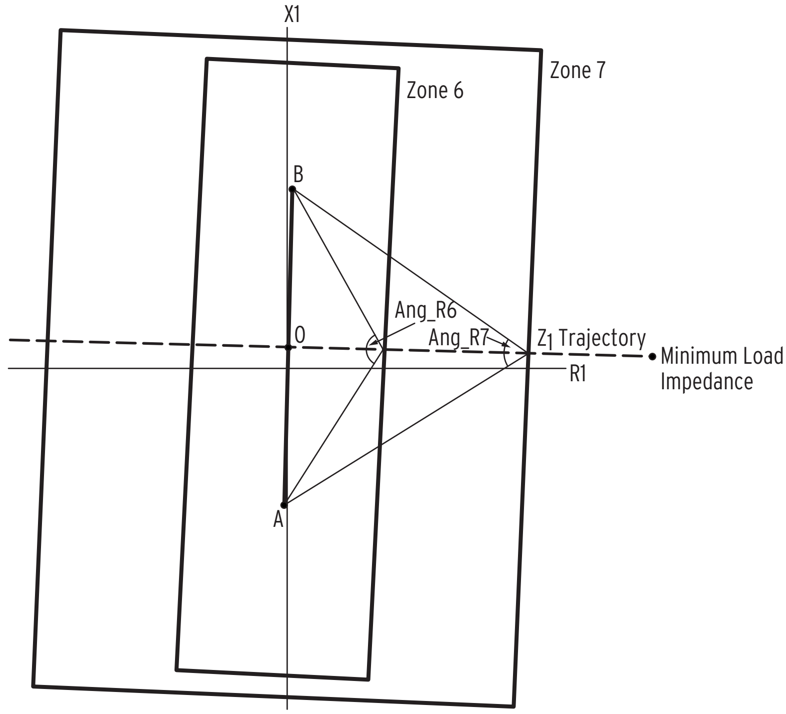


Figure 6.31 Swing Trajectory to Determine the OSBD Setting

Use *Equation 6.76* through *Equation 6.79* to calculate the OSBD setting. These equations are derived from the impedance trajectory shown in *Figure 6.31*. Line section AB is the transfer impedance, Z_T. The horizontal dashed line represents the trajectory of the power swing perpendicular to line section AB. The trajectory passes through the midpoint of line section AB.

$$Z_T = Z_{1S} + Z_{1L1} + Z_{1R}$$

Equation 6.76

where:

Z_T = transfer impedance
$Z1_S$ = positive-sequence source impedance
$Z1_{L1}$ = positive-sequence impedance for Line 1
$Z1_R$ = positive-sequence remote impedance

$$\text{Ang\_R6} = 2 \bullet \operatorname{atan}\left[\frac{\frac{|Z_T|}{2}}{(R1R6)}\right]$$

$$= \left(2 \bullet \operatorname{atan}\left[\frac{\frac{|8.8\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{5.77\ \Omega}\right]\right)$$

$$= 120.9°$$

Equation 6.77

$$\begin{aligned}
\text{Ang_R7} &= 2 \bullet \text{atan}\left[\frac{\frac{|Z_T|}{2}}{\text{R1R7}}\right] \\
&= \left(2 \bullet \text{atan}\left[\frac{\frac{|8.8\ \Omega\angle 88^\circ + 8.00\ \Omega\angle 87.6^\circ + 3.52\ \Omega\angle 88^\circ|}{2}}{15.53\ \Omega}\right]\right) \\
&= 66.4^\circ
\end{aligned}$$

Equation 6.78

A typical stable swing frequency is $f$slip = 5 Hz. Use this value in *Equation 6.79* to find setting OSBD.

$$\begin{aligned}
\text{OSBD} &= \frac{(\text{Ang_R6} - \text{Ang_R7}) \bullet f_{\text{NOM}}}{\frac{360^\circ}{\text{cycle}} \bullet f_{\text{slip}}}\ \text{cycles} \\
&= \frac{(120.9^\circ - 66.4^\circ) \bullet 60\ \text{Hz}}{\frac{360^\circ}{\text{cycle}} \bullet 5\ \text{Hz}}\ \text{cycles} \\
&= 1.82\ \text{cycles}
\end{aligned}$$

Equation 6.79

where:

f_{NOM} = nominal power system frequency (Hz)

f_{slip} = maximum slip frequency (Hz)

The OSBD timer settings are in increments of 0.125 cycle; round up to the nearest valid relay setting.

OSBD := **1.875**. Out-of-Step Block Time Delay (0.500–8000 cycles)

Latch Out-of-Step Blocking

The SEL-421 automatically resets the OSB logic if this logic asserts for more than two seconds while the positive-sequence impedance locus is inside Zone 7. During an unstable power swing, the relay also resets the OSB logic each time the swing impedance exits Zone 7. You can latch on the OSB function during an unstable power swing to continue blocking the distance elements if the power swing impedance locus moves outside of Zone 7 and before it comes back inside Zone 7 on its next swing cycle. If latched, the OSB logic resets one second after the power system stops the out-of-step. Latching the OSB gives you an advantage in that the relay can successfully block uncontrolled distance element operations if a fault occurs when the unstable swing impedance is outside of Zone 7. Relay elements detect internal faults that occur during a power swing and take the appropriate action (unblock).

OSBLTCH := **Y**. Latch Out-of-Step Blocking (Y, N)

Out-of-Step Unblocking

The relay disables out-of-step blocking automatically when a fault occurs during a power swing. Therefore, the distance protection successfully detects all fault types and trips the circuit breaker(s) during internal faults.

Out-of-Step Unblocking During Three-Phase Faults

The trajectories of a three-phase fault and a power swing appear the same to phase-distance elements because both a three-phase fault and a power swing consist of positive-sequence quantities only (V_1 and I_1). Therefore, if a power swing evolves into an internal three-phase fault, typical OSB logic cannot detect the occurrence of the balanced fault. The SEL-421 includes an additional set of inner blinders to provide proper detection of the internal three-phase fault (see *Figure 6.32*). If the positive-sequence impedance resides between these blinders for a specific duration, OSB logic unblocks. The relay calculates this duration (UBOSBD) each time the power swing enters Zone 7. A short timer setting is adequate for fast swings, but the relay needs a longer timer setting for slow power swings. For example, if the positive-sequence impedance passes gradually between the two inner blinders during a slow swing, a short timer setting would cause unwanted tripping.

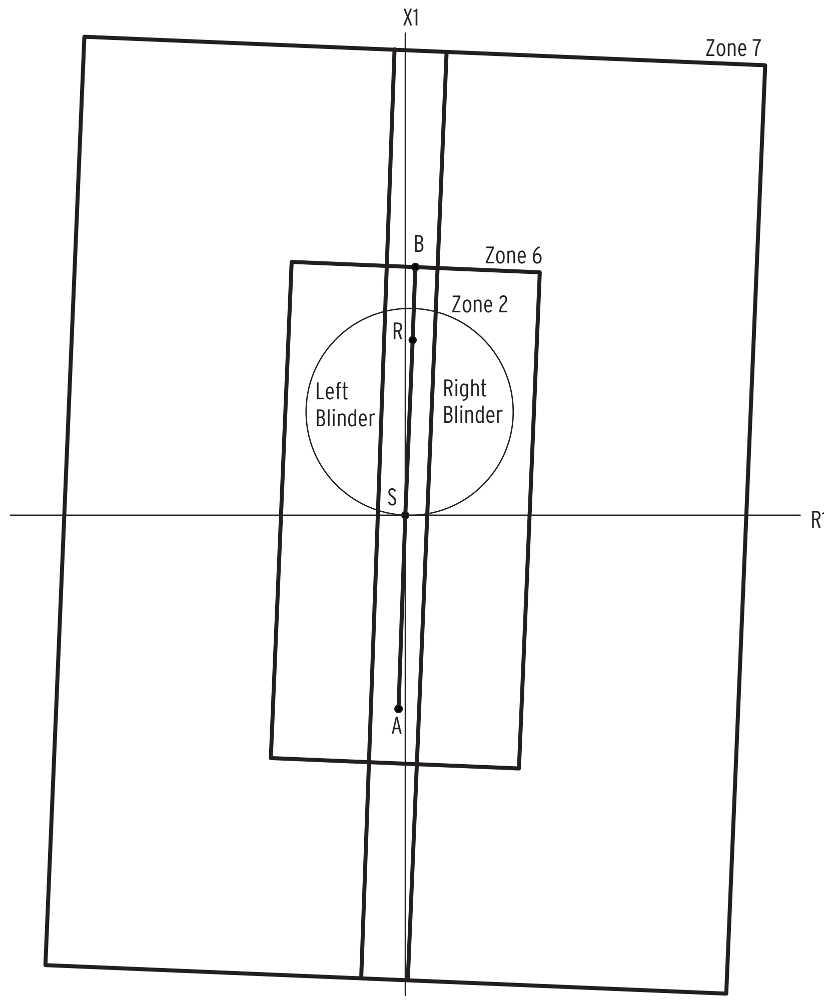


Figure 6.32 Inner Blinders

The UBOSBD timer length is the expected duration of the power swing within the inner blinders. The relay bases the calculation on the actual time required for the swing to traverse from Zone 7 to Zone 6, before entering the inner blinders. If the swing remains inside the inner blinders for a period greater than UBOSBD, an unblock signal asserts.

You can increase the adaptive UBOSBD timer calculation in multiples of setting UBOSBF. If UBOSBF is a multiplier of one, the relay calculates the expected time to traverse across the inner blinders based on the rate at which the swing moved from Zone 7 to Zone 6. Similarly, if UBOSBF is a multiplier of four, the relay multiplies UBOSBD by four.

Out-of-Step Unblocking During Unbalanced Faults

The SEL-421 treats Zone 1 phase and ground-distance elements differently than phase-distance elements of other zones.

Operation of either of two negative-sequence directional elements, 67QUBF (forward-looking), or 67QUBR (reverse-looking), defeats the OSB logic and unblocks the phase-distance elements (except the Zone 1 elements) when an unbalanced fault occurs following a power swing. Therefore, the phase-distance protection operates in the POTT scheme and high-speed clears the unbalanced fault if it is an internal one. The time-delayed elements of associated zones also start timing to initiate backup protection functions. The 67QUBF element unblocks forward-looking zones and 67QUBR unblocks reverse-looking zones.

The relay supervises the 67QUBF and 67QUBR elements with negative-sequence pickup setting 50QUBP. When you set the 50QUBP pickup level to other than OFF, the level of negative-sequence current exceeds the 50QUBP setting threshold, and the relay has made a valid directional decision (32 elements), the relay asserts either the 67QUBF or the 67QUBR directional element after time delay setting UBD. In this manner the relay removes out-of-step blocking for phase-distance elements other than Zone 1 elements during unbalanced faults.

The 50QUBP setting is an advanced setting and must be coordinated with the distance protection for the protected line. Setting UBD is also an advanced setting; set the UBD timer to coordinate clearing times with protection external to the protected line.

For out-of-step unblocking on unbalanced faults you must do the following:

Step 1. Set EADVS := **Y** to enable advanced settings.

Step 2. Set the negative sequence unblocking element pickup with setting 50QUBP (Negative-Sequence Current Supervision).

Coordinate with line distance protection.

Step 3. Set the unblock delay timer UBD (Negative-Sequence Current Unblock Delay).

Coordinate clearing times with other protection.

If a power swing center is on the line under protection, the Zone 1 distance elements at one or both terminals may operate if the OSB is removed. For example, during an unstable swing, if an external A-Phase ground fault occurs beyond the remote terminal R in *Figure 6.28*, the A-Phase ground-distance elements at both terminals operate correctly; that is, A-Phase distance element picks up in Zone 2 at the S terminal, and in reverse Zone 3 at the R terminal. However, all Zone 1 phase and ground-distance elements at both terminals may also operate if the swing center is within the Zone 1 reach and a negative-sequence overcurrent element removes the OSB. The undesirable operations of Zone 1 elements may trip all three phases at both terminals for an external A-Phase fault.

The SEL-421 uses a directional negative-sequence element (67Q1T) to supervise the out-of-step blocking of Zone 1 distance elements. 67Q1T is independent from 67QUBF and 67QUBR, which are used to defeat the OSB for distance elements other than Zone 1 elements. This separation gives you a choice to control the Zone 1 element operations during an unstable swing situation.

For those applications that allow the relay to operate for any internal and external faults on a system during a power swing, set the 67Q1T element similar to the 67QUBF element:

50Q1P := **same value as of 50QUBP**. Level 1 Pickup (OFF, 0.25–100 Amps sec.)

67Q1D := **same value as of UBD**. Level 1 Time Delay (0.000–16000 cycles)

67Q1TC := **1**. Level 1 Torque Control (SELOGIC Equation)

For those applications that require the relay only trip for internal faults during a power swing, disable the 67Q1T element by setting 50Q1P to OFF or E50Q = N. This way, the Zone 1 distance elements are always blocked by the OSB logic. The relay relies on Zone 2 overreaching elements together with the POTT scheme to make high-speed trips for internal faults.

Example Completed

This completes the application example that describes setting the SEL-421 for out-of-step blocking. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.33 lists the settings that the relay automatically calculates and hides when you set EADVS to N and EOOST to N.

Table 6.33 Automatically Calculated/Hidden Settings

Setting	Prompt	Default Setting
X1B7	Zone 7 Reactance—Bottom (–0.05 to –140 Ω secondary)	X1B7 = –X1T7
X1B6	Zone 6 Reactance—Bottom (–0.05 to –140 Ω secondary)	X1B6 = –X1T6
R1L7	Zone 7 Resistance—Left (–0.05 to –140 Ω secondary)	R1L7 = –R1R7
R1L6	Zone 6 Resistance—Left (–0.05 to –140 Ω secondary)	R1L6 = –R1R6
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.500
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	50ABCP = 0.2 • I_{NOM}
50QUBP	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4

Table 6.34 and *Table 6.35* list the protective relay settings available in this example.

Table 6.34 Relay Configuration (Group)

Setting	Prompt	Entry
EOOS	Out-of-Step (Y, Y1, N)	Y
EADVS	Advanced Settings (Y, N)	N

Table 6.35 Out-of-Step Tripping/Blocking

Setting	Prompt	Entry
OOSB1	Block Zone 1 (Y, N)	Y
OOSB2	Block Zone 2 (Y, N)	Y
OOSB3	Block Zone 3 (Y, N)	N
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	1.875
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	Y
EOOST	Out-of-Step Tripping (N, I, O)	N
X1T7	Zone 7 Reactance—Top (0.05 to 140 Ω secondary)	21.29
X1T6	Zone 6 Reactance—Top (0.05 to 140 Ω secondary)	11.52
R1R7	Zone 7 Resistance—Right (0.05 to 140 Ω secondary)	15.53
R1R6	Zone 6 Resistance—Right (0.05 to 140 Ω secondary)	5.77
X1B7	Zone 7 Reactance—Bottom (–0.05 to –140 Ω secondary)	–21.29
X1B6	Zone 6 Reactance—Bottom (–0.05 to –140 Ω secondary)	–11.52
R1L7	Zone 7 Resistance—Left (–0.05 to –140 Ω secondary)	–15.53
R1L6	Zone 6 Resistance—Left (–0.05 to –140 Ω secondary)	–5.77
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	1.00
50QUBP	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4
50Q1P	Level Pickup (OFF, 0.25–100 Amps sec.)	OFF
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1

Out-of-Step Tripping

This example demonstrates how to set the OST (out-of-step tripping) function. Use OST logic to detect an unstable power swing and trip the local terminal. With OST logic, you can split the power system at predetermined locations after an OST condition occurs.

The Zone 6 and Zone 7 settings for the OST logic depend on the positive sequence impedance (Z_1) trajectory of the power swing (see *Figure 6.33*). Set inner Zone 6 at the point along the trajectory where the power system cannot regain stability. Set Zone 7 so that the impedance because of maximum load conditions is outside the Zone 7 characteristic for all loading conditions.

NOTE: This setting philosophy provides the most time for the relay to decide whether the power swing is unstable.

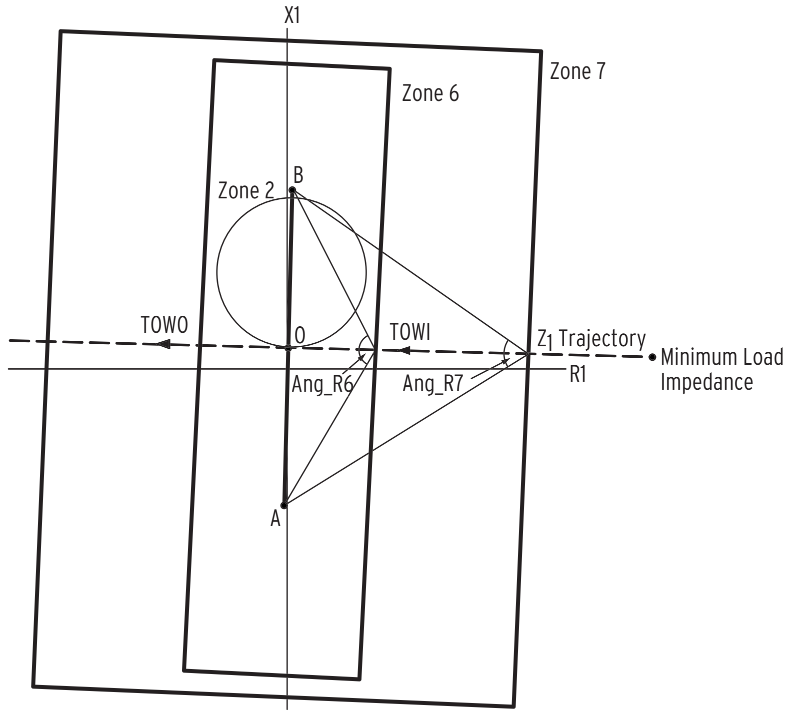


Figure 6.33 OST Characteristics

To configure the OOS logic for out-of-step tripping, enable the OOS logic. Next, calculate the impedance reach settings for Zone 6 and Zone 7 (R1R6, R1R7, X1T6, and X1T7), and then calculate OSTD (out-of-step trip delay) and OSBD (out-of-step block time delay). All of the OOS settings appear in *Table 6.37* and *Table 6.38*.

Enable OOS Logic

Access Group settings to enable the out-of-step logic.

EOOS := **Y**. Out-of-Step (Y, N)

NOTE: *Table 6.36* lists the settings that the relay automatically calculates and hides when you set EADVS to N.

You do not need to enable the Advanced Settings for this application example.

EADVS := **N**. Advanced Settings (Y, N)

Out-of-Step Tripping

When the positive-sequence impedance locus enters Zone 7, both OOS logic timers (OSBD and OSTD) start (see *Figure 6.33*). If OSTD expires before OSBD and Zone 6 asserts, the relay declares an out-of-step tripping condition. Enable the relay to trip when Zone 6 drops out (Trip-On-the-Way-Out). See *Out-of-Step Tripping and Blocking on page 6.133* for OSTD and OSBD calculations.

EOOST := **O**. Out-of-Step Tripping (N, I, O)

where:

I = Enable out-of-step tripping (Trip-On-the-Way-In)
O = Enable out-of-step tripping (Trip-On-the-Way-Out)
N = Disable out-of-step tripping

Phase-Distance Element Blocking

Enable the OSB function to prevent tripping when the positive-sequence impedance locus enters the Zone 1 and Zone 2 distance protection characteristics during an unstable power swing. Therefore, in this application example, the relay trips after the Z_1 impedance locus exits Zone 6 (Zone 6 drops out).

Block Zone 1 and Zone 2 distance protection elements during power swings.

OOSB1 := **Y**. Block Zone 1 (Y, N)

OOSB2 := **Y**. Block Zone 2 (Y, N)

OOSB3 := **N**. Block Zone 3 (Y, N)

Zone 6 and Zone 7 Impedance Settings

The purpose of this OOS application example is to configure the relay to trip when the power system reaches a critical angle limit to prevent system collapse. Thus, the Zone 6 impedance setting differs from *Out-of-Step Blocking on page 6.120*.

Resistance Blinders

If the angle of the power swing Z_1 trajectory passes 120 degrees with respect to the transfer impedance, the power system cannot recover. The transfer impedance is the total impedance of the power system (line AB in *Figure 6.33*). Set the Zone 6 right-hand inner resistance blinder R1R6 so Ang_R6 equals 120 degrees. Rearrange *Equation 6.77* as shown in *Equation 6.80*:

$$\begin{aligned} \text{R1R6} &= \frac{\frac{|Z_T|}{2}}{\tan\left(\frac{\text{Ang\_R6}}{2}\right)} \\ &= \frac{\frac{|8.80\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{\tan\left(\frac{120°}{2}\right)} \\ &= \frac{10.16}{\tan\left(\frac{120°}{2}\right)} \\ &= 5.87\ \Omega \end{aligned}$$

Equation 6.80

R1R6 := **5.87**. Zone 6 Resistance—Right (0.05 to 140 Ω secondary)

Use the minimum load impedance $Z_{L(min)}$ (*Equation 6.71*) and the 90 percent safety margin criterion (see *Equation 6.73*) applied earlier in *Resistance Blinders on page 6.122* to set the Zone 7 right-hand resistance blinder.

$$\begin{aligned} \text{R1R7} &= 0.9 \bullet Z_{L(min)} \bullet \cos[45° + (90° - \text{Z1ANG})] \\ &= 0.9 \bullet 25.49 \bullet \cos[45° + (90° - 87.6°)] \\ &= 0.9 \bullet 25.49 \bullet \cos[47.4°] \\ &= 15.53\ \Omega \end{aligned}$$

Equation 6.81

R1R7 := **15.53**. Zone 7 Resistance—Right (0.05–140 Ω secondary)

Reactance Lines

Set the reactance lines equal to the maximum values to help the relay detect power swings far from the relay location.

Set the Zone 7 top reactance line equal to the maximum setting.

X1T7 := **96**. Zone 7 Reactance—Top (0.05–140 Ω secondary)

Set the Zone 6 top reactance line to the maximum setting minus one ohm.

$$\begin{aligned} X1T6 &= X1T7 - 1\ \Omega \\ &= 96\ \Omega - 1\ \Omega \\ &= 95\ \Omega \end{aligned}$$

Equation 6.82

X1T6 := **95**. Zone 6 Reactance—Top (0.05–140 Ω secondary)

Out-of-Step Tripping and Blocking

The OOS logic uses two zones of concentric polygons, outer Zone 7 and inner Zone 6 (see *Figure 6.33*). The relay uses Zone 6 and Zone 7 for OOS logic timing to differentiate OOS blocking conditions, OOS tripping conditions, and faults. The relay measures a traveling positive-sequence impedance locus (Z_1) in Zone 6 and Zone 7 when a power swing or fault occurs. When the impedance locus initially moves inside Zone 7, the relay starts two OOS logic timers. One OOS timer detects OOS blocking conditions (OSBD), while the other timer detects OOS tripping conditions (OSTD).

NOTE: You must set OSTD shorter than OSBD by at least a half cycle.

The OOS logic declares a blocking condition if OSBD expires before the positive-sequence impedance locus enters Zone 6. The logic declares a tripping condition if OSTD expires and the positive-sequence impedance locus enters Zone 6 prior to OSBD timing out.

Trip-On-Way-In/Trip-On-Way-Out

You can select one of two methods to trip during an unstable swing. You can enable the relay to trip if OSTD expires and the positive-sequence impedance enters Zone 6; this method is Trip-On-the-Way-In (TOWI in *Figure 6.33*). The relay asserts Relay Word bits OSTI and OST for a Trip-On-the-Way-In condition.

You can also enable the relay to trip if OSTD expires and the positive-sequence impedance enters and exits Zone 6; this second method is Trip-On-the-Way-Out (TOWO in *Figure 6.33*). The relay asserts Relay Word bits OSTO and OST for a Trip-On-the-Way-Out condition. Relay Word bit OST is the OR combination of OSTI and OSTO (see *Out-of-Step Logic (Conventional) on page 5.50*).

Trip-On-the-Way-Out (TOWO) is selected for this application example (see *Enable OOS Logic on page 6.131*).

Out-of-Step Tripping Time Delay

Use *Equation 6.83*, *Equation 6.84*, and *Equation 6.85* to calculate the OSTD setting. These equations are derived from the impedance trajectory shown in *Figure 6.33*. Line section AB is the transfer impedance, Z_T. The horizontal dashed line represents the trajectory of the power swing perpendicular to line section AB. The trajectory passes through the midpoint of line section AB.

$$Z_T = Z_{1S} + Z_{1L1} + Z_{1R}$$

Equation 6.83

where:

Z_T = transfer impedance
$Z1_S$ = positive-sequence source impedance
$Z1_{L1}$ = positive-sequence impedance for Line 1
$Z1_R$ = Positive-sequence remote impedance

Angle Ang_R6 was specified at 120.0° as a design criterion for this application example (see *Zone 6 and Zone 7 Impedance Settings on page 6.121*).

$$\begin{aligned} \text{Ang\_R7} &= 2 \bullet \operatorname{atan}\left[\frac{\frac{|Z_T|}{2}}{\text{R1R7}}\right] \\ &= \left(2 \bullet \operatorname{atan}\left[\frac{\frac{|8.80\ \Omega\angle 88° + 8.00\ \Omega\angle 87.6° + 3.52\ \Omega\angle 88°|}{2}}{15.53\ \Omega}\right]\right) \\ &= 66.4° \end{aligned}$$

Equation 6.84

Apply a fast unstable swing frequency and calculate OSTD (for this application example, f_{slip} = 10 Hz for an unstable power swing).

$$\begin{aligned} \text{OSTD} &= \frac{(\text{Ang\_R6} - \text{Ang\_R7}) \bullet f_{NOM}}{\frac{360°}{\text{cycle}} \bullet f_{slip}} \\ &= \frac{(120.0° - 66.4°) \bullet 60\ \text{Hz}}{\frac{360°}{\text{cycle}} \bullet 10\ \text{Hz}} \\ &= 0.89\ \text{cycles} \end{aligned}$$

Equation 6.85

where:

f_{NOM} = nominal power system frequency (Hz)
f_{slip} = maximum slip frequency (Hz)

The OSTD timer settings are in increments of 0.125 cycle; round up to the nearest valid relay setting.

OSTD := **0.875**. Out-of-Step Trip Delay (0.500–8000 cycles)

To find the effective slip rate for OOS tripping, solve *Equation 6.85* for f_{slip}:

$$\begin{aligned} f_{slip} &= \frac{(\text{Ang\_R6} - \text{Ang\_R7}) \bullet f_{NOM}}{\frac{360°}{\text{cycle}} \bullet \text{OSTD}} \\ &= \frac{(120° - 66.4°) \bullet 60\ \text{Hz}}{\frac{360°}{\text{cycle}} \bullet 0.875} \\ &= 10.2\ \text{Hz} \end{aligned}$$

Equation 6.86

Out-of-Step Block Time Delay

Set OSBD longer than OSTD by the next timer setting step (0.125-cycle step size) greater than 0.500 cycle. Thus, the OSBD setting is calculated in *Equation 6.87*.

$$\begin{aligned} \text{OSBD} &= \text{OSTD} + 0.500 \text{ cycle} + \text{timer step} \\ &= 0.875 + 0.500 + 0.125 \\ &= 1.500 \text{ cycles} \end{aligned}$$

Equation 6.87

OSBD := **1.500**. Out-of-Step Block Time Delay (0.500–8000 cycles)

To find the effective slip rate for OOS blocking, solve *Equation 6.88* for f_{slip}.

$$\begin{aligned} f_{slip} &= \frac{(\text{Ang\_R6} - \text{Ang\_R7}) \cdot f_{NOM}}{\frac{360°}{\text{cycle}} \cdot \text{OSBD}} \\ &= \frac{(120.0° - 66.4°) \cdot 60 \text{ Hz}}{\frac{360°}{\text{cycle}} \cdot 1.500 \text{ cycle}} \\ &= 5.5 \text{ Hz} \end{aligned}$$

Equation 6.88

The relay detects OOS blocking conditions for power swing slip frequencies up to 5.95 Hz and OOS tripping conditions for power swing slip frequencies from 5.95 Hz to 10.2 Hz (see *Equation 6.86*). Zone 1 and Zone 2 elements remain blocked during these OSB and OST conditions. The event is not a swing condition if the Z_1 impedance locus crosses Zone 7 and Zone 6 before the OSTD and OSBD timers time out. The relay identifies this event as a fault condition.

Latch Out-of-Step Blocking

Latch out-of-step blocking to maintain the blocking condition throughout the entire swing cycle.

OSBLTCH := **Y**. Latch Out-of-Step Blocking (Y, N)

Control Outputs

For local OOS tripping, configure the relay control outputs for tripping and remote notification of an out-of-step condition. Include Relay Word bit OST in the direct tripping SELOGIC control equation TR. (Add **OR OST** to the existing TR equation; the default is shown here.)

TR := **Z1P OR Z1G OR M2PT OR Z2GT OR OST**. Trip (SELOGIC Equation)

Set a control output for remote notification of the out-of-step tripping condition. This example uses OUT205. Select a relay control output that is appropriate for your particular application.

OUT205 := **OST**. Output OUT205 (SELOGIC Equation)

Example Completed

This completes the application example that describes setting the SEL-421 for out-of-step tripping. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.36 lists the settings that the relay automatically calculates and hides when you set EADVS to N.

Table 6.36 Automatically Calculated/Hidden Settings

Setting	Prompt	Default Setting
X1B7	Zone 7 Reactance—Bottom (–0.05 to –140 Ω secondary)	X1B7 = –X1T7
X1B6	Zone 6 Reactance—Bottom (–0.05 to –140 Ω secondary)	X1B6 = –X1T6
R1L7	Zone 7 Resistance—Left (–0.05 to –140 Ω secondary)	R1L7 = –R1R7
R1L6	Zone 6 Resistance—Left (–0.05 to –140 Ω secondary)	R1L6 = –R1R6
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	50ABCP = 0.2 • I_{NOM}
50QUBP	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4

Table 6.37 and *Table 6.38* list the protective relay settings available in this example.

Table 6.37 Relay Configuration (Group)

Setting	Prompt	Entry
EOOS	Out-of-Step	Y
EADVS	Advanced Settings (Y, N)	N

Table 6.38 Out-of-Step Tripping/Blocking (Sheet 1 of 2)

Setting	Prompt	Entry
OOSB1	Block Zone 1 (Y, N)	Y
OOSB2	Block Zone 2 (Y, N)	Y
OOSB3	Block Zone 3 (Y, N)	N
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	1.500
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	Y
EOOST	Out-of-Step Tripping (N, I, O)	O
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.875
X1T7	Zone 7 Reactance—Top (0.05 to 140 Ω secondary)	96.00
X1T6	Zone 6 Reactance—Top (0.05 to 140 Ω secondary)	95.00
R1R7	Zone 7 Resistance—Right (0.05 to 140 Ω secondary)	15.53
R1R6	Zone 6 Resistance—Right (0.05 to 140 Ω secondary)	5.87
X1B7	Zone 7 Reactance—Bottom (–0.05 to –140 Ω secondary)	–96.00
X1B6	Zone 6 Reactance—Bottom (–0.05 to –140 Ω secondary)	–95.00
R1L7	Zone 7 Resistance—Left (–0.05 to –140 Ω secondary)	–15.53

Table 6.38 Out-of-Step Tripping/Blocking (Sheet 2 of 2)

Setting	Prompt	Entry
R1L6	Zone 6 Resistance—Left (–0.05 to –140 Ω secondary)	–5.87
50ABCP	Positive-Sequence Current Supervision (1.00–100 A secondary)	1.00
50QUBP	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary)	OFF
UBD	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500
UBOSBF	Out-of-Step Angle Unblock Rate (1–10)	4
50Q1P	Level Pickup (OFF, 0.25–100 Amps sec.)	OFF
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1
TR	Trip (SELOGIC Equation)	Z1P OR Z1G OR M2PT OR Z2GT OR OST
OUT205	Output OUT205 (SELOGIC Equation)	OST

Autoreclose Example

This application example is for a double-ended 230 kV overhead transmission line with SEL-421 protection at each end. The one-line drawing for this circuit is shown in *Figure 6.34*. This example shows settings for the SEL-421 at Station S (Harvard) in *Figure 6.35*.

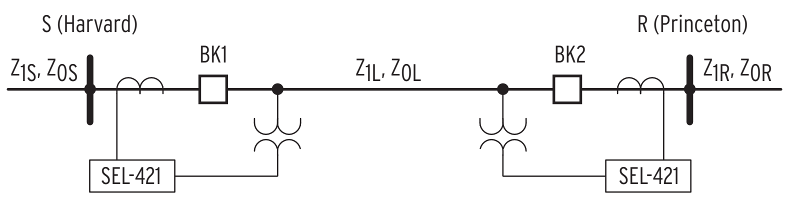


Figure 6.34 230 kV Example Power System

Application

Autoreclose Mode of Operation

Apply the SEL-421 for one shot of three-pole autoreclose.

Solution

Autoreclose Conditions

The relay initiates three-pole autoreclosing if a Zone 1 trip occurs because of a multiphase fault.

Circuit Breaker1 attempts the three-pole reclose if Bus 1 is hot and the line is dead. For this application example, block autoreclose if any of the following events occur:

- Manual trip
- Time-delayed trip
- Bus trip
- Circuit breaker failure trip

If the SEL-421 detects an LOP condition, the autoreclose logic drives the autoreclose function to lockout.

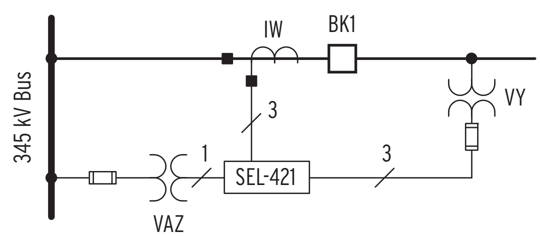


Figure 6.35 Circuit Breaker Arrangement at Station S

Relay Settings

Select the relay settings for this application example.

Relay Configuration

NOTE: Setting E79 := Y1 is intended for certain double circuit breaker applications. Use E79 := Y for a single circuit breaker.

Enable reclosing:

E79 := **Y**. Reclosing (Y, Y1, N)

Recloser Closing

Select one shot of three-pole autoreclose.

N3PSHOT := **1**. Number of Three-Pole Reclosures (N, 1–4)

Use an external switch to select when Circuit Breaker 1 is enabled for three-pole autoreclose.

E3PR1 := **IN106**. Three-Pole Reclose Enable -BK1 (SELOGIC Equation)

If Circuit Breaker 1 fails to close within 10 seconds after the reclose command is received, the autoreclose logic goes to lockout.

BKCFD := **600**. Breaker Close Failure Delay (1–99999 cycles)

Unlatch the reclose command to Circuit Breaker 1 when all three poles are closed.

ULCL1 := **52AA1 AND 52AB1 AND 52AC1**. Unlatch Closing for Circuit Breaker 1 (SELOGIC Equation)

Drive the autoreclose logic to lockout if the SEL-421 detects an LOP condition.

79DTL := **LOP**. Recloser Drive to Lockout (SELOGIC Equation)

You can block the reclaim timing. However, it is not necessary for this single shot application example.

79BRCT := **NA**. Block Reclaim Timer (SELOGIC Equation)

When leaving the lockout condition, the recloser goes to the Ready or Reset state after the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired.

3PMRCD := **900**. Manual Close Reclaim Time Delay (1–99999 cycles)

If Circuit Breaker 1 reclose supervision conditions fail to occur within 300 cycles after the three-pole open interval time delay expires, BK1CLST will assert, and the autoreclose logic goes to lockout.

BK1CLSD := **300**. BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)

Three-Pole Reclose

Set the three-pole open interval time equal to 30 cycles.

3POID1 := **30**. Three-Pole Open Interval 1 Delay (1–99999 cycles)

There is no need to enable fast three-pole autoreclose because we have already used the first and only three-pole shot for this purpose.

3PFARC := **NA**. Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reset time following a three-pole autoreclose cycle equal to 900 cycles.

3PRCD := **900**. Three-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a three-pole autoreclose cycle when the SEL-421 three-pole trips because of Zone 1 phase-distance protection. Communications-assisted tripping is not enabled.

3PRI := **3PT AND Z1P**. Three-Pole Reclose Initiation (SELOGIC Equation)

You can force the autoreclose logic to skip a three-pole shot. However, it is not necessary for this application example.

79SKP := **NA**. Skip Reclosing Shot (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 1 if the bus is hot and the line is dead (setting cannot be set to NA or logical 0).

3P1CLS := **DLLB1**. Three Pole BK 1 Reclose Supervision (SELOGIC Equation)

Voltage Elements

The SEL-421 checks the Bus and Line conditions when you enable the voltage check elements. *Figure 6.36* shows a typical checking scheme. Potentials VAY and VAX are the default synchronism inputs for V_P (setting SYNCP) and VS1 (setting SYNCS1), respectively (see *PT Connections on page 5.162*).

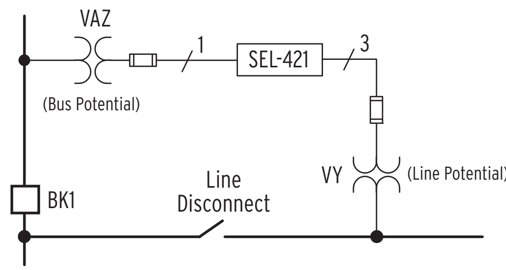


Figure 6.36 Potential Sources

Enable the voltage check elements.

EVCK := **Y**. Reclosing Voltage Check (Y, N)

Set the dead line voltage threshold equal to 15 V secondary.

27LP := **15.0**. Dead Line Voltage (1.0–200 V secondary)

Set the live line voltage threshold equal to 50 V secondary.

59LP := **50.0**. Live Line Voltage (1.0–200 V secondary)

Set the dead bus voltage threshold for Circuit Breaker 1 equal to 15 V secondary.

27BK1P := **15.0**. Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)

Set the live bus voltage threshold for Circuit Breaker 1 equal to 50 V secondary.

59BK1P := **50.0**. Breaker 1 Live Busbar Voltage (1.0–200 V secondary)

Example Complete

This completes the application example that describes setting the SEL-421 for one shot of three-pole reclosing for a single circuit breaker. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.39 provides a list of all the SEL-421 autoreclose settings. Those settings that were applied for this particular application appear in boldface.

Table 6.39 Settings for Autoreclose Example (Sheet 1 of 2)

Setting	Prompt	Entry
Relay Configuration		
E79	Reclosing (Y, Y1, N)	Y
Recloser Closing (Group)		
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	N
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN106
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	600
ULCL1	Unlatch Closing for Breaker 1(SELOGIC Equation)	52AA1
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	LOP
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA

Table 6.39 Settings for Autoreclose Example (Sheet 2 of 2)

Setting	Prompt	Entry
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	300
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 delay (1–99999 cycles)	30
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND Z1P
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS[a]	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)	DLLB1
Voltage Elements (Group)		
EVCK	Reclosing Voltage Check (Y, N)	Y
27LP	Dead Line Voltage (1.0–200 V secondary)	15.0
59LP	Live Line Voltage (1.0–200 V secondary)	50.0
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	50.0

[a] This setting cannot be set to NA or logical 0.

Autoreclose and Synchronism-Check Example

Use the SEL-421 to provide automatic reclosing and synchronism check for overhead transmission lines. This application example is for double-ended 500 kV parallel lines with SEL-421 protection at each end of the first circuit as shown in *Figure 6.37*. This example shows the settings for the SEL-421 at Station S protecting Line 1 in *Figure 6.38* between Buses S (Moscow) and R (Pullman).

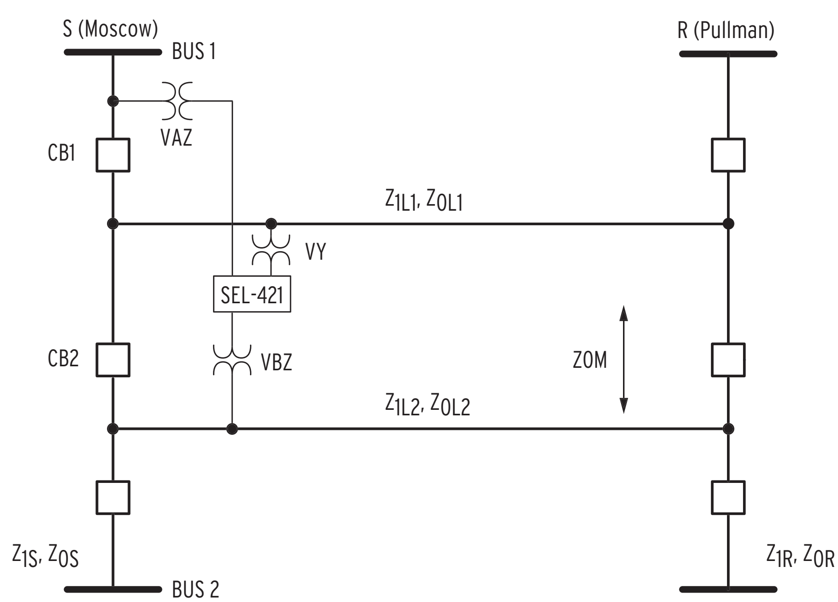


Figure 6.37 500 kV Power System

First set the autoreclose logic, and then set the synchronism-check function.

Autoreclose Application

Apply the SEL-421 for one shot of single-pole reclosing and one shot of three-pole reclosing.

Select the recloser mode with the enable setting E79 := Y or Y1, and set E3PR1 and E3PR2 to logical 1.

Modes of Operation

The SEL-421 autoreclose logic operates in one of two modes at all times:

- Single-pole mode (SPAR)
- Three-pole mode (3PAR)

Single-pole trips initiate single-pole reclosing. For this application example, if the single-pole reclose is unsuccessful, the second trip is a three-pole trip. Three-pole trips initiate three-pole reclosing. If a single-pole autoreclose cycle is in progress and the relay receives an initiation for three-pole reclosing, the relay immediately starts a three-pole autoreclose cycle.

Select the recloser mode with the three-pole enable settings and the single-pole enable settings E3PR1, E3PR2, ESPR1, and ESPR2.

Autoreclose Sequence

The relay performs one shot of reclosing for both single-pole and three-pole automatic reclosing.

When E79 := Y, the leader circuit breaker (CB1) recloses if the line is dead and Bus 1 is hot. If the leader successfully recloses, the follower circuit breaker (CB2) also attempts a reclose if the synchronism check is successful. CB2 can also close if the line is dead and Bus 2 is hot if CB1 is out of service. A similar SEL-421 installation would protect Line 2, and provide autoreclose capabilities.

When E79 := Y1, if CB2 trips from the Line 2 protection (not shown), the SEL-421 on Line 1 would attempt to reclose CB2. This configuration would typically employ a hot bus check.

Open interval timing does not begin until the faulted phase(s) is opened.

If another trip occurs while the single-pole autoreclose cycle is in progress the relay trips the other two poles.

The autoreclose logic resets after the reclaim timer (SPRCD or 3PRCD) expires.

Dynamic Determination of the Leader Circuit Breaker

If Circuit Breaker 1 (the leader breaker) is out of service, the leader settings are automatically routed to Circuit Breaker 2. Circuit Breaker 2 operates as the leader circuit breaker when Circuit Breaker 1 is out of service. When Circuit Breaker 2 is the leader, this circuit breaker can single-pole reclose.

Autoreclose Solution

Autoreclose Conditions

The relay initiates single-pole autoreclose if a Zone 1 trip or a communications-assisted trip occurs for a single phase-to-ground fault. The relay initiates three-pole autoreclose if a Zone 1 trip or a communications-assisted trip occurs for a multiphase fault.

Circuit Breaker 1 can attempt a reclose if Bus 1 is hot and the line is dead. Circuit Breaker 2 can attempt a reclose if the synchronism check is successful or if Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot.

Block autoreclose if any of the following events occur:

- ➤ Manual trip
- ➤ Time-delayed trip
- ➤ Bus trip
- ➤ Circuit breaker failure trip

If the SEL-421 detects a loss-of-potential condition, the autoreclose logic drives the autoreclose function to lockout.

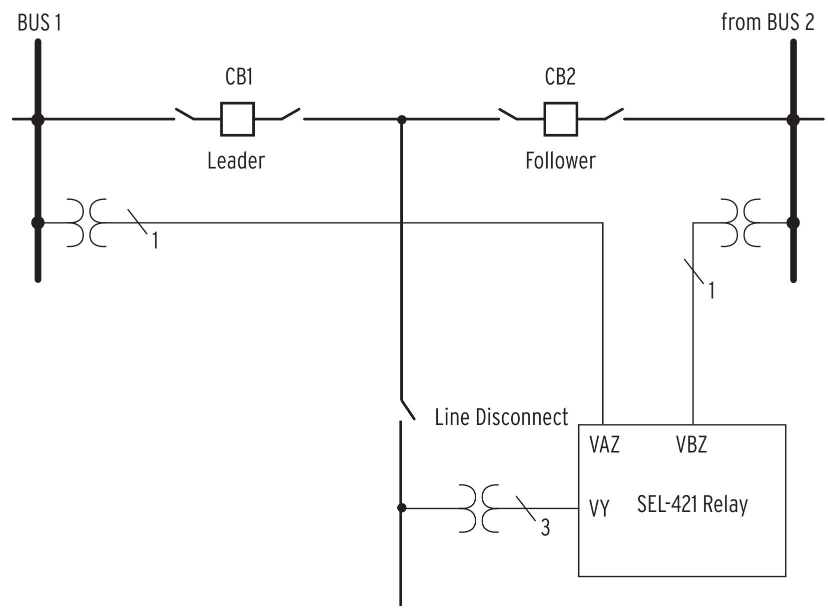


Figure 6.38 Partial Circuit Breaker-and-a-Half Arrangement at Station S, Line 1

Autoreclose Relay Settings

Select the autoreclose relay settings for this application example.

Relay Configuration

Enable reclosing.

E79 := **Y**. Reclosing (Y, Y1, N)

Selection Y1 can be used in circumstances where CB2 can be tripped externally, yet the SEL-421 is to be able to autoreclose.

Recloser Closing

Select one shot of single-pole autoreclose.

NSPSHOT := **1**. Number of Single-Pole Reclosures (N, 1, 2)

Use an external switch to select when the leader or follower circuit breaker is enabled for single-pole autoreclose.

ESPR1 := **IN205**. Single-Pole Reclose Enable—BK1 (SELOGIC Equation)

ESPR2 := **IN206**. Single-Pole Reclose Enable—BK2 (SELOGIC Equation)

Select one shot of three-pole autoreclose.

N3PSHOT := **1**. Number of Three-Pole Reclosures (N, 1–4)

Use an external switch to select when the leader or follower circuit breaker is enabled for three-pole autoreclose.

E3PR1 := **IN207**. Three-Pole Reclose Enable—BK1 (SELOGIC Equation)

E3PR2 := **IN208**. Three-Pole Reclose Enable—BK2 (SELOGIC Equation)

The time delay before Circuit Breaker 2 attempts a reclose after Circuit Breaker 1 has successfully reclosed is 15 cycles. The short delay prevents both circuit breakers closing back into a permanent fault.

TBBKD := **15**. Time Between Breakers for ARC (1–99999 cycles)

If either circuit breaker fails to close within 10 seconds after the reclose command is received, the autoreclose logic goes to lockout for the failed circuit breaker.

BKCFD := **600**. Breaker Close Failure Delay (OFF, 1–99999 cycles)

You can use a normally-closed (a) auxiliary contact from the Circuit Breaker 1 disconnect switch to denote that this circuit breaker is the leader when in service. Use the contact to energize a control input; if the disconnect switch is closed, the input is energized.

SLBK1 := **IN107**. Lead Breaker = Breaker 1 (SELOGIC Equation)

We have selected Circuit Breaker 1 as the leader. The autoreclose logic automatically recognizes Circuit Breaker 2 as the leader when Circuit Breaker 1 is out of service.

SLBK2 := **0**. Lead Breaker = Breaker 2 (SELOGIC Equation)

Circuit Breaker 2 is the follower circuit breaker. The follower can attempt to reclose if all three poles of Circuit Breaker 2 are actually open or if Circuit Breaker 1 is out of service.

FBKCEN := **3POBK2 OR (NOT LEADBK1)**. Follower Breaker Closing Enable (SELOGIC Equation)

Unlatch the reclose command to Circuit Breaker 1 when all three poles are closed.

ULCL1 := **52AA1 AND 52AB1 AND 52AC1**. Unlatch Closing for Breaker 1 (SELOGIC Equation)

Unlatch the reclose command to Circuit Breaker 2 when all three poles are closed.

ULCL2 := **52AA2 AND 52AB2 AND 52AC2**. Unlatch Closing for Breaker 2 (SELOGIC Equation)

Drive the autoreclose logic to lockout if the SEL-421 detects a loss-of-potential condition.

79DTL := **LOP**. Recloser Drive to Lockout (SELOGIC Equation)

You can block reclaim timing. However, it is not necessary for this application example.

79BRCT := **NA**. Block Reclaim Timer (SELOGIC Equation)

When leaving the lockout condition, the recloser goes to the Ready or Reset state after the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired.

3PMRCD := **900**. Manual Close Reclaim Time Delay (1–99999 cycles)

If Circuit Breaker 1 reclose supervision conditions (settings SP1CLS and 3P1-CLS) fail to occur within 300 cycles after the three-pole open interval time delay expires, the autoreclose logic goes to lockout.

BK1CLSD := **300**. BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)

If Circuit Breaker 2 reclose supervision conditions (settings SP2CLS and 3P2-CLS) fail to occur within 300 cycles after the three-pole open interval time delay expires, the autoreclose logic goes to lockout.

BK2CLSD := **300**. BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)

Single-Pole Autoreclose Logic

Initiate a single-pole autoreclose cycle whenever the SEL-421 single-pole trips. Autoreclose is blocked if a manual, time-delayed, bus, or circuit breaker failure trip occurs. None of these events generate a single-pole trip (see *Autoreclose Conditions on page 6.143*).

Set the single-pole open interval time equal to one second.

SPOID := **60**. Single-Pole Open Interval Delay (1–99999 cycles)

Set the reclaim time following a single-pole autoreclose cycle equal to 900 cycles.

SPRCD := **900**. Single-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a single-pole autoreclose cycle whenever the SEL-421 single-pole trips.

SPRI := **SPT AND (Z1G OR COMPRM)**. Single-Pole Reclose Initiation (SELOGIC Equation)

No supervision is required before Circuit Breaker 1 attempts a single-pole reclose. The SEL-421 autoreclose logic only applies synchronism supervision during a single-pole autoreclose cycle in this application example (setting cannot be set to NA or logical 0).

SP1CLS := **1**. Single-Pole BK1 Reclose Supervision (SELOGIC Equation)

No supervision is required before Circuit Breaker 2 attempts a single-pole reclose when this circuit breaker is the leader. The SEL-421 autoreclose logic only applies synchronism supervision during a single-pole autoreclose cycle in this application example (setting cannot be set to NA or logical 0).

SP2CLS := **NOT LEADBK1**. Single-Pole BK2 Reclose Supervision (SELOGIC Equation)

Three-Pole Autoreclose Logic

Set the three-pole open interval time equal to 30 cycles.

3POID1 := **30**. Three-Pole Open Interval 1 Delay (1–99999 cycles)

There is no need to enable fast three-pole autoreclose because we have already used the first and only three-pole shot for this purpose.

3PFARC := **NA**. Three-Pole Fast ARC Enable (SELOGIC Equation)

Set the reclaim time following a three-pole autoreclose cycle equal to 900 cycles.

3PRCD := **900**. Three-Pole Reclaim Time Delay (1–99999 cycles)

Initiate a three-pole autoreclose cycle when the SEL-421 three-pole trips because of Zone 1 phase-distance protection or a communications-assisted trip. No manual, time-delayed, bus, or circuit breaker failure trips are included in the 3PRI SELOGIC control equation for this application example.

3PRI := **3PT AND (Z1P OR COMPRM)**. Three-Pole Reclose Initiation (SELOGIC Equation)

You can force the autoreclose logic to skip a three-pole shot. However, it is not necessary for this application example.

79SKP := **NA**. Skip Reclosing Shot (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 1 if Bus 1 is hot and the line is dead. The SEL-421 autoreclose logic only applies this supervision during a three-pole autoreclose cycle (you cannot set this setting to NA or logical 0; see *Voltage Elements on page 6.139*).

3P1CLS := **DLLB1**. Three Pole BK 1 Reclose Supervision (SELOGIC Equation)

Only attempt to reclose Circuit Breaker 2 if the synchronism check is successful or if Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot. The SEL-421 autoreclose logic only applies synchronism supervision during a three-pole autoreclose cycle in this application example (you cannot set this setting to NA or logical 0).

3P2CLS := **25A2BK2 OR (NOT LEADBK1 AND DLLB2)**. Three Pole BK 2 Reclose Supervision (SELOGIC Equation)

Voltage Elements

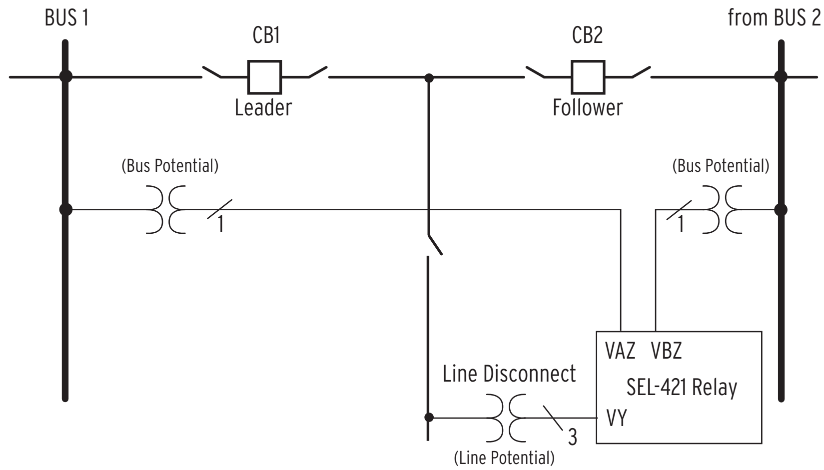


Figure 6.39 Potential Sources

Enable the voltage check elements.

EVCK := **Y**. Reclosing Voltage Check (Y, N)

Set the dead line voltage threshold equal to 15 V secondary.

27LP := **15.0**. Dead Line Voltage (1.0–200 V secondary)

Set the live line voltage threshold equal to 50 V secondary.

59LP := **50.0**. Live Line Voltage (1.0–200 V secondary)

Set the dead bus voltage threshold for Circuit Breakers 1 and 2 equal to 15 volts secondary.

27BK1P := **15.0**. Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)

27BK2P := **15.0**. Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)

Set the live bus voltage threshold for Circuit Breakers 1 and 2 equal to 50 V secondary.

59BK1P := **50.0**. Breaker 1 Live Busbar Voltage (1.0–200 V secondary)

59BK2P := **50.0**. Breaker 2 Live Busbar Voltage (1.0–200 V secondary)

Trip Logic

If you want Circuit Breaker 2 to always three-pole trip, except when Circuit Breaker 2 is the leader, program SELOGIC control equation E3PT2 as follows:

E3PT2 := **NOT LEADBK2**. Breaker 2 3PT (SELOGIC Equation)

Synchronism-Check Application

Reclose Circuit Breaker 1 following a three-pole trip if the line is dead and Bus 1 is hot. Reclose Circuit Breaker 2 following a three-pole trip if a synchronism check across the hot line to Bus 2 is successful or Circuit Breaker 1 is out of service and the line is dead and Bus 2 is hot.

In this application example, the relay does not perform a synchronism check on single-pole reclosing.

Synchronism-Check Solution

Apply the synchronism-check function as follows for Circuit Breaker 2:

- Use the A-Phase voltages from the line and Bus 2 for the synchronism check across Circuit Breaker 2.
- Select the high voltage magnitude and low voltage magnitude thresholds for the synchronism check.
- Select the maximum voltage angle difference allowed for both reclosing and manual closing.
- Select conditions that block the synchronism check.

Synchronism-Check Relay Settings

Select the relay settings for this application example.

Relay Configuration

Enable synchronism check for Circuit Breaker 2 only.

E25BK1 := **N**. Synchronism Check for Breaker 1 (Y, N, Y1, Y2)

E25BK2 := **Y**. Synchronism Check for Breaker 2 (Y, N, Y1, Y2)

Synchronism-Check Element Reference

Select A-Phase voltage from the line source for the synchronism check reference. VAY is the reference for the synchronism check because this analog input is connected to the line potential.

SYNCP := **VAY**. Synch Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)

Set the low-voltage threshold that supervises synchronism check equal to 60 V secondary.

25VL := **60.0**. Voltage Window Low Threshold (20.0–200 V secondary)

Set the high-voltage threshold that supervises synchronism check equal to 70 V secondary.

25VH := **70.0**. Voltage Window High Threshold (20.0–200 V secondary)

Circuit Breaker 2 Synchronism Check

Select A-Phase voltage from Bus 2 for the synchronism check source. VBZ is the source for the synchronism check because this is the bus potential.

SYNCS2 := **VBZ**. Synch Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)

Both the line reference and bus source voltages are measured line-to-neutral. Set the ratio factor equal to unity.

KS2M : = **1.00**. Synch Source 2 Ratio Factor (0.000–30)

You do not need to shift the angle of the synchronism check because both the source and reference voltage are measured A-Phase-to-neutral.

KS2A := **0**. Synch Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)

There is no alternate synchronism source for Circuit Breaker 2 in this application example.

ALTS2 := **NA**. Alternative Synch Source 2 (SELOGIC Equation)

Assume that there is no slip between the source and reference voltages.

25SFBK2 := **OFF**. Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)

Set the maximum allowable voltage angular difference between the source and reference voltages equal to 20 degrees when attempting to reclose Circuit Breaker 2.

ANG1BK2 := **20.0**. Maximum Angle Difference 1—BK2 (3.0–80 degrees)

Set the maximum allowable voltage angular difference between the source and reference voltages equal to 20 degrees when attempting to manually close Circuit Breaker 2.

ANG2BK2 := **20.0**. Maximum Angle Difference 2—BK2 (3.0–80 degrees)

The relay does not compensate the synchronism check to account for circuit breaker closing time because setting 25SFBK2 is OFF. Leave the close time compensation setting at the default.

TCLSBK2 := **1.00**. Breaker 2 Close Time (1.00–30 cycles)

Block the synchronism check if Circuit Breaker 2 is closed.

BSYNBK2 := **52AA2 AND 52AB2 AND 52AC2**. Block Synchronism Check—BK2 (SELOGIC Equation)

Example Complete

This completes the application example that describes setting the SEL-421 for one shot of high-speed single-pole reclosing and one shot of three-pole reclosing for two circuit breakers. This example showed a configuration for synchronism check, as well. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.40 provides a list of all the SEL-421 autoreclose settings.

Table 6.40 Settings for Autoreclose and Synchronism Check Example (Sheet 1 of 3)

Setting	Prompt	Entry
Recloser Closing (Group)		
E79	Reclosing (Y, Y1, N)	Y
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	1
ESPR1	Single-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN205
ESPR2	Single-Pole Reclose Enable—BK2 (SELOGIC Equation)	IN206

Table 6.40 Settings for Autoreclose and Synchronism Check Example (Sheet 2 of 3)

Setting	Prompt	Entry
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	1
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	IN207
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	IN208
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	15
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	600
SLBK1	Lead Breaker = Breaker 1(SELOGIC Equation)	IN107
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	0
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	3POBK2 OR NOT LEADBK1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 AND 52AB1 AND 52AC1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	LOP
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	300
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	300
Single-Pole Reclose (Group)		
SPOID	Single-Pole Open Interval Delay (1–99999 cycles)	60
SPRCD	Single-Pole Reclaim Time Delay (1–99999 cycles)	900
SPRI	Single-Pole Reclose Initiation (SELOGIC Equation)	SPT AND (Z1G AND COMPRM)
SP1CLS[a]	Single-Pole BK1 Reclose Supervision (SELOGIC control equation)	1
SP2CLS[a]	Single-Pole BK2 Reclose Supervision (SELOGIC Equation)	NOT LEADBK1
Three-Pole Reclose (Group)		
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	30
3PFARC	Three-Pole Fast autoreclose Enable (SELOGIC Equation)	NA
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900
3PRI	Three-Pole autoreclose Initiate (SELOGIC Equation)	3PT AND (Z1P OR COMPRM)
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA
3P1CLS[a]	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)	DLLB1
3P2CLS[a]	Three-Pole BK 2 Reclose Supervision (SELOGIC Equation)	25A2BK2 OR (NOT LEADBK1 AND DLLB2)
Voltage Elements (Group)		
EVCK	Reclosing Voltage Check (Y, N)	Y
27LP	Dead Line Voltage (1.0–200 V secondary)	15.0
59LP	Live Line Voltage (1.0–200 V secondary)	50.0

Table 6.40 Settings for Autoreclose and Synchronism Check Example (Sheet 3 of 3)

Setting	Prompt	Entry
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	50.0
27BK2P	Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)	15.0
59BK2P	Breaker 2 Live Busbar Voltage (1.0–200 V secondary)	50.0
Trip Logic (Group)		
E3PT2	Breaker 2 3PT (SELOGIC Equation)	NOT LEADBK2
Relay Configuration (Group)		
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N
E25BK2	Synchronism Check for Breaker 2 (Y, N, Y1, Y2)	Y
Synchronism-Check Element Reference (Group)		
SYNCP	Synchronism Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
25VL	Voltage Window Low Threshold (20.0–200 V secondary)	60.0
25VH	Voltage Window High Threshold (20.0–200 V secondary)	70.0
Breaker 2 Synchronism Check (Group)		
SYNCS2	Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBZ
KS2M	Synchronism Source 2 Ratio Factor (0.10–3)	1.00
KS2A	Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0
ALTS2	Alternative Synchronism Source 2 (SELOGIC Equation)	NA
25SFBK2	Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)	OFF
ANG1BK2	Maximum Angle Difference 1—BK2 (3.0–80 degrees)	20.0
ANG2BK2	Maximum Angle Difference 2—BK2 (3.0–80 degrees)	20.0
TCLSBK2	Breaker 2 Close Time (1.00–30 cycles)	1.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2

[a] These settings cannot be set to NA or logical 0.

Circuit Breaker Failure Application Examples

NOTE: The following discussion designates Circuit Breaker 1. For Circuit Breaker 2, replace the **1** with **2**.

Under normal operating conditions, local station primary protection operates to remove faulted equipment from service. Zones of protection are arranged to minimize service disruption when local primary protection operates. Backup protection clears the fault when local protection fails to do so, typically removing more equipment from service than the primary protection would have removed for a correct operation.

Protection systems typically employ both local and remote backup protection. Local backup protection uses dedicated additional equipment to clear a fault if the local primary protection fails. Remote backup protection consists of overlapping, time-coordinated protection zones situated at remote locations with respect to the local terminal. Remote backup protection operates if a fault outside the local protection zone persists. Circuit breaker failure relaying is local backup protection.

The SEL-421 features four types of circuit breaker failure and retrip protection capability:

1. Failure to interrupt fault current for phase currents
2. No current/residual current circuit breaker failure protection
3. Failure to interrupt load current
4. Flashover circuit breaker failure protection

Protection against failure to interrupt fault current for phase currents is the most common implementation. This subsection describes failure to interrupt fault current circuit breaker failure protection.

Failure to Interrupt Fault Current for Phase Currents

The SEL-421 provides two schemes for failure to interrupt fault current for phase currents. Scheme 1 is protection for basic cases involving both multiphase faults and single-phase faults with a common breaker failure time delay. Scheme 2 is for more elaborate protection that discriminates between multiphase and single-phase faults and features separate circuit breaker failure time delays. Use Scheme 2 for separate circuit breaker failure timing for three-pole and single-pole faults.

Basic Operation—Scheme 1 and Scheme 2

NOTE: The following discussion specifies three elements. There is one element for each phase: ϕ =A, B, and C).

A trip output from the local primary or backup line protection typically initiates the failure to interrupt fault current circuit breaker failure scheme (BFI3P1 and BFIϕ1 for Scheme 1 or BFIϕ1 for Scheme 2). When initiated, the relay starts circuit breaker failure timing; the time delay is BFPU1 (Breaker Failure Time Delay—BK1). The SEL-421 does not require an external BFI contact when applied for local circuit breaker failure protection because the relay detects line faults. In addition, you can add external BFI from an input in parallel with the circuit breaker trip coil to capture additional trip initiations to increase scheme dependability.

Set the instantaneous overcurrent element pickup threshold 50FP1 to pick up for all line faults. The relay asserts Relay Word bit 50Fϕ1 when the phase current exceeds the 50FP1 threshold. The 50Fϕ1 element must reset quickly even during the presence of subsidence current at the circuit breaker opening.

If 50Fϕ1 is asserted when timer BFPU1 expires, the relay asserts circuit breaker failure protection Relay Word bit FBF1 (Breaker 1 Breaker Failure). Assign FBF1 to SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) as one of the circuit breaker failure elements that can cause a circuit breaker failure trip. When SELOGIC control equation BFTRI asserts, the relay asserts corresponding Relay Word bit BFTRIP1 (Breaker 1 Failure Trip Output). Assign BFTRIP1 to a high-current interrupting control output to perform circuit breaker failure tripping or to a standard control output to operate an 86 lockout relay.

Scheme Components

The following are components of the circuit breaker failure schemes in the SEL-421:

- Circuit Breaker Failure Initiation (BFI3P1 or BFIϕ1)
- Phase Fault Current Pickup (50FP1)
- Breaker Failure Pickup Time Delay (BFPU1)

For a detailed description see *Circuit Breaker Failure Trip Logic on page 5.154*.

Circuit Breaker Failure Initiation (BFI3P1 or BFIϕ1)

All circuit breaker trips typically initiate the circuit breaker failure scheme. The SEL-421 detects power system faults; the relay does not need an external BFI contact for local circuit breaker failure protection applications.

Scheme 1

Scheme 1 uses initiation SELOGIC control equation BFI3P1 for three-pole tripping applications and BFIϕ1 for single-pole tripping applications.

Scheme 2

Scheme 2 uses initiation SELOGIC control equations BFIϕ1 for both three-pole (multiphase) and single-phase faults.

Phase Fault Current Pickup (50FP1)

Circuit breaker failure protection must pick up for all faults on the protected line. Two settings philosophies are prevalent. One philosophy is to set the instantaneous overcurrent element (50Fϕ1) to pick up above load current and below the minimum fault current (under minimum generation), if possible ($I_{load\ max}$ < 50FP1 < $I_{minimum\ fault}$). Another settings philosophy is to set the threshold to match the line protection sensitivity; this increases circuit breaker failure protection dependability.

In the following application examples, we use the first settings philosophy because this approach gives greater security. In either case, when input phase currents exceed the overcurrent element threshold, the relay asserts Relay Word bit 50Fϕ1.

Subsidence current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load. Subsidence current exponentially decays and delays resetting of instantaneous overcurrent elements. However, the open-phase detection logic causes the SEL-421 50Fϕ1 element to reset in less than one cycle during subsidence current conditions. The open-phase detection logic determines that a pol e is open during the presence of subsidence current and immediately resets the corresponding current level detectors.

Breaker Failure Pickup Time Delay (BFPU1)

Scheme 1

Relay Word bit FBF1 (Breaker 1 Breaker Failure) asserts when the time delay on pickup timer BFPU1 expires and the corresponding 50Fϕ1 element is asserted.

Scheme 2

Relay Word bit FBF1 (Breaker 1 Breaker Failure) asserts for these conditions:

- A *single phase-to-ground fault occurs*: FBF1 asserts when time delay on pickup timers BFPU1 (Breaker Failure Time Delay—BK1) followed by SPBFPU1 (SPT Breaker Failure Time Delay—BK1) expire. The corresponding 50FPϕ1 element and only one single-phase breaker failure initiation (for example, BFIA1) are asserted.
- A *multiphase fault occurs*: FBF1 asserts when time delay on pickup timer BFPU1 (Breaker Failure Time Delay—BK1) expires. The corresponding 50Fϕ1 elements and at least two single-phase breaker failure initiations (for example, BFIA1 and BFIB1) are asserted.

Timing Sequence

Figure 6.40 and *Figure 6.41* illustrate the timing sequence for circuit breaker failure schemes.

Scheme 1

Scheme 1 follows *Figure 6.40*.

Scheme 2

Scheme 2 uses both timing sequences in *Figure 6.40* and *Figure 6.41*, depending on the fault type (multiphase fault and single-phase fault, respectively).

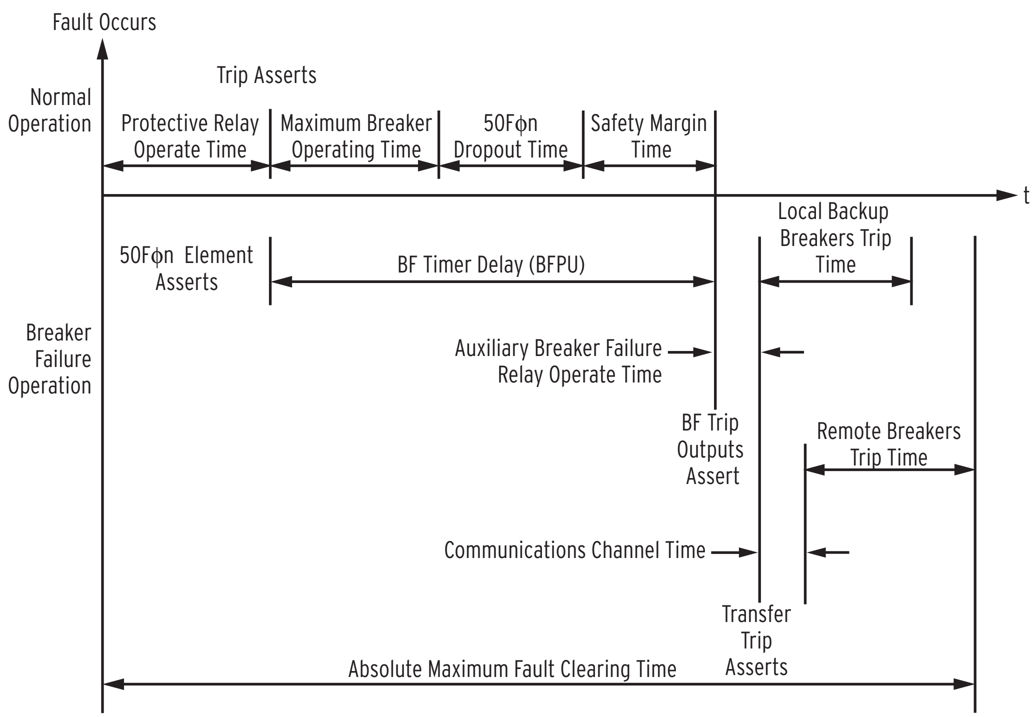


Figure 6.40 Scheme 1 All Faults and Scheme 2 Multiphase Fault Timing Diagram

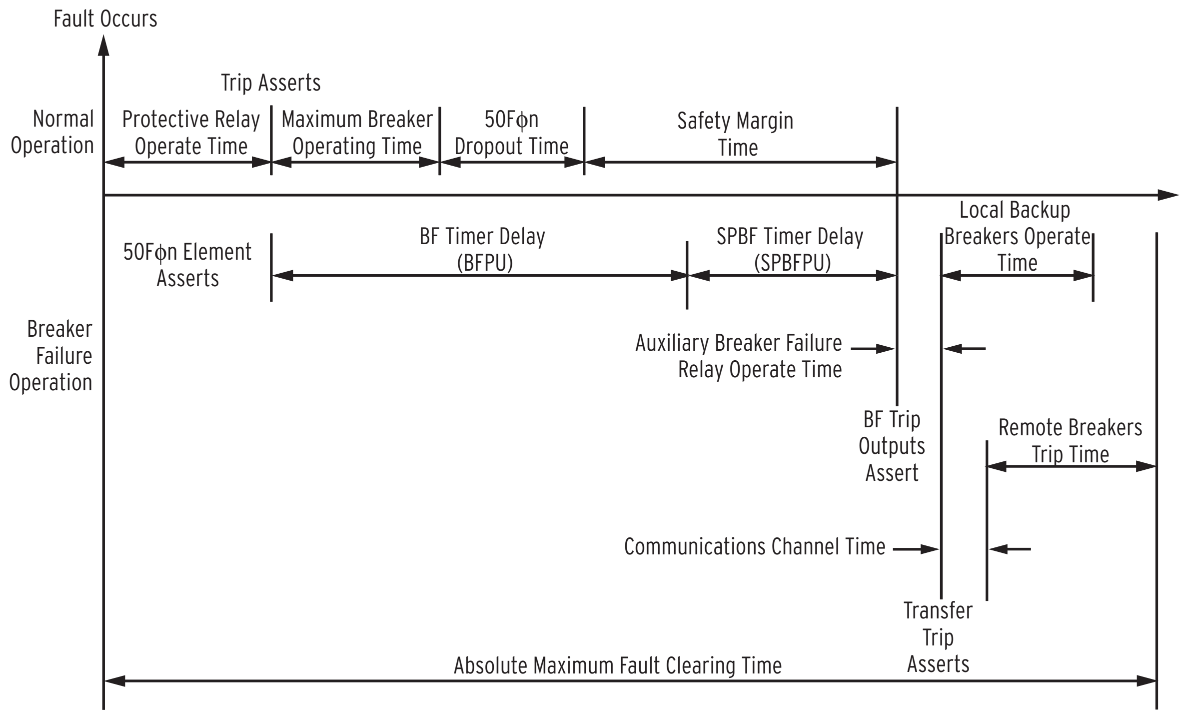


Figure 6.41 Scheme 2 Single-Phase Fault Timing Diagram

The absolute maximum fault clearing time depends on power system transient stability and the thermal withstand capability of the equipment. If a circuit breaker fails, the total time required to trip all electrically adjacent circuit breakers must be less than this absolute maximum clearing time. Set the time delay on pickup timer to allow time for the protected circuit breaker to operate and the instantaneous overcurrent element (50Fϕ1) to reset. Always include a safety margin, remembering that the operating time of the line relays and the electrically adjacent circuit breakers limit this margin.

Circuit Breaker Failure Protection—Example 1

Use the SEL-421 to provide circuit breaker failure protection for one circuit breaker. This is a circuit breaker failure protection Scheme 1 application example for three-pole tripping circuit breakers (you can also use this scheme for single-pole tripping applications). For a single-pole tripping circuit breaker application example (Scheme 2), see *Circuit Breaker Failure Protection—Example 2 on page 6.161*. This example uses a 230 kV power system similar to the system in 230 kV Overhead Distribution Line Example. *Figure 6.42* shows the SEL-421 at the S terminal of the two-terminal line between Harvard and Princeton. *Table 6.41* provides the related power system parameters.

Figure 6.42 230 kV Power System for Circuit Breaker Failure Scheme 1

Table 6.41 Secondary Quantities

Parameter	Value
Line impedances Z_{1L} Z_{0L}	 1.95 Ω ∠84° secondary 6.2 Ω ∠81.5° secondary
Source S impedances $Z_{1S} = Z_{0S}$	2.5 Ω ∠86° secondary
Source R impedances $Z_{1R} = Z_{0R}$	2.5 Ω ∠86° secondary
Nominal frequency (f_{NOM})	60 Hz
Maximum operating current load (I_{load})	4.95 A secondary

Relay Configuration

Enable Scheme 1 circuit breaker failure protection for Circuit Breaker BK1.

EBFL1 := 1. Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)

Circuit Breaker 1 Failure Logic

Phase Current Level Detector

NOTE: This is one method for calculating setting 50FP1. Use your company practices and policies for determining the pickup setting for your particular application.

Set the phase current level detector equal to 120 percent of the maximum load current I_{load}. Check that this setting is less than the minimum fault current (ϕϕ fault) with minimum generation. Circuit breaker failure protection for faults involving ground (SLG and ϕϕG faults) is covered in this application example by no current/residual current circuit breaker failure protection (see *Residual Current Circuit Breaker Failure Protection on page 6.158*). This settings philosophy provides security for the circuit breaker failure protection. For this power system, the maximum load current is 4.95 A secondary and the minimum ϕϕ fault current is 13.0 A secondary.

$$50FP1 = 120\% \bullet I_{load} = 120\% \bullet 4.95 \text{ A} = 5.94 \text{ A}$$

50FP1 := **5.94**. Phase Fault Current Pickup—BK1 (0.50–50 A secondary)

Circuit Breaker Failure Protection Time Delay

The recommended setting for BFPU1 (Breaker Failure Time Delay—BK1) is the sum of the following (see *Figure 6.43*):

- Maximum circuit breaker operating time
- 50FA1 maximum dropout time
- Safety margin

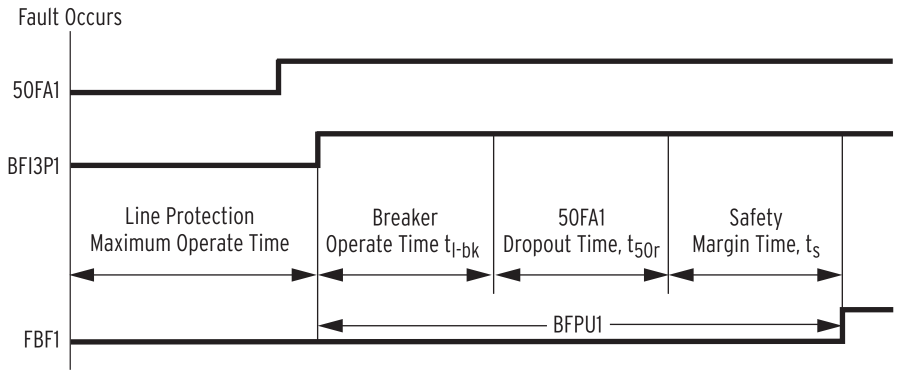


Figure 6.43 Timing Diagram for Setting BFPU1—Scheme 1

To maintain system stability, the relay must clear the fault within the total clearing time. Use the maximum operating time of the local and remote circuit breakers. The maximum operating time of the circuit breaker, $t_{l\text{-}bk}$, is 3 cycles for this example. Also, use the maximum dropout time for Relay Word bit 50FA1; the maximum dropout time of the phase current level detector, t_{50r}, is 1 cycle. You must also include the communications channel time, t_{ch}, for remote circuit breaker tripping.

To determine setting BFPU1, you must find the safety margin, ts. Determine the safety margin from *Figure 6.40*:

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 17 - (2 + 3 + 1 + 1 + 1 + 3) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 6.89

where:

t_s = safety margin
t_t = total clearing time (17 cycles)
t_{lr} = line protection maximum operating time (2 cycles)
$t_{l\text{-}bk}$ = local circuit breaker maximum operating time (3 cycles)
t_{50r} = circuit breaker failure overcurrent element 50FA1 maximum reset time (1 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
$t_{r\text{-}bk}$ = remote circuit breaker maximum operating time (3 cycles)

Use the safety margin result from *Equation 6.89* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 6.90

BFPU1 := **10.000**. Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

Retrip Time Delay

If the circuit breaker is equipped with two trip coils, the relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. Wait 4 cycles for the retrip.

RTPU1 := **4.000**. Retrip Time Delay—BK1 (0.000–6000 cycles)

Circuit Breaker Failure Protection Initiation

To initiate circuit breaker failure protection for Circuit Breaker BK1, assign the protection elements to Relay Word bit BFI3P1 (Three-Pole Breaker Failure Initiate—BK1). This protection example uses three-pole tripping only.

BFI3P1 := **3PT**. Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIA1 := **NA**. A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIB1 := **NA**. B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIC1 := **NA**. C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

Circuit Breaker Failure Protection Initiation Dropout Delay

Set the circuit breaker failure initiate dropout time delay to zero. Disable this feature for this application example because this is not a dual circuit breaker scheme.

BFIDO1 := **0.000**. Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)

Circuit Breaker Failure Protection Initiation Seal-In Delay

Set the latch logic circuit breaker failure pickup time delay to zero. Disable this feature for this application example. Relay Word bit 3PT internally initiates circuit breaker failure protection and has a minimum duration three-pole time delay on dropout (that is, TDUR3D).

BFISP1 := **0.000**. Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)

Residual Current Circuit Breaker Failure Protection

Enable no current/residual circuit breaker failure protection for Circuit Breaker BK1. Use this logic to detect a circuit breaker failure and take appropriate action when a weak source drives the fault or if the protected circuit breaker fails to trip during a high-resistance ground fault.

ENCBF1 := **Y**. No Current/Residual Current Logic—BK1 (Y, N)

Residual Current Pickup

Set the pickup of the residual current level detector greater than maximum system unbalance; assume a 15 percent maximum unbalance.

$$50RP1 = 0.15 \bullet I_{load} = 0.15 \bullet 4.95\ A = 0.74\ A$$

50RP1 := **0.74**. Residual Current Pickup—BK1 (0.25–50 A secondary)

Residual Current Circuit Breaker Failure Time Delay

Setting NPU1 is the time delay on pickup before the relay asserts a low current circuit breaker failure trip for Circuit Breaker BK1. You can set this delay greater than BFPU1; a high-resistance ground fault is not as much a threat to power system transient stability as is a phase fault, because synchronizing power still flows through the two unfaulted phases.

NPU1 := **12.000**. No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)

Residual Current Circuit Breaker Failure Initiation

This particular application uses the residual current circuit breaker failure scheme only to detect when the circuit breaker fails to trip during high-resistance ground faults. Set SELOGIC control equation BFIN1 (No Current Breaker Failure Initiate) to NA.

If you want to apply this scheme for no current conditions (e.g., weak source), assign the 52A contact from Circuit Breaker BK1 (52AA1) to the SELOGIC control equation BFIN1 (No Current Breaker Failure Initiate).

BFIN1 := **NA**. No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)

Load Current Circuit Breaker Failure Protection

Disable load current circuit breaker failure protection for Circuit Breaker BK1.

ELCBF1 := **N**. Load Current Breaker Failure Logic—BK1 (Y, N)

Flashover Circuit Breaker Failure Protection

Disable flashover current circuit breaker failure protection for Circuit Breaker BK1.

EFOBF1 := **N**. Flashover Breaker Failure Logic—BK1 (Y, N)

Circuit Breaker Failure Protection Trip Logic

Circuit Breaker 1 Failure Trip Equation

The SEL-421 has dedicated circuit breaker failure trip logic. Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for either Circuit Breaker BK1 circuit breaker failure trip or Circuit Breaker BK1 residual current circuit breaker failure trip. When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 to logical 1 until BFTR1 deasserts, the TDUR3D timer times out, and an unlatch or reset condition is active.

BFTR1 := **FBF1 OR NBF1**. Breaker Failure Trip—BK1 (SELOGIC Equation)

Unlatch Circuit Breaker 1 Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition

BFTRIP1 (Breaker Failure Trip for Circuit Breaker BK1). Assign a control input that is energized externally to signal the relay when the circuit breaker failure trip clears the fault successfully.

BFULTR1 := **IN104**. Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)

Control Outputs

Use SELOGIC control equations to assign control outputs for tripping Circuit Breaker BK1, retripping Circuit Breaker BK1, and circuit breaker failure tripping. *Figure 6.44* shows dc connections for the circuit breaker failure trip and circuit breaker trip/retrip.

Use the main board high current interrupting control output for the retrip signal (RT1) because this output can interrupt large circuit breaker coil currents. There is no TDUR3D (3PT Minimum Trip Duration Time Delay) for RT1; the RT1 signal can drop out while there is current flowing through the trip coil, if the auxiliary circuit breaker contacts have not yet opened.

OUT101 := **3PT**.

OUT103 := **RT1**.

OUT107 := **BFTRIP1**.

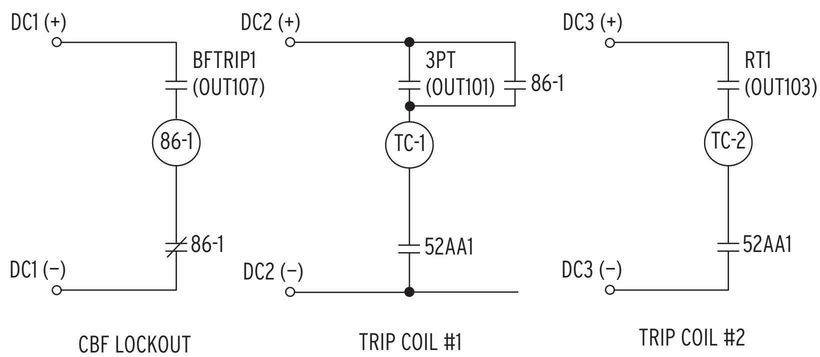


Figure 6.44 Circuit Breaker Failure Trip and Circuit Breaker Trip DC Connections

Example Completed

This completes the application example that describes setting of the SEL-421 for circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Table 6.42 lists all protective relay settings applied for this example.

Table 6.42 Settings for Circuit Breaker Failure Example 1 (Sheet 1 of 2)

Setting	Prompt	Entry
Relay Configuration (Group)		
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	1

Table 6.42 Settings for Circuit Breaker Failure Example 1 (Sheet 2 of 2)

Setting	Prompt	Entry
Breaker 1 Failure Logic (Group)		
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary)	5.94
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	10.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	4.000
BFI3PI	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	3PT
BFIA1	A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
BFIB1	B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
BFIC1	C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	0.000
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)	0.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	Y
50RP1	Residual Current Pickup—BK1 (0.25–50 A secondary)	0.74
NPU1	No Current Breaker Failure Delay—BK1 (0.000–6000 cycles)	12.000
BFIN1	No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	FBF1 OR NBF1
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	IN104
Main Board (Outputs)		
OUT101		3PT
OUT103		RT1
OUT107		BFTRIP1

Circuit Breaker Failure Protection—Example 2

Use the SEL-421 to provide circuit breaker failure protection for both circuit breakers in breaker-and-a-half schemes. This application example explains setting the relay for Circuit Breaker BK1 (see *Figure 6.45*). You can apply these same settings for Circuit Breaker BK2. You can apply circuit breaker failure Scheme 2 protection for single-pole trip circuit breakers. Scheme 2 provides separate timers for multiphase faults (BFPU1) and single-phase faults (SPBFPU1). For more information on Scheme 2 circuit breaker failure protection, see *Failure to Interrupt Fault Current: Scheme 2 on page 5.148*.

NOTE: This application example is for two circuit breakers. Apply the same settings for Circuit Breaker BK2 as for Circuit Breaker BK1. For Circuit Breaker BK2, substitute 2 for 1 in the following settings.

This example uses a 500 kV power system with single-pole tripping enabled (see *Figure 6.45*). *Table 6.43* provides the power system parameters.

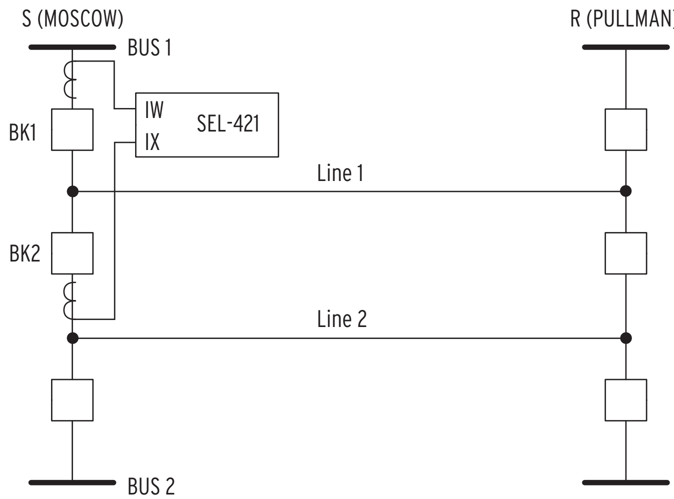


Figure 6.45 500 kV Power System for Circuit Breaker Failure Scheme 2

Table 6.43 Secondary Quantities

Parameter	Value
Line impedances Z_{1L1} Z_{0L1}	 3.98 Ω ∠87.6° secondary 14.48 Ω ∠82.1° secondary
Source S impedances $Z_{1S} = Z_{0S}$	 4.4 Ω ∠88° secondary
Source R impedances $Z_{1R} = Z_{0R}$	 1.78 Ω ∠88° secondary
Nominal frequency (f_{NOM})	60 Hz
Maximum operating current (I_{load})	3.25 A secondary

Relay Configuration

Enable Scheme 2 circuit breaker failure protection for two circuit breakers.

EBFL1 := **2**. Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)

EBFL2 := **2**. Breaker 2 Failure Logic (N, 1, 2, Y1, Y2)

Circuit Breaker 1 Failure Logic

Phase Current Level Detector

Set the phase fault current pickup greater than maximum load and less than the fault current that flows through Circuit Breaker BK1 ($I_{S(BK1)}$). Maximum load current, I_S, is 3.25 A secondary.

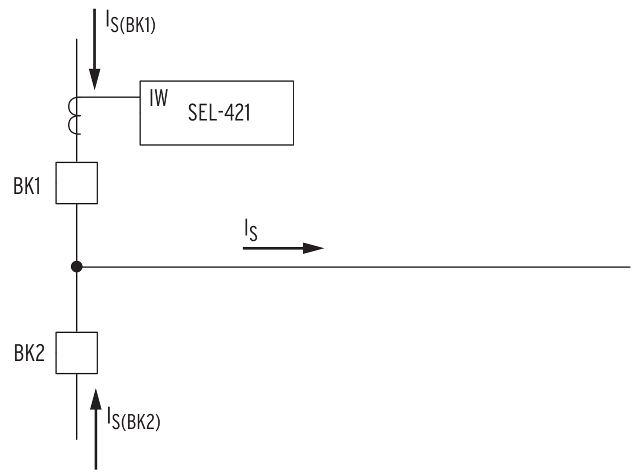


Figure 6.46 Fault Current Distribution Through Faulted Line at Station S

Assume that the total load current (I_S) supplied from Substation S flows through BK1 only; $I_{S(BK1)} = I_S$ (see *Figure 6.46*). Calculate setting 50FP1 with all the load current I_S through Circuit Breaker BK1.

$$\begin{aligned} 50FP1 &= 120\% \bullet (\text{Percent Current} \bullet I_S) \\ &= (120\% \bullet (100\% \bullet 3.25\ \text{A})) \\ &= 3.91\ \text{A secondary} \end{aligned}$$

Equation 6.91

A fault study shows that the minimum ground fault current, $I_{fault\ minimum}$, is 4.2 A secondary when the parallel line is in service at minimum generation. Calculate the 50FP1 setting for dependability at 1/2 of the minimum fault current.

$$\begin{aligned} 50FP1 &= 0.5 \bullet (\text{Percent Current} \bullet I_{fault\text{-}minimum}) \\ &= (0.5 \bullet (100\% \bullet 4.20\ \text{A})) \\ &= 2.10\ \text{A secondary} \end{aligned}$$

Equation 6.92

Although the result of this setting calculation is below maximum load (see *Equation 6.91*), use this calculation to set the 50FP1 element for dependability.

50FP1 := **2.10**. Phase Fault Current Pickup—BK1 (0.50–50 A secondary)

Circuit Breaker Failure Time Delay

NOTE: This is one method for calculating setting 50FP1. Use your company practices and policies for determining the pickup setting for your particular application.

BFPU1 (Breaker Failure Time Delay—BK1) is the time delay on pickup for a circuit breaker trip following a multiphase fault. You can also add an additional delay, SPBFPU1 (SPT Breaker Failure Time Delay—BK1).

The recommended setting for BFPU1 is the sum of the following (see *Figure 6.47*):

- Maximum circuit breaker operating time
- 50FA1 maximum dropout time
- Safety margin

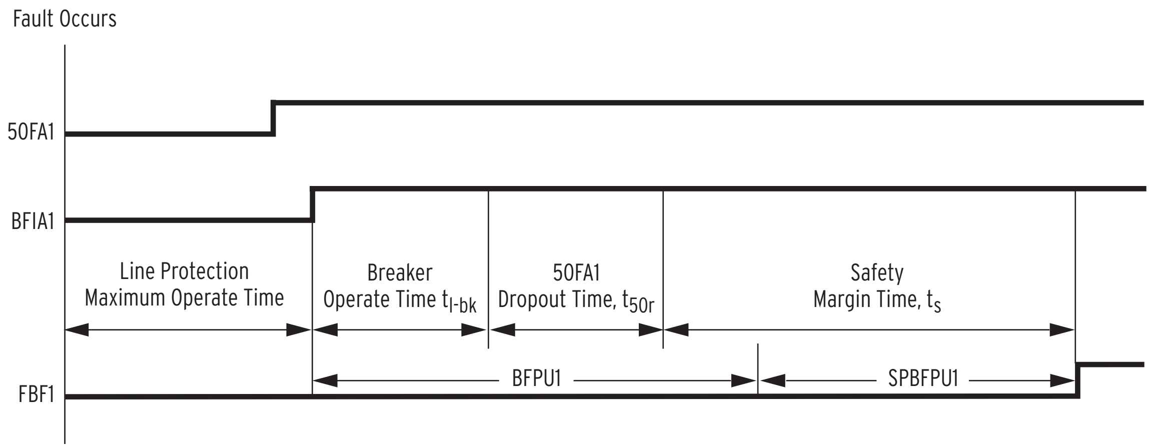


Figure 6.47 Timing Diagram for Setting BFPU1—Scheme 2

To maintain system stability, you must clear the fault within the total clearing time. Use the maximum operating time of the local and remote circuit breakers. The maximum operating time of the circuit breaker, $t_{l\text{-}bk}$, is 2 cycles for this example. Also use the maximum reset time of 50FA1; the maximum reset (dropout) time of the phase current level detector, t_{50r}, is 1 cycle. You must also include the communications channel time, t_{ch}, for remote circuit breaker tripping.

To determine setting BFPU1, you must find the safety margin, t_s. Determine the safety margin from *Figure 6.40*.

$$\begin{aligned} t_s &= t_t - (t_{1r} + t_{1-bk} + t_{50r} + t_{86} + t_{ch} + t_{r-bk}) \\ &= 15 - (2 + 2 + 1 + 1 + 1 + 2) \\ &= 6 \text{ cycles} \end{aligned}$$

Equation 6.93

where:

t_s = safety margin
t_t = total clearing time (15 cycles)
t_{lr} = line protection maximum operating time (2 cycles)
$t_{l\text{-}bk}$ = local circuit breaker maximum operating time (2 cycles)
t_{50r} = circuit breaker failure overcurrent element 50FA1 maximum reset time (1 cycle)
t_{86} = auxiliary breaker failure relay operating time (1 cycle)
t_{ch} = communications channel maximum operating time (1 cycle)
$t_{r\text{-}bk}$ = remote circuit breaker maximum operating time (2 cycles)

Use the safety margin result from *Equation 6.94* to calculate BFPU1:

$$\begin{aligned} \text{BFPU1} &= t_{1-bk} + t_{50r} + t_s \\ &= 3 + 1 + 6 \\ &= 10 \text{ cycles} \end{aligned}$$

Equation 6.94

BFPU1 := **10.000**. Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

SPBFPU1 is an additional delay you can cascade to BFPU1 for single-phase faults (see *Figure 6.48*). Set SPBFPU1 to extend breaker failure pickup time delay as long as the total clearing time t_t = 15 cycles.

SPBFPU1 := **5.000**. SPT Breaker Failure Time Delay—BK1 (0.000–6000 cycles)

Retrip Time Delay

Scheme 2 provides retrip timers RT3PPU1 for multiphase faults and RTPU1 for single-phase faults. Set the retrip following a single-pole trip to occur 3 cycles after circuit breaker failure initiation.

RTPU1 := **3.000**. Retrip Time Delay—BK1 (0.000–6000 cycles)

A three-pole retrip follows a three-pole trip. The relay should attempt to retrip the protected circuit breaker before a circuit breaker failure trip asserts. Apply the default setting for the three-pole retrip time delay on pickup.

RT3PPU1 := **3.000**. Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)

Figure 6.48 compares the complete timing sequence for single-pole versus three-pole circuit breaker failure operations.

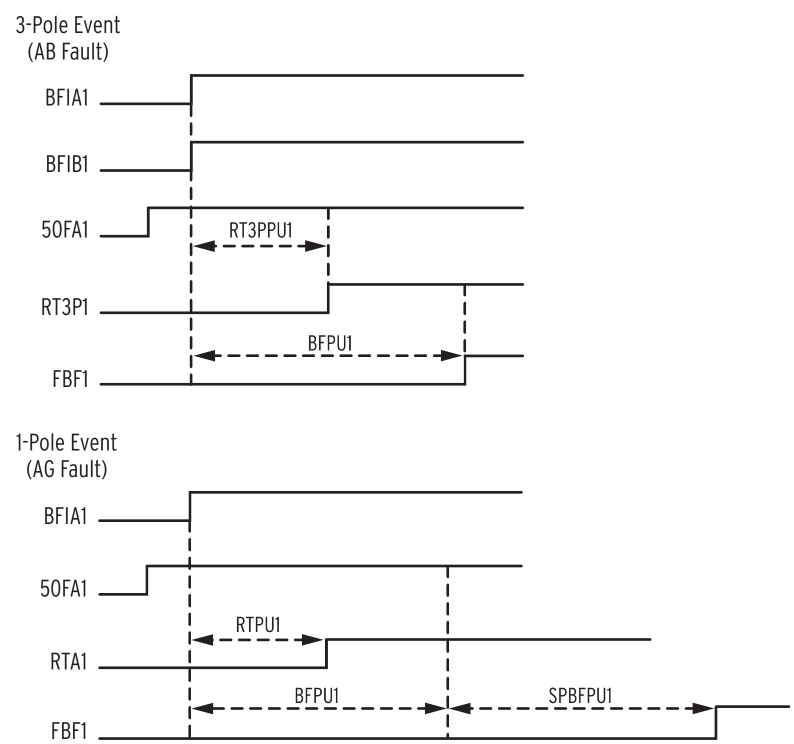


Figure 6.48 Timing Sequences for Circuit Breaker Failure Protection Scheme 2

Circuit Breaker Failure Initiation

Scheme 2 does not use Relay Word bit BFI3P1 to initiate failure to interrupt fault current circuit breaker failure protection.

BFI3P1 := **NA**. Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)

Assign the protection elements to Relay Word bits BFIA1, BFIB1, and BFIC1 to initiate single-pole trip circuit breaker failure protection for Circuit Breaker BK1. For a complete description of circuit breaker failure initiation, see *Circuit Breaker Failure Protection on page 5.146*. This application example uses the POTT tripping scheme, step-distance backup protection, and SOTF protection.

BFIA1 := **BFIAT1 OR TPA1**. A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIB1 := **BFIBT1 OR TPB1**. B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

BFIC1 := **BFICT1 OR TPC1**. C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)

Relay Word bits BFIAT1, BFIBT1, and BFICT1 (Circuit Breaker 1 Latched Single-Pole Circuit Breaker Failure Initiation) latch the BFIA1, BFIB1, and BFIC1 inputs to the circuit breaker failure protection.

Circuit Breaker Failure Protection Initiation Dropout Delay

Set the circuit breaker failure initiate time delay on dropout to stretch a short pulsed circuit breaker failure initiation. Enable this feature for this application example because you are protecting dual circuit breakers.

BFIDO1 := **3.000**. Breaker Failure Initiate Dropout Delay—BK1 (0.000–1000 cycles)

Circuit Breaker Failure Protection Initiation Seal-In Delay

Set the circuit breaker failure initiate time delay on pickup for the latch logic to qualify extended circuit breaker failure initiation latch seal-in.

BFISP1 := **4.000**. Breaker Failure Initiate Seal-In Delay—BK1 (0.000–1000 cycles)

For these BFIDO1 and BFISP1 settings, if the circuit breaker failure initiate is 1 cycle or more, the relay seals in the circuit breaker failure extended initiation after the initiate signal deasserts until the BFIDO1 time (3 cycles) expires and all 50Fϕ1 elements deassert.

Residual Current Circuit Breaker Failure Protection

Disable residual current circuit breaker failure protection for Circuit Breaker BK1 because a strong source drives this terminal.

ENCBF1 := **N**. No Current/Residual Current Logic—BK1 (Y, N)

Load Current Circuit Breaker Failure Protection

Disable load current circuit breaker failure protection for Circuit Breaker BK1.

ELCBF1 := **N**. Load Current Breaker Failure Logic—BK1 (Y, N)

Flashover Circuit Breaker Failure Protection

Disable flashover current circuit breaker failure protection for Circuit Breaker BK1.

EFOBF1 := **N**. Flashover Breaker Failure Logic—BK1 (Y, N)

Circuit Breaker Failure Protection Trip Logic

Circuit Breaker 1 Failure Trip Equation

The SEL-421 has dedicated circuit breaker failure trip logic. Set SELOGIC control equation BFTR1 (Breaker Failure Trip—BK1) to assert for a Circuit Breaker BK1 circuit breaker failure trip. When this SELOGIC control equation asserts, the relay sets Relay Word bit BFTRIP1 to logical 1 until BFTR1 deasserts, the TDUR1D timer times out, and an unlatch or reset condition is active.

BFTR1 := **FBF1**. Breaker Failure Trip—BK1 (SELOGIC Equation)

Unlatch Circuit Breaker Failure Trip Equation

Use SELOGIC control equation BFULTR1 (Breaker Failure Unlatch Trip—BK1) to define the conditions that unlatch the control outputs that assert during a circuit breaker failure trip. BFULTR1 unlatches the circuit breaker trip condition BFTRIP1 (Breaker Failure Trip for Circuit Breaker 1). Assign a control input that is energized externally to signal the relay when the circuit breaker failure trip clears the fault successfully.

BFULTR1 := **IN104**. Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)

Use the same input signal to unlatch the circuit breaker failure trip on Circuit Breaker BK2.

Control Outputs

Use SELOGIC control equations to assign the control outputs for tripping and retripping Circuit Breaker BK1 and Circuit Breaker BK2 and circuit breaker failure tripping. These output assignments are for the SEL-421 with an additional INT6 I/O interface board (see *I/O Interface Boards on page 2.13*).

NOTE: The symbol ϕ indicates A, B, and C for A-Phase, B-Phase, or C-phase of the power system.

Assign the trip outputs to the hybrid (high current interrupting) control outputs. Use the high current interrupting control outputs for the retrip signal (RTϕ1) because these outputs can interrupt large circuit breaker coil currents. There is no TDUR3D (3PT Minimum Trip Duration Time Delay) for RTϕ1; the RTϕ1 signal can drop out while there is current flowing through the trip coil, if the auxiliary circuit breaker contacts have not yet opened.

OUT101 := **TPA1**.

OUT102 := **TPB1**.

OUT103 := **TPC1**.

OUT107 := **BFTRIP1**.

OUT201 := **TPA2**.

OUT202 := **TPB2**.

OUT203 := **TPC2**.

OUT204 := **RTA1**.

OUT205 := **RTB1**.

OUT206 := **RTC1**.

OUT207 := **RTA2**.

OUT208 := **RTB2**.

OUT209 := **RTC2**.

Figure 6.49 illustrates the corresponding dc connections for Circuit Breaker BK1. Circuit Breaker BK2 connections are similar.

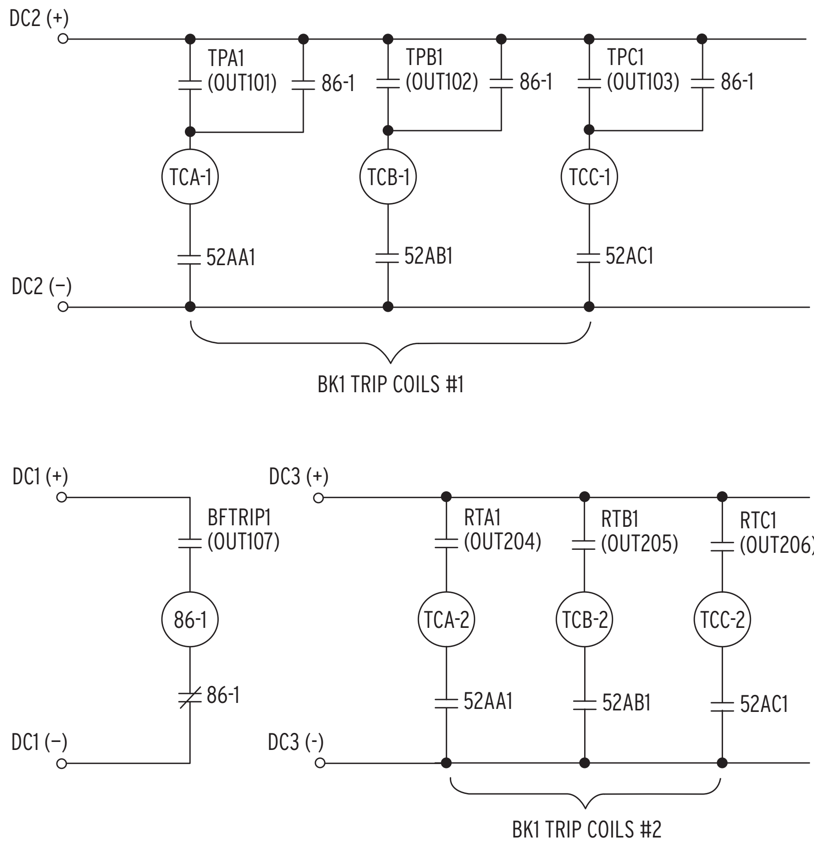


Figure 6.49 Circuit Breaker BK1 DC Connections (Two Trip Coils)

Example Completed

This completes the application example that describes setting the SEL-421 for Scheme 2 circuit breaker failure protection. Analyze your particular power system to determine the appropriate settings for your application.

Relay Settings

Figure 6.44 lists all protective relay settings applied for this example. These settings are for Circuit Breaker BK1; settings for Circuit Breaker BK2 are similar unless otherwise noted.

Table 6.44 Settings for Circuit Breaker Failure Example 2 (Sheet 1 of 2)

Setting	Prompt	Entry
Relay Configuration (Group)		
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	2
EBFL2	Breaker 2 Failure Logic (N, 1, 2, Y1, Y2)	2

Table 6.44 Settings for Circuit Breaker Failure Example 2 (Sheet 2 of 2)

Setting	Prompt	Entry
Breaker 1 Failure Logic (Group)		
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary)	2.10
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	10.000
SPBFU1	SPT Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	5.000
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000
RT3PPU1	Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000
BFI3P1	Three-Pole Breaker Failure Initiate—BK1	NA
BFIAI	A-Phase Breaker Failure Initiate—BK1(SELOGIC Equation)	BFIAT1 OR TPA1
BFIB1	B-Phase Breaker Failure Initiate—BK1(SELOGIC Equation)	BFIBT1 OR TPB1
BFIC1	C-Phase Breaker Failure Initiate—BK1(SELOGIC Equation)	BFICT1 OR TPC1
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	3.000
BFISP1	Breaker Fail Initiate Seal-In Delay—BK1 (0.000–1000 cycles)	4.000
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	N
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	FBF1
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	IN104
Control Outputs		
OUT101		TPA1
OUT102		TPB1
OUT103		TPC1
OUT107		BFTRIP1
OUT201		TPA2
OUT202		TPB2
OUT203		TPC2
OUT204		RTA1
OUT205		RTB1
OUT206		RTC1
OUT207		RTA2
OUT208		RTB2
OUT209		RTC2

230 kV Tapped Transmission Line Application Example

This example shows you how to automate the complete restoration sequence, including autoreclose and synchronism check, **for the tapped 230/115 kV autotransformer located at Substation T.** *Figure 6.50* shows a one-line diagram of the tapped 230 kV overhead transmission line.

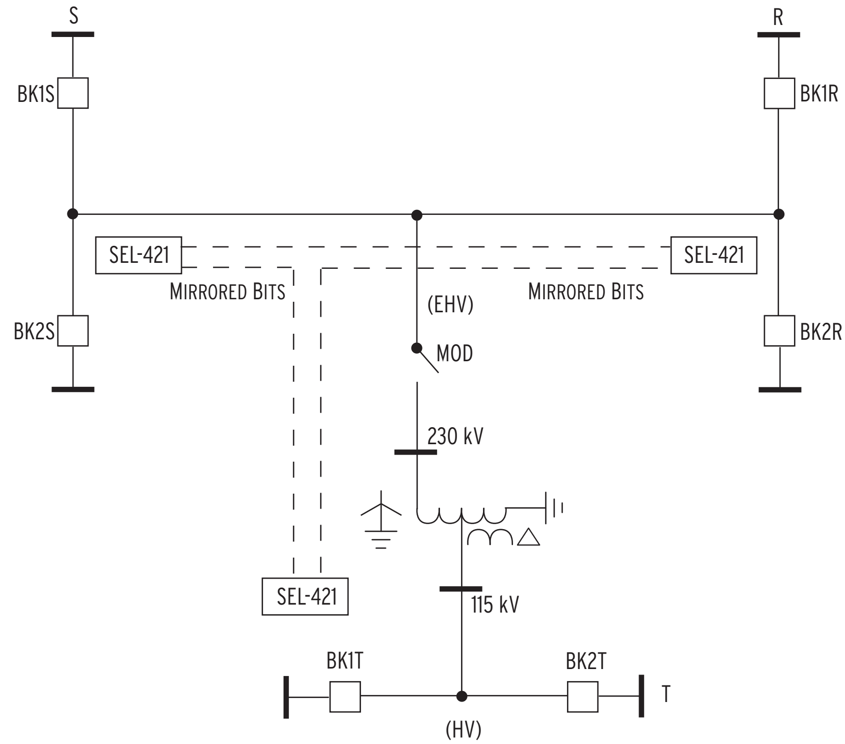


Figure 6.50 230 kV Tapped Overhead Transmission Line

The tapped autotransformer at Substation T has a high-side MOD (motor-operated disconnect) and two low-side circuit breakers. Whenever an internal fault occurs on the 230 kV overhead transmission line, the SEL-421 Relays at each of the three terminals open all of the circuit breakers, followed by the high-side MOD at Substation T. The SEL-421 Relays replace separate line relays, discrete reclosing and synchronism check relays, timers, latching relays, and extensive wiring for this particular example.

Use the SEL-421 protection freeform SELOGIC control equations in *Table 6.48* to automate the following actions at Substation T:

- ➤ Restore tapped Substation T to service after a successful 230 kV overhead transmission line autoreclose operation.
- ➤ Restore the 230 kV overhead transmission line to service after an autotransformer failure or a low-side circuit breaker failure operation.
- ➤ Restore Substation T station service and 115 kV bus continuity after an unsuccessful automatic line reclose operation or a remote 230 kV circuit breaker failure trip.

Philosophy

System Protection Philosophy

SEL-421 Relays located at each of the three 230 kV terminals protect the tapped 230 kV transmission line; the relays operate in the DCB (directional comparison blocking) trip scheme. Zone 1 distance protection also operates in the DUTT (direct underreaching transfer trip) scheme. When the high-side MOD is closed, the SEL-421 at Substation T direct transfer trips the other two terminals if a 115 kV circuit breaker fails to operate or an autotransformer failure occurs; the SEL-421 at Substation T also receives direct transfer trip commands from Substation S and Substation R.

Autoreclose Philosophy

Refer to *Table 6.46* for a timing diagram of the complete autoreclose cycle.

Use the SEL-421 to provide autoreclose at Substation T as follows.

Circuit Breaker BK1T

- ➤ If the high-side MOD is closed and the synchronism check across Circuit Breaker BK1T with respect to the 230 kV potential is successful for at least four seconds, the SEL-421 recloses Circuit Breaker BK1T in five seconds total.
- ➤ If the high-side MOD is open and the 115 kV system has been energized for at least four seconds, the relay recloses Circuit Breaker BK1T in five seconds total.

Circuit Breaker BK2T

- ➤ If Circuit Breaker BK1T recloses and the synchronism check is successful across Circuit Breaker BK2T with respect to the 230 kV potential for at least four seconds, the SEL-421 recloses Circuit Breaker BK2T in five seconds total.
- ➤ If the high-side MOD is open, Circuit Breaker BK1T recloses, and the 115 kV system has been energized for at least four seconds, the relay recloses Circuit Breaker BK2T in five seconds total.

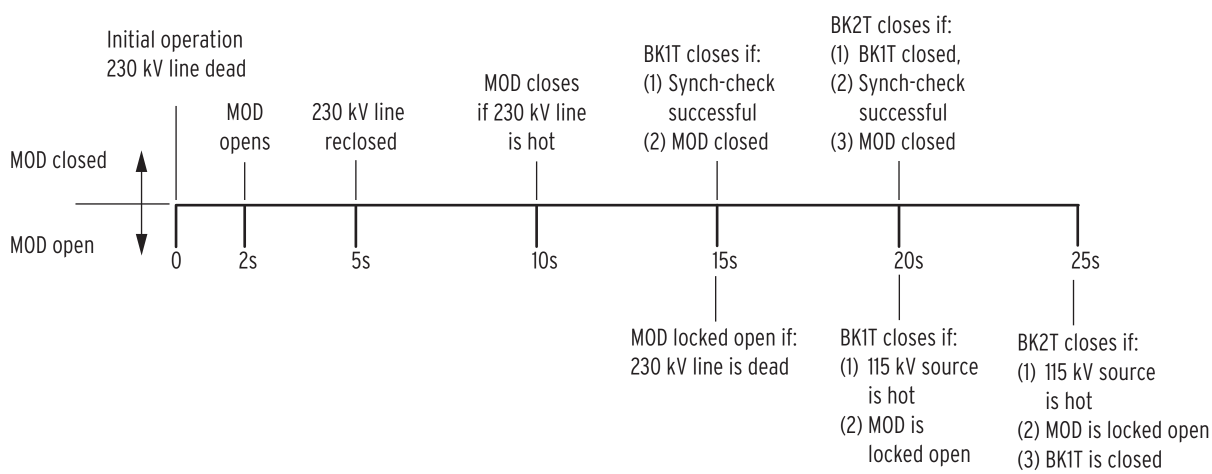


Figure 6.51 Automatic Restoration Timing Diagram

Automatic Restoration Philosophy

Refer to *Figure 6.51* for a timing diagram of the complete automatic restoration cycle. The SEL-421 at Substation T automatically restores service in response to the following system conditions:

- ➤ Low-side circuit breaker or autotransformer failure at Substation T
- ➤ Successful 230 kV line reclose
- ➤ Permanent 230 kV line fault or circuit breaker failure at Substation S or Substation R

Transmission Line Faults or Circuit Breaker/Autotransformer Failure

The SEL-421 at Substation T responds to a 230 kV transmission line fault, low-side circuit breaker failure or autotransformer failure at the local substation, and any circuit breaker failure at Substations S and R. For these situations, the relay does the following:

- ➤ Sends a pulsed open command to the high-side MOD. The 230 kV transmission line must be dead for two seconds, and the relay must have successfully opened the 115 kV circuit breakers.
- ➤ Disables DTT (direct transfer trip) via MIRRORED BITS communications (issued at Substation T) when the high-side MOD is open
- ➤ Inhibits reception of any DTT via MIRRORED BITS communications from any of the two remote 230 kV terminals when the high-side MOD is open

Low-Side Circuit Breaker or Autotransformer Failure

The following actions occur if a low-side circuit breaker or autotransformer failure occurs at Substation T:

- ➤ Substation S and R reclose five seconds later.
- ➤ Lockout relays at Substation T locks out the high-side MOD and low-side circuit breakers. The relay uses an external lockout relay (86 a and 86 b contacts in the breaker trip and close circuits, and an 86 b contact in the MOD close circuit); Substation T remains locked out pending further action from operations or field personnel.

Successful 230 kV Line Reclose

The SEL-421 at Substation T issues the following actions if the 230 kV transmission line autoreclose is successful at Substation S and Substation R:

- ➤ Sends a pulsed close command to the high-side MOD at Substation T to energize the autotransformer if the relay measures balanced nominal voltage from the high-side PTs for five seconds and the low-side circuit breakers are open; the tertiary windings of the autotransformer restore station service.
- ➤ Recloses Circuit Breaker BK1T five seconds after the high-side MOD closes, if the voltage is nominal and synchronized.
- ➤ Recloses Circuit Breaker BK2T five seconds later if the voltage is still nominal and synchronized.

Thus, the local SEL-421 restores the 115 kV system at Substation T.

Permanent 230 kV Line Fault Or Circuit Breaker Failure

If a permanent 230 kV line fault or circuit breaker failure operation occurs at Substation S or Substation R, the SEL-421 at Substation T executes the following actions:

- ➤ Locks open the high-side MOD if there is no voltage on the 230 kV side for 13 seconds. (You can implement this logically via a timer and latch bit combination.) The latch resets if the 230 kV system is hot for 60 seconds and both low-side circuit breakers (BK1T and BK2T) are open.
- ➤ Recloses Circuit Breaker BK1T after five seconds if there is nominal voltage on the 115 kV side and the high-side MOD is locked open.
- ➤ Recloses Circuit Breaker BK2T five seconds later if there is nominal voltage on the 115 kV side, the high-side MOD is locked open, and Circuit Breaker BK1T reclosed successfully.

These actions restore station service and low-side continuity at Substation T. Substation T operates in this configuration until operations or field personnel take further action.

SEL-421 Configuration

In this example, the SEL-421 at Substation T measures a single set of three-phase potentials (input VY) and a single set of three-phase currents (input IW) on the 230 kV side of the autotransformer. The relay uses single-phase potential inputs VAZ and VBZ to provide synchronism check across the low-side circuit breakers. *Figure 6.52* shows the connection diagram.

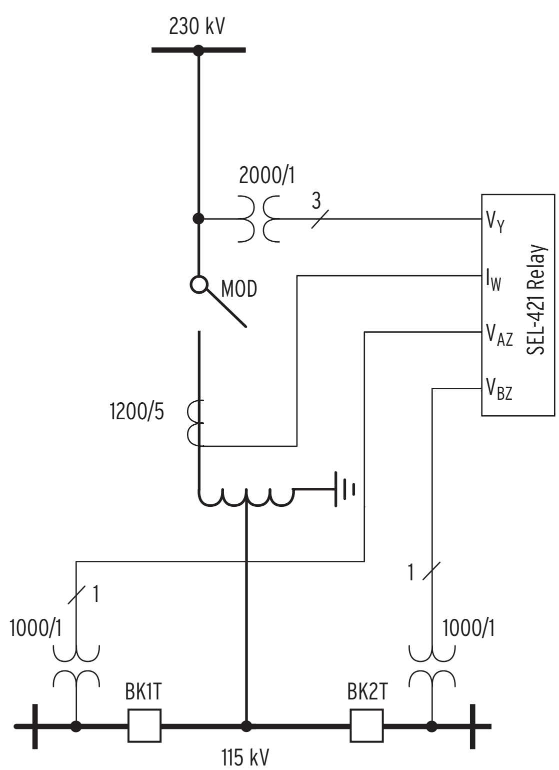


Figure 6.52 SEL-421 Inputs

SEL-421 Settings at Substation T

The settings in *Table 6.45* through *Table 6.50* provide 230 kV transmission line protection, autoreclose, and substation restoration at Substation T as described in this application example.

Protection freeform SELOGIC control equations appear in tabular form (see *Figure 6.48*). These equations, which are the freeform settings extracted from a SEL-421, are also shown in *Figure 6.53*.

Global Settings

Table 6.45 Global Settings[a]

Setting	Prompt	Entry
General Global Settings		
SID	Station Identifier	Station T
RID	Relay Identifier	SEL-421
NUMBK	Number of Breakers in Scheme	2
BID1	Breaker 1 Identifier	Circuit Breaker 1–115 kV
BID2	Breaker 2 Identifier	Circuit Breaker 2–115 kV
NFREQ	Nominal System Frequency (Hz)	60
PHROT	System Phase Rotation	ABC
Current and Voltage Source Selection		
ESS	Current and Voltage Source Selection	Y
LINEI	Line Current Source	IW
BK1I	Breaker 1 Current Source	NA
BK2I	Breaker 2 Current Source	NA

[a] This table shows only the global settings relevant to this particular application example.

Breaker Monitor

Table 6.46 Breaker Monitor Settings[a]

Setting	Prompt	Entry
Breaker Configuration		
BK1TYP	Breaker 1 Trip Type (Single-Pole = 1, Three-Pole = 3)	3
BK2TYP	Breaker 2 Trip Type (Single-Pole = 1, Three-Pole = 3)	3
Breaker 1 Inputs		
52AA1	N/O Contact Input—BK1 (SELOGIC)	NOT IN101
Breaker 2 Inputs		
52AA2	N/O Contact Input—BK2 (SELOGIC)	NOT IN102

[a] This table shows only the breaker monitor settings relevant to this particular application example.

Group Settings

Table 6.47 Group Settings (Sheet 1 of 2)

Setting	Prompt	Entry
Line Configuration		
CTRW	CT Ratio—Input W	240
CTRX	CT Ratio—Input X	240
PTRY	PT Ratio—Input Y	2000.0
VNOMY	PT Nominal Voltage (L-L)—Input Y	115
PTRZ	PT Ratio—Input Z	1000.0
VNOMZ	PT Nominal Voltage (L-L)—Input Z	115
DCB Trip Scheme[a]		
BT	Block Trip	RMB1A OR RMB1B
Synchronism-Check Element Reference (Group)		
SYNCP	Synch Reference	VAY
25VL	Voltage Window Low Threshold (volts)	60.0
25VH	Voltage Window High Threshold (volts)	70.0
Breaker 1 Synchronism Check (Group)		
SYNCS1	Synch Source 1	VAZ
KS1M	Synch Source 1 Ratio Factor	1.00
KS1A	Synch Source 1 Angle Shift (degrees)	0.00
25SFBK1	Maximum Slip Frequency—BK1	OFF
ANG1BK1	Maximum Angle Difference 1—BK1(degrees)	20.00
ANG2BK1	Maximum Angle Difference 2—BK1 (degrees)	20.00
BSYNBK1	Block Synchronism Check—BK1 (SELOGIC)	NA
Breaker 2 Synchronism Check (Group)		
SYNCS2	Synch Source 2	VBZ
KS2M	Synch Source 2 Ratio Factor	1.00
KS2A	Synch Source 2 Angle Shift (degrees)	0.00
ALTS2	Alternative Synch Source 2 (SELOGIC)	NA
25SFBK2	Maximum Slip Frequency—BK2	OFF
ANG1BK2	Maximum Angle Difference 1—BK2 (degrees)	20.00
ANG2BK2	Maximum Angle Difference 2—BK2 (degrees)	20.00
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC)	NA
Recloser and Manual Closing		
NSPSHOT	Number of Single-Pole Reclosures	N
N3PSHOT	Number of Three-Pole Reclosures	1
E3PRI1	Three-Pole Reclose Enable—BK1 (SELOGIC)	1
E3PRI2	Three-Pole Reclose Enable—BK2 (SELOGIC)	NOT LEADBK2
TBBKD	Time Between Breakers for ARC (cycles)	300
BKCFD	Breaker Close Failure Delay (cycles)	300
SLBK1	Leader = Circuit Breaker 1 (SELOGIC)	1
SLBK2	Leader = Circuit Breaker 2 (SELOGIC)	0

Table 6.47 Group Settings (Sheet 2 of 2)

Setting	Prompt	Entry
FBKCEN	Follower Breaker Closing Enable (SELOGIC)	52AA1
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC)	52AA1
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC)	52AA2
79DTL	Recloser Drive to Lockout (SELOGIC)	NA
79BRCT	Block Reclaim Timer (SELOGIC)	NA
BK1CLSD	BK1 Reclose Supervision Delay (cycles)	1200
BK2CLSD	BK2 Reclose Supervision Delay (cycles)	1200
Three-Pole Reclose Settings (Group)		
3POID1	Three-Pole Open Interval 1 Delay (cycles)	300
3PFARC	Three-Pole Fast ARC Enable (SELOGIC)	NA
3PRCD	Three-Pole Reclaim Time Delay (cycles)	1200
3PRI	Three-Pole Reclose Initiation (SELOGIC)	Z1P OR Z1G OR RXPRM
79SKP	Skip Reclosing Shot (SELOGIC)	NA
3P1CLS	Three-Pole BK1 Reclose Supervision (SELOGIC)	PCT01Q
3P2CLS	Three-Pole BK2 Reclose Supervision (SELOGIC)	PCT02Q
Trip Logic[a]		
TR	Zone 1 direct transfer trip	RMB2A OR RMB2B OR
	Step-distance or time-overcurrent protection	Z1T OR Z2T OR 51S1T OR
	Direct transfer trip if MOD closed	(RMB3A OR RMB3B) AND NOT IN103…

[a] This portion of the table shows all of the receive MIRRORED BITS (RMB*n*) communications assignments.

Protection Freeform SELOGIC Control Equations

Table 6.48 Protection Freeform SELOGIC Control Equations (Sheet 1 of 2)

Setting	Description	Entry	Comments
PSV01	Protection Comparison 1	PSV01 := V1M >= 119.500	Logical 1 if V1 greater than or equal to 90% nominal voltage
PSV02	Protection Comparison 2	PSV02 := V1M < 26.500	Logical 1 if V1 is less than 20% nominal voltage
PLT01S	Protection Latch 1 set	PLT01S := R_TRIG PST02Q AND NOT PLT01	MOD latch set
PLT01R	Protection Latch 1 reset	PLT01R := R_TRIG PST03Q AND PLT01	MOD latch reset
PST01PT	Protection Sequence Timer 1 preset	PST01PT := 150.00	Pulse open the MOD if:
PST01R	Protection Sequence Timer 1 reset	PST01R := NOT PSV02 OR NOT IN101 OR NOT IN102 OR PST01Q OR IN103	230 kV bus is not dead OR BK1T OR BK2T is closed OR PST01 output equals logical 1 OR MOD is open
PST01IN	Protection Sequence Timer 1 enable	PSTO1IN := PSV02 AND IN101 AND IN102 AND NOT IN103	230 kV bus is dead AND BK1T AND BK2T are open AND MOD is closed
OUT103[a]	Output 103	PST01ET > 120.00 AND NOT PCN01Q	MOD open command
PST02PT	Protection Sequence Timer 2 preset	PST02PT := 780.00	MOD latch is set if:

Table 6.48 Protection Freeform SELogic Control Equations (Sheet 2 of 2)

Setting	Description	Entry	Comments
PST02R	Protection Sequence Timer 2 reset	PST02R := PLT01	
PST02IN	Protection Sequence Timer 2 enable	PST02IN := PSV02 AND IN103	230 kV bus is dead AND MOD is open
PST03PT	Protection Sequence Timer 3 preset	PST03PT := 3600.00	MOD latch reset if:
PST03R	Protection Sequence Timer 3 reset	PST03R := NOT PLT01	
PST03IN	Protection Sequence Timer 3 enable	PST03IN := PSV01 AND IN101 AND IN102	230 kV bus is hot AND BK1T AND BK2T are open for 60 s
PST04PT	Protection Sequence Timer 4 preset	PST04PT := 330.00	Pulse close the MOD if:
PST04R	Protection Sequence Timer 4 reset	PST04R := NOT PSV01 OR NOT IN101 OR NOT IN102 OR NOT IN103 OR PLT01 OR PST04Q	230 kV bus is not hot OR BK1T OR BK2T is closed OR MOD is closed OR PST04 output equals logical 1
PST04IN	Protection Sequence Timer 4 enable	PST04IN := PSV01 AND IN101 AND IN102 AND IN103 AND NOT PLT01	230 kV bus is hot AND BK1T AND BK2T are open AND MOD is open AND MOD latch reset
OUT106*	Output 106 AND NOT PCN02Q	PST04ET > 300.00 AND NOT PCN02Q	MOD close command
PCN01PV	Protection Counter 1 preset	PCN01PV := 2	MOD block trip if:
PCN01R	Protection Counter 1 reset	PCN01R := IN103	
PCN01IN	Protection Counter 1 enable	PCN01IN := OUT103	Two trips without MOD open
PCN02PV	Protection Counter 2 preset	PCN02PV := 2	MOD block close if:
PCN02R	Protection Counter 2 reset	PCN02R := NOT IN103	
PCN02IN	Protection Counter 2 enable	PCN02IN := OUT106	Two closes without MOD closed
PCT01PU	Protection Conditioning Timer 1 Pickup	240.00	
PCT01DO	Protection Conditioning Timer 1 Dropout	0.00	
PCT01IN	Protection Conditioning Timer 1 Enable	NOT IN103 AND 25A1BK1 OR PLT01 AND IN103 AND 59VS1	MOD is closed AND synchronized OR MOD latch set AND MOD is open AND BK1T bus is hot for 4 s
PCT02PU	Protection Conditioning Timer 2 Pickup	240.00	
PCT02DO	Protection Conditioning Timer 2 Dropout	0.00	
PCT02IN	Protection Conditioning Timer 2 Enable	NOT IN103 AND 25A1BK2 AND NOT IN101 OR PLT01 AND IN103 AND 59VS2 AND NOT IN101	MOD is closed AND synchronized AND BK1T is closed OR MOD latch set AND MOD is open AND BK2T bus is hot AND BK11T is closed for 4 s

[a] This control output assignment is not a protection freeform SELogic control equation, but appears in this table for continuity of the overall logic.

```
=>> SHO L <Enter>

Protection 1

Free-Form Protection SELogic
1:  ###  PROTECTION FREE-FORM AUTOMATION EXAMPLE
2:  ###
3:  ###  SET CONTROL VARIABLE 1
4:  ###  ASSERTS WHEN PRIMARY POSITIVE SEQUENCE VOLTAGE IS
5:  ###  GREATER THAN 90% OF NOMINAL
```

Figure 6.53 Protection Free-Form SELogic Control Equations

```
PSV01 := V1M >= 119.500 # 90% OF 230 KV DIVIDED BY SQRT 3
###
###  SET CONTROL VARIABLE 2
###  ASSERTS WHEN PRIMARY POSITIVE SEQUENCE VOLTAGE IS
###  LESS THAN 20% OF NOMINAL
PSV02 := V1M < 26.500 # 20% OF 230 KV DIVIDED BY SQRT 3
###
###  SET LATCH 1
PLT01S := R_TRIG PST02Q AND NOT PLT01 # SET LATCH WITH TIMER 2 OUTPUT
PLT01R := R_TRIG PST03Q AND PLT01 # RESET LATCH WITH TIMER 3 OUTPUT
###
###  SET SEQUENCING TIMER 1
###  TIMES IF PSV02 IS ASSERTED, BREAKER 1 AND 2 ARE OPEN, AND
###  THE MOD IS CLOSED. RESETS IF PSV02 IS NOT ASSERTED, OR BREAKER
###  1 OR 2 IS CLOSED, OR MOD IS OPEN, OR TIMER 1 OUTPUT ASSERTED
PST01PT := 150.00 # TIMER 1 PICKUP 150 CYCLES
PST01R := NOT PSV02 OR NOT IN101 OR NOT IN102 OR IN103 OR PST01Q
PST01IN := PSV02 AND IN101 AND IN102 AND NOT IN103
###
###  SET SEQUENCING TIMER 2
###  TIMES IF PSV02 IS ASSERTED AND THE MOD IS OPEN. RESETS IF
###  LATCH 1 IS SET
PST02PT := 780.00 # TIMER 2 PICKUP 780 CYCLES
PST02R := PLT01
PST02IN := PSV02 AND IN103
###
###  SET SEQUENCING TIMER 3
###  TIMES IF PSV01 IS ASSERTED AND BREAKER 1 AND 2 ARE OPEN
###  RESETS WHEN LATCH 1 IS RESET
PST03PT := 3600.00 # TIMER 3 PICKPUP 3600 CYCLES
PST03R := NOT PLT01
PST03IN := PSV01 AND IN101 AND IN102
###
###  SET SEQUENCING TIMER 4
###  TIMES IF PSV01 IS ASSERTED AND BREAKER 1 AND 2 ARE OPEN
###  THE MOD IS OPEN, AND LATCH 1 IS NOT SET. RESET IF PSV01 NOT
###  ASSERTED, OR BREAKER 1 OR 2 NOT OPEN, OR MOD NOT OPEN
###  OR LATCH 1 SET, OR TIMER 4 OUTPUT ASSERTED
PST04PT := 330.00 # TIMER 4 PICKUP 330 CYCLES
PST04R := NOT PSV01 OR NOT IN101 OR NOT IN102 OR NOT IN103 OR PLT01 OR \
PST04Q
PST04IN := PSV01 AND IN101 AND IN102 AND NOT PLT01 AND IN103
###
###  SET COUNTER 1
###  MOD TRIP ANTI-PUMP, TWO TRIPS WITHOUT AN OPEN LOCKS OUT TRIP
PCN01PV := 2.00 # A TWO COUNT COUNTER
PCN01R := IN103 # AN OPEN MOD RESETS COUNTER
PCN01IN := OUT103 # COUNTS ON THE RISING EDGE OF AN MOD TRIP
###
###  SET COUNTER 2
###  MOD CLOSE ANTI-PUMP, TWO CLOSES WITHOUT A CLOSE LOCKS OUT CLOSE
PCN02PV := 2.00 # A TWO COUNT COUNTER
PCN02R := NOT IN103 # A CLOSED MOD RESETS THE COUNTER
PCN02IN := OUT106 # COUNTS ON THE RISING EDGE OF AN MOD CLOSE
```

Figure 6.53 Protection Free-Form SELOGIC Control Equations (Continued)

```
59: ###
60: ###  SET CONDITIONING TIMER 1
61: ###  SUPERVISES BK1 RECLOSING, ASSERTS IF MOD IS CLOSED AND IN SYNC. OR
62: ###  MOD LATCH SET AND MOD OPEN AND BK1 BUS HOT FOR FOUR SECONDS
63: PCT01PU := 240.00 # FOUR SECOND PICKUP TIME
64: PCT01DO := 0.0 # NO DELAY ON DROPOUT
65: PCT01IN := NOT IN103 AND 25A1BK1 OR PLT01 AND IN103 AND 59VS1
66: ###
67: ###  SET CONDITIONING TIMER 2
68: ###  SUPERVISES BK2 RECLOSING, ASSERTS IF MOD IS CLOSED AND IN SYNC. AND BK1
69: ###  CLOSED OR MOD LATCH SET AND MOD OPEN AND BK2 BUS HOT AND BK1 CLOSED
70: ###  FOR FOUR SECONDS
71: PCT02PU := 240.00 # FOUR SECOND PICKUP TIME
72: PCT02DO := 0.0 # NO DELAY ON DROPOUT
73: PCT02IN := NOT IN103 AND 25A1BK2 AND NOT IN101 OR PLT01 AND IN103 AND \
              59VS2 AND NOT IN101
```

Figure 6.53 Protection Free-Form SELogic Control Equations (Continued)

Control Inputs

Connect the relay control inputs as specified in *Table 6.49*. This table shows the substation equipment that each control input monitors.

Table 6.49 Control Inputs

Input	Monitor Condition
IN101	115 kV BK1T 52 b contact
IN102	115 kV BK2T 52 b contact
IN103	230 kV MOD b contact
IN104	Circuit breaker and autotransformer failure lockouts (86)

Control Outputs

Table 6.50 Control Outputs (SELogic Control Equations) (Sheet 1 of 2)

Setting	Function	Entry
Main Board		
OUT101	Trip BK1T	TRIP
OUT102	Trip BK2T	TRIP
OUT103	Trip MOD	PST01ET > 120.00 AND NOT PCN01Q
OUT104	Close BK1T	BK1CL
OUT105	Close BK2T	BK2CL
OUT106	Close MOD	PST04ET > 300.00 AND NOT PCN02Q
OUT107	General alarm	NOT HALARM OR NOT SALARM OR NOT ILOP
Mirrored Bits Transmit Equations (SELogic Control Equations)		
TMB1A	Blocking signal	Z3P OR Z3G OR DSTRT
TMB2A	Zone 1 direct underreaching transfer trip	Z1P OR Z1G
TMB3A	Direct transfer trip: 86BF or 86T and MOD closed	NOT IN103 AND IN104

Table 6.50 Control Outputs (SELOGIC Control Equations) (Sheet 2 of 2)

Setting	Function	Entry
TMB1B	Blocking signal	Z3P OR Z3G OR DSTRT
TMB2B	Zone 1 direct underreaching transfer trip	Z1P OR Z1G
TMB3B	Direct transfer trip: 86BF or 86T and MOD closed	NOT IN103 AND IN104

Figure 6.54 is a logical representation of the freeform protection SELOGIC control equations.

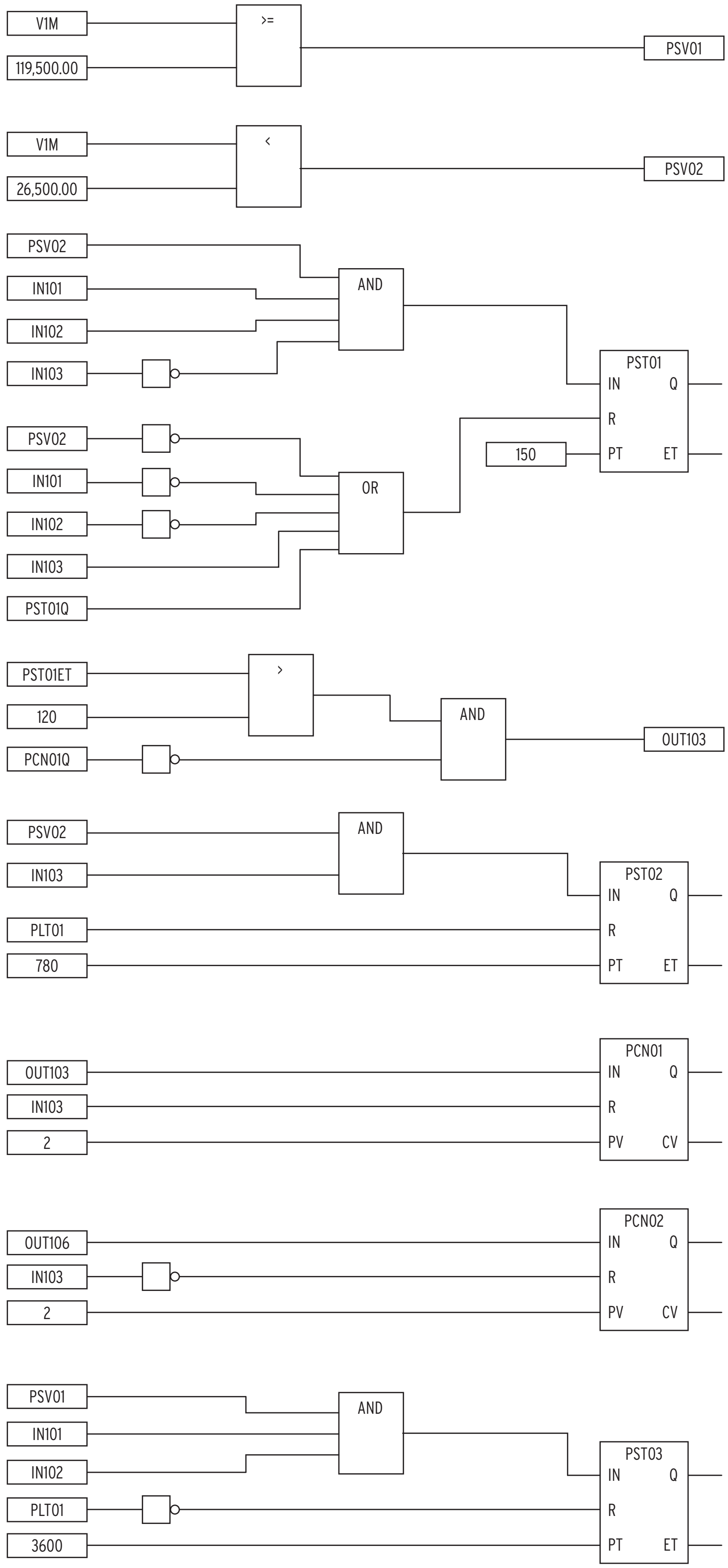


Figure 6.54 Protection Freeform SELogic Control Equations

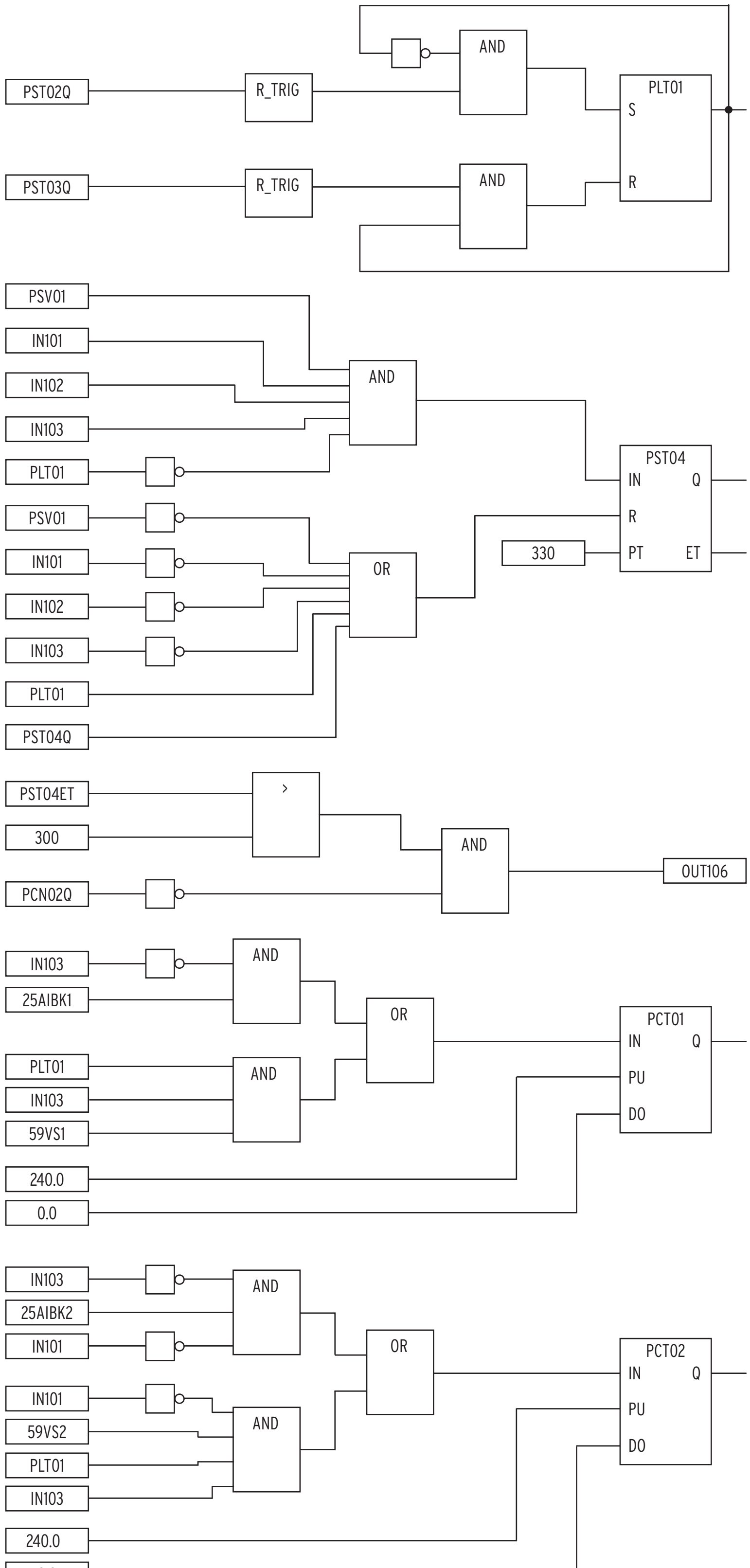


Figure 6.54 Protection Freeform SELogic Control Equations (Continued)

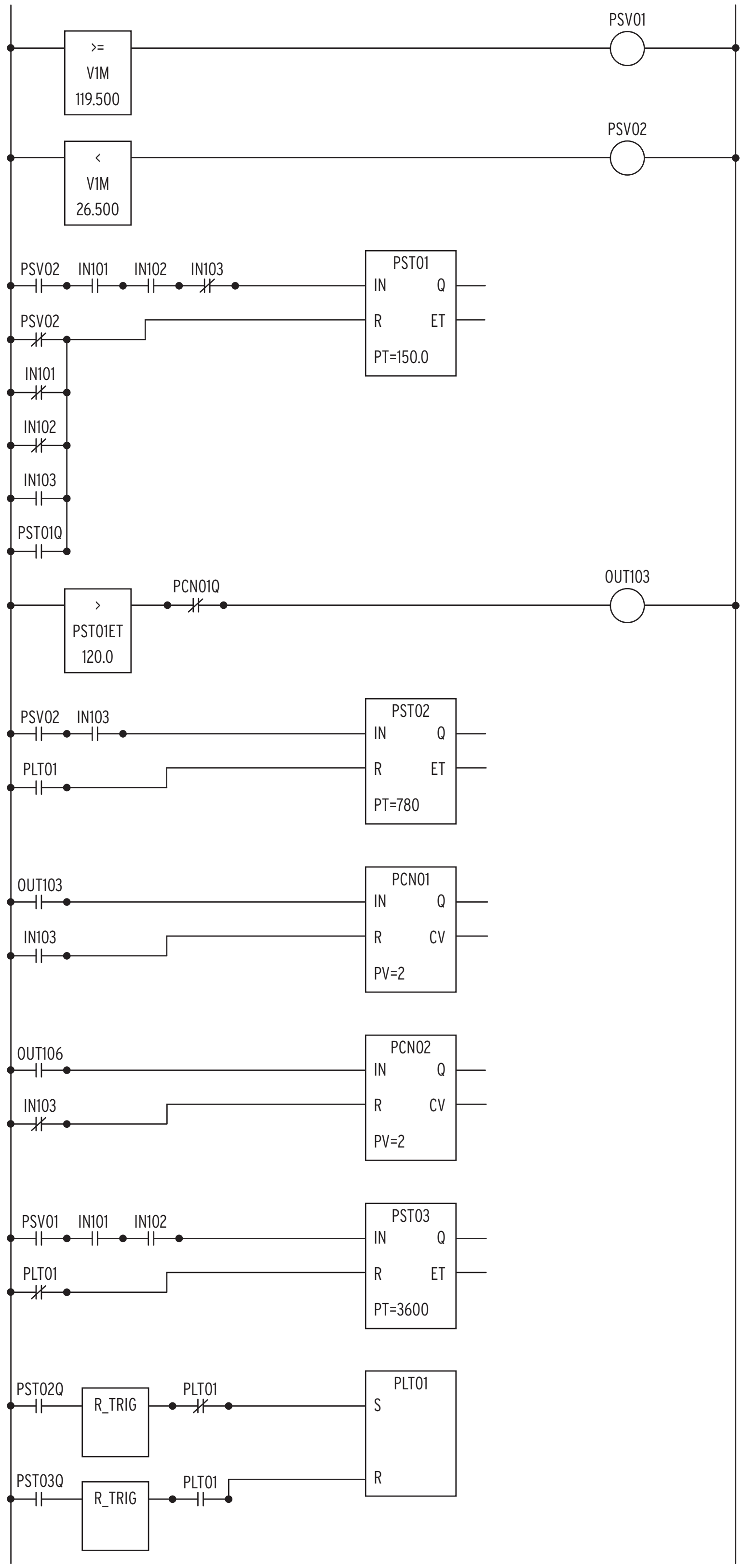


Figure 6.55 Ladder Logic Representation, Protection Freeform SELOGIC Control Equations

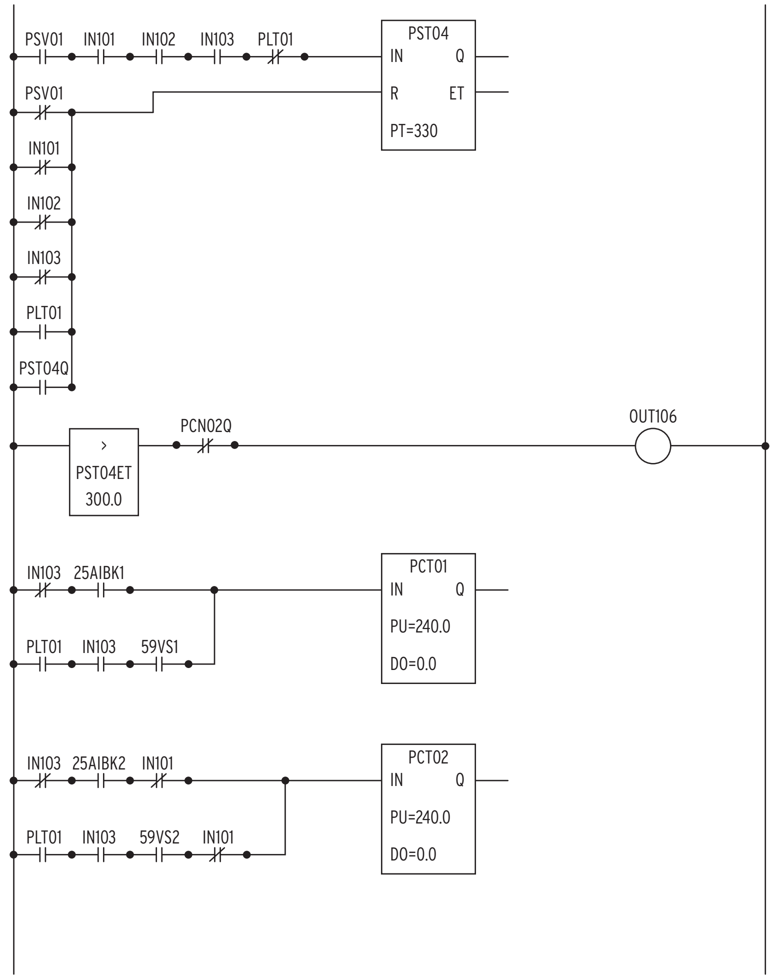


Figure 6.55 Ladder Logic Representation, Protection Freeform SELogic Control Equations (Continued)

S E C T I O N 7

Metering, Monitoring, and Reporting

The SEL-421 Relay provides extensive capabilities for monitoring substation components, metering important power system parameters, and reporting on power system performance. The relay provides the following useful features:

- ➤ *Metering on page 7.1*
- ➤ *Circuit Breaker Monitor on page 7.7*
- ➤ *Station DC Battery System Monitor on page 7.7*
- ➤ *Reporting on page 7.7*

See *Section 7: Metering, Section 8: Monitoring*, and *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual* for general information. This section contains details specific to the SEL-421.

Metering

The SEL-421 provides five metering modes for measuring power system operations:

- ➤ *Instantaneous Metering on page 7.2*
- ➤ *Maximum/Minimum Metering on page 7.5*
- ➤ *Demand Metering on page 7.6*
- ➤ *Energy Metering on page 7.6*
- ➤ *Synchrophasor Metering on page 7.7*

Monitor present power system operating conditions with instantaneous metering. Maximum/Minimum metering displays the largest and smallest system deviations since the last reset. Demand metering includes either thermal or rolling analyses of the power system and peak demand metering. Energy metering displays the megawatt-hours imported, megawatt-hours exported, and total megawatt-hours. Time-synchronized metering displays the line voltage and current synchrophasors.

The SEL-421 processes three sets of current quantities: LINE, BK1, and BK2 (when configured for two circuit breakers). In one configuration using two circuit breakers, Terminal W is usually connected as BK1, and Terminal X is generally connected as BK2. The line voltage from Terminal Y (VϕY) provides the voltage quantities for LINE. See *Current and Voltage Source Selection on page 5.2* for more information on configuring the SEL-421 inputs.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns the fundamental frequency measurement quantities listed in *Table 7.2*. The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1 to 32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions. With other command options, you can view currents from either circuit breaker. For example, you can monitor the fundamental currents on Circuit

Breaker 1 or Circuit Breaker 2 by entering **MET BK1** or **MET BK2**, respectively. Additionally, the **MET PM** command provides time-synchronized phasor measurements at a specific time, e.g., **MET PM 12:00:00**.

Table 7.1 lists **MET** command variants for instantaneous, maximum/minimum, demand, and energy metering. See *METER on page 14.37 in the SEL-400 Series Relays Instruction Manual* and *METER on page 9.4* in this manual for more information on these and other **MET** command options. Other **MET** command options are for viewing protection and automation variables, analog values from MIRRORED BITS communications, and synchronism check.

Table 7.1 MET Command

Name[a]	Description
MET	Display Fundamental Line metering information
MET BK*n*	Display Fundamental Circuit Breaker *n* metering information
MET RMS	Display rms Line metering information
MET BK*n* RMS	Display rms Circuit Breaker *n* metering information
MET M	Display Line Maximum/Minimum metering information
MET BK*n* M	Display Circuit Breaker *n* Maximum/Minimum metering information
MET RM	Reset Line Maximum/Minimum metering information
MET BK*n* RM	Reset Circuit Breaker *n* Maximum/Minimum metering information
MET D	Display Demand Line metering information
MET RD	Reset Demand Line metering information
MET RP	Reset Peak Demand Line metering information
MET E	Display Energy Line metering information
MET RE	Reset Energy Line metering information
MET SYN	Display Synchronism Check voltage and slip angle/frequency information
MET BAT	Display DC Battery Monitor information
MET PM	Display Phasor Measurement (Synchrophasor) metering information

[a] *n* is 1 or 2, representing Circuit Breaker 1 and Circuit Breaker 2, respectively.

Instantaneous Metering

Use instantaneous metering to monitor power system parameters in real time. The SEL-421 provides these fundamental frequency readings:

- Fundamental frequency phase voltages and currents
- Phase-to-phase voltages
- Sequence voltages and currents
- Fundamental real, reactive, and apparent power
- Displacement power factor

You can also monitor these real-time rms quantities (with harmonics included):

- RMS phase voltages and currents
- Real and apparent rms power
- True power factor

Both the fundamental and the rms-metered quantities are available for the LINE input. The relay also provides both the fundamental and rms circuit breaker currents for circuit breakers BK1 and BK2.

Voltages, Currents, Frequency

NOTE: After power up, automatic restart, or a warm start, including settings change and group switch, in the beginning period of 20 cycles, the 10-cycle average values are initialized with the latest calculated 1-cycle average values.

Table 7.2 summarizes the metered voltage, current, and frequency quantities available in the SEL-421. The relay reports all instantaneous voltage magnitudes, current magnitudes, and frequency as absolute value 10-cycle averages (for example, the LINE A-Phase filtered magnitude LIAFM_10c; see *Section 12: Analog Quantities*). Instantaneous metering also reports sequence quantities referenced to A-Phase. The SEL-421 references angle measurements to positive-sequence quantities. The relay reports angle measurements in the range of ±180.00 degrees.

Table 7.2 Instantaneous Metering Quantities—Voltages, Currents, Frequency

Metered Quantity	Symbol	Fundamental	RMS
Phase voltage magnitude	$\lvert V_\phi \rvert$	X	X
Phase voltage angle	$\angle(V_\phi)$	X	
Phase current magnitude	$\lvert I_\phi \rvert$	X	X
Phase current angle	$\angle(I_\phi)$	X	
Phase-to-phase voltage magnitude	$\lvert V_{\phi\phi} \rvert$	X	X
Phase-to-phase voltage angle	$\angle(V_{\phi\phi})$	X	
Positive-sequence voltage magnitude	$\lvert V_1 \rvert$	X	
Positive-sequence voltage angle	$\angle(V_1)$	X	
Negative-sequence voltage magnitude	$\lvert 3V_2 \rvert$	X	
Negative-sequence voltage angle	$\angle(3V_2)$	X	
Zero-sequence voltage magnitude	$\lvert 3V_0 \rvert$	X	
Zero-sequence voltage angle	$\angle(3V_0)$	X	
Positive-sequence current magnitude	$\lvert I_1 \rvert$	X	
Positive-sequence current angle	$\angle(I_1)$	X	
Negative-sequence current magnitude	$\lvert 3I_2 \rvert$	X	
Negative-sequence current angle	$\angle(3I_2)$	X	
Zero-sequence current magnitude	$\lvert 3I_0 \rvert$	X	
Zero-sequence current angle	$\angle(3I_0)$	X	
Battery voltages	Vdc	X	
Frequency	f	X	X
Circuit breaker current magnitudes	$\lvert I_\phi \rvert$	X	X
Circuit breaker current angles	$\angle(I_\phi)$	X	

Power

Table 7.3 shows the power quantities that the relay measures. The instantaneous power measurements are derived from 10-cycle averages that the SEL-421 reports by using the generator condition of the positive power flow convention; for example, real and reactive power flowing out (export) is positive, and real and reactive power flowing in (import) is negative (see *Figure 7.1*).

For power factor, LAG and LEAD refer to whether the current lags or leads the applied voltage. The reactive power Q is positive when the voltage angle is greater than the current angle ($\theta_V > \theta_I$), which is the case for inductive loads where the current *lags* the applied voltage. Conversely, Q is negative when the voltage angle is less than the current angle ($\theta_V < \theta_I$); this is when the current *leads* the voltage, as in the case of capacitive loads.

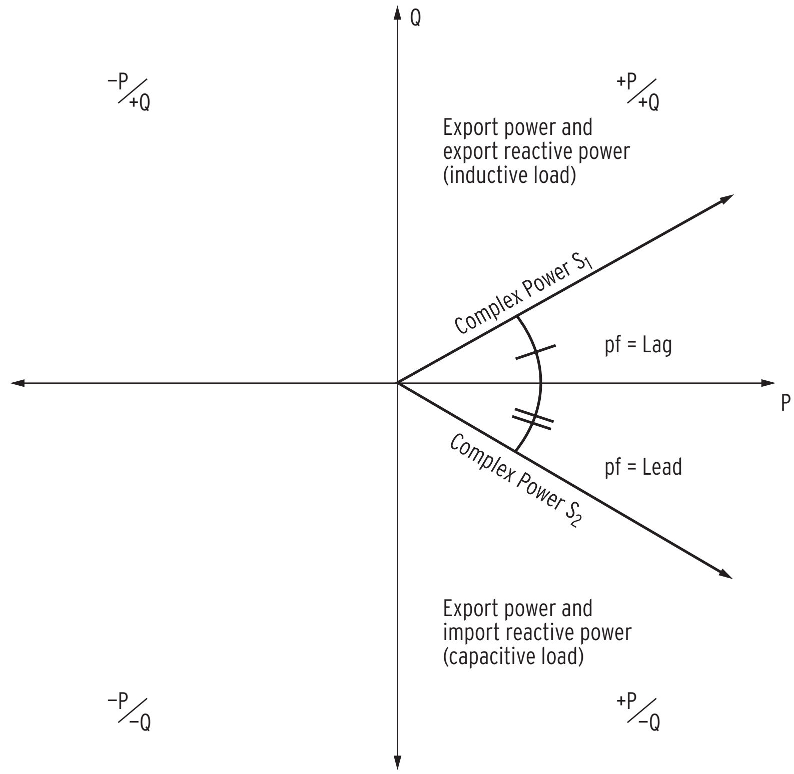


Figure 7.1 Complex Power (P/Q) Plane

The SEL-421 includes Relay Word bits to indicate the leading or lagging power factor (see *Section 11: Relay Word Bits*). In the case of a unity power factor or loss of phase or potential condition, the resulting power factor angle will be on the axis of the complex power (P/Q) plane shown in *Figure 7.1*. This causes the power factor Relay Word bits to rapidly change state (chatter). Be aware of expected system conditions when monitoring the power factor Relay Word bits. SEL does not recommend the use of chattering Relay Word bits in the SER or anything that will trigger an event.

Table 7.3 Instantaneous Metering Quantities—Power (Sheet 1 of 2)

Metered Quantity	Symbol	Fundamental (50 Hz/ 60 Hz Only)	RMS (Harmonics Included)
Per-phase fundamental real power	$P_{\phi 1}$	X	
Per-phase true real power	$P_{\phi rms}$		X
Per-phase reactive power	$Q_{\phi 1}$	X	X
Per-phase fundamental apparent power	$S_{\phi 1}$	X	
Per-phase true apparent power	$U_{\phi rms}$		X
Three-phase fundamental real power	$3P_1$	X	
Three-phase true real power	$3P_{rms}$		X
Three-phase reactive power	$3Q_1$	X	X
Three-phase fundamental apparent power	$3S_1$	X	

Table 7.3 Instantaneous Metering Quantities—Power (Sheet 2 of 2)

Metered Quantity	Symbol	Fundamental (50 Hz/ 60 Hz Only)	RMS (Harmonics Included)
Three-phase true apparent power	$3U_{rms}$		X
Per-phase displacement power factor	$PF_{\phi 1}$	X	
Per-phase true power factor	PF_{ϕ}		X
Three-phase displacement power factor	$3PF_1$	X	
Three-phase true power factor	3PF		X

Relay Word bits PFφ_OK and DPFφ_OK are provided to indicate that the information coming into the relay is sufficient to provide a valid power factor measurement. The per-phase power factor bit, PFφ_OK, is equal to 1 if the measured per-phase rms voltage, $V\varphi_{rms}$, is greater than 10 percent of the nominal voltage setting and the relay does not detect an open-phase condition. Otherwise, PFφ_OK = 0. Similarly, for the per-phase displacement power factor check, DPFφ_OK, is equal to 1 if the magnitude of the per-phase fundamental voltage, VφFM, is greater than 10 percent of the nominal voltage setting and the relay does not detect an open-phase condition. Otherwise, DPFφ_OK = 0.

High-Accuracy Instantaneous Metering

The SEL-421 is a high-accuracy metering instrument. See *Section 7: Metering in the SEL-400 Series Relays Instruction Manual* for details of the accuracy and how to calculate error coefficients.

Maximum/Minimum Metering

See *Maximum/Minimum Metering on page 7.5 in the SEL-400 Series Relays Instruction Manual* for a complete description of using and controlling maximum/minimum metering.

The SEL-421 provides maximum/minimum metering for LINE input rms voltages, rms currents, rms powers, and frequency; it also conveys the maximum/minimum rms currents for circuit breakers BK1 and BK2, as well as both dc battery voltage maximums and minimums. The SEL-421 also records the maximum values of the sequence voltages and sequence currents. *Table 7.4* lists these quantities.

Table 7.4 Maximum/Minimum Metering Quantities—Voltages, Currents, Frequency, and Powers (Sheet 1 of 2)

Metered Quantity	Symbol
RMS phase voltage	$V_{\phi rms}$
RMS phase current	$I_{\phi rms}$
Positive-sequence voltage magnitude[a]	$\lvert V_1 \rvert$
Negative-sequence voltage magnitude[a]	$\lvert 3V_2 \rvert$
Zero-sequence voltage magnitude[a]	$\lvert 3V_0 \rvert$
DC battery voltage	VDC1, VDC2
Positive-sequence current magnitude[a]	$\lvert I_1 \rvert$
Negative-sequence current magnitude[a]	$\lvert 3I_2 \rvert$
Zero-sequence current magnitude[a]	$\lvert 3I_0 \rvert$

Table 7.4 Maximum/Minimum Metering Quantities—Voltages, Currents, Frequency, and Powers (Sheet 2 of 2)

Metered Quantity	Symbol
Frequency	f
Circuit breaker rms current	$I_{\phi rms}$
Three-phase true real power	$3P_{rms}$
Three-phase reactive power	$3Q_1$
Three-phase true apparent power	$3U_{rms}$

[a] Sequence components are maximum values only.

Demand Metering

See *Demand Metering on page 7.6 in the SEL-400 Series Relays Instruction Manual* for a complete description of how demand metering works. The SEL-421 provides demand metering and peak demand metering for the LINE quantities. *Table 7.5* lists the quantities used for demand and peak demand metering.

Table 7.5 Demand and Peak Demand Metering Quantities—LINE

Symbol	Units	Description
$I_{\phi rms}$	A, primary	Input rms current
I_{Grms}[a]	A, primary	Residual ground rms current
$3I_2$	A, primary	Negative-sequence current
P_ϕ	MW, primary	Single-phase real powers (with harmonics)
Q_ϕ	MVAR, primary	Single-phase reactive powers
U_ϕ	MVA, primary	Single-phase total powers (with harmonics)
3P	MW, primary	Three-phase real power (with harmonics)
3Q	MVAR, primary	Three-phase reactive power
3U	MVA, primary	Three-phase total power (with harmonics)

[a] (IG = 3I0 = IA + IB + IC).

Energy Metering

Energy is the power consumed or developed in the electric power system measured over time. See *Energy Metering on page 7.6 in the SEL-400 Series Relays Instruction Manual* for complete details of energy metering computation, viewing, and control. Energy metering is available only for the LINE data. *Table 7.6* lists the energy metering quantities that the relay displays.

Table 7.6 Energy Metering Quantities—(LINE)

Analog Quantity	Units	Description
MWHϕOUT	MWh, primary	Single-phase energy export
MWHϕIN	MWh, primary	Single-phase energy import
MWHϕT	MWh, primary	Single-phase energy total
3MWHOUT	MWh, primary	Three-phase energy export
3MWHIN	MWh, primary	Three-phase energy import
3MWH3T	MWh, primary	Three-phase energy total

Synchrophasor Metering

The SEL-421 provides synchrophasor measurement with an angle reference according to IEEE C37.118. See *Section 7: Metering in the SEL-400 Series Relays Instruction Manual* for details of synchrophasor metering.

Circuit Breaker Monitor

The SEL-421 features advanced circuit breaker monitoring. The general features of the circuit breaker monitor are described in *Circuit Breaker Monitor on page 8.1 in the SEL-400 Series Relays Instruction Manual*. The SEL-421 supports monitoring of two breakers, designated 1 and 2.

Station DC Battery System Monitor

The SEL-421 automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. The relay provides two dc monitor channels, Vdc1 and Vdc2. See *Station DC Battery System Monitor on page 7.7 in the SEL-400 Series Relays Instruction Manual* for a complete description of the battery monitor.

Reporting

The SEL-421 features comprehensive power system data analysis capabilities, which are described in *Section 9: Reporting in the SEL-400 Series Relays Instruction Manual*. This section describes reporting characteristics that are unique to the SEL-421.

Duration of Data Captures and Event Reports

The SEL-421 stores high-resolution raw data and filtered data. The number of stored high-resolution raw data captures and event reports is a function of the quantity of data contained in each capture.

Table 7.7 lists the maximum number of data captures/event reports the relay stores in nonvolatile memory when ERDIG = S for various report lengths and sample rates. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

NOTE: Consider the total capture time when choosing a value for setting LER at the SRATE := 8 kHz. At LER := 3.0 the relay records at least 13 data captures when ERDIG = S. These and smaller LER settings are sufficient for most power system disturbances.

The relay stores high-resolution raw and filtered event data in nonvolatile memory. *Table 7.7* lists the storage capability of the SEL-421 for common event reports.

The lower rows of *Table 7.7* show the number of event reports the relay stores at the maximum data capture times for each SRATE sampling rate setting. Table entries are the maximum number of stored events; these can vary by 10 percent according to relay memory usage.

Table 7.7 Event Report Nonvolatile Storage Capability When ERDIG = S

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	161	193	212	248
0.50 seconds	98	123	139	173
1.0 seconds	54	70	82	107
3.0 seconds	19	25	30	41
6.0 seconds	N/A	12	15	21
12.0 seconds	N/A	N/A	7	10
24.0 seconds	N/A	N/A	N/A	4

When the event report digital setting is set to include all Relay Word bits in the event report (ERDIG = A), the maximum number of stored reports is reduced, as shown in *Table 7.8*.

Table 7.8 Event Report Nonvolatile Storage Capability When ERDIG = A

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	125	148	159	180
0.50 seconds	74	89	98	112
1.0 seconds	N/A	49	54	64
3.0 seconds	N/A	N/A	19	23
6.0 seconds	N/A	N/A	N/A	11
12.0 seconds	N/A	N/A	N/A	N/A
24.0 seconds	N/A	N/A	N/A	N/A

Event Reports, Event Summaries, and Event Histories

See *Event Reports, Event Summaries, and Event Histories on page 9.13 in the SEL-400 Series Relays Instruction Manual* for an overview of event reports, event summaries, and event histories. This section describes the characteristics of those that are unique to the SEL-421.

Base Set of Relay Word Bits

The following Relay Word bits are always including in 8 kHz oscillography and compressed event reports: TLED_1, TLED_2, TLED_3, TLED_4, TLED_5, TLED_6, TLED_7, TLED_8, TLED_9, TLED_10, TLED_11, TLED_12, TLED_13, TLED_14, TLED_15, TLED_16, TLED_17, TLED_18, TLED_19, TLED_20, TLED_21, TLED_22, TLED_23, TLED_24, SPOA, SPOB, SPOC, FSA, FSB, FSC, Z1P, Z2P, Z3P, Z4P, Z5P, Z123PFL, 67Q1, 67Q2, 67Q3,67Q4, 51S1, 51S2, 51S3, Z1G, Z2G, Z3G, Z4G, Z5G, Z123GFL, 67G1, 67G2, 67G3, 67G4, RMB*n*A, TMB*n*A, RMB*n*B, TMB*n*B, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TRIP, TP*x*1, TP*x*2, 52*x*CL1, 52*x*CL2, BK1CL, BK2CL (*n* = 1–8, *x* = A, B, C).

Event Report

Report Header and Analog Section of the Event Report

The first portion of an event report is the report header and the analog section. See *Figure 7.2* for the location of items included in a sample analog section of an event report. If you want to view only the analog portion of an event report, use the **EVE A** command.

The report header is the standard SEL-421 header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event. The report lists the RID setting (Relay ID) and the SID setting (Station ID). The FID string identifies the relay model, flash firmware version, and the date code of the firmware. See *Firmware Version Number on page 10.18 in the SEL-400 Series Relays Instruction Manual* for a description of the FID string. The relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event. The relay reports the firmware checksum as CID.

The event report column labels follow the header. The data underneath the analog column labels contain samples of power system voltages and currents in primary kilovolts and primary amperes, respectively. These quantities are instantaneous values scaled by $\sqrt{2}/2$ (0.707) and are described in *Table 7.9*. To obtain phasor rms values, use the methods illustrated in *Obtaining RMS Phasors From 4-Samples/Cycle Event Reports on page 9.17*, *Figure 9.7 on page 9.18*, and *Figure 9.8 on page 9.20 in the SEL-400 Series Relays Instruction Manual*.

```
Relay 1                                           Date: 03/15/2001  Time: 23:30:49.026
Station A                                         Serial Number: 2001001234
FID=SEL-421-R101-V0-Z001001-D20010315             Event Number = 10007      CID=0x3425


Currents (Amps Pri)                 Voltages (kV Pri)
    IA     IB     IC      IG     VA     VB     VC    VS1    VS2  V1mem


[1]
  -267    167     44     -56 -288.0  337.7  -47.8  215.3  144.9 -287.9
   -76   -203    241     -37 -223.7 -138.4  361.3 -290.5  331.3 -223.7
   266   -166    -45      55  288.2 -337.5   47.5 -215.2 -145.0  288.1
    76    202   -242      36  223.4  138.7 -361.4  290.5 -331.2  223.5
                                           •
                                           •
                                           •
[6]
  -269    167     46     -56 -289.3  336.9  -45.8  215.5  144.7 -289.4
   -74   -202    240     -35 -222.2 -140.2  361.5 -290.2  331.4 -221.8
   268   -165    -45      57  289.4 -336.7   45.6 -215.4 -144.6  289.5
    93    151   -888    -643  221.1  133.5 -335.0  290.2 -331.4  220.8

[7]
  -208   2701  -3760   -1267 -288.7  293.7  -24.1  215.5  144.5 -286.3
  -146   2941    173    2968 -219.6  -87.6  261.6 -290.1  331.4 -214.0>
   134  -5748   8310    2696  286.9 -232.4    3.5 -215.6 -144.4  273.3
   179  -6677   1811   -4688  219.8   47.4 -214.2  290.0 -331.5  202.8

[8]
  -125   5661  -8506   -2971 -286.1  213.6   -3.8  215.8  144.2 -256.5
  -177   6857  -1950    4730 -220.8  -46.9  214.2 -289.9  331.6 -193.2*
   129  -5508   8382    3003  286.9 -213.8    3.6 -216.0 -144.0  243.9
   174  -6726   1839   -4712  220.4   47.2 -214.2  289.8 -331.6  185.9

[9]
  -128   5623  -8479   -2984 -287.1  213.9   -3.5  216.1  143.8 -234.5
  -173   6821  -1924    4724 -219.8  -47.3  214.0 -289.7  331.7 -180.4
   126  -5540   8404    2990  286.6 -213.7    3.5 -216.3 -143.7  227.3
   177  -6749   1860   -4713  220.0   47.4 -212.9  289.6 -331.8  176.2
```

- Header
- Firmware ID in bold
- One Cycle of Data
- See Figure 3.7 and Figure 3.8 to calculate phasors for the data in bold
- Trigger
- Largest Current (to Event Summary)

Figure 7.2 Fixed Analog Section of the Event Report

```
[10]
  -126   4616  -6204  -1714 -282.9  178.6   41.9  216.4  143.5 -222.1
  -106   4288  -1047   3135 -231.6  -64.5   95.3 -289.4  331.9 -162.6
    65  -1722   1878    221  140.2  -72.1  -43.6 -216.6 -143.3  194.6

    16   -807      4   -786  105.1   41.3   10.5  289.2 -332.0  130.7      Circuit Breaker Open
[11]
    -1     -1     -2     -5   13.8    1.1    0.3  216.8  143.1 -147.1
     2      3      4      9   54.8   -0.7   -0.3 -289.1  332.1  -93.5
     1      1      2      5   -8.1   -1.6   -1.1 -217.0 -142.8  109.8
    -2     -2     -3     -8  -58.2    0.2    0.2  289.0 -332.2   65.3
```

Figure 7.2 Fixed Analog Section of the Event Report (Continued)

Table 7.9 Event Report Metered Analog Quantities

Quantity	Description
IA	Instantaneous filtered line current, A-Phase
IB	Instantaneous filtered line current, B-Phase
IC	Instantaneous filtered line current, C-Phase
IG	Instantaneous filtered line current, residual (or ground)
VA	Instantaneous filtered A-Phase voltage
VB	Instantaneous filtered B-Phase voltage
VC	Instantaneous filtered C-Phase voltage
VS1	Instantaneous filtered synchronization Source 1 voltage
VS2	Instantaneous filtered synchronization Source 2 voltage
V1Mem	Instantaneous memorized positive-sequence polarization voltage

Figure 7.2 contains selected data from the analog section of a 4-samples/cycle event report for a BCG fault on a 400 kV line with CT ratio := 400/1 and PT ratio := 3636/1. The bracketed numbers at the left of the report (for example, [11]) indicate the cycle number; *Figure 7.2* presents seven cycles of 4-samples/cycle data.

The trigger row includes a > character following immediately after the V1Mem column to indicate the trigger point. This is the dividing point between the pre-fault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the currents in the event summary is the row with the largest current magnitudes; the relay marks this row on the event report with an asterisk (*) character immediately after the V1Mem column. The (*) takes precedence over the > if both occur on the same row in the analog section of the event report.

Digital Section of the Event Report

The second portion of an event report is the digital section. Inspect the digital data to evaluate relay element response during an event. See *Figure 7.3* for the locations of items in a sample event report digital section. If you want to view only the digital portion of an event report, use the **EVE D** command (see *EVE D on page 14.24 in the SEL-400 Series Relays Instruction Manual* for details). In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk (*) character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the two 8-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report.

The report displays the digital label header for each column in a vertical fashion, aligned on the last character. For example, if the first digital section elements are IN101, #, RMBA5, Z2P, LOKA, #, OUT203, OUT204, and HALARM, the header appears as in *Figure 7.4*. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report.

```
                                                                      22 B B
                                                             C        55 F F
                      VZ             S      66     66  55    O BBBBBB AA T T
         MMM      ZZZ PL        3333 05 666 77 666 77 511  Z M KKKKKK 11 RFRF     Digital Column Labels
TTT MMMM 234 ZZZZ 234 OOL OO 3S 2222 TO 777 GG 777 QQ 1SS  3KP 121212 BB IBIB
PPP 1234 PPP 1234 GGG LAO SS PP QQGG FP GGG 23 QQQ 23 S11 PRER RRLLCC KK PFPF
ABC PPPP TTT GGGG TTT VDP BT OO FRFR T1 123 TT 123 TT 1TR TBYM SSOOLL 12 1122


[1]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....     One Cycle of Data
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
                                •
                                •
                                •
[6]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
[7]
*** **.. ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....>    Trigger

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[8]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....*    Largest Current (to Event Summary)

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[9]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[10]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....

*** .... ... .... ... *.. .. .* .... .. ... .. ... .. ... .... ...... .. ....     Circuit Breaker Open

*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....

[11]
*** .... ... .... ... *.. .. *. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Figure 7.3 Digital Section of the Event Report

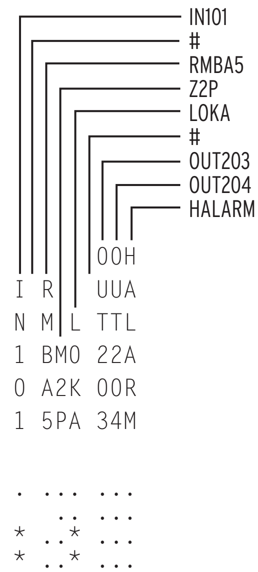


Figure 7.4 Sample Digital Portion of the Event Report

Example 7.1 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in *Figure 7.3*. The sample digital event report shows seven cycles of 4-samples/cycle data for a BCG fault that trips a single-pole-capable circuit breaker.

In this particular report, the mho phase-distance elements Z1P and Z2P pick up in the first sample of Cycle [7]. The relay asserts the tripping Relay Word bits TPA, TPB, and TPC when the distance elements operate because of programming in the TR (Unconditional Tripping) SELOGIC control equation.

In the next reported sample (the second sample of Cycle [7]), the digital event report shows that the relay has asserted the negative-sequence directional element, 32QF, and the ground directional element, 32GF.

Approximately three cycles later, the digital event report shows that the circuit breaker has tripped. In Cycle [10], Relay Word bit SPO indicates that the relay has detected a single-pole open; one of the poles of the circuit breaker has opened. The remaining poles open and the relay asserts Relay Word bit 3PO (Three-Pole Open). Note that the relay polarizing voltage for element security, VPOLV, is always available.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 7.5* for the locations of items included in a sample summary section of an event report. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command (see *EVENT on page 14.23 in the SEL-400 Series Relays Instruction Manual*).

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report. See *Event Summary on page 7.13* for a description of the items in the summary portion of the event report.

```
Event: BCG T              Location:  48.17                   Time Source: OTHER
Event Number#: 10007      Shot 1P: 0   Shot 3P: 0       Freq: 60.01     Group: 1
Targets: INST TIME ZONE_1 A_PHASE B_PHASE bk1rs
Breaker 1: OPEN           Trip Time: 23:30:49.026
Breaker 2: OPEN           Trip Time: 23:30:49.026

PreFault:      IA      IB      IC      IG     3I2       VA       VB       VC    V1mem

MAG(A/kV)     276     262     246      65      17  364.704  364.903  364.452  364.614

ANG(DEG)     22.1   -91.7   138.2     5.1   178.5      0.0   -119.9    120.3      0.2
Fault:
MAG(A/kV)     217    8892    8727    5586   11403  361.421  218.687  214.239  321.083

ANG(DEG)    -17.0   167.3    24.8    95.6    94.4      0.1   -129.9    126.7      0.7

                                                     L C R      L C R
                                                     B B B R    B B B R
                                                     O A A O    O A A O
                                                     K D D K    K D D K
MB:8->1       RMBA      TMBA      RMBB      TMBB     A A A A    B B B B
  TRIG    00000000  00000000  00000000  00000000     0 0 0 0    0 0 0 0
```

Event Information

Prefault Data

Fault Data

MIRRORED BITS Channel Status

Figure 7.5 Summary Section of the Event Report

Event Summary

You can retrieve a summary version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events. See *Figure 7.6* for a sample event summary.

```
Relay 1                                      Date: 03/15/2001  Time: 23:30:49.026
Station A                                    Serial Number: 2001001234

Event: BCG T              Location:  48.17                   Time Source: OTHER
Event Number#: 10007      Shot 1P: 0   Shot 3P: 0       Freq: 60.01     Group: 1

Targets: INST TIME ZONE_1 A_PHASE B_PHASE bk1rs
Breaker 1: OPEN           Trip Time: 23:30:49.026
Breaker 2: OPEN           Trip Time: 23:30:49.026
PreFault:      IA      IB      IC      IG     3I2       VA       VB       VC    V1mem

MAG(A/kV)     276     262     246      65      17  364.704  364.903  364.452  364.614

ANG(DEG)     22.1   -91.7   138.2     5.1   178.5      0.0   -119.9    120.3      0.2

Fault:
MAG(A/kV)     217    8892    8727    5586   11403  361.421  218.687  214.239  321.083
ANG(DEG)    -17.0   167.3    24.8    95.6    94.4      0.1   -129.9    126.7      0.7

                                                     L C R      L C R
                                                     B B B R    B B B R
                                                     O A A O    O A A O
                                                     K D D K    K D D K
MB:8->1       RMBA      TMBA      RMBB      TMBB     A A A A    B B B B
  TRIG    00000000  00000000  00000000  00000000     0 0 0 0    0 0 0 0
  TRIP    00000000  00000000  00000000  00000000     0 0 0 0    0 0 0 0
```

Report Header

Event Information

Circuit Breaker Status

Prefault Data

Fault Data

MIRRORED BITS Channels Status

Figure 7.6 Sample Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Location of fault (if applicable)
- Time source (HIRIG or OTHER)
- Event number
- Recloser shot counter at the trigger time
- System frequency

- Active group at trigger time
- Targets
- Circuit breaker trip and close times; and auxiliary contact(s) status
- Prefault and fault voltages, currents, and sequence current (from the event report row with the largest current)
- MIRRORED BITS communications channel status (if enabled)

The relay derives the summary target information and circuit breaker trip and close times from the rising edge of relevant Relay Word bits during the event. If no trip or circuit breaker element asserted during the event, the relay uses the last row of the event.

Fault location data can be indeterminate (for example, when there is no fault on the power system). If this is the case, the relay displays "$$$$.$$" for the Location entry in the event summary. You will also see the "$$$$.$$" display if the fault location enable setting EFLOC is N.

The SEL-421 reports the event type according to the output of the fault location algorithm. *Table 7.10* lists event types in fault reporting priority. Fault event types (AG, BG, and BCG, for example) have reporting priority over indeterminate fault events. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 7.10 Event Types

Event	Event Trigger
AG, BG, CG, ABC, AB, BC, CA, ABG, BCG, CAG	The relay reports phase involvement. If Relay Word bit TRIP asserts at any time during the event, the relay appends a T to the phase (AG T, for example).
TRIP	The event report includes the rising edge of Relay Word bit TRIP, but phase involvement is indeterminate.
ER	The relay generates the event with elements in the SELOGIC control equation ER, but phase involvement is indeterminate.
TRIG	The relay generates the event in response to the **TRI** command.

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 7.7* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- Event number
- Event date and time
- Event type
- Location of fault (if applicable)
- Maximum phase current from summary fault data

- ➤ Active group at the trigger instant
- ➤ Targets

Figure 7.7 is a sample event history from a terminal.

```
Relay 1                                    Date: 03/16/2001  Time: 11:57:27.803
Station A                                    Serial Number: 2001001234

#       DATE        TIME      EVENT  LOCAT    CURR GRP TARGETS
10007 03/15/2001 23:30:49.026 BCG T   48.17   8892  1  INST TIME ZONE_1 B_PHASE
10006 03/15/2001 07:15:00.635 ABC T   22.82   8203  1  INST ZONE_1 A_PHASE bk1rs
10005 03/15/2001 06:43:53.428  TRIG  $$$$.$$     0  1

Event                         Event Fault    Active
Number                        Type  Location Group
```

Figure 7.7 Sample Event History

Fault location data can be indeterminate (for example, when you trigger an event and there is no fault on the power system). If this is the case, the relay displays $$$$.$$ for the Location entry in the event history. You will also see the $$$$.$$ display if the fault location enable setting EFLOC is N.

The event types in the event history are the same as the event types in the event summary (see *Table 7.10* for event types).

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SECTION 8

Settings

Section 12: Settings in the SEL-400 Series Relays Instruction Manual describes common platform settings. This section contains tables of relay settings for the SEL-421 Relay.

⚠WARNING
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The relay hides some settings based upon other settings. If you set an enable setting to OFF, for example, the relay hides all settings associated with that enable setting. This section does not explain rules for hiding settings; these rules are discussed in the applications sections of the instruction manual where appropriate.

The settings prompts in this section are similar to the ASCII terminal and ACSELERATOR QuickSet SEL-5030 software prompts. The prompts in this section are unabbreviated and show all possible setting options.

For information on using settings in protection and automation, see the examples in *Section 6: Protection Applications Examples*. The section contains information on the following settings classes.

Alias Settings

See *Alias Settings on page 12.20 in the SEL-400 Series Relays Instruction Manual* for a complete description of alias settings. *Table 8.1* lists the default alias settings for the SEL-421.

Table 8.1 Global Settings Changes

Setting	Default Value
EN	RLY_EN

Global Settings

Table 8.2 Global Settings Categories

Settings	Reference
General Global Settings	*Table 8.3*
Global Enables	*Table 8.4*
Station DC1 Monitor (and Station DC2 Monitor)	*Table 8.5*
Control Inputs (Global)	*Table 8.6*
Main Board Control Inputs	*Table 8.7*
Interface Board #1 Control Inputs	*Table 8.8*
Interface Board #2 Control Inputs	*Table 8.9*
Settings Group Selection	*Table 8.10*
Frequency Estimation	*Table 8.11*
Time-Error Calculation	*Table 8.12*
Current and Voltage Source Selection	*Table 8.13*
Synchronized Phasor Measurement	*Table 8.14*
Time and Date Measurement	*Table 8.19*
Data Reset Controls	*Table 8.20*
DNP	*Table 8.21*

Table 8.3 General Global Settings

Setting	Prompt	Default Value
SID	Station Identifier (40 characters)	Station A
RID	Relay Identifier (40 characters)	Relay 1
NUMBK	Number of Breakers in Scheme (1, 2)	1
BID1	Breaker 1 Identifier (40 characters)	Breaker 1
BID2	Breaker 2 Identifier (40 characters)	Breaker 2
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC
FAULT	Fault Condition Equation SELOGIC Equation)	50P1 OR 51S1 OR Z2P OR Z2G OR Z3P OR Z3G

Table 8.4 Global Enables

Setting	Prompt	Default Value
EDCMON	Station DC Battery Monitor (N, 1, 2)	N
EICIS	Independent Control Input Settings (Y, N)	N
EDRSTC	Data Reset Control (Y, N)	N
EGADVS	Advanced Global Settings (Y, N)	N
EPMU	Synchronized Phasor Measurement (Y, N)	N

Make *Table 8.5* settings when Global enable setting EDCMON := 1 or 2. These settings are hidden when EDCMON := N.

Table 8.5 Station DC1 Monitor (and Station DC2 Monitor)

Setting[a]	Prompt	Default Value
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	100
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	127
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)	137
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)	142
DC1RP	Peak to Peak AC Ripple Pickup (1–300 Vac)	9
DC1GF	Ground Detection Factor (1.00–2.00)	1.05

[a] Replace 1 with 2 in the setting for DC2 Monitor settings.

Make *Table 8.6* settings when Global enable setting EICIS := N.

Table 8.6 Control Inputs

Setting	Prompt	Default Value	Increment
GINP[a]	Input Pickup Level (15–265 Vdc)	85[b]	1
GINDF[a,c]	Input Dropout Level (10–100% of pickup level)	80	1
IN1XXD[d]	Main Board Debounce Time (0.0000–5 cyc)	0.1250	0.0001
IN2XXD[e]	Int Board #1 Debounce Time (0.0000–5 cyc[f])	0.1250	0.0001
IN3XXD[g]	Int Board #2 Debounce Time (0.0000–5 cyc[f])	0.1250	0.0001

[a] Setting applies to all direct coupled contact inputs if available, otherwise, the setting is not available.
[b] Factory set at 18 for 24–48 Vdc rated power supply, 36 for 48–125 Vdc rated power supply, and 85 for 125–240 Vdc rated power supply. See *Control Inputs on page 2.6* for setting guidelines.
[c] Setting applies to all direct coupled contact inputs independent of EICIS set to Y or N.
[d] Setting applies to all the main board input contacts.
[e] Setting applies to all the Interface Board #1 input contacts.
[f] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[g] Setting applies to all the Interface Board #2 input contacts.

Make *Table 8.7* settings when Global enable setting EICIS := Y.

Table 8.7 Main Board Control Inputs

Setting	Prompt	Default Value	Increment
IN101PU	Input IN101 Pickup Delay (0.0000–5 cyc)	0.1250[a]	0.0001
IN101DO	Input IN101 Dropout Delay (0.0000–5 cyc)	0.1250[a]	0.0001
• • •	• • •	• • •	
IN107PU	Input IN107 Pickup Delay (0.0000–5 cyc)	0.1250[a]	0.0001
IN107DO	Input IN107 Dropout Delay (0.0000–5 cyc)	0.1250[a]	0.0001

[a] Set to Global setting IN1XXD when EICIS := N.

Make *Table 8.8* settings for Interface Board #1 when Global enable setting EICIS := Y.

Table 8.8 Interface Board #1 Control Inputs

Setting	Prompt	Default Value	Increment
IN201P[a]	Input IN201 Pickup Level (15–265 Vdc)	85[b]	1
• • •	• • •	• • •	• • •
IN2*mm*P[a]	Input IN2*mm* Pickup Level (15–265 Vdc)	85[b]	1
IN201PU	Input IN201 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
IN201DO	Input IN201 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
• • •	• • •	• • •	• • •
IN2*mm*PU[e]	Input IN2*mm*[e] Pickup Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
IN2*mm*DO[e]	Input IN2*mm*[e] Dropout Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24–48 Vdc rated power supply, 36 for 48–125 Vdc rated power supply, and 85 for 125–240 Vdc rated power supply. See *Control Inputs on page 2.6* for setting guidelines.
[c] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[d] Set to Global setting IN2XXD when EICIS :-= N
[e] *mm* is the number of available input contacts on the interface board.

Make *Table 8.9* settings for Interface Board #2 when Global enable setting EICIS := Y.

Table 8.9 Interface Board #2 Control Inputs

Setting	Prompt	Default Value	Increment
IN301P[a]	Input IN301 Pickup Level (15–265 Vdc)	85[b]	1
• • •	• • •	• • •	
IN3*mm*P[a]	Input IN3*mm* Pickup Level (15–265 Vdc)	85[b]	1
IN301PU	Input IN301 Pickup Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
IN301DO	Input IN301 Dropout Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
• • •	• • •	• • •	
IN3*mm*PU[e]	Input IN3*mm*[e] Pickup Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001
IN3*mm*DO[e]	Input IN3*mm*[e] Dropout Delay (0.0000–5 cyc[c])	0.1250[d]	0.0001

[a] Setting is not available for interface boards INT2, INT4, INT7, and INT8. Set to Global setting GINP when EICIS := N.
[b] Factory set at 18 for 24–48 Vdc rated power supply, 36 for 48–125 Vdc rated power supply, and 85 for 125–240 Vdc rated power supply. See *Control Inputs on page 2.6* for setting guidelines.
[c] If the interface board has more than eight input contacts, the upper range is 1 cycle.
[d] Set to Global setting IN3XXD when EICIS := N.
[e] *mm* is the number of available input contacts on the interface board.

Table 8.10 Settings Group Selection

Setting	Prompt	Default Value
SS1	Select Setting Group 1 (SELOGIC Equation)	PB3 AND NOT SG1
SS2	Select Setting Group 2 (SELOGIC Equation)	PB3 AND SG1
SS3	Select Setting Group 3 (SELOGIC Equation)	0
SS4	Select Setting Group 4 (SELOGIC Equation)	0
SS5	Select Setting Group 5 (SELOGIC Equation)	0
SS6	Select Setting Group 6 (SELOGIC Equation)	0
TGR	Group Change Delay (0–54000 cycles)	180

Make *Table 8.11* settings when Global enable setting EGADVS := Y.

Table 8.11 Frequency Estimation

Setting	Prompt	Default Value
EAFSRC	Alternate Frequency Source (SELOGIC Equation)	NA
VF01	Local Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY
VF02	Local Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBY
VF03	Local Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCY
VF11	Alternate Frequency Source 1 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF12	Alternate Frequency Source 2 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO
VF13	Alternate Frequency Source 3 (ZERO, VAY, VBY, VCY, VAZ, VBZ, VCZ)	ZERO

Table 8.12 Time-Error Calculation

Setting	Prompt	Default Value
STALLTE	Stall Time-Error Calculation (SELOGIC Equation)	NA
LOADTE	Load TECORR Factor (SELOGIC Equation)	NA

See *Current and Voltage Source Selection on page 5.2* for more information on *Table 8.13* settings.

Table 8.13 Current and Voltage Source Selection

Setting	Prompt	Default Value
ESS	Current and Voltage Source Selection (Y, N, 1, 2, 3, 4)	N
LINEI	Line Current Source (IW, COMB)	IW
ALINEI	Alternate Line Current Source (IX, NA)	NA
ALTI	Alternate Current Source (SELOGIC Equation)	NA
BK1I	Breaker 1 Current Source (IW, IX, NA)	IW
BK2I	Breaker 2 Current Source (IX, COMB, NA)	NA
IPOL	Polarizing Current (IAX, IBX, ICX, NA)	NA
ALINEV	Alternate Line Voltage Source (VZ, NA)	NA
ALTV	Alternate Voltage Source (SELOGIC Equation)	NA

Table 8.14 Synchronized Phasor Configuration Settings

Setting	Prompt	Default
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE[a]	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)[b]	2
PMAPP	PMU Application (F, N, 1)[c]	N
PMLEGCY[a]	Synchrophasor Legacy Settings (Y, N)	N
NUMPHDC[a,d]	Number of Data Configurations (1–5)	1
PMSTN*q*[a,e]	Station Name (16 characters)	STATION A
PMID*q*[a,e]	PMU Hardware ID (1–65534)	1
PHVOLT[f]	Include Voltage Terminal (combo of Y,Z)	Y
PHDATAV[f]	Phasor Data Set, Voltages (V1, PH, ALL, NA)	V1
PHCURR[f]	Include Current Terminal (combo of W, X, S)	W
PHDATAI[f]	Phasor Data Set, Currents (I1, PH, ALL, NA)	NA

[a] Only available in MFRMT = C37.118.
[b] If NFREQ = 50 then the range is 1, 2, 5, 10, 25, 50.
[c] Option 1 is available only if MRATE = 60.
[d] Only available if PMLEGCY = N.
[e] *q* = 1–NUMPHDC. If PMLEGACY = Y, then these two settings become PMSTN and PMID.
[f] Only available if PMLEGCY = Y.

Phasors Included in the Data *q*
Terminal Name, Relay Word Bit, Alternate Terminal Name

Specify the terminal for Synchrophasor measurement and transmission in the synchrophasor data stream *q*.

This is a freeform setting category for enabling the terminals for synchrophasor measurement and transmission. This freeform setting has three arguments. Specify the terminal name (any one of W, X, S, Y, or Z) for the first argument. Specify any Relay Word bit for the second argument. Specify the alternate terminal name (any one of W, X, S, Y, or Z) for the third argument.

The second and third arguments are optional unless switching between terminals is required. Whenever the Relay Word bit in the second argument is asserted the terminal synchrophasor data are replaced by the alternate terminal data.

Table 8.15 Phasors Included in the Data

Setting	Prompt	Default
PHDV*q*[a]	Phasor Data Set, Voltages (V1, PH, ALL)	V1
PHDI*q*[a]	Phasor Data Set, Currents (I1, PH, ALL)	ALL
PHNR*q*[a]	Phasor Num. Representation (I = Integer, F = Float)	I
PHFMT*q*[a]	Phasor Format (R = Rectangular, P = Polar)	R
FNR*q*[a]	Freq. Num. Representation (I = Integer, F = Float)	I

[a] *q* = 1–NUMPHDC.

Phasor Aliases in Data Configuration *q*
Phasor Name, Alias

This is a freeform setting category with two arguments. Specify the phasor name and an optional 16-character alias to be included in the synchrophasor data stream *q*. See *Table 10.17 on page 10.30* and *Table 10.18 on page 10.30* for a list of phasor names that the PMU supports. The PMU can be configured for as many as 20 unique phasors for each PMU configuration.

Setting	Prompt	Default
NUMAN*q*	Number of Analog Quantities (0–16)	0

Synchrophasor Analog Quantities in Data Configuration *q* (Maximum 16 Analog Quantities)
Analog Quantity Name or Alias

This is a freeform setting category with one argument. Specify the analog quantity name or its alias to be included in the synchrophasor data stream *q*. See *Section 12: Analog Quantities* for a list of analog quantities that the PMU supports. The PMU can be configured for as many as 16 unique analog quantities for each data configuration *q*. The analog quantities are floating point values, so each analog quantity the PMU includes will take four bytes.

Setting	Prompt	Default
NUMDW*q*	Number of 16-bit Digital Status Words (0, 1, 2, 3, 4)	1

Synchrophasor Digitals in Data Configuration *q* (Maximum 64 Digitals)
Relay Word Bit Name or Alias.

This is a freeform setting category with one argument. Specify the Relay Word bit name or its alias that you need to include in the synchrophasor data stream *q*. See *Section 11: Relay Word Bits* for a list of Relay Word bits that the PMU supports. You can configure the PMU for as many as 64 unique digitals for each data configuration *q*.

Table 8.16 Synchronized Phasor Configuration Settings Part 2

Setting	Prompt	Default	Increment
TREA[4]	Trigger Reason Bit [4] (SELOGIC Equation)	NA	
PMTRIG	Trigger (SELOGIC Equation)	NA	
PMTEST	PMU in Test Mode (SELOGIC Equation)	NA	
V*k*[a]COMP	Comp. Angle Terminal *k* (–179.99° to 180°)	0.00	0.01
I*n*[b]COMP	Comp. Angle Terminal *n* (–179.99° to 180°)	0.00	0.01
PMFRQST	PMU Primary Frequency Source Terminal (Y, Z)	Y	
PMFRQA	PMU Frequency Application (F, S)	S	
PHCOMP	Freq. Based Phasor Compensation (Y, N)	Y	

[a] *k* = Y and Z.
[b] *n* = W, X, S.

Table 8.17 Synchronized Phasor Recorder Settings (Sheet 1 of 2)

Setting	Prompt	Default
EPMDR	Enable PMU Data Recording (Y, N)	N
SPMDR	Select Data Configuration for PMU Recording (1–NUMPHDC)	1
CONAM	Company Name (3 characters)	abc

Table 8.17 Synchronized Phasor Recorder Settings (Sheet 2 of 2)

Setting	Prompt	Default
PMLER	Length of PMU Triggered Data (2–120 s)	30
PMPRE	Length of PMU Pre-Triggered Data (1–20 s)	5

Table 8.18 Synchronized Phasor Real Time Control Settings

Setting	Prompt	Default
RTCRATE	Remote Messages per Second (1, 2, 5, 10, or 50 when NFREQ := 50) (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60)	2
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500

Table 8.19 Time and Date Management

Setting	Prompt	Default Value
DATE_F	Date Format (MDY, YMD, DMY)	MDY
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None
UTCOFF[b]	Offset From UTC to Local Time (–15.5 to 15.5)	–8
BEG_DST[c]	Begin DST (hh, n, d, mm, or OFF)	“2, 2, 1, 3”
END_DST	End DST (hh, n, d, mm)	“2, 1, 1, 11”

[a] When EPMU = Y and MFRMT = C37.118, IRIGC is forced to C37.118.

[b] All data, reports, and commands from the relay are stored and displayed in local time, referenced to an internal UTC master clock. Use the UTCOFF setting to specify the time offset from UTC time reference with respect to the relay location. (The only data still displayed in UTC time is streaming synchrophasor and IEC 61850 data.)

[c] The BEG_DST (and END_DST) daylight-saving time setting consists of four fields or OFF:
hh = local time hour (0–23); defines when daylight-saving time begins.
n = the week of the month when daylight-saving time begins (1–3, L); occurs in either the 1st, 2nd, 3rd, or last week of the month.
d = day of week (1–7); Sunday is the first day of the week.
mm = month (1–12).
OFF = hides the daylight-saving time settings.

Make *Table 8.20* settings when Global enable setting EDRSTC := Y.

Table 8.20 Data Reset Control (Sheet 1 of 2)

Setting	Prompt	Default Value
RST_DEM	Reset Demand Metering (SELOGIC Equation)	NA
RST_PDM	Reset Peak Demand Metering (SELOGIC Equation)	NA
RST_ENE	Reset Energy Metering (SELOGIC Equation)	NA
RSTMML	Reset Maximum/Minimum Line (SELOGIC Equation)	NA
RSTMMB1	Reset Maximum/Minimum Breaker 1 (SELOGIC Equation)	NA
RSTMMB2	Reset Maximum/Minimum Breaker 2 (SELOGIC Equation)	NA
RST_BK1	Reset Monitoring Breaker 1 (SELOGIC Equation)	NA
RST_BK2	Reset Monitoring Breaker 2 (SELOGIC Equation)	NA
RST_BAT	Reset Battery Monitoring (SELOGIC Equation)	NA
RST_79C	Reset Recloser Shot Count Accumulators (SELOGIC Equation)	NA
RSTTRGT	Target Reset (SELOGIC Equation)	NA
RSTFLOC	Reset Fault Locator (SELOGIC Equation)	NA

Table 8.20 Data Reset Control (Sheet 2 of 2)

Setting	Prompt	Default Value
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC Equation)	TRGTR
RST_HAL	Reset Warning Alarm Pulsing (SELOGIC Equation)	NA

Table 8.21 DNP

Setting	Prompt	Default Value
EVELOCK	Event Summary Lock Period (0-1000 s)	0
DNPSRC	DNP Session Time Base (LOCAL,UTC)	UTC

Breaker Monitor Settings

NOTE: If you want to enable the circuit breaker monitor on Circuit Breaker 2, confirm that the relay is set for two-circuit breaker operation; global setting NUMBK must be 2. Once you have set NUMBK := 2, you can set the Circuit Breaker 2 monitor settings, including EB2MON.

Table 8.22 Breaker Monitor Settings Categories

Settings	Reference
Enables	*Table 8.23*
Breaker 1 Inputs	*Table 8.24*
Breaker 2 Inputs	*Table 8.25*
Breaker 1 Monitor (and Breaker 2 Monitor)	*Table 8.26*
Breaker 1 Contact Wear (and Breaker 2 Contact Wear)	*Table 8.27*
Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time)	*Table 8.28*
Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time)	*Table 8.29*
Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy)	*Table 8.30*
Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed)	*Table 8.31*
Breaker 1 Motor Running Time (Breaker 2 Motor Running Time)	*Table 8.32*
Breaker 1 Current Interrupted (Breaker 2 Current Interrupted)	*Table 8.33*

Make *Table 8.23* EB1MON and BK1TYP settings when Global setting NUMBK := 1 or 2. make EB2MON and BK2TYP settings when Global setting NUMBK := 2.

Table 8.23 Enables

Setting	Prompt	Default Value
EB1MON	Breaker 1 Monitoring (Y, N)	N
EB2MON	Breaker 2 Monitoring (Y, N)	N
BK1TYP	Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)	3
BK2TYP	Breaker 2 Trip Type (Single Pole = 1, Three Pole = 3)	3

Table 8.24 Breaker 1 Inputs (Sheet 1 of 2)

Setting	Prompt	Default Value
52AA1	Normally Open Contact Input—BK1 (SELOGIC Equation)[a]	IN101
52AA1	A-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)[b]	IN101

Table 8.24 Breaker 1 Inputs (Sheet 2 of 2)

Setting	Prompt	Default Value
52AB1	B-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)[b]	52AA1
52AC1	C-Phase Normally Open Contact Input—BK1 (SELOGIC Equation)[b]	52AA1

[a] This setting for three-pole trip applications when setting BK1TYP := 3.
[b] This setting for single-pole trip applications when setting BK1TYP := 1.

Make *Table 8.25* settings if Global setting NUMBK := 2.

Table 8.25 Breaker 2 Inputs

Setting	Prompt	Default Value
52AA2	Normally Open Contact Input—BK2 (SELOGIC Equation)[a]	NA
52AA2	A-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)[b]	NA
52AB2	B-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)[b]	52AA2
52AC2	C-Phase Normally Open Contact Input—BK2 (SELOGIC Equation)[b]	52AA2

[a] This setting for three-pole trip applications when setting BK2TYP := 3.
[b] This setting for single-pole trip applications when setting BK2TYP := 1.

Make *Table 8.26* through *Table 8.33* settings when Breaker Monitor setting EB1MON := Y or EB2MON := Y.

Table 8.26 Breaker 1 Monitor (and Breaker 2 Monitor)

Setting[a]	Prompt	Default Value
BM1TRPA	Breaker Monitor Trip—BK1 (SELOGIC Equation)[b]	TPA1
BM1TRPA	Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)[c]	TPA1
BM1TRPB	Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)[c]	BM1TRPA
BM1TRPC	Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)[c]	BM1TRPA
BM1CLSA	Breaker Monitor Close—BK1 (SELOGIC Equation)[b]	BK1CL
BM1CLSA	Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)[c]	BK1CL
BM1CLSB	Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)[c]	BM1CLSA
BM1CLSC	Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)[c]	BM1CLSA

[a] Replace 1 with 2 in the setting, prompt, and default value for Breaker 2 settings.
[b] This setting for three-pole trip applications when setting BK1TYP := 3.
[c] This setting for single-pole trip applications when setting BK1TYP := 1.

Table 8.27 Breaker 1 Contact Wear (and Breaker 2 Contact Wear)

Setting[a]	Prompt	Default Value
B1COSP1	Close/Open Set Point 1—BK1 (0–65000 operations)	1000
B1COSP2	Close/Open Set Point 2—BK1 (0–65000 operations)	100
B1COSP3	Close/Open Set Point 3—BK1 (0–65000 operations)	10
B1KASP1	kA Interrupted Set Point 1—BK1 (1.0–999 kA)	20.0
B1KASP2	kA Interrupted Set Point 2—BK1 (1.0–999 kA)	60.0
B1KASP3	kA Interrupted Set Point 3—BK1 (1.0–999 kA)	100.0
B1BCWAT	Contact Wear Alarm Threshold—BK1 (0–100%)	90

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.28 Breaker 1 Electrical Operating Time (and Breaker 2 Electrical Operating Time)

Setting[a]	Prompt	Default Value
B1ESTRT	Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1ESCLT	Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.29 Breaker 1 Mechanical Operating Time (and Breaker 2 Mechanical Operating Time)

Setting[a]	Prompt	Default Value
B1MSTRT	Mechanical Slow Trip Alarm Threshold—BK1 (1–999 ms)	50
B1MSCLT	Mechanical Slow Close Alarm Threshold—BK1 (1–999 ms)	120

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.30 Breaker 1 Pole Scatter and Pole Discrepancy (and Breaker 2 Pole Scatter and Pole Discrepancy)

Setting[a]	Prompt	Default Value
B1PSTRT	Pole Scatter Trip Alarm Threshold—BK1 (1–999 ms)	20
B1PSCLT	Pole Scatter Close Alarm Threshold—BK1 (1–999 ms)	20
B1PDD	Pole Discrepancy Time Delay—BK1 (1–9999 ms)	1400
E1PDCS	Pole Discrepancy Current Supervision—BK1 (Y, N)	N

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.31 Breaker 1 Inactivity Time Elapsed (and Breaker 2 Inactivity Time Elapsed)

Setting[a]	Prompt	Default Value
B1ITAT	Inactivity Time Alarm Threshold—BK1 (N, 1–9999 days)	365

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.32 Breaker 1 Motor Running Time (and Breaker 2 Motor Running Time)

Setting[a]	Prompt	Default Value
B1MRTIN	Motor Run Time Contact Input—BK1 (SELOGIC Equation)	NA
B1MRTAT	Motor Run Time Alarm Threshold—BK1 (1–9999 seconds)	25

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Table 8.33 Breaker 1 Current Interrupted (and Breaker 2 Current Interrupted)

Setting[a]	Prompt	Default Value
B1KAIAT	kA Interrupt Capacity Alarm Threshold—BK1 (N, 1–100%)	90
B1MKAI	Maximum kA Interrupt Rating—BK1 (1–999 kA)	50

[a] Replace 1 with 2 in the setting and prompt for Breaker 2 settings.

Group Settings

Table 8.34 Group Settings Categories (Sheet 1 of 2)

Settings	Reference
Line Configuration	*Table 8.35*
Relay Configuration	*Table 8.36*
Mho Phase Distance Element Reach	*Table 8.37*
Quadrilateral Phase Distance Element Reach	*Table 8.38*
Phase Distance Element Time Delay	*Table 8.39*
Mho Ground Distance Element Reach	*Table 8.40*
Quad Ground Distance Element Reach	*Table 8.41*
Zero-Sequence Compensation Factor	*Table 8.42*
Ground Distance Element Time Delay	*Table 8.43*
Series Compensation	*Table 8.44*
Distance Element Common Time Delay	*Table 8.45*
Switch-Onto-Fault Scheme	*Table 8.46*
Out-of-Step Tripping/Blocking	*Table 8.47*
Load Encroachment	*Table 8.48*
Phase Instantaneous Overcurrent Pickup	*Table 8.49*
Phase Definite-Time Overcurrent Time Delay	*Table 8.50*
Phase Instantaneous Definite-Time Overcurrent Torque Control	*Table 8.51*
Residual Ground Instantaneous Overcurrent Pickup	*Table 8.52*
Residual Ground Definite-Time Overcurrent Time Delay	*Table 8.53*
Residual Ground Instantaneous Definite-Time Overcurrent Torque Control	*Table 8.54*
Negative-Sequence Instantaneous Overcurrent Pickup	*Table 8.55*
Negative-Sequence Definite-Time Overcurrent Time Delay	*Table 8.56*
Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control	*Table 8.53*
Selectable Operating Quantity Inverse Time Overcurrent Element 1	*Table 8.58*
Selectable Operating Quantity Inverse Time Overcurrent Element 2	*Table 8.59*
Selectable Operating Quantity Inverse Time Overcurrent Element 3	*Table 8.60*
81 Elements	*Table 8.61*
Under Voltage (27) Elements	*Table 8.62*
Over Voltage (59) Elements	*Table 8.63*
Zone/Level Direction	*Table 8.64*
Directional Control Element	*Table 8.65*
Pole-Open Detection	*Table 8.66*
POTT Trip Scheme	*Table 8.67*
DCUB Trip Scheme	*Table 8.68*
DCB Trip Scheme	*Table 8.69*
Breaker 1 Failure Logic (and Breaker 2 Failure Logic)	*Table 8.70*
Synchronism Check Element Reference	*Table 8.71*
Breaker 1 Synchronism Check	*Table 8.72*
Breaker 2 Synchronism Check	*Table 8.73*

Table 8.34 Group Settings Categories (Sheet 2 of 2)

Settings	Reference
Recloser and Manual Closing	*Table 8.74*
Single-Pole Reclose Settings	*Table 8.75*
Three-Pole Reclose Settings	*Table 8.76*
Voltage Elements	*Table 8.77*
Demand Metering	*Table 8.78*
MIRRORED BITS Communications Settings	*Table 8.79*
Trip Logic	*Table 8.80*

Table 8.35 Line Configuration

Setting	Prompt	Default Value		Increment
		5 A	1 A	
CTRW	Current Transformer Ratio—Input W (1–50000)	200	200	1
CTRX	Current Transformer Ratio—Input X (1–50000)	200	200	1
PTRY	Potential Transformer Ratio—Input Y (1–10000)	2000	2000.0	0.1
VNOMY	PT Nominal Voltage (L-L)—Input Y (60–300 V secondary)	115	115	1
PTRZ	Potential Transformer Ratio—Input Z (1–10000)	2000	2000.0	0.1
VNOMZ	PT Nominal Voltage (L-L)—Input Z (60–300 V secondary)	115	115	1
Z1MAG	Positive-Sequence Line Impedance Magnitude (0.05–255 W secondary) 5 A (0.25–1275 W secondary) 1 A	7.80	39.00	0.01
Z1ANG	Positive-Sequence Line Impedance Angle (5.00–90 degrees)	84.00	84.00	0.01
Z0MAG	Zero-Sequence Line Impedance Magnitude (0.05–255 W secondary) 5 A (0.25–1275 W secondary) 1 A	24.80	124.00	0.01
Z0ANG	Zero-Sequence Line Impedance Angle (5.00–90 degrees)	81.50	81.50	0.01
EFLOC	Fault Location (Y, N)	Y	Y	
LL	Line Length (0.10–999)	100.00	100.00	0.01

Table 8.36 Relay Configuration (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
EMBA	Channel A MIRRORED BITS Enable (Y, N)	N	
EMBB	Channel B MIRRORED BITS Enable (Y, N)	N	
E21MP	Mho Phase Distance Zones (N, 1–5)	3	
E21XP	Quadrilateral Phase Distance Zones (N, 1–5)	3	
E21MG	Mho Ground Distance Zones (N, 1–5)	3	
E21XG	Quadrilateral Ground Distance Zones (N, 1–5)	N	
ECVT	Capacitive Voltage Transformer Transient Detection (Y, N)	N	
ESERCMP	Series-Compensated Line Logic (Y, N)	N	

NOTE: The SEL-421-4 does not provide series-compensated line protection logic. This setting is unavailable in the SEL-421-4.

NOTE: The SEL-421-4 does not provide series-compensated line protection logic. This setting is unavailable in the SEL-421-4.

Table 8.36 Relay Configuration (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
ECDTD	Distance Element Common Time Delay (Y, N)	N	
ESOTF	Switch-Onto-Fault (Y, N)	Y	
EOOS	Out-of-Step (Y, Y1, N)	N	
ELOAD	Load Encroachment (Y, N)	Y	
E50P	Phase Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	1	
E50G	Residual Ground Instantaneous Definite-Time Overcurrent Element (N, 1–4)	N	
E50Q	Negative-Sequence Instantaneous Definite-Time Overcurrent Elements (N, 1–4)	N	
E51S	Selectable Operating Quantity Inverse Time Overcurrent Element (N, 1–3)	1	
E81	Enable Frequency Elements (N, 4–6)	N	
E27	Enable Under Voltage Elements (N, 1–6)	N	
E59	Enable Over Voltage Elements (N, 1–6)	N	
E32	Directional Control (Y, AUTO, AUTO2)	AUTO2	
ECOMM	Communications-Assisted Tripping (N, DCB, POTT, POTT2, POTT3, DCUB1, DCUB2)	POTT	
EBFL1	Breaker 1 Failure Logic (N, 1, 2, Y1, Y2)	N	
EBFL2	Breaker 2 Failure Logic (N, 1, 2, Y1, Y2)	N	
E25BK1	Synchronism Check for Breaker 1 (Y, N, Y1, Y2)	N	
E25BK2	Synchronism Check for Breaker 2 (Y, N, Y1, Y2)	N	
E79	Reclosing (Y, Y1, N)	Y	
EMANCL	Manual Closing (Y, N)	Y	
ELOP	Loss-of-Potential (Y, Y1, N)	Y1	
EDEM	Demand Metering (N, THM, ROL)	N	
VMEMC[a]	Memory Voltage Control (SELOGIC Equation)	0	
EFID[b]	Enable FID Logic (Y, N)	Y	
EADVS	Advanced Settings (Y, N)	N	
Z50G1[b]	Zone 1 Ground Distance Fault Detector (0.50–100.00 A, secondary)[c]	0.5	0.01
Z50P1[b]	Zone 1 Phase Distance Fault Detector (0.50–170.00 A, secondary)[c]	0.5	0.01

[a] Only available if EADVS = Y and ESERCMP = N.
[b] Only available if EADVS = Y.
[c] Range and default are for a 5 A relay. For a 1 A relay, divide the range and default by 5.

The number of pickup settings in *Table 8.37* is dependent on Group setting E21P := 1–5. When E21P := N, no settings are made for *Table 8.37*.

Table 8.37 Mho Phase-Distance Element Reach

Setting	Prompt	Default Value		Increment
		5 A	1 A	
ZIMP	Zone 1 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	6.24	31.2	0.01
Z2MP	Zone 2 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	9.36	46.8	0.01
Z3MP	Zone 3 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	1.87	9.35	0.01
Z4MP	Zone 4 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
Z5MP	Zone 5 Reach (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01

The number of pickup settings in *Table 8.38* is dependent on Group setting E21XP := 1–5. When E21XP := N, no settings are made for *Table 8.38*.

Table 8.38 Quadrilateral Phase-Distance Element Reach (Sheet 1 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
XP1	Zone 1 Reactance (ohms, secondary) (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RP1	Zone 1 Resistance (ohms, secondary) (OFF, 0.05–50 Ω secondary) 5 A (OFF, 0.25–250 Ω secondary) 1 A	12.48	62.40	0.01
XP2	Zone 2 Reactance (ohms, secondary) (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RP2	Zone 2 Resistance (ohms, secondary) (OFF, 0.05–50 Ω secondary) 5 A (OFF, 0.25–250 Ω secondary) 1 A	18.72	93.60	0.01
XP3	Zone 3 Reactance (ohms, secondary) (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RP3	Zone 3 Resistance (ohms, secondary) (OFF, 0.05–50 Ω secondary) 5 A (OFF, 0.25–250 Ω secondary) 1 A	3.64	18.20	0.01
XP4	Zone 4 Reactance (ohms, secondary) (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RP4	Zone 4 Resistance (ohms, secondary) (OFF, 0.05–150 Ω secondary) 5 A (OFF, 0.25–750 Ω secondary) 1 A	31.20	156.00	0.01

Table 8.38 Quadrilateral Phase-Distance Element Reach (Sheet 2 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
XP5	Zone 5 Reactance (ohms, secondary) (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RP5	Zone 5 Resistance (ohms, secondary) (OFF, 0.05–150 Ω secondary) 5 A (OFF, 0.25–750 Ω secondary) 1 A	50.00	250.00	0.01
TANGP[a]	Phase Nonhomogenous Corr. Ang (–40 to 40 deg)	–7.0	–7.0	0.1

[a] Hidden and forced to default if EAVDS = N or E21XP = N.

Make corresponding zone *n* = 1–5 settings in *Table 8.39* for any Z*n*P settings that are made in *Table 8.37* or *Table 8.38*.

Table 8.39 Phase-Distance Element Time Delay

Setting	Prompt	Default Value	Increment
Z1PD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000	0.125
Z2PD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000	0.125
Z3PD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000	0.125
Z4PD	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125
Z5PD	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125

The number of pickup settings in *Table 8.40* is dependent on Group setting E21MG := 1–5. When E21MG := N, no settings are made for *Table 8.40*.

Table 8.40 Mho Ground-Distance Element Reach

Setting	Prompt	Default Value		Increment
		5 A	1 A	
Z1MG	Zone 1 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	6.24	31.2	0.01
Z2MG	Zone 2 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	9.36	46.8	0.01
Z3MG	Zone 3 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	1.87	9.35	0.01
Z4MG	Zone 4 (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
Z5MG	Zone 5 (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	OFF	OFF	0.01

The number of pickup settings in *Table 8.41* is dependent on Group setting E21XG := 1–5. When E21XG := N, no settings are made for *Table 8.41*.

Table 8.41 Quad Ground-Distance Element Reach

Setting	Prompt	Default Value		Increment
		5 A	1 A	
ARESE	Enable Adaptive Resistive Element (Y, N)	N	N	
XG1	Zone 1 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RG1	Zone 1 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	12.48	62.4	0.01
XG2	Zone 2 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RG2	Zone 2 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	18.72	93.6	0.01
XG3	Zone 3 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RG3	Zone 3 Resistance (0.05–50 Ω secondary) 5 A (0.25–250 Ω secondary) 1 A	3.64	18.2	0.01
XG4	Zone 4 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RG4	Zone 4 Resistance (0.05–150 Ω secondary) 5 A (0.25–750 Ω secondary) 1 A	31.2	156	0.01
XG5	Zone 5 Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01
RG5	Zone 5 Resistance (0.05–150 Ω secondary) 5 A (0.25–750 Ω secondary) 1 A	50	250	0.01
XGPOL[a]	Quad Ground Polarizing Quantity (I2, IG)	I2	I2	
TANGG[a, b]	Nonhomogeneous Correction Angle (–40.0 to +40.0 degrees)	–7.0	–7.0	0.1

[a] Setting only available when Group setting EADVS := Y.
[b] Hide and force to TANGP if XGPOL = I2.

Make *Table 8.42* settings when Group setting E21MG := 1–5 or E21XG := 1–5.

Table 8.42 Zero-Sequence Compensation Factor

Setting	Prompt	Default Value	Increment
k0M1	Zone 1 Zero-Sequence Compensation Factor Magnitude (AUTO, 0.000–10)	0.726	0.001
k0A1	Zone 1 Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69	0.01
k0M[a]	Forward Zones Zero-Sequence Compensation Factor Magnitude (0.000–10)	0.726	0.001
k0A[a]	Forward Zones Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69	0.01
k0MR[a]	Reverse Zones Zero-Sequence Compensation Factor Magnitude (0.000–10)	0.726	0.001
k0AR[a]	Reverse Zones Zero-Sequence Compensation Factor Angle (–180.0 to +180.0 degrees)	–3.69	0.01

[a] Setting only available when Group setting EADVS := Y.

The number of pickup settings in *Table 8.43* is dependent on Group settings E21G := 1–5 and E21XG := 1–5, and the settings made from *Table 8.40* and *Table 8.41*.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.43 Ground-Distance Element Time Delay

Setting	Prompt	Default Value	Increment
Z1GD	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000	0.125
Z2GD	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000	0.125
Z3GD	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000	0.125
Z4GD	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125
Z5GD	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125

Make *Table 8.44* settings when Group setting ESERCMP := Y.

NOTE: The SEL-421-4 does not provide series-compensated line protection logic. This setting is available in the SEL-421-5.

Table 8.44 Series Compensation

Setting	Prompt	Default Value		Increment
		5 A	1 A	
XC	Series Capacitor Reactance (OFF, 0.05–64 Ω secondary) 5 A (OFF, 0.25–320 Ω secondary) 1 A	OFF	OFF	0.01

Make *Table 8.45* settings only when Group setting ECDTD := Y; the number of settings is dependent on Group settings E21P := 1–5, E21G := 1–5, and E21XG := 1–5, and the settings made from *Table 8.37*, *Table 8.40* and *Table 8.41*.

Table 8.45 Distance Element Common Time Delay (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
Z1D	Zone 1 Time Delay (OFF, 0.000–16000 cycles)	0.000	0.125
Z2D	Zone 2 Time Delay (OFF, 0.000–16000 cycles)	20.000	0.125

Table 8.45 Distance Element Common Time Delay (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
Z3D	Zone 3 Time Delay (OFF, 0.000–16000 cycles)	60.000	0.125
Z4D	Zone 4 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125
Z5D	Zone 5 Time Delay (OFF, 0.000–16000 cycles)	OFF	0.125

Make *Table 8.46* settings when Group setting ESOTF := Y.

Table 8.46 Switch-Onto-Fault Scheme

Setting	Prompt	Default Value	Increment
ESPSTF	Single-Pole Switch-Onto-Fault (Y, N)	N	
EVRST	Switch-Onto-Fault Voltage Reset (Y, N)	N	
VRSTPU	Switch-Onto-Fault Reset Voltage (0.60–1.00 pu)	0.60–1.00 pu	0.01
52AEND	52A Pole Open Time Delay (OFF, 0.000–16000 cycles)	10.000	0.125
CLOEND	CLSMON or Single Pole Open Delay (OFF, 0.000–16000 cycles)	OFF	0.125
SOTFD	Switch-Onto-Fault Enable Duration (0.500–16000 cycles)	10.000	0.125
CLSMON	Close Signal Monitor (SELOGIC Equation)	NA	

Make *Table 8.47* settings only when Group setting EOOS := Y; the number of settings is dependent on Group settings E21P := 1–5 and E21G := 1–5.

Table 8.47 Out-of-Step Tripping/Blocking (Sheet 1 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
OOSB1	Block Zone 1 (Y, N)	Y	Y	
OOSB2	Block Zone 2 (Y, N)	Y	Y	
OOSB3	Block Zone 3 (Y, N)	Y	Y	
OOSB4	Block Zone 4 (Y, N)	N	N	
OOSB5	Block Zone 5 (Y, N)	N	N	
OSBD	Out-of-Step Block Time Delay (0.500–8000 cycles)	2.000	2.000	0.125
OSBLTCH	Latch Out-of-Step Blocking (Y, N)	N	N	
EOOST	Out-of-Step Tripping (N, I, O)	N	N	
OSTD	Out-of-Step Trip Delay (0.500–8000 cycles)	0.500	0.500	0.125
X1T7	Zone 7 Reactance—Top (0.05 to 140 Ω secondary) 5 A (0.25 to 700 Ω secondary) 1 A	23.0	115	0.01
X1T6	Zone 6 Reactance—Top (0.05 to 140 Ω secondary) 5 A (0.25 to 700 Ω secondary) 1 A	21.0	105	0.01
R1R7	Zone 7 Resistance—Right (0.05 to 140 Ω secondary) 5 A (0.25 to 700 Ω secondary) 1 A	23.0	115	0.01

Table 8.47 Out-of-Step Tripping/Blocking (Sheet 2 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
R1R6	Zone 6 Resistance—Right (0.05 to 140 Ω secondary) 5 A (0.25 to 700 Ω secondary) 1 A	21.0	105	0.01
X1B7[a]	Zone 7 Reactance—Bottom (–0.05 to –140 Ω secondary) 5 A (–0.25 to –700 Ω secondary) 1 A	–23.0	–115	0.01
X1B6[a]	Zone 6 Reactance—Bottom (–0.05 to –140 Ω secondary) 5 A (–0.25 to –700 Ω secondary) 1 A	–21.0	–105	0.01
R1L7[a]	Zone 7 Resistance—Left (–0.05 to –140 Ω secondary) 5 A (–0.25 to –700 Ω secondary) 1 A	–23.0	–115	0.01
R1L6[a]	Zone 6 Resistance—Left (–0.05 to –140 Ω secondary) 5 A (–0.25 to –700 Ω secondary) 1 A	–21.0	–105	0.01
50ABCP[a]	Positive-Sequence Current Supervision (1.00–100 A secondary) 5 A (0.20–20 A secondary) 1 A	1	0.2	0.01
50QUBP[a]	Negative-Sequence Current Supervision (OFF, 0.50–100 A secondary) 5 A (OFF, 0.10–20 A secondary) 1 A	OFF	OFF	0.01
UBD[a]	Negative-Sequence Current Unblock Delay (0.500–120 cycles)	0.500	0.500	0.125
UBOSBF[a]	Out-of-Step Angle Unblock Rate (1–10)	4	4	1
OOSPSC	Number of Pole Slips Before Tripping (1-10)	1	1	1

[a] Setting only available when Group setting EADVS := Y.

Make *Table 8.48* settings when Group setting ELOAD := Y.

Table 8.48 Load Encroachment

Setting	Prompt	Default Value		Increment
		5 A	1 A	
ZLF	Forward Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.1	0.01
ZLR	Reverse Load Impedance (0.05–64 Ω secondary) 5 A (0.25–320 Ω secondary) 1 A	9.22	46.1	0.01
PLAF	Forward Load Positive Angle (–90 to +90 degrees)	30.0	30.0	0.1
NLAF	Forward Load Negative Angle (–90 to +90 degrees)	–30.0	–30.0	0.1
PLAR	Reverse Load Positive Angle (+90 to +270 degrees)	150.0	150.0	0.1
NLAR	Reverse Load Negative Angle (+90 to +270 degrees)	210.0	210.0	0.1

The number of pickup settings in *Table 8.49* is dependent on Group setting E50P := 1–4. When E50P := N, no settings are made for *Table 8.49* through *Table 8.51*.

Table 8.49 Phase Instantaneous Overcurrent Pickup

Setting	Prompt	Default Value		Increment
		5 A	1 A	
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	10.0	2	0.01
50P2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50P3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50P4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01

Make corresponding zone *n* = 1–4 settings in *Table 8.50* and *Table 8.51* for any 50P*n*P settings that are made in *Table 8.49*.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.50 Phase Definite-Time Overcurrent Time Delay

Setting	Prompt	Default Value	Increment
67P1D	Level 1 Time Delay (0.000–16000 cycles)	0.000	0.125
67P2D	Level 2 Time Delay (0.000–16000 cycles)	0.000	0.125
67P3D	Level 3 Time Delay (0.000–16000 cycles)	0.000	0.125
67P4D	Level 4 Time Delay (0.000–16000 cycles)	0.000	0.125

Table 8.51 Phase Instantaneous Definite-Time Overcurrent Torque Control[a]

Setting	Prompt	Default Value
67P1TC	Level 1 Torque Control (SELOGIC Equation)	1
67P2TC	Level 2 Torque Control (SELOGIC Equation)	1
67P3TC	Level 3 Torque Control (SELOGIC Equation)	1
67P4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 8.52* is dependent on Group setting E50G := 1–4. When E50G := N, no settings are made for *Table 8.52* through *Table 8.54*.

Table 8.52 Residual Ground Instantaneous Overcurrent Pickup

Setting	Prompt	Default Value		Increment
		5 A	1 A	
50G1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50G2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50G3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50G4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01

Make corresponding zone *n* = 1–4 settings in *Table 8.53* and *Table 8.54* for any 50G*n*P settings that are made in *Table 8.52*.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.53 Residual Ground Definite-Time Overcurrent Time Delay

Setting	Prompt	Default Value	Increment
67G1D	Level 1 Time Delay (0.000–16000 cycles)	0.000	0.125
67G2D	Level 2 Time Delay (0.000–16000 cycles)	0.000	0.125
67G3D	Level 3 Time Delay (0.000–16000 cycles)	0.000	0.125
67G4D	Level 4 Time Delay (0.000–16000 cycles)	0.000	0.125

Table 8.54 Residual Ground Instantaneous Definite-Time Overcurrent Torque Control[a]

Setting	Prompt	Default Value
67G1TC	Level 1 Torque Control (SELOGIC Equation)	1
67G2TC	Level 2 Torque Control (SELOGIC Equation)	1
67G3TC	Level 3 Torque Control (SELOGIC Equation)	1
67G4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

The number of pickup settings in *Table 8.55* is dependent on Group setting E50Q := 1–4. When E50Q := N, no settings are made for *Table 8.55* through *Table 8.57*.

Table 8.55 Negative-Sequence Instantaneous Overcurrent Pickup

Setting	Prompt	Default Value		Increment
		5 A	1 A	
50Q1P	Level 1 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50Q2P	Level 2 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50Q3P	Level 3 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01
50Q4P	Level 4 Pickup (OFF, 0.25–100 A secondary) 5 A (OFF, 0.05–20 A secondary) 1 A	OFF	OFF	0.01

Make corresponding zone *n* = 1–4 settings in *Table 8.56* and *Table 8.57* for any 50Q*n*P settings that are made in *Table 8.55*.

Table 8.56 Negative-Sequence Definite-Time Overcurrent Time Delay

Setting	Prompt	Default Value	Increment
67Q1D	Level 1 Time Delay (0.000–16000 cycles)	0.000	0.125
67Q2D	Level 2 Time Delay (0.000–16000 cycles)	0.000	0.125
67Q3D	Level 3 Time Delay (0.000–16000 cycles)	0.000	0.125
67Q4D	Level 4 Time Delay (0.000–16000 cycles)	0.000	0.125

Table 8.57 Negative-Sequence Instantaneous Definite-Time Overcurrent Torque Control[a]

Setting	Prompt	Default Value
67Q1TC	Level 1 Torque Control (SELOGIC Equation)	1
67Q2TC	Level 2 Torque Control (SELOGIC Equation)	1
67Q3TC	Level 3 Torque Control (SELOGIC Equation)	1
67Q4TC	Level 4 Torque Control (SELOGIC Equation)	1

[a] These settings cannot be set to NA or to logical 0.

Make *Table 8.58* settings if Group setting E51S := 1–3.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.58 Selectable Operating Quantity Inverse Time Overcurrent Element 1 (Sheet 1 of 2)

Setting	Prompt	Default Value	
		5 A	1 A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I0L	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	0.75	0.15

Table 8.58 Selectable Operating Quantity Inverse Time Overcurrent Element 1 (Sheet 2 of 2)

Setting	Prompt	Default Value	
		5 A	1 A
51S1C	51S1 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S1TD	51S1 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.0	1.0
51S1RS	51S1 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S1TC[b]	51S1 Torque Control (SELOGIC Equation)	32GF	32GF

[a] Parameter *n* = L for line, 1 for BK1, and 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 8.59* settings if Group setting E51S := 2 or 3.

Table 8.59 Selectable Operating Quantity Inverse Time Overcurrent Element 2

Setting	Prompt	Default Value	
		5 A	1 A
51S2O	51S2 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	3I2L	3I2L
51S2P	51S2 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00
51S2C	51S2 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S2TD	51S2 Inverse Time Overcurrent Time Dial (0.50–15.00) (0.05–1.00) IEC	1.0	1.0
51S2RS	51S2 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S2TC[b]	51S2 Torque Control (SELOGIC Equation)	32QF	32QF

[a] Parameter *n* = L for line, 1 for BK1, 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 8.60* settings if Group setting E51S := 3.

Table 8.60 Selectable Operating Quantity Inverse Time Overcurrent Element 3 (Sheet 1 of 2)

Setting	Prompt	Default Value	
		5 A	1 A
51S3O	51S3 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, I1L, 3I2L, 3I0*n*)[a]	IMAXL	IMAXL
51S3P	51S3 Overcurrent Pickup (0.25–16 A secondary) 5 A (0.05–3.2 A secondary) 1 A	5.00	1.00

Table 8.60 Selectable Operating Quantity Inverse Time Overcurrent Element 3 (Sheet 2 of 2)

Setting	Prompt	Default Value	
		5 A	1 A
51S3C	51S3 Inverse Time Overcurrent Curve (U1–U5) US (C1–C5) IEC	U3	U3
51S3TD	51S3 Inverse Time Overcurrent Time Dial (0.50–15.00) US (0.05–1.00) IEC	1.0	1.0
51S3RS	51S3 Inverse Time Overcurrent Electromagnetic Reset (Y, N)	N	N
51S3TC[b]	51S3 Torque Control (SELOGIC Equation)	Z2P	Z2P

[a] Parameter *n* = L for line, 1 for BK1, 2 for BK2.
[b] This setting cannot be set to NA or to logical 0.

Make *Table 8.61* settings if E81 is not N.

Table 8.61 81 Elements

Setting	Prompt	Default Value
81UVSP	81 Element Under Voltage Supervision (20.00–200 V, sec)	85
81D*n*P[a]	Level *n* Pickup (40.01–69.99 Hz)	61
81D*n*D[a]	Level *n* Time Delay (0.04–400 s)	2

[a] Where *n* is 1-E81.

Make *Table 8.62* settings if E27 is not set to N.

Table 8.62 Under Voltage (27) Element *e*[a]

Setting	Prompt	Default Value
27O*e*	Under Voltage *e* Operating Quantity	V1F1M
27P*e*P1	Under Voltage *e* Level 1 Pickup (2.00–300 V, sec)	20
27TC*e*	Under Voltage *e* Torque Control (SELOGIC Equation)	1
27P*e*D1	Under Voltage *e* Level 1 Delay (0.00–16000 cycles)	10
27P*e*P2	Under Voltage *e* Level 2 Pickup (2.00–300 V, sec)	15

[a] Where *e* is 1-E27.

Make *Table 8.63* settings if E27 is not set to N.

Table 8.63 Over Voltage (59) Element *e*[a]

Setting	Prompt	Default Value
59O*e*	Over Voltage *e* Operating Quantity	V1F1M
59P*e*P1	Over Voltage *e* Level 1 Pickup (2.00–300 V, sec)	76
59TC*e*	Over Voltage *e* Torque Control (SELOGIC Equation)	1
59P*e*D1	Over Voltage *e* Level 1 Delay (0.00–16000 cycles)	10
59P*e*P2	Over Voltage *e* Level 2 Pickup (2.00–300 V, sec)	80

[a] Where *e* is 1-E59.

Make *Table 8.64* settings if any of the Group settings E21P, E21G, E21XG, E50P, E50G or E50Q := 3, 4, or 5.

Table 8.64 Zone/Level Direction

Setting	Prompt	Default Value
DIR3	Zone/Level 3 Directional Control (F, R)	R
DIR4	Zone/Level 4 Directional Control (F, R)	F
DIR5	Zone/Level 5 Directional Control (F, R)	F

Table 8.65 Directional Control Element

Setting	Prompt	Default Value		Increment
		5 A	1 A	
ORDER	Ground Directional Element Priority (combine Q, V, I)	QV	QV	
50FP[a]	Forward Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.50	0.10	0.01
50RP[a]	Reverse Directional Overcurrent Pickup (0.25–5 A secondary) 5 A (0.05–1 A secondary) 1 A	0.25	0.05	0.01
Z2F[a]	Forward Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	–0.30	–1.50	0.01
Z2R[a]	Reverse Directional Z2 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	0.30	1.50	0.01
a2[a]	Positive-Sequence Restraint Factor, I2/I1 (0.02–0.50)	0.10	0.10	0.01
k2[a]	Zero-Sequence Restraint Factor, I2/I0 (0.10–1.20)	0.20	0.20	0.01
Z0F[a]	Forward Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	–0.30	–1.50	0.01
Z0R[a]	Reverse Directional Z0 Threshold (–64.00 to +64.00 Ω secondary) 5 A (–320.00 to +320.00 Ω secondary) 1 A	0.30	1.50	0.01
a0[a]	Positive-Sequence Restraint Factor, I0/I1 (0.02–0.5)	0.10	0.10	0.01
E32IV	Zero-Sequence Voltage and Current Enable (SELOGIC Equation)	1	1	

[a] Setting only available when Group setting E32 := Y. Setting automatically calculated when E32 := AUTO or AUTO2.

Table 8.66 Pole-Open Detection

Setting	Prompt	Default Value	Increment
EPO	Pole Open Detection (52, V)	52	
27PO	Undervoltage Pole Open Threshold (1–200 V)	40	1
SPOD	Single Pole Open Dropout Delay (0.000–60 cycles)	0.500	0.125
3POD	Three Pole Open Dropout Delay (0.000–60 cycles)	0.500	0.125

Make *Table 8.67* settings if Group setting ECOMM := POTT, POTT2, POTT3, DCUB1, or DCUB2. Some settings are not required for every mode (see *Table 5.70 on page 5.123*, *Table 5.72 on page 5.127*, and *Table 5.74 on page 5.134* for details).

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.67 POTT Trip Scheme

Setting	Prompt	Default Value	Increment
Z3RBD	Zone 3 Reverse Block Time Delay (0.000–16000 cycles)	5.000	0.125
EBLKD	Echo Block Time Delay (OFF, 0.000–16000 cycles)	10.000	0.125
ETDPU	Echo Time Delay Pickup (OFF, 0.000–16000 cycles)	2.000	0.125
EDURD	Echo Duration Time Delay (0.000–16000 cycles)	4.000	0.125
EWFC	Weak Infeed Trip (Y, N, SP)	N	
27PWI	Weak Infeed Phase Undervoltage Pickup (1.0–200 V secondary)	47	0.1
27PPW	Weak Infeed Phase-to-Phase Undervoltage Pickup (1.0–300 V secondary)	80	0.1
59NW	Weak Infeed Zero-Sequence Overvoltage Pickup (1.0–200 V secondary)	5	0.1
PT1	General Permissive Trip Received (SELOGIC Equation)	IN102 AND PLT02	
PT3	Three-Pole Permissive Trip Received (SELOGIC Equation)	NA	
PTA	A-Phase Permissive Trip Received (SELOGIC Equation)	NA	
PTB	B-Phase Permissive Trip Received (SELOGIC Equation)	NA	
PTC	C-Phase Permissive Trip Received (SELOGIC Equation)	NA	
EPTDIR	Enable Directional Element Permissive Trip (Y, N)	N	
PTDIR	Dir. Ele. Permissive Trip Recvd (SELOGIC Equation)	NA	
COMZDTC	Dir. Ele. Comm.-Assisted Trip Enable (SELOGIC Equation)	NA	

Make *Table 8.68* settings if Group setting ECOMM := DCUB1 or DCUB2.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay coordination times to account for this added delay.

Table 8.68 DCUB Trip Scheme

Setting	Prompt	Default Value	Increment
GARD1D	Guard Present Security Delay (0.000–16000 cycles)	120.000	0.125
UBDURD	DCUB Disabling Time Delay (0.000–16000 cycles)	180.000	0.125
UBEND	DCUB Duration Time Delay (0.000–16000 cycles)	20.000	0.125
PT2	Channel 2 Permissive Trip Received (SELOGIC Equation)	NA	
LOG1	Channel 1 Loss-of-Guard (SELOGIC Equation)	NA	
LOG2	Channel 2 Loss-of-Guard (SELOGIC Equation)	NA	

Make *Table 8.69* settings if Group setting ECOMM := DCB.

Table 8.69 DCB Trip Scheme

Setting	Prompt	Default Value	Increment
Z3XPU	Zone 3 Reverse Pickup Time Delay (0.000–16000 cycles)	1.000	0.125
Z3XD	Zone 3 Reverse Dropout Delay (0.000–16000 cycles)	6.000	0.125
BTXD	Block Trip Receive Extension Time (0.000–16000 cycles)	1.000	0.125
21SD	Zone 2 Distance Short Delay (0.000–16000 cycles)	2.000	0.125
67SD	Level 2 Overcurrent Short Delay (0.000–16000 cycles)	2.000	0.125
BT	Block Trip Received (SELOGIC Equation)	NA	

Make *Table 8.70* settings if Group settings EBFL1 := 1, 2, Y1, or Y2; or EBFL2 := 1, 2, Y1, or Y2.

Table 8.70 Breaker 1 Failure Logic (and Breaker 2 Failure Logic[a]) (Sheet 1 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
50FP1	Phase Fault Current Pickup—BK1 (0.50–50 A secondary) 5 A (0.10–10 A secondary) 1 A	6.00	1.20	0.01
BFPU1	Breaker Failure Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000	0.125
SPBFPU1[b]	SPT Breaker Fail. Time Delay—BK1 (0.000–6000 cycles)	6.000	6.000	0.125
RTPU1	Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000	3.000	0.125
RT3PPU1[b]	Three-Pole Retrip Time Delay—BK1 (0.000–6000 cycles)	3.000	3.000	0.125
BFI3P1	Three-Pole Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA	
BFIA1	A-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA	
BFIB1	B-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA	
BFIC1	C-Phase Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA	
BFIDO1	Breaker Fail Initiate Dropout Delay—BK1 (0.000–1000 cycles)	1.500	1.500	0.125
BFISP1	Brkr Fail Init Seal-in Delay—BK1 (0.000–1000 cycles)	2.000	2.000	0.125
ENCBF1	No Current/Residual Current Logic—BK1 (Y, N)	N	N	
50RP1	Residual Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	1.00	0.20	0.01
NPU1	No Current Brkr Fail. Delay—BK1 (0.000–6000 cycles)	12.000	12.000	0.125
BFIN1	No Current Breaker Failure Initiate—BK1 (SELOGIC Equation)	NA	NA	
ELCBF1	Load Current Breaker Failure Logic—BK1 (Y, N)	N	N	
50LP1	Phase Load Current Pickup—BK (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10	0.01
LCPU1	Load Pickup Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000	0.125
BFILC1	Breaker Failure Load Current Initiate—BK1 (SELOGIC Equation)	NA	NA	
EFOBF1	Flashover Breaker Failure Logic—BK1 (Y, N)	N	N	
50FO1	Flashover Current Pickup—BK1 (0.25–50 A secondary) 5 A (0.05–10 A secondary) 1 A	0.50	0.10	0.01

Table 8.70 Breaker 1 Failure Logic (and Breaker 2 Failure Logic[a]) (Sheet 2 of 2)

Setting	Prompt	Default Value		Increment
		5 A	1 A	
FOPU1	Flashover Time Delay—BK1 (0.000–6000 cycles)	9.000	9.000	0.125
BLKFOA1	Block A-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA	
BLKFOB1	Block B-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA	
BLKFOC1	Block C-Phase Flashover—BK1 (SELOGIC Equation)	NA	NA	
BFTR1	Breaker Failure Trip—BK1 (SELOGIC Equation)	NA	NA	
BFULTR1	Breaker Failure Unlatch Trip—BK1 (SELOGIC Equation)	NA	NA	

[a] Replace 1 with 2 in the setting for Breaker 2.
[b] Setting only available when EBFL1 := 2, Y2 or EBFL2 := 2, Y2.

Make *Table 8.71* settings if Group settings E25BK1 := Y or E25BK2 := Y.

Table 8.71 Synchronism-Check Element Reference

Setting	Prompt	Default Value	Increment
SYNCP	Synchronism Reference (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAY	
25VL	Voltage Window Low Threshold (20.0–200 V secondary)	55.0	0.1
25VH	Voltage Window High Threshold (20.0–200 V secondary)	70.0	0.1

Make *Table 8.72* settings if Group setting E25BK1 := Y.

NOTE: If the relay is using a remote data acquisition system, such as TiDL, the operating times will be delayed by 1.5 ms. Use caution when setting the relay for synchronism check to account for this added delay

Table 8.72 Breaker 1 Synchronism Check

Setting	Prompt	Default Value	Increment
SYNCS1	Synchronism Source 1 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VAZ	
KS1M	Synchronism Source 1 Ratio Factor (0.10–3)	1.00	0.01
KS1A	Synchronism Source 1 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0	30
25SFBK1	Maximum Slip Frequency—BK1 (OFF, 0.005–0.5 Hz)	0.050	0.001
ANG1BK1	Maximum Angle Difference 1—BK1 (3.0–80 degrees)	10.0	0.1
ANG2BK1	Maximum Angle Difference 2—BK1 (3.0–80 degrees)	10.0	0.1
TCLSBK1	Breaker 1 Close Time (1.00–30 cycles)[a]	8.00	0.25
BSYNBK1	Block Synchronism Check—BK1(SELOGIC Equation)	NA	

[a] Adjust setting TCLSBK1 in 0.25-cycle steps.

Make *Table 8.73* settings if Group setting E25BK2 := Y.

Table 8.73 Breaker 2 Synchronism Check (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
SYNCS2	Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VBZ	
KS2M	Synchronism Source 2 Ratio Factor (0.10–3)	1.00	0.01
KS2A	Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0	30

Table 8.73 Breaker 2 Synchronism Check (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
ALTS2	Alternative Synchronism Source 2 (SELOGIC Equation)	NA	
ASYNCS2	Alternative Synchronism Source 2 (VAY, VBY, VCY, VAZ, VBZ, VCZ)	VCZ	
AKS2M	Alternative Synchronism Source 2 Ratio Factor (0.10–3)	1.00	0.01
AKS2A	Alternative Synchronism Source 2 Angle Shift (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 degrees)	0	30
25SFBK2	Maximum Slip Frequency—BK2 (OFF, 0.005–0.5 Hz)	0.050	0.001
ANG1BK2	Maximum Angle Difference 1—BK2 (3.0–80 degrees)	10.0	0.1
ANG2BK2	Maximum Angle Difference 2—BK2 (3.0–80 degrees)	10.0	0.1
TCLSBK2	Breaker 2 Close Time (1.00–30 cycles)[a]	8.00	0.25
BSYNBK2	Block Synchronism Check—BK2 (SELOGIC Equation)	NA	

[a] Adjust setting TCLSBK2 in 0.25-cycle steps.

Make *Table 8.74* through *Table 8.76* settings if Group settings E79 := Y or Y1 or EMANCL := Y. The number of settings also depends on the Global settings NUMBK := 1 or 2, BK1TYP := 1 or 3, and BK2TYP := 1 or 3.

Table 8.74 Recloser and Manual Closing[a] (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
NSPSHOT	Number of Single-Pole Reclosures (N, 1, 2)	N	
ESPR1	Single-Pole Reclose Enable—BK1 (SELOGIC Equation)	NA	
ESPR2	Single-Pole Reclose Enable—BK2 (SELOGIC Equation)	NA	
N3PSHOT	Number of Three-Pole Reclosures (N, 1–4)	2	
E3PR1	Three-Pole Reclose Enable—BK1 (SELOGIC Equation)	PLT06	
E3PR2	Three-Pole Reclose Enable—BK2 (SELOGIC Equation)	PLT06	
TBBKD	Time Between Breakers for Automatic Reclose (1–99999 cycles)	300	1
BKCFD	Breaker Close Failure Delay (OFF, 1–99999 cycles)	300	1
SLBK1	Lead Breaker = Breaker 1 (SELOGIC Equation)	1	
SLBK2	Lead Breaker = Breaker 2 (SELOGIC Equation)	NA	
FBKCEN	Follower Breaker Closing Enable (SELOGIC Equation)	1	
ULCL1	Unlatch Closing for Breaker 1 (SELOGIC Equation)	52AA1 AND 52AB1 AND 52AC1	
ULCL2	Unlatch Closing for Breaker 2 (SELOGIC Equation)	52AA2 AND 52AB2 AND 52AC2	
79DTL	Recloser Drive to Lockout (SELOGIC Equation)	NA	
79BRCT	Block Reclaim Timer (SELOGIC Equation)	NA	

Table 8.74 Recloser and Manual Closing[a] (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
BK1MCL	Breaker 1 Manual Close (SELOGIC Equation)		
	8 pushbuttons	(CC1 OR PB7_PUL) AND PLT04	
	12 pushbuttons	(CC1 OR PB11PUL) AND PLT04	
	12 pushbuttons and auxiliary TRIP/CLOSE push-buttons	CC1 AND PLT04	
BK2MCL	Breaker 2 Manual Close (SELOGIC Equation)	NA	
3PMRCD	Manual Close Reclaim Time Delay (1–99999 cycles)	900	1
BK1CLSD	BK1 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200	1
BK2CLSD	BK2 Reclose Supervision Delay (OFF, 1–99999 cycles)	7200	1

[a] Adjust all timers in 1-cycle steps.

Table 8.75 Single-Pole Reclose Settings

Setting[a]	Prompt	Default Value	Increment
SPOISC	Single-Pole Open Interval Supervision (SELOGIC Equation)[b]	1	
SPOISD	Single-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1	1
SPOID	Single-Pole Open Interval Delay (1–99999 cycles)	60	1
SPRCD	Single-Pole Reclaim Time Delay (1–99999 cycles)	900	1
SPRI	Single-Pole Reclose Initiation (SELOGIC Equation)	SPT	
SP1CLS	Single-Pole BK1 Reclose Supervision (SELOGIC Equation)[b]	1	
SP2CLS	Single-Pole BK2 Reclose Supervision (SELOGIC Equation)[b]	1	

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.

Table 8.76 Three-Pole Reclose Settings[a] (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
3PRIH	Three-Pole Reclose Open Failure Delay (OFF, 1–99999)	15	1
3POISC	Three-Pole Open Interval Supervision (SELOGIC Equation)[b]	1	
3POISD	Three-Pole Open Interval Supervision Delay (OFF, 1–99999 cycles)	1	1
3POID1	Three-Pole Open Interval 1 Delay (1–99999 cycles)	180	1
3POID2	Three-Pole Open Interval 2 Delay (1–99999 cycles)	180	1
3POID3	Three-Pole Open Interval 3 Delay (1–99999 cycles)	180	1
3POID4	Three-Pole Open Interval 4 Delay (1–99999 cycles)	180	1

Table 8.76 Three-Pole Reclose Settings[a] (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
3PFARC	Three-Pole Fast Automatic Reclose Enable (SELOGIC Equation)	NA	
3PFOID	Three-Pole Fast Open Interval Delay (1–99999 cycles)	60	1
3PRCD	Three-Pole Reclaim Time Delay (1–99999 cycles)	900	1
3PRI	Three-Pole Reclose Initiation (SELOGIC Equation)	3PT AND NOT (M2PT OR Z2GT OR M3PT OR Z3GT OR SOTFT)	
79SKP	Skip Reclosing Shot (SELOGIC Equation)	NA	
3P1CLS	Three-Pole BK 1 Reclose Supervision (SELOGIC Equation)[b]	1	
3P2CLS	Three-Pole BK 2 Reclose Supervision (SELOGIC Equation)[b]	1	

[a] Adjust all timers in 1-cycle steps.
[b] These settings cannot be set to NA or to logical 0.

Make *Table 8.77* settings if Group settings E79 := Y or Y1 or EMANCL := Y.

Table 8.77 Voltage Elements

Setting	Prompt	Default Value	Increment
EVCK	Reclosing Voltage Check (Y, N)	N	
27LP	Dead Line Voltage (1.0–200 V secondary)	14.0	0.1
59LP	Live Line Voltage (1.0–200 V secondary)	53.0	0.1
27BK1P	Breaker 1 Dead Busbar Voltage (1.0–200 V secondary)	14.0	0.1
59BK1P	Breaker 1 Live Busbar Voltage (1.0–200 V secondary)	53.0	0.1
27BK2P	Breaker 2 Dead Busbar Voltage (1.0–200 V secondary)	14.0	0.1
59BK2P	Breaker 2 Live Busbar Voltage (1.0–200 V secondary)	53.0	0.1

Make *Table 8.78* settings if Group setting EDEM := THM or ROL.

Table 8.78 Demand Metering

Setting	Prompt	Default Value		Increment
		5 A	1 A	
DMTC	Demand Metering Time Constant (5, 10, . . . , 300 minutes)	15	15	5
PDEMP	Phase Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF	0.01
GDEMP	Residual Ground Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF	0.01
QDEMP	Negative-Sequence Current Pickup (OFF, 0.50–16 A secondary) 5 A (OFF, 0.10–3.2 A secondary) 1 A	OFF	OFF	0.01

If a port is configured for MBGA or MBGB communications and the corresponding group setting EMBA or EMBB is enabled, then use the settings shown in *Table 8.79*.

Table 8.79 MIRRORED BITS Communications Settings

Setting	Prompt	Default
TX_IDA	MIRRORED BITS ID of This Device (1-4)	2
RX_IDA	MIRRORED BITS ID of Device Receiving From (1-4)	1
TX_IDB	MIRRORED BITS ID of This Device (1-4)	2
RX_IDB	MIRRORED BITS ID of Device Receiving From (1-4)	1
TMB*m*A[a]	Transmit MIRRORED BITS (SELOGIC Equation)	NA
RMB*m*A[a]	Transmit MIRRORED BITS (SELOGIC Equation)	NA

[a] Where *m* is 1-8.

Table 8.80 Trip Logic (Sheet 1 of 2)

Setting	Prompt	Default Value	Increment
TR	Trip (SELOGIC Equation)	Z1P OR Z1G OR M2PT OR Z2GT	
TRCOMM	Communications-Assisted Trip (SELOGIC Equation)	(Z2P OR Z2G) AND PLT02	
TRCOMMD	Directional Element Communications-Assisted Trip (SELOGIC Equation)	NA	
TRSOTF	Switch-Onto-Fault Trip (SELOGIC Equation)	50P1 OR Z2P OR Z2G	
DTA	Direct Transfer Trip A-Phase (SELOGIC Equation)	NA	
DTB	Direct Transfer Trip B-Phase (SELOGIC Equation)	NA	
DTC	Direct Transfer Trip C-Phase (SELOGIC Equation)	NA	
BK1MTR	Breaker 1 Manual Trip—BK1 (SELOGIC Equation)		
	8 pushbuttons	OC1 OR PB8_PUL	
	12 pushbuttons	OC1 OR PB12PUL	
	12 pushbuttons and auxiliary TRIP/CLOSE pushbuttons	OC1	
BK2MTR	Breaker 2 Manual Trip—BK2 (SELOGIC Equation)	NA	
ULTR	Unlatch Trip (SELOGIC Equation)	TRGTR	
ULMTR1	Unlatch Manual Trip—BK1 (SELOGIC Equation)	NOT (52AA1 AND 52AB1 AND 52AC1)	
ULMTR2	Unlatch Manual Trip—BK2 (SELOGIC Equation)	1	
TOPD	Trip During Open Pole Time Delay (2.000–8000 cycles)	2.000	0.125
TULO	Trip Unlatch Option (1, 2, 3, 4)	3	
Z2GTSP	Zone 2 Ground Distance Time Delay for Single-Pole Tripping (Y, N)	N	
67QGSP	Zone 2 Directional Negative-Sequence/Residual Overcurrent Single-Pole Trip (Y, N)	N	
TDUR1D	Single-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	6.000	0.125
TDUR3D	Three-Pole Trip Minimum Trip Duration Time Delay (2.000–8000 cycles)	12.000	0.125
E3PT	Three-Pole Trip Enable (SELOGIC Equation)	1	
E3PT1	Breaker 1 Three-Pole Trip (SELOGIC Equation)	1	

Table 8.80 Trip Logic (Sheet 2 of 2)

Setting	Prompt	Default Value	Increment
E3PT2	Breaker 2 Three-Pole Trip (SELOGIC Equation)	1	
ER	Event Report Trigger Equation (SELOGIC Equation)	R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S1 OR R_TRIG Z3P OR R_TRIG Z3G	

Protection Freeform SELOGIC Control Equations

Protection freeform SELOGIC control equations are in classes 1 through 6 corresponding to settings Groups 1 through Group 6 (see *Multiple Setting Groups on page 12.4 in the SEL-400 Series Relays Instruction Manual*).

Table 8.81 only shows the factory-default protection freeform SELOGIC control equations. Up to 250 lines of freeform equations may be entered in each of six settings groups, although the actual maximum capacity may be less. See *SELOGIC Control Equation Capacity on page 13.5 in the SEL-400 Series Relays Instruction Manual* for more information.

Table 8.81 Protection Freeform SELOGIC Control Equations

Setting	Default Value
PLT02S	PB2_PUL AND NOT PLT02 # COMM SCHEME ENABLED
PLT02R	PB2_PUL AND PLT02
PLT04S	PB4_PUL AND NOT PLT04 # RELAY TEST MODE
PLT04R	PB4_PUL AND PLT04
PLT05S	PB5_PUL AND NOT PLT05 # MANUAL CLOSE ENABLED
PLT05R	PB5_PUL AND PLT05
PLT06S	PB6_PUL AND NOT PLT06 # RECLOSE ENABLED
PLT06R	PB6_PUL AND PLT06

Automation Freeform SELOGIC Control Equations

See *Automation Freeform SELOGIC Control Equations on page 12.21 in the SEL-400 Series Relays Instruction Manual* for a description of automation SELOGIC control equations. The SEL-421-4 supports a single block of 100 lines; the SEL-421-5 supports 10 blocks of 100 lines.

Notes Settings

Use the Notes settings like a text pad to leave notes about the relay in Notes area of the relay. See *Notes Settings on page 12.24 in the SEL-400 Series Relays Instruction Manual* for additional information on Notes settings.

Output Settings

Output Settings on page 12.22 in the SEL-400 Series Relays Instruction Manual contains a description of the relay's output settings. This subsection describes SEL-421-specific default values.

Table 8.82 Main Board Default Values

Setting	Default Value
OUT101	(3PT OR TPA1) AND NOT PLT04 #THREE POLE TRIP
OUT102	(3PT OR TPA1) AND NOT PLT04 #THREE POLE TRIP
OUT103	BK1CL AND NOT PLT04#BREAKER CLOSE COMMAND
OUT104	KEY AND PLT02 AND NOT PLT04#KEY TX
OUT105	NA
OUT106	NA
OUT107	PLT04 #RELAY TEST MODE
OUT108	NOT (SALARM OR HALARM)

All Interface Board output SELOGIC equations default to NA.

Front-Panel Settings

See *Front-Panel Settings on page 12.15 in the SEL-400 Series Relays Instruction Manual* for a complete description of front-panel settings. This subsection lists the SEL-421-specific default settings values.

Table 8.83 Front-Panel Settings Defaults (Sheet 1 of 4)

Setting	Default Value
FP_TO	15
EN_LEDC	G
TR_LEDC	R
PB1_LED	NOT E3PT #SPT ENABLED
PB1_COL	AO
PB2_LED	PLT02 #COMM SCHEME ENABLED
PB2_COL	AO
PB3_LED	NOT SG1 #ALT SETTINGS
PB3_COL	AO
PB4_LED	PLT04 #RELAY TEST MODE
PB4_COL	AO
PB5_LED	PLT05 #MANUAL CLOSE ENABLED
PB5_COL	AO
PB6_LED	PLT06 #RECLOSE ENABLED
PB6_COL	AO
PB7_LED	52ACL1 AND 52AB1 AND 52AC1 #BREAKER CLOSED (8 Pushbuttons) 0#AUX (12 Pushbuttons)
PB7_COL	AO

Table 8.83 Front-Panel Settings Defaults (Sheet 2 of 4)

Setting	Default Value
PB8_LED	NOT (52ACL1 AND 52AB1 AND 52AC1) #BREAKER OPEN (8 Pushbuttons) 0#AUX (12 Pushbuttons)
PB8_COL	AO
PB9_LED[a]	0 #AUX
PB9_COL[a]	AO
PB10LED[a]	0 #AUX
PB10COL[a]	AO
PB11LED[a]	52ACL1 AND 52AB1 AND 52AC1 #BREAKER CLOSED 0 #AUX (Auxiliary TRIP/CLOSE Pushbuttons)
PB11COL[a]	AO
PB12LED[a]	NOT (52ACL1 AND 52AB1 AND 52AC1) #BREAKER OPEN 0 #AUX (Auxiliary TRIP/CLOSE Pushbuttons)
PB12COL[a]	AO
T1_LED	(Z1P OR Z1G) AND NOT (SOTFT OR TLED_3)
T1LEDL	Y
T1LEDC	RO
T2_LED	(Z2PT OR Z2GT OR Z3PT OR Z3GT OR Z4PT OR Z4GT) AND NOT (TLED_1 OR TLED_3 OR TLED_4)
T2LEDL	Y
T2LEDC	RO
T3_LED	COMPRM AND NOT (Z1P OR Z1G OR TLED_1 OR SOTFT)
T3LEDL	Y
T3LEDC	RO
T4_LED	SOTFT
T4LEDL	Y
T4LEDC	RO
T5_LED	(Z1P OR Z1G) AND NOT (TLED_6 OR TLED_7 OR TLED_8)
T5LEDL	Y
T5LEDC	RO
T6_LED	(Z2P OR Z2G) AND NOT (Z1P OR Z1G OR TLED_5)
T6LEDL	Y
T6LEDC	RO
T7_LED	(Z3P OR Z3G) AND NOT (Z1P OR Z2P OR Z1G OR Z2G OR TLED_5 OR TLED_6)
T7LEDL	Y
T7LEDC	RO
T8_LED	(Z4P OR Z4G) AND NOT (Z1P OR Z2P OR Z3P OR Z1G OR Z2G OR Z3G OR TLED_5 OR TLED_6 OR TLED_7)
T8LEDL	Y
T8LEDC	RO
T9_LED	PHASE_A
T9LEDL	Y
T9LEDC	RO

Table 8.83 Front-Panel Settings Defaults (Sheet 3 of 4)

Setting	Default Value
T10_LED	PHASE_B
T10LEDL	Y
T10LEDC	RO
T11_LED	PHASE_C
T11LEDL	Y
T11LEDC	RO
T12_LED	GROUND
T12LEDL	Y
T12LEDC	RO
T13_LED	50P1 OR 50P2 OR 50P3 OR 50P4 OR 50Q1 OR 50Q2 OR 50Q3 OR 50Q4 OR 50G1 OR 50G2 OR 50G3 OR 50G4
T13LEDL	Y
T13LEDC	RO
T14_LED	51S1T OR 51S2T OR 51S3T
T14LEDL	Y
T14LEDC	RO
T15_LED	BK1RS
T15LEDL	N
T15LEDC	RO
T16_LED	BK1LO
T16LEDL	N
T16LEDC	RO
T17_LED[b]	79CY1 OR 79CY3
T17LEDL[b]	N
T17LEDC[b]	RO
T18_LED[b]	25A1BK1
T18LEDL[b]	N
T18LEDC[b]	RO
T19_LED[b]	BK1CL
T19LEDL[b]	N
T19LEDC[b]	RO
T20_LED[b]	BFTRIP1
T20LEDL[b]	N
T20LEDC[b]	RO
T21_LED[b]	OSB
T21LEDL[b]	N
T21LEDC[b]	RO
T22_LED[b]	LOP
T22LEDL[b]	N
T22LEDC[b]	RO
T23_LED[b]	PMDOK AND TSOK

Table 8.83 Front-Panel Settings Defaults (Sheet 4 of 4)

Setting	Default Value
T23LEDL[b]	N
T23LEDC[b]	RO
T24_LED[b]	TIRIG
T24LEDL[b]	N
T24LEDC[b]	RO

[a] PB9–PB12 settings are only available on 12-pushbutton models.
[b] T17–T24 settings are only available on 12-pushbutton models.

The SEL-421 contains all of the selectable screen choices listed in *Table 12.29 on page 12.18 in the SEL-400 Series Relays Instruction Manual* except DIFF_L, DIFF_T, DIFF, and ZONECFG.

Report Settings

The SEL-421 contains the report settings described in *Report Settings on page 12.23 in the SEL-400 Series Relays Instruction Manual* except that the SEL-421 does not support HIF event reports.

The rows containing the following elements are always included as part of the 100 rows of event reporting digital elements: TLED_1, TLED_2, TLED_3, TLED_4, TLED_5, TLED_6, TLED_7, TLED_8, TLED_9, TLED_10, TLED_11, TLED_12, TLED_13, TLED_14, TLED_15, TLED_16, SPOA, SPOB, SPOC, FSA, FSB, FSC, Z1P, Z2P, Z3P, Z4P, Z5P, 67Q1, 67Q2, 67Q3, 67Q4, 51S1, 51S2, 51S3, Z1G, Z2G, Z3G, Z4G, Z5G, 67G1, 67G2, 67G3, 67G4, RMB*n*A, TMB*n*A, RMB*n*B, TMB*n*B, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, TRIP TPϕ1, TPϕ2, 52ϕCL1, 52ϕCL2, BK1CL, BK2CL (n = 1–8, ϕ = A,B,C). For row descriptions see *Section 11: Relay Word Bits*.

Port Settings

The SEL-421 port settings are as described in *Port Settings on page 12.6 in the SEL-400 Series Relays Instruction Manual*.

The fast message read data access settings listed in *Table 12.8 on page 12.7 in the SEL-400 Series Relays Instruction Manual* are all included in the SEL-421.

Table 8.84 MIRRORED BITS Protocol Default Settings

Setting	Default Value
MBANA1	LIAFM
MBANA2	LIBFM
MBANA3	LICFM
MBANA4	VAFM
MBANA5	VBFM
MBANA6	VCFM
MBANA7	VABRMS

DNP3 Settings—Custom Maps

The SEL-421 DNP3 custom map settings operate as described in the *DNP3 Settings—Custom Maps on page 12.15 in the SEL-400 Series Relays Instruction Manual*. See *Table 10.14 on page 10.16* to see the default map configuration.

Bay Settings

Table 8.85 Bay Settings (Sheet 1 of 2)

Setting	Prompt	Default Value
MIMIC	Busbar One-Line Screen Number (1–999)	9
BAYNAME	Bay Name (20 characters)	BAY 1
BAYLAB*y*[a]	Bay Label *y*[a] (max 35 pixels, 5–9 characters)	LABEL *y*[a]
EPOLDIS	Enable Single-Pole Discrepancy Logic (Y, N)	Y
BUSNAM*y*[a]	Busbar *y*[a] Name (max 40 pixels, 6–10 characters)	BUSNAM *y*[a]
B*y*HMINM	Breaker *y*[a] HMI Name (max 17 pixels, 3–4 characters)	BK*y*[a]
B*z*CTLNM[b]	Breaker *z*[b] Cntl. Scr. Name (max 15 characters)	Breaker *z*[b]
52*y*CLSM[a]	Breaker *y*[a] Close Status (SELOGIC Equation)	52ACL*y*[a] 523CLSM = NA
52*y*_ALM[a]	Breaker *y*[a] Alarm Status (SELOGIC Equation)	52AAL*y*[a] 523_ALM = NA
D*r*HMIN[c]	Disconnect *m* HMI Name (max 17 pixels, 3–4 characters)[d]	SW[*m*]
D*r*CTLN[c]	Disconnect *m* Control Scr. Name (max 15 char.)[d]	BB [*m*]
89AM*r*[c]	Disconnect *m* N/O Contact (SELOGIC Equation)[d]	1
89BM*r*[c]	Disconnect *m* N/C Contact (SELOGIC Equation)[d]	0
89ALP*r*[c]	Disconnect *m* Alarm Pickup Delay (1–99999 cyc)[d]	300
89CCN*r*[c]	Dis. *m* Remote Close Control (SELOGIC Equation)[d]	89CC*r*
89OCN*r*[c]	Dis. *m* Remote Open Control (SELOGIC Equation)[d]	89OC*r*
89CST*r*[c]	Dis. *m* Close Seal-in Time (OFF, 1–99999 cyc)[d]	280
89CIT*r*[c]	Dis. *m* Close Immobility Time (OFF, 1–99999 cyc)[d]	20
89CRS*r*[c]	Disconnect *m* Close Reset (SELOGIC Equation)[d]	89CL*r* OR 89CSI*r*
89CBL*r*[c]	Disconnect *m* Close Block (SELOGIC Equation)[d]	NA
89OST*r*[c]	Dis. *m* Open Seal-in Time (OFF, 1–99999 cyc)[d]	280
89OIT*r*[c]	Dis. *m* Open Immobility Time (OFF, 1–99999 cyc)[d]	20
89ORS*r*[c]	Disconnect *m* Open Reset (SELOGIC Equation)[d]	89OPN*r* OR 89OSI*r*
89OBL*r*[c]	Disconnect *m* Open Block (SELOGIC Equation)[d]	NA
89CIR*r*[c]	Dis. *m* Close Immob. Time Reset (SELOGIC Equation)[d]	NOT 89OPN*r*
89OIR*r*[c]	Dis. *m* Open Immob. Time Reset (SELOGIC Equation)[d]	NOT 89CL*r*
MDELE*n*[e]	Analog Quantity	<Blank>
MDNAM*n*[e]	Pretext	<Blank>
MDSET*n*[e]	Text Formatting {w.d}	<Blank>
MDCLR*n*[e]	Post-Text	

Table 8.85 Bay Settings (Sheet 2 of 2)

Setting	Prompt	Default Value
MDSCA*n*[e]	Scale Format {s}	1
LOCAL	Local Control (SELOGIC Equation)	PLT06

[a] *y* = 1–3.
[b] *z* = 1–2.
[c] *r* = 01–10.
[d] *m* = 1–10.
[e] *n* = 1–24.

SECTION 9

ASCII Command Reference

You can use a communications terminal or terminal emulation program to set and operate the SEL-421 Relay. This section explains the commands that you send to the SEL-421 using SEL ASCII communications protocol. The relay responds to commands such as settings, metering, and control operations.

This section lists all the commands supported by the relay but most are described in *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual*. This section provides information on commands and command options that are unique to the SEL-421.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lower case italic letters and words in a command represent command variables that you determine based on the application (for example, circuit breaker number *n* = 1 or 2, remote bit number *nn* = 01–32, and *level*).

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return <CR> character, or a carriage return character followed by a line feed character <CR><LF> to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a <CR>. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the SEL-421 are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), and Access Level 2.

Description of Commands

Table 9.1 lists all the commands supported by the relay and the corresponding links to the descriptions in *Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual*.

Command List

Table 9.1 SEL-421 List of Commands (Sheet 1 of 3)

Command	Location of Command in Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual
2ACCESS	*2ACCESS on page 14.1*
89CLOSE *n*	*89CLOSE n on page 14.2* (The SEL-421 supports 10 disconnects.)
89OPEN *n*	*89OPEN n on page 14.2* (The SEL-421 supports 10 disconnects.)
AACCESS	*AACCESS on page 14.3*
ACCESS	*ACCESS on page 14.3*
BACCESS	*BACCESS on page 14.3*
BNAME	*BNAME on page 14.4*
BREAKER	*BREAKER on page 14.4* (The SEL-421 supports two circuit breakers, designated 1 and 2.)
CAL	*CAL on page 14.5*
CASCII	*CASCII on page 14.5*
CBREAKER	*CBREAKER on page 14.6* (The SEL-421 supports two circuit breakers, designated 1 and 2.)
CEVENT	*CEVENT on page 14.6* (In the SEL-421, CEV L provides an 8 samples/cycle large resolution event report.)
CFG CTNOM *i*	*CFG CTNOM on page 14.10* (In the SEL-421, the nominal current choices are 1 and 5 for 1 A nominal and 5 A nominal CT inputs.)
CFG NFREQ *f*	*CFG NFREQ on page 14.11*
CHISTORY	*CHISTORY on page 14.11*
CLOSE *n*	*CLOSE n on page 14.11* (The SEL-421 supports two circuit breakers, designated 1 and 2.)
COMMUNICATIONS	*COMMUNICATIONS on page 14.12*
CONTROL *nn*	*CONTROL nn on page 14.16*
COPY	*COPY on page 14.17*
CPR	*CPR on page 14.17*
CSER	*CSER on page 14.18*
CSTATUS	*CSTATUS on page 14.19*
CSUMMARY	*CSUMMARY on page 14.19*
DATE	*DATE on page 14.21*
DNAME X	*DNAME X on page 14.21*
DNP	*DNP on page 14.22*
ETHERNET	*ETHERNET on page 14.22*
EVENT	*EVENT on page 14.23* (The SEL-421 supports large resolution event reports of 8 samples/cycle.)
EXIT	*EXIT on page 14.27*
FILE	*FILE on page 14.27*
GOOSE	*GOOSE on page 14.28*
GROUP	*GROUP on page 14.31*

Table 9.1 SEL-421 List of Commands (Sheet 2 of 3)

Command	Location of Command in Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual
HELP	*HELP on page 14.32*
HISTORY	*HISTORY on page 14.32*
ID	*ID on page 14.33*
IRIG	*IRIG on page 14.34*
LOOPBACK	*LOOPBACK on page 14.35*
MAC	*MAC on page 14.36*
MAP	*MAP on page 14.37*
METER	See *METER on page 9.4* in this section.
MET	See *MET on page 9.4* in this section.
MET AMV	*MET AMV on page 14.38*
MET ANA	*MET ANA on page 14.38*
MET BAT	*MET BAT on page 14.38* (The SEL-421 provides battery metering for two battery monitor channels.)
MET D	*MET D on page 14.39*
MET E	See *MET E on page 9.5* in this section.
MET M	*MET M on page 14.39*
MET PM	*MET PM on page 14.39*
MET PMV	*MET PMV on page 14.40*
MET RMS	See *MET RMS on page 9.5* in this section.
MET RTC	*MET RTC on page 14.41*
MET SYN	See *MET SYN on page 9.5* in this section.
MET T	*MET T on page 14.41*
OACCESS	*OACCESS on page 14.41*
OPEN *n*	*OPEN n on page 14.42* (The SEL-421 supports two circuit breakers, designated 1 and 2.)
PACCESS	*PACCESS on page 14.42*
PASSWORD	*PASSWORD on page 14.42*
PING	*PING on page 14.43*
PORT	*PORT on page 14.44*
PROFILE	*PROFILE on page 14.45*
PULSE	*PULSE on page 14.45*
QUIT	*QUIT on page 14.46*
RTC	*RTC on page 14.46*
SER	*SER on page 14.46*
SET	*SET on page 14.48* (*Table 9.6* lists the class and instance options available in the SEL-421.)
SHOW	*SHOW on page 14.50* (*Table 9.7* lists the class and instance options available in the SEL-421.)
SNS	*SNS on page 14.50*
STATUS	*STATUS on page 14.50*
SUMMARY	*SUMMARY on page 14.52*
TARGET	*TARGET on page 14.53*
TEC	*TEC on page 14.54*
TEST DB	*TEST DB on page 14.55*

Table 9.1 SEL-421 List of Commands (Sheet 3 of 3)

Command	Location of Command in Section 14: ASCII Command Reference in the SEL-400 Series Relays Instruction Manual
TEST DB2	*TEST DB2 on page 14.56*
TEST FM	*TEST FM on page 14.57*
TIME	*TIME on page 14.59*
TRIGGER	*TRIGGER on page 14.61*
VECTOR	*VECTOR on page 14.61*
VERSION	*VERSION on page 14.61*
VIEW	*VIEW on page 14.62*

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, and so on) and internal relay operating quantities (math variables and synchronism-check values). For more information on power system measurements, see *Metering on page 7.1*.

LINE, BK1, and BK2 command options generally measure feeder lines parameters and circuit breaker currents, depending on relay configuration (see *Current and Voltage Source Selection on page 5.2*).

MET

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics and subharmonics to present only measured quantities at the power system fundamental operating frequency.

Table 9.2 MET Command

Command[a]	Description	Access Level
MET	Display Line fundamental metering data.	1, B, P, A, O, 2
MET *k*	Display Line fundamental metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n*	Display Circuit Breaker *n* fundamental metering data.	1, B, P, A, O, 2
MET BK*n* *k*	Display Circuit Breaker *n* fundamental metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter *n* is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

The **MET** command without options defaults to the LINE fundamental metering data. Specify Circuit Breaker 1 and Circuit Breaker 2 by using the BK1 and BK2 command options, respectively.

Some situations require that you repeatedly monitor the power system for a brief period; specify a number after any **MET** command to automatically repeat the command.

MET E

Use the **MET E** command to view the energy import and export quantities.

Table 9.3 MET E Command

Command	Description	Access Level
MET E	Display Line energy metering data.	1, B, P, A, O, 2
MET E *k*	Display Line energy metering data successively for *k* times.	1, B, P, A, O, 2
MET RE	Reset Line energy metering data.	P, A, O, 2

The reset command, **MET RE**, resets the Line, BK1, and BK2 energy metering quantities. When you issue the **MET RE** command, the relay responds with `Reset Energy Metering (Y/N)`? If you answer **Y <Enter>**, the relay responds with `Energy Metering Reset`.

MET RMS

Use the **MET RMS** command to view root-mean-square (rms) metering quantities. The relay includes power system harmonics and subharmonics in rms quantities.

NOTE: In firmware R310 and newer, the rms value is zero when the current is below 0.02 • I_{NOM}.

Table 9.4 MET RMS Command

Command[a]	Description	Access Level
MET RMS	Display Line rms metering data.	1, B, P, A, O, 2
MET RMS *k*	Display Line rms metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n* RMS	Display Circuit Breaker *n* rms metering data.	1, B, P, A, O, 2
MET BK*n* RMS *k*	Display Circuit Breaker *n* rms metering data successively for *k* times.	1, B, P, A, O, 2

[a] Parameter *n* is 1 or 2 to indicate Circuit Breaker 1 or Circuit Breaker 2.

MET SYN

Use the **MET SYN** command to view the synchronism-check reference voltage, normalized source voltages, angles, and slip calculations.

Table 9.5 MET SYN Command

Command	Description	Access Level
MET SYN	Display the synchronism-check values.	1, B, P, A, O, 2
MET SYN *k*	Display the synchronism-check values successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the synchronism-check function, the relay responds with `Synchronism Check Element Is Not Available`. (Enable synchronism check with the Global settings E25BK1, E25BK2, and NUMBK; see *Synchronism Check on page 5.158*).

SET

See *SET on page 14.48 in the SEL-400 Series Relays Instruction Manual*. The following table lists the options specifically available in the SEL-421.

NOTE: The SEL-421-4 has only one 100-line block of automation freeform SELOGIC control equation programming.

Table 9.6 SET Command Overview

Command	Description	Access Level
SET[a]	Set the Group relay settings, beginning at the first setting in the active group.	P, 2
SET *n*[a]	Set the Group *n* relay settings, beginning at the first setting *n* each.	P, 2
SET A[b]	Set the Automation SELOGIC control equation relay settings in Block 1.	A, 2
SET A *m*[b]	Set the Automation SELOGIC control equation relay settings in Block *m*.	A, 2
SET B	Bay control settings, beginning at the first setting in this class.	P, A, O, 2
SET D	Set the DNP3 remapping settings, beginning at the first setting in this class for instance 1.	P, A, O, 2
SET D *instance*	Set the DNP3 remapping settings beginning at the first setting of *instance*.	P, A, O, 2
SET F	Set the front-panel relay settings, beginning at the first setting in this class.	P, A, O, 2
SET G	Set the Global relay settings, beginning at the first setting in this class.	P, A, O, 2
SET L[a]	Set the Protection SELOGIC control equation relay settings for the active settings group.	P, 2
SET L *n*[a]	Set the Protection SELOGIC relay settings for Instance *n*, which is Group *n*.	P, 2
SET M	Set the Breaker Monitor relay settings, beginning at the first setting in this class.	P, 2
SET N	Enter text using the text-edit format.	P, A, O, 2
SET O	Set the Output SELOGIC control equation relay settings, beginning at OUT101.	O, 2
SET P[c]	Set the port presently in use, beginning at the first setting for this port.	P, A, O, 2
SET P *p*[c]	Set the communications Port relay settings for Port *p*, beginning at the first setting for this port.	P, A, O, 2
SET R	Set the Report relay settings, beginning at the first setting for this class.	P, A, O, 2
SET T	Set the alias settings.	P, A, O, 2

[a] Parameter *n* = 1–6, representing Group 1 through Group 6.
[b] Parameter *m* = 1–10 for Block 1 through Block 10.
[c] Parameter *p* = 1–3, F, or 5, corresponding to PORT 1–PORT 3, PORT F, or PORT 5.

SHOW

See *SHOW on page 14.50 in the SEL-400 Series Relays Instruction Manual*. The following table lists the class and instance options available in the SEL-421.

Table 9.7 SHO Command Overview

Command	Description	Access Level
SHO[a]	Show the Group relay settings, beginning at the first setting in the active group.	1, B, P, A, O, 2
SHO *n*[a]	Show the Group *n* relay settings, beginning at the first setting in each instance.	1, B, P, A, O, 2
SHO A[b]	Show the Automation SELOGIC control equation relay settings in Block 1.	1, B, P, A, O, 2
SHO A *m*[b]	Show the Automation SELOGIC control equation relay settings in Block *m*.	1, B, P, A, O, 2
SHO B	Show the Bay Control relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO D	Show the DNP3 remapping settings for instance 1.	P, A, O, 2
SHO D *instance*	Show the DNP3 remapping settings for *instance*.	P, A, O, 2
SHO F	Show the front-panel relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO G	Show the Global relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO L[a]	Show the Protection SELOGIC control equation relay settings for the active group.	1, B, P, A, O, 2
SHO L *n*[a]	Show the Protection SELOGIC control equation relay settings for Instance *n*, which is Group *n*.	1, B, P, A, O, 2
SHO M	Show the Breaker Monitor relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO N	Show notes in the relay.	1, B, P, A, O, 2
SHO O	Show the Output SELOGIC control equation relay settings, beginning at OUT101.	1, B, P, A, O, 2
SHO P[c]	Show the relay settings for the port presently in use, beginning at the first setting.	1, B, P, A, O,
SHO P *p*[c]	Show the communications Port relay settings for Port *p*, beginning at the first setting for this port.	1, B, P, A, O, 2
SHO R	Show the Report relay settings, beginning at the first setting for this class.	1, B, P, A, O, 2
SHO T	Show the alias settings.	1, B, P, A, O, 2

[a] Parameter *n* = 1–6, representing Group 1 through Group 6.
[b] Parameter *m* = 1–10 for Block 1 through Block 10.
[c] Parameter *p* = 1–3, F, and 5, which corresponds to PORT 1–PORT 3, PORT F, and PORT 5.

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SECTION 10

Communications Interfaces

Section 15: Communications Interfaces through *Section 18: Synchrophasors in the SEL-400 Series Relays Instruction Manual* describes the various communications interfaces and protocols used in SEL-400 series relays. This section describes aspects of the communications protocols that are unique to the SEL-421. The following topics are discussed:

Communications Database

The SEL-421 maintains a database to describe itself to external devices via the Fast Message Data Access protocol. This database includes a variety of data within the relay that are available to devices connected in a serial or Ethernet network. The database includes the regions and data described in *Table 10.1*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions. See *Section 9: ASCII Command Reference* for more information on the **MAP** and **VIEW** commands.

Table 10.1 SEL-421 Database Regions

Region Name	Contents	Update Rate
LOCAL	Relay identification data including FID, Relay ID, Station ID, and active protection settings group	Updated on settings change and whenever monitored values change
METER	Metering and measurement data	0.5 s
DEMAND	Demand and peak demand measurement data	15 s
TARGET	Selected rows of Relay Word bit data	0.5 s
HISTORY	Relay event history records for the 10 most recent events	Within 15 s of any new event
BREAKER	Circuit breaker monitor summary data	15 s
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.5 s

Data within the regions are available for access by external devices via the SEL Fast Message protocol.

The LOCAL region contains the device FID, SID, and RID. It will also provide appropriate status points. This region is updated on settings changes and whenever monitored status points change (see *Table 10.2*).

Table 10.2 SEL-421 Database Structure—LOCAL Region

Address (Hex)	Name	Type	Description
0000	FID	char[48]	FID string
0030	BFID	char[48]	SELBOOT FID string
0060	SER_NUM	char[16]	Device Serial number, from factory settings
0070	PART_NUM	char[24]	Device part number, from factory settings
0088	CONFIG	char[8]	Device configuration string (as reported in ID command)
0090	SPECIAL	char[8]	Special device configuration string (as reported in ID command)
0098	DEVICE_ID	char[40]	Relay ID setting, from global settings
00C0	NODE_ID	char[40]	Station ID from global settings
00E8	GROUP	int	Active group
00E9	STATUS	int	Bit map of status flags: 0 for okay, 1 for failure

The METER region contains all the basic meter and energy information. This region is updated every 0.5 seconds. See *Table 10.3* for the Map.

Table 10.3 SEL-421 Database Structure—METER Region (Sheet 1 of 3)

Address (Hex)	Name	Type	Description
1000	_YEAR	int	4-digit year when data were sampled
1001	DAY_OF_YEAR	int	1–366 day when data were sampled
1002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,00)
1004	FREQ	float	System frequency
1006	VDC1	float	Battery 1 voltage
1008	VDC2	float	Battery 2 voltage
100A, 100C	IA1	float[2]	Line A-Phase current magnitude and phase
100E, 1010	IB1	float[2]	Line B-Phase current magnitude and phase
1012, 1014	IC1	float[2]	Line C-Phase current magnitude and phase
1016, 1018	I0_1	float[2]	Line 0-sequence current magnitude and phase
101A, 101C	I1_1	float[2]	Line 1-sequence current magnitude and phase
101E, 1020	I2_1	float[2]	Line 2-sequence current magnitude and phase
1022, 1024	IA2	float[2]	Breaker 1 A-Phase current magnitude and phase
1026, 1028	IB2	float[2]	Breaker 1 B-Phase current magnitude and phase
102A, 102C	IC2	float[2]	Breaker 1 C-Phase current magnitude and phase
102E, 1030	IA3	float[2]	Breaker 2 A-Phase current magnitude and phase

Table 10.3 SEL-421 Database Structure—METER Region (Sheet 2 of 3)

Address (Hex)	Name	Type	Description
1032, 1034	IB3	float[2]	Breaker 2 B-Phase current magnitude and phase
1036, 1038	IC3	float[2]	Breaker 2 C-Phase current magnitude and phase
103A, 103C	VA	float[2]	A-Phase voltage magnitude and phase
103E, 1040	VB	float[2]	B-Phase voltage magnitude and phase
1042, 1044	VC	float[2]	C-Phase voltage magnitude and phase
1046, 1048	V0	float[2]	0-sequence voltage magnitude and phase
104A, 104C	V1	float[2]	1-sequence voltage magnitude and phase
104E, 1050	V2	float[2]	2-sequence voltage magnitude and phase
1052	VP	float	Polarizing voltage magnitude
1054	VS1	float	Synchronizing Voltage 1 magnitude
1056	VS2	float	Synchronizing Voltage 2 magnitude
1058	ANG1_DIF	float	VS1 and VP angle difference, in degrees
105A	VS1_SLIP	float	VS1 frequency slip with respect to VP, in HZ
105C	ANG2_DIF	float	VS2 and VP angle difference, in degrees
105E	VS2_SLIP	float	VS2 frequency slip with respect to VP, in HZ
1060	PA	float	A-Phase real power
1062	PB	float	B-Phase real power
1064	PC	float	C-Phase real power
1066	P	float	Total real power
1068	QA	float	A-Phase reactive power
106A	QB	float	B-Phase reactive power
106C	QC	float	C-Phase reactive power
106E	Q	float	Total reactive power
1070	SA	float	A-Phase apparent power, if available
1072	SB	float	B-Phase apparent power, if available
1074	SC	float	C-Phase apparent power, if available
1076	S	float	Total apparent power
1078	PFA	float	A-Phase power factor
107A	PFB	float	Phase power factor
107C	PFC	float	Phase power factor
107E	PF	float	Three-phase power factor
1080	PEA	float	Positive A-Phase energy in KWh
1082	PEB	float	Positive B-Phase energy in KWh
1084	PEC	float	Positive C-Phase energy in KWh
1086	PE	float	Total positive energy in KWh

Table 10.3 SEL-421 Database Structure—METER Region (Sheet 3 of 3)

Address (Hex)	Name	Type	Description
1088	NEA	float	Negative A-Phase energy in KWh
108A	NEB	float	Negative B-Phase energy in KWh
108C	NEC	float	Negative C-Phase energy in KWh
108E	NE	float	Total negative energy in KWh

The DEMAND region contains demand and peak demand information. This region is updated every 15 seconds. See *Table 10.4* for the Map.

Table 10.4 SEL-421 Database Structure—DEMAND Region

Address (Hex)	Name	Type	Description
2000	_YEAR	int	Four-digit year when data were sampled
2001	DAY_OF_YEAR	int	1–366 day when data were sampled
2002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,00)
2004	IA	float	A-Phase demand current
2006	IB	float	B-Phase demand current
2008	IC	float	C-Phase demand current
200A	I0	float	0-sequence demand current
200C	I2	float	2-sequence demand current
200E	PA	float	A-Phase demand real power
2010	PB	float	B-Phase demand real power
2012	PC	float	C-Phase demand real power
2014	P	float	Total demand real power
2016	SA	float	A-Phase demand apparent power
2018	SB	float	B-Phase demand apparent power
201A	SC	float	C-Phase demand apparent power
201C	S	float	Total demand apparent power
201E	PK_IA	float	A-Phase demand current
2020	PK_IB	float	B-Phase demand current
2022	PK_IC	float	C-Phase demand current
2024	PK_I0	float	Zero-sequence demand current
2026	PK_I2	float	Two-sequence demand current
2028	PK_PA	float	A-Phase demand real power
202A	PK_PB	float	B-Phase demand real power
202C	PK_PC	float	C-Phase demand real power
202E	PK_P	float	Total demand real power
2030	PK_SA	float	A-Phase demand apparent power
2032	PK_SB	float	B-Phase demand apparent power
2034	PK_SC	float	C-Phase demand apparent power
2036	PK_S	float	Total demand apparent power

The TARGET region contains the entire visible Relay Word plus the rows designated specifically for the TARGET region. This region is updated every 0.5 seconds. See *Table 10.5* for the Map. See *Section 11: Relay Word Bits* for detailed information on the Relay Word bits.

Table 10.5 SEL-421 Database Structure—TARGET Region

Address (Hex)	Name	Type	Description
3000	_YEAR	int	Four-digit year when data were sampled
3001	DAY_OF_YEAR	int	1–366 day when data were sampled
3002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
3004	TARGET	char[~240]	Entire Relay Word with bit labels

The HISTORY region contains all information available in a History report for the most recent 10 events. This region is updated within 15 seconds of any new events. See *Table 10.6* for the Map.

Table 10.6 SEL-421 Database Structure—HISTORY Region

Address (Hex)	Name	Type	Description
4000	_YEAR	int	Four-digit year when data were sampled
4001	DAY_OF_YEAR	int	1–366 day when data were sampled
4002	TIME(ms)	long int	Time of day in ms when data were sample (0–86,400,000)
4004	REF_NUM	int[10]	Event serial number
400E	MONTH	int[10]	Month of event
4018	DAY	int[10]	Day of event
4022	YEAR	int[10]	Year of event
402C	HOUR	int[10]	Hour of event
4036	MIN	int[10]	Minute of event
4040	SEC	int[10]	Second of event
404A	MSEC	int[10]	Milliseconds of event
4054	EVENT	char[60]	Event type string
4090	GROUP	int[10]	Active group during fault
409A	FREQ	float[10]	System frequency at time of fault
40AE	TARGETS	char[160]	System targets from event
414E	FAULT_LOC	float[10]	Fault location
4162	SHOT	int[10]	Recloser shot counter (sum of 1-pole and 3-pole)
416C	SHOT_1P	int[10]	Single-pole recloser counter
4176	SHOT_3P	int[10]	Three-pole recloser counter
4180	CURR	int[10]	Fault current in primary amperes

The BREAKER region contains some of the information available in a summary Breaker report. This region is updated every 15 seconds. See *Table 10.7* for the Map.

Table 10.7 SEL-421 Database Structure—BREAKER Region

Address (Hex)	Name	Type	Description
5000	_YEAR	int	Four-digit year when data were sampled
5001	DAY_OF_YEAR	int	1–366 day when data were sampled
5002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
5004	BCWA1	float	Breaker 1 A-Phase breaker wear (%)
5006	BCWB1	float	Breaker 1 B-Phase breaker wear (%)
5008	BCWC1	float	Breaker 1 C-Phase breaker wear (%)
500A	BCWA2	float	Breaker 2 A-Phase breaker wear (%)
500C	BCWB2	float	Breaker 2 B-Phase breaker wear (%)
500E	BCWC2	float	Breaker 2 C-Phase breaker wear (%)
5010	CURA1	float	Breaker 1 A-Phase accumulated current (kA)
5012	CURB1	float	Breaker 1 B-Phase accumulated current (kA)
5014	CURC1	float	Breaker 1 C-Phase accumulated current (kA)
5016	CURA2	float	Breaker 2 A-Phase accumulated current (kA)
5018	CURB2	float	Breaker 2 B-Phase accumulated current (kA)
501A	CURC2	float	Breaker 2 C-Phase accumulated current (kA)
501C	NOPA1	long int	Breaker 1 A-Phase number of operations
501E	NOPB1	long int	Breaker 1 B-Phase number of operations
5020	NOPC1	long int	Breaker 1 C-Phase number of operations
5022	NOPA2	long int	Breaker 2 A-Phase number of operations
5024	NOPB2	long int	Breaker 2 B-Phase number of operations
5026	NOPC2	long int	Breaker 2 C-Phase number of operations

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table 10.8* for the Map.

Table 10.8 SEL-421 Database Structure—STATUS Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
6000	_YEAR	int	Four-digit year when data were sampled
6001	DAY_OF_YEAR	int	1–366 day when data were sampled
6002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86,400,000)
6004	CH1(mV)	int	Channel 1 offset
6005	CH2(mV)	int	Channel 2 offset
6006	CH3(mV)	int	Channel 3 offset
6007	CH4(mV)	int	Channel 4 offset
6008	CH5(mV)	int	Channel 5 offset
6009	CH6(mV)	int	Channel 6 offset
600A	CH7(mV)	int	Channel 7 offset
600B	CH8(mV)	int	Channel 8 offset
600C	CH9(mV)	int	Channel 9 offset

Table 10.8 SEL-421 Database Structure—STATUS Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
600D	CH10(mV)	int	Channel 10 offset
600E	CH11(mV)	int	Channel 11 offset
600F	CH12(mV)	int	Channel 12 offset
6010	MOF(mV)	int	Master offset
6011	OFF_WARN	char[8]	Offset warning string
6019	OFF_FAIL	char[8]	Offset failure string
6021	PS3(V)	float	3.3 Volt power supply voltage
6023	PS5(V)	float	5 Volt power supply voltage
6025	PS_N5(V)	float	–5 Volt regulated voltage
6027	PS15(V)	float	15 Volt power supply voltage
6029	PS_N15(V)	float	–15 Volt power supply voltage
602B	PS_WARN	char[8]	Power supply warning string
6033	PS_FAIL	char[8]	Power supply failure string
603B	HW_FAIL	char[40]	Hardware failure strings
6063	CC_STA	char[40]	Comm. card status strings
608B	PORT_STA	char[160]	Serial port status strings
612B	TIME_SRC	char[10]	Time source
6135	LOG_ERR	char[40]	SELOGIC error strings
615D	TEST_MD	char[160]	Test mode string

The ANALOGS region contains protection and automation variables. This region is updated every 0.5 seconds. See *Table 10.9* for the Map.

Table 10.9 SEL-421 Database Structure—ANALOGS Region

Address (Hex)	Name	Type	Description
7000	_YEAR	int	Four-digit year when data were sampled
7001	DAY_OF_YEAR	int	1–366 day when data were sampled
7002	TIME(ms)	long int	Time of day in ms when data were sampled (0–86400000)
7004	PMV01_64	float[64]	PMV01–PMV64
7084	AMV001_256	float[256]	AMV001–AMV256

The database is virtual device 1 in the relay. You can display the contents of a region using the **MAP 1:*region*** command (where *region* is one of the database region names listed in *Table 10.1*). An example of the **MAP** command is shown in *Figure 10.1*.

```
=>>MAP 1 METER <Enter>
Virtual Device 1, Data Region METER Map

Data Item    Starting Address   Type

_YEAR        1000h              int
DAY_OF_YEAR  1001h              int
TIME(ms)     1002h              int[2]
FREQ         1004h              float
VDC1         1006h              float
VDC2         1008h              float

IA1          100ah              float[2]
IB1          100eh              float[2]
IC1          1012h              float[2]
I0_1         1016h              float[2]
I1_1         101ah              float[2]
I2_1         101eh              float[2]
IA2          1022h              float[2]
IB2          1026h              float[2]
IC2          102ah              float[2]
IA3          102eh              float[2]
IB3          1032h              float[2]
IC3          1036h              float[2]
VA           103ah              float[2]
VB           103eh              float[2]
VC           1042h              float[2]
V0           1046h              float[2]
V1           104ah              float[2]
V2           104eh              float[2]

VP           1052h              float
VS1          1054h              float
VS2          1056h              float
ANG1_DIF     1058h              float
VS1_SLIP     105ah              float
ANG2_DIF     105ch              float
VS2_SLIP     105eh              float
PA           1060h              float
PB           1062h              float
PC           1064h              float
P            1066h              float
QA           1068h              float
QB           106ah              float
QC           106ch              float

Q            106eh              float
SA           1070h              float
SB           1072h              float
SC           1074h              float
S            1076h              float
PFA          1078h              float
PFB          107ah              float
PFC          107ch              float
PF           107eh              float
PEA          1080h              float
PEB          1082h              float
PEC          1084h              float
PE           1086h              float
NEA          1088h              float
NEB          108ah              float
NEC          108ch              float
NE           108eh              float
```

Figure 10.1 MAP 1:METER Command Example

DNP3 Communication

DNP3 operation is described in *Section 16: DNP3 Communication in the SEL-400 Series Relays Instruction Manual*. This subsection describes aspects of DNP3 communication that are unique to the SEL-421.

Reference Data Map

Table 10.10 shows the SEL-421 DNP3 reference data map. The reference data map contains all of the data available to the DNP3 protocol. You can use the default map or the custom DNP3 mapping functions of the SEL-421 to include only the points required by your application.

The entire Relay Word (See *Section 11: Relay Word Bits*) is part of the DNP3 reference map. You may include any label in the Relay Word as part of a DNP3 custom map.

The SEL-421 scales analog values by the indicated settings or fixed scaling. Analog inputs for event (fault) summary reporting use a default scale factor of 1 and dead band of ANADBM. Per-point scaling and dead band settings specified in a custom DNP3 map will override defaults.

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 1 of 6)

Object	Label	Description
Binary Inputs		
01, 02	RLYDIS	Relay disabled
01, 02	STFAIL	Relay diagnostic failure
01, 02	STWARN	Relay diagnostic warning
01, 02	STSET	Settings change or relay restart
01, 02	UNRDEV	New relay event available
01, 02	NUNREV	An unread event exists, newer than the event in the Event summary AIs
01, 02	LDATPFW	Leading true power factor A-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDBTPFW	Leading true power factor B-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDCTPFW	Leading true power factor C-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LD3TPFW	Leading true power factor three-phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	Relay Word	Relay Word bit label (See *Section 11: Relay Word Bits*)
Binary Outputs		
10, 12	RB01–RB32	Remote bits RB01–RB32
10, 12	RB01:RB02 RB03:RB04 RB05:RB06 • • • RB29:RB30 RB31:RB32	Remote bit pairs RB01–RB32
10, 12	OC1	Pulse Open Circuit Breaker 1 command
10, 12	CC1	Pulse Close Circuit Breaker 1 command
10, 12	OC1:CC1	Open/Close pair for Circuit Breaker 1
10, 12	OC2	Pulse Open Circuit Breaker 2 command
10, 12	CC2	Pulse Close Circuit Breaker 2 command
10, 12	OC2:CC2	Open/Close pair for Circuit Breaker 2
10, 12	89OC01–89OC10	Open Disconnect Switch Control 1–10
10, 12	89CC01–89CC10	Close Disconnect Switch Control 1–10
10, 12	89OC01:89CC01 89OC02:89CC02 89OC03:89CC03 • • • 89OC09:89CC09 89OC10:89CC10	Open/Close Disconnect Switch Control Pair 1–10

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 2 of 6)

Object	Label	Description
10, 12	RST_DEM	Reset demands
10, 12	RST_PDM	Reset demand peaks
10, 12	RST_ENE	Reset energies
10, 12	RSTMML	Reset min/max metering data for the line
10, 12	RSTMMB1	Reset min/max metering data for Circuit Breaker 1
10, 12	RSTMMB2	Reset min/max metering data for Circuit Breaker 2
10, 12	RST_BK1	Reset Breaker 1 monitor data
10, 12	RST_BK2	Reset Breaker 2 monitor data
10, 12	RST_BAT	Reset Battery monitor data
10, 12	RST_79C	Reset recloser shot counter
10, 12	RSTFLOC	Reset fault location data
10, 12	RSTTRGT	Reset front-panel targets
10, 12	RSTDNPE	Reset (clear) DNP3 Event Summary AIs
10, 12	NXTEVE	Load next fault event into DNP3 Event Summary AIs
Binary Counters		
20, 22	ACTGRP	Active settings group
20, 22	BKR1OPA	Number of breaker operations on Circuit Breaker 1 A-Phase
20, 22	BKR1OPB	Number of breaker operations on Circuit Breaker 1 B-Phase
20, 22	BKR1OPC	Number of breaker operations on Circuit Breaker 1 C-Phase
20, 22	BKR2OPA	Number of breaker operations on Circuit Breaker 2 A-Phase
20, 22	BKR2OPB	Number of breaker operations on Circuit Breaker 2 B-Phase
20, 22	BKR2OPC	Number of breaker operations on Circuit Breaker 2 C-Phase
20, 22	ACN01CV–ACN32CV	Automation SELOGIC Counter value 1–32
20, 22	PCN01CV–PCN32CV	Protection SELOGIC Counter value 1–32
20, 22[a, b]	KWHAOUT	Positive A-Phase energy (export), kWh
20 22[a, b]	KWHBOUT	Positive B-Phase energy (export), kWh
20 22[a, b]	KWHCOUT	Positive C-Phase energy (export), kWh
20 22[a, b]	KWHAIN	Negative A-Phase energy (import), kWh
20 22[a, b]	KWHBIN	Negative B-Phase energy (import), kWh
20 22[a, b]	KWHCIN	Negative C-Phase energy (import), kWh
20 22[a, b]	3KWHOUT	Positive three-phase energy (export), kWh
20 22[a, b]	3KWHIN	Negative three-phase energy (import), kWh
Analog Inputs		
30, 32	LIAFM, LIAFA[c]	Line A-Phase current magnitude (amperes) and angle
30, 32	LIBFM, LIBFA[c]	Line B-Phase current magnitude (amperes) and angle
30, 32	LICFM, LICFA[c]	Line C-Phase current magnitude (amperes) and angle
30, 32	LI1M, LI1A[c]	Line positive-sequence current magnitude (amperes) and angle
30, 32	L3I2M, L3I2A[c]	Line negative-sequence current (3I2) magnitude in amperes and angle
30, 32	LIGM, LIGA[c]	Line zero-sequence current (3I0) magnitude in amperes and angle
30, 32	B1IAFM, B1IAFA[c]	Circuit Breaker 1 A-Phase current magnitude (amperes) and angle
30, 32	B1IBFM, B1IBFA[c]	Circuit Breaker 1 B-Phase current magnitude (amperes) and angle

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 3 of 6)

Object	Label	Description
30, 32	B1ICFM, B1ICFA[c]	Circuit Breaker 1 C-Phase current magnitude (amperes) and angle
30, 32	B2IAFM, B2IAFA[c]	Circuit Breaker 2 A-Phase current magnitude (amperes) and angle
30, 32	B2IBFM, B2IBFA[c]	Circuit Breaker 2 B-Phase current magnitude (amperes) and angle
30, 32	B2ICFM, B2ICFAc	Circuit Breaker 2 C-Phase current magnitude (amperes) and angle
30, 32	VAFM, VAFA[d]	Line A-Phase voltage magnitude (kV) and angle
30, 32	VBFM, VBFA[d]	Line B-Phase voltage magnitude (kV) and angle
30, 32	VCFM, VCFA[d]	Line C-Phase voltage magnitude (kV) and angle
30, 32	V1M, V1A[d]	Positive-sequence voltage magnitude (V1) in kV and angle
30, 32	3V2M, 3V2A[d]	Negative-sequence voltage magnitude (3V2) in kV and angle
30, 32	3V0M, 3V0A[d]	Zero-sequence voltage magnitude (3V0) in kV and angle
30, 32	PA_F[e]	A-Phase real power in MW
30, 32	PB_F[e]	B-Phase real power in MW
30, 32	PC_F[e]	C-Phase real power in MW
30, 32	3P_Fe	Three-phase real power in MW
30, 32	QA_F[e]	A-Phase reactive power in MVAR
30, 32	QB_F[e]	B-Phase reactive power in MVAR
30, 32	QC_F[e]	C-Phase reactive power in MVAR
30, 32	3Q_F[e]	Three-phase reactive power in MVAR
30, 32	SA_F[e]	A-Phase apparent power in MVA
30, 32	SB_F[e]	B-Phase apparent power in MVA
30, 32	SC_F[e]	C-Phase apparent power in MVA
30, 32	3S_F[e]	Three-phase apparent power in MVA
30, 32	DPFA[f]	A-Phase power factor
30, 32	DPFB[f]	B-Phase power factor
30, 32	DPFC[f]	C-Phase power factor
30, 32	3DPF	Power factor
30, 32	VPM[e]	Polarizing voltage magnitude (volts)
30, 32	NVS1M[d]	Synchronizing Voltage 1 magnitude (volts)
30, 32	NVS2M[d]	Synchronizing Voltage 2 magnitude (volts)
30, 32	ANG1DIF[f]	VS1 angle - VP angle (degrees)
30, 32	ANG2DIF[f]	VS2 angle - VP angle (degrees)
30, 32	SLIP1[e]	FREQ S1 - FREQ P (Hz)
30, 32	SLIP2[e]	FREQ S2 - FREQ P (Hz)
30, 32	DC1[g]	DC Battery 1 voltage (V)
30, 32	DC2[g]	DC Battery 2 voltage (V)
30, 32	IAPKD[c]	Peak A-Phase demand current (amperes)
30, 32	IBPKD[c]	Peak B-Phase demand current (amperes)
30, 32	ICPKD[c]	Peak C-Phase demand current (amperes)
30, 32	3I2PKD[c]	Peak negative-sequence demand current (amperes)
30, 32	IGPKD[c]	Peak zero-sequence demand current (amperes)
30, 32	PAPKD[e]	A-Phase peak demand power (MW)

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 4 of 6)

Object	Label	Description
30, 32	PBPKD[e]	B-Phase peak demand power (MW)
30, 32	PCPKD[e]	C-Phase peak demand power (MW)
30, 32	3PPKD[e]	Three-phase peak demand power (MW)
30, 32	QAPKD[e]	A-Phase peak demand reactive power (MW)
30, 32	QBPKD[e]	B-Phase peak demand reactive power (MW)
30, 32	QCPKD[e]	C-Phase peak demand reactive power (MW)
30, 32	3QPKD[e]	Three-phase peak reactive power (MW)
30, 32	UAPKD[e]	A-Phase peak demand phase apparent power (MW)
30, 32	UBPKD[e]	B-Phase peak demand phase apparent power (MW)
30, 32	UCPKD[e]	C-Phase peak demand phase apparent power (MW)
30, 32	3UPKD[e]	Three-phase peak demand apparent power (MW)
30, 32	IAD[c]	A-Phase demand current (amperes)
30, 32	IBD[c]	B-Phase demand current (amperes)
30, 32	ICD[c]	C-Phase demand current (amperes)
30, 32	3I2D[c]	Demand negative-sequence current (amperes)
30, 32	IGD[c]	Demand zero-sequence current (amperes)
30, 32	PAD, PBD, PCD[e]	A-Phase, B-Phase, and C-Phase demand power (MW)
30, 32	3PD[e]	Three-phase demand power (MW)
30, 32	QAD, QBD, QCD[e]	A-Phase, B-Phase, and C-Phase demand reactive power (MW)
30, 32	3QD[e]	Three-phase demand reactive power (MW)
30, 32	UAD, UBD, UCD[e]	A-Phase, B-Phase, and C-Phase demand apparent power (MW)
30, 32	3UD[e]	Three-phase demand apparent power (MW)
30, 32	MWHAIN, MWHAOUT[e]	A-Phase total energy in and out (MWh)
30, 32	MWHBIN, MWHBOUT[e]	B-Phase total energy in and out (MWh)
30, 32	MWHCIN, MWHCOUT[e]	C-Phase total energy in and out (MWh)
30, 32	MWHAT[c]	Total A-Phase energy (MWh)
30, 32	MWHBT[c]	Total B-Phase energy (MWh)
30, 32	MWHCT[c]	Total C-Phase energy (MWh)
30, 32	3MWHIN, 3MWHOUT[e]	Three-phase total energy in and out (MWh)
30, 32	3MWH3T[c]	Total three-phase energy (MWh)
30, 32	PMV001–PMV064[g]	Protection SELOGIC math variables
30, 32	AMV001–AMV256[g]	Automation SELOGIC math variables
30, 32	B1BCWPA, B1BCWPB, B1BCWPC[g]	Circuit Breaker 1 contact wear percentage multiplied by 100
30, 32	B2BCWPA, B2BCWPB, B2BCWPC[g]	Circuit Breaker 2 contact wear percentage multiplied by 100
30, 32	FREQ[f]	Frequency (Hz)
30, 32	FREQP[f]	Frequency for under- and overfrequency elements (Hz)
30, 32	FREQPM[f]	Frequency for synchrophasor data (Hz)
30, 32	DFDTP[f]	Rate-of-change of frequency (Hz/s)
30, 32	DFDTPM[f]	Rate-of-change of frequency for synchrophasor data (Hz/s)
30, 32	TODMS[g]	UTC time of day in milliseconds (0–86400000)

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 5 of 6)

Object	Label	Description
30, 32	THR[g]	UTC time, hour (0–23)
30, 32	TMIN[g]	UTC time, minute (0–59)
30, 32	TSEC[g]	UTC time, seconds (0–59)
30, 32	TMSEC[g]	UTC time, milliseconds (0–999)
30, 32	DDOM[g]	UTC date, day of the month (1–31)
30, 32	DMON[g]	UTC date, month (1–12)
30, 32	DYEAR[g]	UTC date, year (2000–2200)
30, 32	TLODMS[e]	Local time of day in milliseconds (0–86400000)
30, 32	TLHR[e]	Local time, hour (0–23)
30, 32	TLMIN[e]	Local time, minute (0–59)
30, 32	TLSEC[e]	Local time, seconds (0–59)
30, 32	TLMSEC[e]	Local time, milliseconds (0–999)
30, 32	DLDOW[e]	Local date, day of the week (1-SU,.., 7-SA)
30, 32	DLDOM[e]	Local date, day of the month (1–31)
30, 32	DLDOY[e]	Local date, day of the year (1–366)
30, 32	DLMON[e]	Local date, month (1–12)
30, 32	DLYEAR[e]	Local date, year (2000–2200)
30, 32	SPSHOT[g]	Present value of single pole shot counter
30, 32	3PSHOT[g]	Present value of three pole shot counter
30, 32	SHOT1_1[g]	Total number of 1st shot single pole recloses
30, 32	SHOT1_2[g]	Total number of 2nd shot single pole recloses
30, 32	SHOT1_T[g]	Total number of single pole reclosing shots issued
30, 32	SHOT3_1[g]	Total number of 1st shot three pole recloses
30, 32	SHOT3_2[g]	Total number of 2nd shot three pole recloses
30, 32	SHOT3_3[g]	Total number of 3rd shot three pole recloses
30, 32	SHOT3_4[g]	Total number of 4th shot three pole recloses
30, 32	SHOT3_T[g]	Total number of three pole reclosing shots issued
30, 32	FLOC[g]	Location of most recent fault
30, 32	RLYTEMP[g]	Relay internal temperature (deg. C)
30, 32	RA001–RA256[e]	Remote analogs
30, 32	RAO001–RAO064[e]	Remote analog output
30, 32	MAXGRP[e]	Maximum number of protection groups
Event Summary Analog Inputs		
30, 32[h]	FTYPE[g, h]	Fault type (*Table 10.12* and *Table 10.13*)
30, 32[h]	FTAR1[g, h]	Fault targets (upper byte is 1st target row, lower byte is 2nd target row)
30, 32[h]	FTAR2[g, h]	Fault targets (upper byte is 3rd target row, lower byte is 0)
30, 32[h]	FSLOC[g, h]	Fault summary location
30, 32[h]	FCURR[c, i]	Fault current
30, 32[h]	FFREQ[g]	Fault frequency (Hz)
30, 32[h]	FGRP[g]	Fault settings group

Table 10.10 SEL-421 DNP3 Reference Data Map (Sheet 6 of 6)

Object	Label	Description
30, 32[h]	FTIMEH, FTIMEM, FTIMEL[g, h]	Fault time (local) in DNP3 format (high, middle, and low 16 bits)
30, 32[f]	FTIMEUH, FTIMEUM, FTIMEUL[g]	Fault time (UTC) in DNP format (high, middle, and low 16 bits)
30, 32[h]	FSHOT1[g]	Recloser single-pole reclose count
30, 32[h]	FSHOT2[g]	Recloser three-pole reclose count
30, 32[h]	FUNR[g, h]	Number of unread fault summaries
Analog Outputs		
40, 41	ACTGRP0	Active settings group
40, 41	TECORR[j]	Time-error preload value
40, 41	RA001–RA256	Remote analogs

[a] The counters use 1 as default or per point counter dead-band setting for the actual counter dead band.
[b] Convert the absolute value to force the counter to a positive value.
[c] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Dead band ANADBA on magnitudes and ANADBM on angles.
[d] Default voltage scaling DECPLV on magnitudes and scale factor of 100 on angles. Dead band ANADBV on magnitudes and ANADBM on angles.
[e] Default miscellaneous scaling DECPLM and dead band ANADBM.
[f] Default scale factor of 100 and dead-band ANADBM.
[g] Default scale factor of 1 and dead-band ANADBM.
[h] Event data shall be generated for all Event Summary Analog Inputs if any of them change beyond their dead band after scaling.
[i] Default dead band of 0.
[j] In milliseconds, $-30000 \leq$ time ≤ 30000. Relay Word bit PLDTE asserts for approximately 1.5 cycles after this value is written.

Binary Outputs

Use the Trip and Close, Latch On/Off and Pulse On operations with Object 12 control relay output block command messages to operate the points shown in *Table 10.11*. Pulse operations provide a pulse with duration of one protection processing interval. Cancel an operation in progress by issuing a NUL Trip/Close Code with a NUL Operation Type.

Table 10.11 SEL-421 Object 12 Control Operations (Sheet 1 of 2)

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
RB01–RB32	Pulse Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32	Set Remote Bit RB01–RB32	Clear Remote Bit RB01–RB32	Pulse Remote Bit RB01–RB32	Clear Remote Bit RB01–RB32
RB*xx*: RB*yy*	Pulse RB*yy* RB01–RB32	Pulse RB*xx* RB01–RB32	Pulse RB*yy*	Pulse RB*xx*	Pulse RB*yy*	Pulse RB*xx*
OC*x*	Open circuit breaker *x* (Pulse OC*x*) *x* = 1–2	Open circuit breaker *x* (Pulse OC*x*) *x* = 1–2	Set OC*x* *x* = 1–2	Clear OC*x* *x* = 1–2	Open circuit breaker *x* (Pulse OCx) *x* = 1–2	Clear OC*x* *x* = 1–2
CC*x*	Close circuit breaker x (Pulse CC*x*) *x* = 1–2	Close circuit breaker *x* (Pulse CC*x*) *x* = 1–2	Set CC*x* *x* = 1–2	Clear CC*x* *x* = 1–2	Close circuit breaker *x* (Pulse CC*x*) *x* = 1–2	Clear CC*x* *x* = 1–2
OC*x*: CC*x*	Close circuit breaker *x* (Pulse CC*x*) *x* = 1–2	Open circuit breaker *x* (Pulse OC*x*) *x* = 1–2	Pulse CC*x*	Pulse OC*x*	Pulse CC*x*	Pulse OC*x*
89OC01–89OC10	Pulse Disconnect open 89OC01–89OC10	Pulse Disconnect open 89OC01–89OC10	Set Disconnect open 89OC01–89OC10	Clear Disconnect open 89OC01–89OC10	Pulse Disconnect open 89OC01–89OC10	Clear Disconnect open 89OC01–89OC10

Table 10.11 SEL-421 Object 12 Control Operations (Sheet 2 of 2)

Label	Close/Any	Trip/Any	NUL/Latch On	NUL/Latch Off	NUL/Pulse On	NUL/Pulse Off
89CC01–89CC10	Pulse Disconnect close 89CC01–89CC10	Pulse Disconnect close 89CC01–89CC10	Set Disconnect close 89CC01–89CC10	Clear Disconnect close 89CC01–89CC10	Pulse Disconnect close 89CC01–89CC10	Clear Disconnect close 89CC01–89CC10
89OC*x*: 89CC*x*	Pulse 89CC*x*, Disconnect Close bit *x* = 01–10	Pulse 89OC*x*, Disconnect Open bit *x* = 01–10	Pulse 89CC*x*	Pulse 89OC*x*	Pulse 89CC*x*	Pulse 89OC*x*
RST_DEM	Reset demand meter data	Reset demand meter data	Reset demand meter data	No action	Reset demand meter data	No action
RST_PDM	Reset peak demand meter data	Reset peak demand meter data	Reset peak demand meter data	No action	Reset peak demand meter data	No action
RST_ENE	Reset accumulated energy meter data	Reset accumulated energy meter data	Reset accumulated energy meter data	No action	Reset accumulated energy meter data	No action
RSTMML	Reset min/max meter data for the line	Reset min/max meter data for line	Reset min/max meter data for the line	No action	Reset min/max meter data for the line	No action
RSTMMB1	Reset min/max meter data for breaker 1	Reset min/max meter data for breaker 1	Reset min/max meter data for breaker 1	No action	Reset min/max meter data for breaker 1	No action
RSTMMB2	Reset min/max meter data for breaker 2	Reset min/max meter data for breaker 2	Reset min/max meter data for breaker 2	No action	Reset min/max meter data for breaker 2	No action
RST_BK1	Reset breaker monitor 1 data	Reset breaker monitor 1 data	Reset breaker monitor 1 data	No action	Reset breaker monitor 1 data	No action
RST_BK2	Reset breaker monitor 2 data	Reset breaker monitor 2 data	Reset breaker monitor 2 data	No action	Reset breaker monitor 2 data	No action
RST_BAT	Reset Battery Monitoring	Reset Breaker Monitoring	Reset Battery Monitoring	No action	Reset Battery Monitoring	No action
RST_79C	Reset recloser shot counters	Reset recloser shot counters	Reset recloser shot counters	No action	Reset recloser shot counters	No action
RSTFLOC	Reset fault location	Reset fault location	Reset fault location	No action	Reset fault location (Pulse RSSFLOC)	No action
RST_HAL	Reset hardware alarm	Reset hardware alarm	Reset hardware alarm	No action	Reset hardware alarm	No action
RSTTRGT	Reset front-panel targets	Reset front-panel targets	Reset front-panel targets	No action	Reset front-panel targets	No action
RSTDNPE	Reset DNP3 Event Summary	Reset DNP3 Event Summary	Reset DNP3 Event Summary	No action	Reset DNP3 Event Summary	No action
NXTEVE	Load oldest relay event (FIFO)	Load oldest relay event (FIFO)	Load oldest relay event (FIFO)	Load newest relay event (LIFO)	Load oldest relay event (FIFO)	Load newest event summary (LIFO)

Fault Summary Data

When a relay event occurs, (TRIP asserts, ER asserts, or TRI asserts) whose fault location is in the range of MINDIST to MAXDIST, the data shall be made available to DNP. If MINDIST is set to OFF, then there is no minimum. Similarly, if MAXDIST is set to OFF, there is no maximum.

In either mode, DNP3 events for all event summary analog inputs (see *Table 10.11*) will be generated if any of them change beyond their dead band value after scaling (usually whenever a new relay event occurs and is loaded into the event summary analog inputs). Events are detected approximately twice a second by the scanning process.

See *Table 10.12* and *Table 10.13* for the components of the FTYPE analog input point. The single bit asserted in the upper byte indicates the event cause (Trigger, Trip, or ER element). The bit(s) asserted in the lower byte indicate which phase(s) were affected by the fault. If no bits are asserted in the upper byte, there is no valid fault summary loaded. If no bits are asserted in the lower byte, the affected phase could not be determined.

Table 10.12 Object 30, 32, FTYPE Upper Byte-Event Cause

Bit Position								Event Cause
7	6	5	4	3	2	1	0	
								No fault summary loaded
							X	Trigger command
					X			Trip element
				X				Event report element

Table 10.13 Object 30, 32, FTYPE Lower Byte-Affected Phase(s)

Bit Position								Affected Phase
7	6	5	4	3	2	1	0	
								Indeterminate
							X	A-Phase
						X		B-Phase
					X			C-Phase
				X				Ground

Lower byte bits will be set according to the event's affected phases. For example, a three-phase fault will set bits 0, 1, and 2, for a decimal value of 7. If this event caused a trip, the upper byte would also have bit 2 set, for a total decimal value of 1031 (0407 in hexadecimal).

Default Data Map

Table 10.14 shows the SEL-421 default DNP3 data map. The default data map is an automatically generated subset of the reference map. All data maps are initialized to the default values. If the default maps are not appropriate, you can also use the custom DNP mapping commands **SET D *n*** and **SHOW D *n***, where *n* is the map number, to edit or create the map required for your application.

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 1 of 7)

Object	Default Index	Label	Description
Binary Inputs			
01, 02	0	RLYDIS	Relay disabled
01, 02	1	TRIPLED	Trip LED
01, 02	2	STFAIL	Relay diagnostic failure
01, 02	3	STWARN	Relay diagnostic warning

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 2 of 7)

Object	Default Index	Label	Description
01, 02	4	STSET	Settings change or relay restart
01, 02	5	SALARM	Software alarm
01, 02	6	HALARM	Hardware alarm
01, 02	7	BADPASS	Invalid password attempt alarm
01, 02	8	UNRDEV	New relay event available
01, 02	9	SPO	One or two poles open
01, 02	10	3PO	All three poles open
01, 02	11	BK1RS	Circuit Breaker 1 in ready state
01, 02	12	BK2RS	Circuit Breaker 2 in ready state
01, 02	13	BK1LO	Circuit Breaker 1 in lockout state
01, 02	14	BK2LO	Circuit Breaker 2 in lockout state
01, 02	15	52AA1	Circuit Breaker 1, Pole A status
01, 02	16	52AB1	Circuit Breaker 1, Pole B status
01, 02	17	52AC1	Circuit Breaker 1, Pole C status
01, 02	18	52AAL1	Circuit Breaker 1, Pole A alarm
01, 02	19	52BAL1	Circuit Breaker 1, Pole B alarm
01, 02	20	52CAL1	Circuit Breaker 1, Pole C alarm
01, 02	21	52AA2	Circuit Breaker 2, Pole A status
01, 02	22	52AB2	Circuit Breaker 2, Pole B status
01, 02	23	52AC2	Circuit Breaker 2, Pole C status
01, 02	24	52AAL2	Circuit Breaker 2, Pole A alarm
01, 02	25	52BAL2	Circuit Breaker 2, Pole B alarm
01, 02	26	52CAL2	Circuit Breaker 2, Pole C alarm
01, 02	27	TLED_1	Front-panel target LED 1
01, 02	28	TLED_2	Front-panel target LED 2
01, 02	29	TLED_3	Front-panel target LED 3
01, 02	30	TLED_4	Front-panel target LED 4
01, 02	31	TLED_5	Front-panel target LED 5
01, 02	32	TLED_6	Front-panel target LED 6
01, 02	33	TLED_7	Front-panel target LED 7
01, 02	34	TLED_8	Front-panel target LED 8
01, 02	35	TLED_9	Front-panel target LED 9
01, 02	36	TLED_10	Front-panel target LED 10
01, 02	37	TLED_11	Front-panel target LED 11
01, 02	38	TLED_12	Front-panel target LED 12
01, 02	39	TLED_13	Front-panel target LED 13
01, 02	40	TLED_14	Front-panel target LED 14
01, 02	41	TLED_15	Front-panel target LED 15
01, 02	42	TLED_16	Front-panel target LED 16
01, 02	43	LDATPFW	Leading true power factor A-Phase Terminal W
01, 02	44	LDBTPFW	Leading true power factor B-Phase Terminal W

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 3 of 7)

Object	Default Index	Label	Description
01, 02	45	LDCTPFW	Leading true power factor C-Phase Terminal W
01, 02	46	LD3TPFW	Leading true power factor three-phase Terminal W
01, 02	47	IN101	Main board Input 1
01, 02	48	IN102	Main board Input 2
01, 02	49	IN103	Main board Input 3
01, 02	50	IN104	Main board Input 4
01, 02	51	IN105	Main board Input 5
01, 02	52	IN106	Main board Input 6
01, 02	53	IN107	Main board Input 7
01, 02	54	PSV01	Protection SELOGIC Variable 1
01, 02	55	PSV02	Protection SELOGIC Variable 2
01, 02	56	PSV03	Protection SELOGIC Variable 3
01, 02	57	PSV04	Protection SELOGIC Variable 4
01, 02	58	PSV05	Protection SELOGIC Variable 5
01, 02	59	PSV06	Protection SELOGIC Variable 6
01, 02	60	PSV07	Protection SELOGIC Variable 7
01, 02	61	PSV08	Protection SELOGIC Variable 8
01, 02	62	ASV001	Automation SELOGIC Variable 1
01, 02	63	ASV002	Automation SELOGIC Variable 2
01, 02	64	ASV003	Automation SELOGIC Variable 3
01, 02	65	ASV004	Automation SELOGIC Variable 4
01, 02	66	ASV005	Automation SELOGIC Variable 5
01, 02	67	ASV006	Automation SELOGIC Variable 6
01, 02	68	ASV007	Automation SELOGIC Variable 7
01, 02	69	ASV008	Automation SELOGIC Variable 8
01, 02	70	OUT101	Main board Output 1
01, 02	71	OUT102	Main board Output 2
01, 02	72	OUT103	Main board Output 3
01, 02	73	OUT104	Main board Output 4
01, 02	74	OUT105	Main board Output 5
01, 02	75	OUT106	Main board Output 6
01, 02	76	OUT107	Main board Output 7
Binary Outputs			
10, 12	0–31	RB01–RB32	Remote bits RB01–RB32
10, 12	32	OC1	Pulse Open Circuit Breaker 1 command
10, 12	33	CC1	Pulse Close Circuit Breaker 1 command
10, 12	34	OC2	Pulse Open Circuit Breaker 2 command
10, 12	35	CC2	Pulse Close Circuit Breaker 2 command
10, 12	36	89OC01	Open Disconnect Switch Control 1
10, 12	37	89CC01	Close Disconnect Switch Control 1
10, 12	38	89OC02	Open Disconnect Switch Control 2

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 4 of 7)

Object	Default Index	Label	Description
10, 12	39	89CC02	Close Disconnect Switch Control 2
10, 12	40	89OC03	Open Disconnect Switch Control 3
10, 12	41	89CC03	Close Disconnect Switch Control 3
10, 12	42	89OC04	Open Disconnect Switch Control 4
10, 12	43	89CC04	Close Disconnect Switch Control 4
10, 12	44	89OC05	Open Disconnect Switch Control 5
10, 12	45	89CC05	Close Disconnect Switch Control 5
10, 12	46	89OC06	Open Disconnect Switch Control 6
10, 12	47	89CC06	Close Disconnect Switch Control 6
10, 12	48	89OC07	Open Disconnect Switch Control 7
10, 12	49	89CC07	Close Disconnect Switch Control 7
10, 12	50	89OC08	Open Disconnect Switch Control 8
10, 12	51	89CC08	Close Disconnect Switch Control 8
10, 12	52	89OC09	Open Disconnect Switch Control 9
10, 12	53	89CC09	Close Disconnect Switch Control 9
10, 12	54	89OC10	Open Disconnect Switch Control 10
10, 12	55	89CC10	Close Disconnect Switch Control 10
10, 12	56	RST_DEM	Reset demands
10, 12	57	RST_PDM	Reset demand peaks
10, 12	58	RST_ENE	Reset energies
10, 12	59	RST_BK1	Reset Breaker 1 monitor data
10, 12	60	RST_BK2	Reset Breaker 2 monitor data
10, 12	61	RSTTRGT	Reset front-panel targets
10, 12	62	RSTMML	Reset min/max metering data for the line
10, 12	63	RSTDNPE	Reset (clear) DNP3 event summary analog inputs
Binary Counters			
20, 22	0	ACTGRP	Active settings group
20, 22	1	BKR1OPA	Number of breaker operations on Circuit Breaker 1 A-Phase
20, 22	2	BKR1OPB	Number of breaker operations on Circuit Breaker 1 B-Phase
20, 22	3	BKR1OPC	Number of breaker operations on Circuit Breaker 1 C-Phase
20, 22	4	BKR2OPA	Number of breaker operations on Circuit Breaker 2 A-Phase
20, 22	5	BKR2OPB	Number of breaker operations on Circuit Breaker 2 B-Phase
20, 22	6	BKR2OPC	Number of breaker operations on Circuit Breaker 2 C-Phase
20, 22[a, b]	7	KWHAOUT	Positive (export) A-Phase energy, kilowatt hours
20, 22[a, b]	8	KWHBOUT	Positive (export) B-Phase energy, kilowatt hours
20, 22[a, b]	9	KWHCOUT	Positive (export) C-Phase energy, kilowatt hours
20, 22[a, b]	10	KWHAIN	Negative (import) A-Phase energy, kilowatt hours
20, 22[a, b]	11	KWHBIN	Negative (import) B-Phase energy, kilowatt hours
20, 22[a, b]	12	KWHCIN	Negative (import) C-Phase energy, kilowatt hours
20, 22[a, b]	13	3KWHOUT	Positive (export) three-phase energy, kilowatt hours
20, 22[a, b]	14	3KWHIN	Negative (import) three-phase energy, kilowatt hours

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 5 of 7)

Object	Default Index	Label	Description
20, 22	15	MWHAOUT	Positive A-Phase energy (export), MWh
20, 22	16	MWHBOUT	Positive B-Phase energy (export), MWh
20, 22	17	MWHCOUT	Positive C-Phase energy (export), MWh
20, 22	18	MWHAIN	Negative A-Phase energy (import), MWh
20, 22	19	MWHBIN	Negative B-Phase energy (import), MWh
20, 22	20	MWHCIN	Negative C-Phase energy (import), MWh
20, 22	21	3MWHOUT	Positive three-phase energy (export), MWh
20, 22	22	3MWHIN	Negative three-phase energy (export), MWh
Analog Inputs			
30, 32	0, 1	LIAFM, LIAFA	Line A-Phase current magnitude (amperes) and angle
30, 32	2, 3	LIBFM, LIBFA	Line B-Phase current magnitude (amperes) and angle
30, 32	4, 5	LICFM, LICFA	Line C-Phase current magnitude (amperes) and angle
30, 32	6, 7	B1IAFM, B1IAFA	Circuit Breaker 1 A-Phase current magnitude (amperes) and angle
30, 32	8, 9	B1IBFM, B1IBFA	Circuit Breaker 1 B-Phase current magnitude (amperes) and angle
30, 32	10, 11	B1ICFM, B1ICFA	Circuit Breaker 1 C-Phase current magnitude (amperes) and angle
30, 32	12, 13	B2IAFM, B2IAFA	Circuit Breaker 2 A-Phase current magnitude (amperes) and angle
30, 32	14, 15	B2IBFM, B2IBFA	Circuit Breaker 2 B-Phase current magnitude (amperes) and angle
30, 32	16, 17	B2ICFM, B2ICFA	Circuit Breaker 2 C-Phase current magnitude (amperes) and angle
30, 32	18, 19	VAFM, VAFA	Line A-Phase voltage magnitude (kV) and angle
30, 32	20, 21	VBFM, VBFA	Line B-Phase voltage magnitude (kV) and angle
30, 32	22, 23	VCFM, VCFA	Line C-Phase voltage magnitude (kV) and angle
30, 32	24	VPM	Polarizing voltage magnitude (volts)
30, 32	25	NVS1M	Synchronizing Voltage 1 magnitude (volts)
30, 32	26	NVS2M	Synchronizing Voltage 2 magnitude (volts)
30, 32	27, 28	LIGM, LIGA	Line zero-sequence current (3I0) magnitude in amperes and angle
30, 32	29, 30	LI1M, LI1A	Line positive-sequence current magnitude (amperes) and angle
30, 32	31, 32	L3I2M, L3I2A	Line negative-sequence current (3I2) magnitude in amperes and angle
30, 32	33, 34	3V0M, 3V0A	Zero-sequence voltage magnitude (3V0) in kV and angle
30, 32	35, 36	V1M, V1A	Positive-sequence voltage magnitude (V1) in kV and angle
30, 32	37, 38	3V2M, 3V2A	Negative-sequence voltage magnitude (3V2) in kV and angle
30, 32	39	PA_F	A-Phase real power in MW
30, 32	40	PB_F	B-Phase real power in MW
30, 32	41	PC_F	C-Phase real power in MW
30, 32	42	3P_F	Three-phase real power in MW
30, 32	43	QA_F	A-Phase reactive power in MVAR
30, 32	44	QB_F	B-Phase reactive power in MVAR
30, 32	45	QC_F	C-Phase reactive power in MVAR
30, 32	46	3Q_F	Three-phase reactive power in MVAR
30, 32	47	DPFA	A-Phase displacement power factor
30, 32	48	DPFB	B-Phase displacement power factor
30, 32	49	DPFC	C-Phase displacement power factor

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 6 of 7)

Object	Default Index	Label	Description
30, 32	50	3DPF	Three-phase displacement power factor
30, 32	51	DC1	DC Battery 1 voltage (V)
30, 32	52	DC2	DC Battery 2 voltage (V)
30, 32	53	FREQ	Frequency (Hz)
30, 32	54, 55	MWHAIN, MWHAOUT	A-Phase total energy in and out (MWh)
30, 32	56, 57	MWHBIN, MWHBOUT	B-Phase total energy in and out (MWh)
30, 32	58, 59	MWHCIN, MWHCOUT	C-Phase total energy in and out (MWh)
30, 32	60, 61	3MWHIN, 3MWHOUT	Three-phase total energy in and out (MWh)
30, 32	62	IAD	A-Phase demand current (amperes)
30, 32	63	IBD	B-Phase demand current (amperes)
30, 32	64	ICD	C-Phase demand current (amperes)
30, 32	65	3I2D	Demand negative-sequence current (amperes)
30, 32	66	IGD	Demand zero-sequence current (amperes)
30, 32	67–69	PAD, PBD, PCD	A-Phase, B-Phase, and C-Phase demand power (MW)
30, 32	70	3PD	Three-phase demand power (MW)
30, 32	71	IAPKD	Peak A-Phase demand current (amperes)
30, 32	72	IBPKD	Peak B-Phase demand current (amperes)
30, 32	73	ICPKD	Peak C-Phase demand current (amperes)
30, 32	74	IGPKD	Peak zero-sequence demand current (amperes)
30, 32	75	3I2PKD	Peak negative-sequence demand current (amperes)
30, 32	76	PAPKD	A-Phase peak demand power (MW)
30, 32	77	PBPKD	B-Phase peak demand power (MW)
30, 32	78	PCPKD	C-Phase peak demand power (MW)
30, 32	79	3PPKD	Three-phase peak demand power (MW)
30, 32	80–82	B1BCWPA, B1BCWPB, B1BCWPC	Circuit Breaker 1 contact wear percentage multiplied by 100
30, 32	83–85	B2BCWPA, B2BCWPB, B2BCWPC	Circuit Breaker 2 contact wear percentage multiplied by 100
30, 32	86	FTYPE	Fault type (*Table 10.12* and *Table 10.13*)
30, 32	87	FTAR1	Fault targets (upper byte is 1st target row, lower byte is 2nd target row)
30, 32	88	FTAR2	Fault targets (upper byte is 3rd target row, lower byte is 0)
30, 32	89	FSLOC	Fault summary location
30, 32	90	FCURR	Fault current
30, 32	91	FFREQ	Fault frequency (Hz)
30, 32	92	FGRP	Fault settings group
30, 32	93–95	FTIMEH, FTIMEM, FTIMEL	Fault time in DNP3 format (high, middle, and low 16 bits)
30, 32	96	FSHOT1	Recloser single-pole reclose count
30, 32	97	FSHOT2	Recloser three-pole reclose count
30, 32	98	FUNR	Number of unread fault summaries
30, 32	99	SHOT3_T	Total number of three pole reclosing shots issued
30. 32	100	RLYTEMP	Relay internal temperature (degrees C)

Table 10.14 SEL-421 DNP3 Default Data Map (Sheet 7 of 7)

Object	Default Index	Label	Description
Analog Outputs			
40, 41	0	ACTGRP	Active settings group

[a] The counters use 1 as default or per point Counter dead-band setting for the actual counter dead band.
[b] Convert the absolute value to force the counter to a positive value.

IEC 61850 Communication

General IEC 61850 operation is described in *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*. This section describes characteristics of IEC 61850 that are specific to the SEL-421.

Logical Nodes

Table 10.15–Table 10.16 show the logical nodes (LNs) supported in the SEL-421 and the Relay Word bits or Measured Values mapped to those LNs. Additionally, the relay supports the CON and ANN Logical Device logical nodes as described in *Section 17: IEC 61850 Communication in the SEL-400 Series Relays Instruction Manual*.

Table 10.15 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table 10.15 Logical Device: PRO (Protection) (Sheet 1 of 6)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
BKR1CSWI1	Pos.Oper.ctlVal	CC1:OC1	Circuit Breaker 1 close/open command
BKR2CSWI2	Pos.Oper.ctlVal	CC2:OC2	Circuit Breaker 2 close/open command
DC10CSWI10	Pos.Oper.ctlVal	89CC10:89OC10	ASCII Close/Open Disconnect 10 command
DC1CSWI1	Pos.Oper.ctlVal	89CC01:89OC01	ASCII Close/Open Disconnect 1 command
DC2CSWI2	Pos.Oper.ctlVal	89CC02:89OC02	ASCII Close/Open Disconnect 2 command
DC3CSWI3	Pos.Oper.ctlVal	89CC03:89OC03	ASCII Close/Open Disconnect 3 command
DC4CSWI4	Pos.Oper.ctlVal	89CC04:89OC04	ASCII Close/Open Disconnect 4 command
DC5CSWI5	Pos.Oper.ctlVal	89CC05:89OC05	ASCII Close/Open Disconnect 5 command
DC6CSWI6	Pos.Oper.ctlVal	89CC06:89OC06	ASCII Close/Open Disconnect 6 command
DC7CSWI7	Pos.Oper.ctlVal	89CC07:89OC07	ASCII Close/Open Disconnect 7 command
DC8CSWI8	Pos.Oper.ctlVal	89CC08:89OC08	ASCII Close/Open Disconnect 8 command
DC9CSWI9	Pos.Oper.ctlVal	89CC09:89OC09	ASCII Close/Open Disconnect 9 command
Functional Constraint = ST			
BFR1RBRF1	OpEx.general	FBF1[a]	Circuit Breaker 1 circuit breaker failure
BFR1RBRF1	OpEx.phsA	FBFA1[a]	Circuit Breaker 1 A-Phase circuit breaker failure
BFR1RBRF1	OpEx.phsB	FBFB1[a]	Circuit Breaker 1 B-Phase circuit breaker failure
BFR1RBRF1	OpEx.phsC	FBFC1[a]	Circuit Breaker 1 C-Phase circuit breaker failure
BFR1RBRF1	OpIn.general	RT1[a]	Circuit Breaker 1 retrip
BFR1RBRF1	OpIn.phsA	RTA1[a]	Circuit Breaker 1 A-Phase retrip

Table 10.15 Logical Device: PRO (Protection) (Sheet 2 of 6)

Logical Node	Attribute	Data Source	Comment
BFR1RBRF1	OpIn.phsB	RTB1[a]	Circuit Breaker 1 B-Phase retrip
BFR1RBRF1	OpIn.phsC	RTC1[a]	Circuit Breaker 1 C-Phase retrip
BFR1RBRF1	Str.general	CSV02	BFI3P1 OR BFIA1 OR BFIB1 OR BFIC1
BFR2RBRF2	OpEx.general	FBF2[a]	Circuit Breaker 2 circuit breaker failure
BFR2RBRF2	OpEx.phsA	FBFA2[a]	Circuit Breaker 2 A-Phase circuit breaker failure
BFR2RBRF2	OpEx.phsB	FBFB2[a]	Circuit Breaker 2 B-Phase circuit breaker failure
BFR2RBRF2	OpEx.phsC	FBFC2[a]	Circuit Breaker 2 C-Phase circuit breaker failure
BFR2RBRF2	OpIn.general	RT2[a]	Circuit Breaker 2 retrip
BFR2RBRF2	OpIn.phsA	RTA2[a]	Circuit Breaker 2 A-Phase retrip
BFR2RBRF2	OpIn.phsB	RTB2[a]	Circuit Breaker 2 B-Phase retrip
BFR2RBRF2	OpIn.phsC	RTC2[a]	Circuit Breaker 2 C-Phase retrip
BFR2RBRF2	Str.general	CSV03	BFI3P2 OR BFIA2 OR BFIB2 OR BFIC2
BK1AXCBR1	Pos.stVal	52ACL1?1:2[a]	Circuit Breaker 1, Pole A closed
BK1BXCBR2	Pos.stVal	52BCL1?1:2[a]	Circuit Breaker 1, Pole B closed
BK1CXCBR3	Pos.stVal	52CCL1?1:2[a]	Circuit Breaker 1, Pole C closed
BK2AXCBR4	Pos.stVal	52ACL2?1:2[a]	Circuit Breaker 2, Pole A closed
BK2BXCBR5	Pos.stVal	52BCL2?1:2[a]	Circuit Breaker 2, Pole B closed
BK2CXCBR6	Pos.stVal	52CCL2?1:2[a]	Circuit Breaker 2, Pole C closed
BKR1CSWI1	OpCls.general	CC1[a]	Circuit Breaker 1 close command
BKR1CSWI1	OpOpn.general	OC1[a]	Circuit Breaker 1 open command
BKR1CSWI1	Pos.stVal	52ACL1?1:2[a]	Circuit Breaker 1, Pole A closed
BKR1PTRC2	Tr.general	CSV06	TPA1 OR TPB1 OR TPC1
BKR1PTRC2	Tr.phsA	TPA1[a]	Circuit Breaker 1 Trip A
BKR1PTRC2	Tr.phsB	TPB1[a]	Circuit Breaker 1 Trip B
BKR1PTRC2	Tr.phsC	TPC1[a]	Circuit Breaker 1 Trip C
BKR2CSWI2	OpCls.general	CC2[a]	Circuit Breaker 2 close command
BKR2CSWI2	OpOpn.general	OC2[a]	Circuit Breaker 2 open command
BKR2CSWI2	Pos.stVal	52ACL2?1:2[a]	Circuit Breaker 2, Pole A closed
BKR2PTRC3	Tr.general	CSV07	TPA2 OR TPB2 OR TPC2
BKR2PTRC3	Tr.phsA	TPA2[a]	Circuit Breaker 2 Trip A
BKR2PTRC3	Tr.phsB	TPB2[a]	Circuit Breaker 2 Trip B
BKR2PTRC3	Tr.phsC	TPC2[a]	Circuit Breaker 2 Trip C
DC10CSWI10	OpCls.general	89CC10[a]	ASCII Close Disconnect 10 command
DC10CSWI10	OpOpn.general	89OC10[a]	ASCII Open Disconnect 10 command
DC10CSWI10	Pos.stVal	89CL10|89OPN10?0:1:2:3[a]	Disconnect 10 status
DC1CSWI1	OpCls.general	89CC01[a]	ASCII Close Disconnect 1 command
DC1CSWI1	OpOpn.general	89OC01[a]	ASCII Open Disconnect 1 command
DC1CSWI1	Pos.stVal	89CL01|89OPN01?0:1:2:3[a]	Disconnect 1 status
DC2CSWI2	OpCls.general	89CC02[a]	ASCII Close Disconnect 2 command
DC2CSWI2	OpOpn.general	89OC02[a]	ASCII Open Disconnect 2 command
DC2CSWI2	Pos.stVal	89CL02|89OPN02?0:1:2:3[a]	Disconnect 2 status

Table 10.15 Logical Device: PRO (Protection) (Sheet 3 of 6)

Logical Node	Attribute	Data Source	Comment
DC3CSWI3	OpCls.general	89CC03[a]	ASCII Close Disconnect 3 command
DC3CSWI3	OpOpn.general	89OC03[a]	ASCII Open Disconnect 3 command
DC3CSWI3	Pos.stVal	89CL03|89OPN03?0:1:2:3[a]	Disconnect 3 status
DC4CSWI4	OpCls.general	89CC04[a]	ASCII Close Disconnect 4 command
DC4CSWI4	OpOpn.general	89OC04[a]	ASCII Open Disconnect 4 command
DC4CSWI4	Pos.stVal	89CL04|89OPN04?0:1:2:3[a]	Disconnect 4 status
DC5CSWI5	OpCls.general	89CC05[a]	ASCII Close Disconnect 5 command
DC5CSWI5	OpOpn.general	89OC05[a]	ASCII Open Disconnect 5 command
DC5CSWI5	Pos.stVal	89CL05|89OPN05?0:1:2:3[a]	Disconnect 5 status
DC6CSWI6	OpCls.general	89CC06[a]	ASCII Close Disconnect 6 command
DC6CSWI6	OpOpn.general	89OC06[a]	ASCII Open Disconnect 6 command
DC6CSWI6	Pos.stVal	89CL06|89OPN06?0:1:2:3[a]	Disconnect 6 status
DC7CSWI7	OpCls.general	89CC07[a]	ASCII Close Disconnect 7 command
DC7CSWI7	OpOpn.general	89OC07[a]	ASCII Open Disconnect 7 command
DC7CSWI7	Pos.stVal	89CL07|89OPN07?0:1:2:3[a]	Disconnect 7 status
DC8CSWI8	OpCls.general	89CC08[a]	ASCII Close Disconnect 8 command
DC8CSWI8	OpOpn.general	89OC08[a]	ASCII Open Disconnect 8 command
DC8CSWI8	Pos.stVal	89CL08|89OPN08?0:1:2:3[a]	Disconnect 8 status
DC9CSWI9	OpCls.general	89CC09[a]	ASCII Close Disconnect 9 command
DC9CSWI9	OpOpn.general	89OC09[a]	ASCII Open Disconnect 9 command
DC9CSWI9	Pos.stVal	89CL09|89OPN09?0:1:2:3[a]	Disconnect 9 status
DCBPSCH2	Op.general	RXPRM[a]	Receiver trip permission
DCBPSCH2	RxPrm1.general	BTX[a]	Block extension picked up
DCBPSCH2	TxBlk.general	Z3RB[a]	Current reversal guard asserted
DCBPSCH2	TxPrm.general	CSV01	DSTRT OR NSTRT
DCUBPSCH3	EchoWei.stVal	EKEY[a]	Echo received permissive trip signal
DCUBPSCH3	EchoWeiOp.stVal	ECTT[a]	Echo conversion to trip signal
DCUBPSCH3	Op.general	RXPRM[a]	Receiver trip permission
DCUBPSCH3	RxPrm1.general	PTRX[a]	Permissive trip received Channel 1 and Channel 2
DCUBPSCH3	TxBlk.general	Z3RB[a]	Current reversal guard asserted
DCUBPSCH3	TxPrm.general	KEY[a]	Transmit permissive trip signal
F32GRDIR1	Dir.dirGeneral	32GF?0:1[a]	Forward ground directional element
F32GRDIR1	Dir.general	32GF[a]	Forward ground directional element
F32PRDIR5	Dir.dirGeneral	F32P?0:1[a]	Forward phase directional declaration
F32PRDIR5	Dir.general	F32P[a]	Forward phase directional declaration
F32QRDIR3	Dir.dirGeneral	F32Q?0:1[a]	Forward negative-sequence phase directional declaration
F32QRDIR3	Dir.general	F32Q[a]	Forward negative-sequence phase directional declaration
FLTRDRE1	FltNum.stVal	FLRNUM	Event number
FLTRDRE1	RcdMade.stVal	FLREP	Event report present
G1PIOC2	Op.general	50G1[a]	Level 1 residual overcurrent element
G1PTOC2	Op.general	67G1T[a]	Level 1 residual delayed directional overcurrent element

Table 10.15 Logical Device: PRO (Protection) (Sheet 4 of 6)

Logical Node	Attribute	Data Source	Comment
G1PTOC2	Str.general	67G1[a]	Level 1 residual directional overcurrent element
G2PIOC5	Op.general	50G2[a]	Level 2 residual overcurrent element
G2PTOC5	Op.general	67G2T[a]	Level 2 residual delayed directional overcurrent element
G2PTOC5	Str.general	67G2[a]	Level 2 residual directional overcurrent element
G3PIOC8	Op.general	50G3[a]	Level 3 residual overcurrent element
G3PTOC8	Op.general	67G3T[a]	Level 3 residual delayed directional overcurrent element
G3PTOC8	Str.general	67G3[a]	Level 3 residual directional overcurrent element
G4PIOC11	Op.general	50G4[a]	Level 4 residual overcurrent element
G4PTOC11	Op.general	67G4T[a]	Level 4 residual delayed directional overcurrent element
G4PTOC11	Str.general	67G4[a]	Level 4 residual directional overcurrent element
OSB1RPSB2	BlkZn.stVal	OSB1[a]	Block Zone 1 during an out-of-step condition
OSB1RPSB2	Str.general	OSB[a]	Out-of-step block
OSB2RPSB3	BlkZn.stVal	OSB2[a]	Block Zone 2 during an out-of-step condition
OSB2RPSB3	Str.general	OSB[a]	Out-of-step block
OSB3RPSB4	BlkZn.stVal	OSB3[a]	Block Zone 3 during an out-of-step condition
OSB3RPSB4	Str.general	OSB[a]	Out-of-step block
OSB4RPSB5	BlkZn.stVal	OSB4[a]	Block Zone 4 during an out-of-step condition
OSB4RPSB5	Str.general	OSB[a]	Out-of-step block
OSB5RPSB6	BlkZn.stVal	OSB5[a]	Block Zone 5 during an out-of-step condition
OSB5RPSB6	Str.general	OSB[a]	Out-of-step block
OSTRPSB1	Op.general	OST[a]	Out-of-step tripping
P1PIOC1	Op.general	50P1[a]	Level 1 phase overcurrent element
P1PTOC1	Op.general	67P1T[a]	Level 1 phase-delayed directional overcurrent element
P1PTOC1	Str.general	67P1[a]	Level 1 phase directional overcurrent element
P2PIOC4	Op.general	50P2[a]	Level 2 phase overcurrent element
P2PTOC4	Op.general	67P2T[a]	Level 2 phase-delayed directional overcurrent element
P2PTOC4	Str.general	67P2[a]	Level 2 phase directional overcurrent element
P3PIOC7	Op.general	50P3[a]	Level 3 phase overcurrent element
P3PTOC7	Op.general	67P3T[a]	Level 3 phase-delayed directional overcurrent element
P3PTOC7	Str.general	67P3[a]	Level 3 phase directional overcurrent element
P4PIOC10	Op.general	50P4[a]	Level 4 phase overcurrent element
P4PTOC10	Op.general	67P4T[a]	Level 4 phase-delayed directional overcurrent element
P4PTOC10	Str.general	67P4[a]	Level 4 phase directional overcurrent element
POTTPSCH1	EchoWei.stVal	EKEY[a]	Echo received permissive trip signal
POTTPSCH1	EchoWeiOp.stVal	ECTT[a]	Echo conversion to trip signal
POTTPSCH1	Op.general	RXPRM[a]	Receiver trip permission
POTTPSCH1	RxPrm1.general	PTRX[a]	Permissive trip received Channel 1 and Channel 2
POTTPSCH1	TxBlk.general	Z3RB[a]	Current reversal guard asserted
POTTPSCH1	TxPrm.general	KEY[a]	Transmit permissive trip signal
Q1PIOC3	Op.general	50Q1[a]	Level 1 negative-sequence overcurrent element
Q1PTOC3	Op.general	67Q1T[a]	Level 1 negative sequence delayed directional overcurrent element

Table 10.15 Logical Device: PRO (Protection) (Sheet 5 of 6)

Logical Node	Attribute	Data Source	Comment
Q1PTOC3	Str.general	67Q1[a]	Level 1 negative-sequence directional overcurrent element
Q2PIOC6	Op.general	50Q2[a]	Level 2 negative-sequence overcurrent element
Q2PTOC6	Op.general	67Q2T[a]	Level 2 negative-sequence delayed directional overcurrent element
Q2PTOC6	Str.general	67Q2[a]	Level 2 negative-sequence directional overcurrent element
Q3PIOC9	Op.general	50Q3[a]	Level 3 negative-sequence overcurrent element
Q3PTOC9	Op.general	67Q3T[a]	Level 3 negative-sequence delayed directional overcurrent element
Q3PTOC9	Str.general	67Q3[a]	Level 3 negative-sequence directional overcurrent element
Q4PIOC12	Op.general	50Q4[a]	Level 4 negative-sequence overcurrent element
Q4PTOC12	Op.general	67Q4T[a]	Level 4 negative-sequence delayed directional overcurrent element
Q4PTOC12	Str.general	67Q4[a]	Level 4 negative-sequence directional overcurrent element
R32GRDIR2	Dir.dirGeneral	32GR?0:2[a]	Reverse ground directional element
R32GRDIR2	Dir.general	32GR[a]	Reverse ground directional element
R32PRDIR6	Dir.dirGeneral	R32P?0:2[a]	Reverse phase directional declaration
R32PRDIR6	Dir.general	R32P[a]	Reverse phase directional declaration
R32QRDIR4	Dir.dirGeneral	R32Q?0:2[a]	Reverse negative-sequence phase directional declaration
R32QRDIR4	Dir.general	R32Q[a]	Reverse negative-sequence phase directional declaration
S1PTOC13	Op.general	51S1T[a]	Inverse-Time Overcurrent Element 1 timed out
S1PTOC13	Str.general	51S1[a]	Inverse-Time Overcurrent Element 1 pickup
S2PTOC14	Op.general	51S2T[a]	Inverse-Time Overcurrent Element 2 timed out
S2PTOC14	Str.general	51S2[a]	Inverse-Time Overcurrent Element 2 pickup
S3PTOC15	Op.general	51S3T[a]	Inverse-Time Overcurrent Element 3 timed out
S3PTOC15	Str.general	51S3[a]	Inverse-Time Overcurrent Element 3 pickup
TRIPPTRC1	Tr.general	TRIP[a]	TPA OR TPB OR TPC
TRIPPTRC1	Tr.phsA	TPA[a]	Trip A
TRIPPTRC1	Tr.phsB	TPB[a]	Trip B
TRIPPTRC1	Tr.phsC	TPC[a]	Trip C
Z1GPDIS2	Op.general	Z1GT[a]	Zone 1 ground distance, time-delayed
Z1GPDIS2	Str.general	Z1G[a]	Zone 1 ground distance element
Z1PPDIS1	Op.general	Z1PT[a]	Zone 1 phase distance, time-delayed
Z1PPDIS1	Str.general	Z1P[a]	Zone 1 phase distance element
Z2GPDIS4	Op.general	Z2GT[a]	Zone 2 ground distance, time-delayed
Z2GPDIS4	Str.general	Z2G[a]	Zone 2 ground distance element
Z2PPDIS3	Op.general	Z2PT[a]	Zone 2 phase distance, time-delayed
Z2PPDIS3	Str.general	Z2P[a]	Zone 2 phase distance element
Z3GPDIS6	Op.general	Z3GT[a]	Zone 3 ground distance, time-delayed
Z3GPDIS6	Str.dirGeneral	RVRS3?1:2	Asserts when Global setting DIR3=R
Z3GPDIS6	Str.general	Z3G[a]	Zone 3 ground distance element
Z3PPDIS5	Op.general	Z3PT[a]	Zone 3 phase distance, time-delayed
Z3PPDIS5	Str.dirGeneral	RVRS3?1:2	Asserts when Global setting DIR3=R
Z3PPDIS5	Str.general	Z3P[a]	Zone 3 phase distance element
Z4GPDIS8	Op.general	Z4GT[a]	Zone 4 ground distance, time-delayed

Table 10.15 Logical Device: PRO (Protection) (Sheet 6 of 6)

Logical Node	Attribute	Data Source	Comment
Z4GPDIS8	Str.dirGeneral	RVRS4?1:2	Asserts when Global setting DIR4=R
Z4GPDIS8	Str.general	Z4G[a]	Zone 4 ground distance element
Z4PPDIS7	Op.general	Z4PT[a]	Zone 4 phase distance, time-delayed
Z4PPDIS7	Str.dirGeneral	RVRS4?1:2	Asserts when Global setting DIR4=R
Z4PPDIS7	Str.general	Z4P[a]	Zone 4 phase distance element
Z5GPDIS10	Op.general	Z5GT[a]	Zone 5 ground distance, time-delayed
Z5GPDIS10	Str.dirGeneral	RVRS5?1:2	Asserts when Global setting DIR5=R
Z5GPDIS10	Str.general	Z5G[a]	Zone 5 ground distance element
Z5PPDIS9	Op.general	Z5PT[a]	Zone 5 phase distance, time-delayed
Z5PPDIS9	Str.dirGeneral	RVRS5?1:2	Asserts when Global setting DIR5=R
Z5PPDIS9	Str.general	Z5P[a]	Zone 5 phase distance element

[a] Data source is high-speed GOOSE data if included in an outgoing GOOSE dataset.

Table 10.16 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table 10.16 Logical Device: MET (Metering) (Sheet 1 of 3)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = MX			
DCZBAT1	Vol.instMag.f	DC1	Filtered Station Battery DC Voltage 1
DCZBAT2	Vol.instMag.f	DC2	Filtered Station Battery DC Voltage 2
DMDMDST1	A.phsA.instCVal.mag.f	IAD	Demand A-Phase current
DMDMDST1	A.phsB.instCVal.mag.f	IBD	Demand B-Phase current
DMDMDST1	A.phsC.instCVal.mag.f	ICD	Demand C-Phase current
DMDMDST1	SeqA.c1.instMag.f	3I2D	Demand negative sequence current
DMDMDST1	SeqA.c2.instMag.f	3I2D	Demand negative sequence current
DMDMDST1	SeqA.c3.instMag.f	IGD	Demand zero sequence current
DMDMDST1	TotVA.instMag.f	3UD	Demand three-phase apparent power
DMDMDST1	TotVAr.instMag.f	3QD	Demand three-phase reactive power
DMDMDST1	TotW.instMag.f	3PD	Demand three-phase real power
DMDMDST1	VA.phsA.instCVal.mag.f	UAD	Demand A-Phase apparent power
DMDMDST1	VA.phsB.instCVal.mag.f	UBD	Demand B-Phase apparent power
DMDMDST1	VA.phsC.instCVal.mag.f	UCD	Demand C-Phase apparent power
DMDMDST1	VAr.phsA.instCVal.mag.f	QAD	Demand A-Phase reactive power
DMDMDST1	VAr.phsB.instCVal.mag.f	QBD	Demand B-Phase reactive power
DMDMDST1	VAr.phsC.instCVal.mag.f	QCD	Demand C-Phase reactive power
DMDMDST1	W.phsA.instCVal.mag.f	PAD	Demand A-Phase real power
DMDMDST1	W.phsB.instCVal.mag.f	PBD	Demand B-Phase real power
DMDMDST1	W.phsC.instCVal.mag.f	PCD	Demand C-Phase real power
METMMXU1	A1.phsA.instCVal.ang.f	LIAFA	10-cycle average fundamental A-Phase current (angle)
METMMXU1	A1.phsA.instCVal.mag.f	LIAFM	10-cycle average fundamental A-Phase current (magnitude)
METMMXU1	A1.phsB.instCVal.ang.f	LIBFA	10-cycle average fundamental B-Phase current (angle)

Table 10.16 Logical Device: MET (Metering) (Sheet 2 of 3)

Logical Node	Attribute	Data Source	Comment
METMMXU1	A1.phsB.instCVal.mag.f	LIBFM	10-cycle average fundamental B-Phase current (magnitude)
METMMXU1	A1.phsC.instCVal.ang.f	LICFA	10-cycle average fundamental C-Phase current (angle)
METMMXU1	A1.phsC.instCVal.mag.f	LICFM	10-cycle average fundamental C-Phase current (magnitude)
METMMXU1	A2.phsA.instCVal.ang.f	B1IAFA	10-cycle average fundamental A-Phase current angle (Breaker 1)
METMMXU1	A2.phsA.instCVal.mag.f	B1IAFM	10-cycle average fundamental A-Phase current magnitude (Breaker 1)
METMMXU1	A2.phsB.instCVal.ang.f	B1IBFA	10-cycle average fundamental B-Phase current angle (Breaker 1)
METMMXU1	A2.phsB.instCVal.mag.f	B1IBFM	10-cycle average fundamental B-Phase current magnitude (Breaker 1)
METMMXU1	A2.phsC.instCVal.ang.f	B1ICFA	10-cycle average fundamental C-Phase current angle (Breaker 1)
METMMXU1	A2.phsC.instCVal.mag.f	B1ICFM	10-cycle average fundamental C-Phase current magnitude (Breaker 1)
METMMXU1	A3.phsA.instCVal.ang.f	B2IAFA	10-cycle average fundamental A-Phase current angle (Breaker 2)
METMMXU1	A3.phsA.instCVal.mag.f	B2IAFM	10-cycle average fundamental A-Phase current magnitude (Breaker 2)
METMMXU1	A3.phsB.instCVal.ang.f	B2IBFA	10-cycle average fundamental B-Phase current angle (Breaker 2)
METMMXU1	A3.phsB.instCVal.mag.f	B2IBFM	10-cycle average fundamental B-Phase current magnitude (Breaker 2)
METMMXU1	A3.phsC.instCVal.ang.f	B2ICFA	10-cycle average fundamental C-Phase current angle (Breaker 2)
METMMXU1	A3.phsC.instCVal.mag.f	B2ICFM	10-cycle average fundamental C-Phase current magnitude (Breaker 2)
METMMXU1	Hz.instMag.f	FREQ	Tracking frequency
METMMXU1	PF.phsA.instCVal.mag.f	DPFA	A-Phase displacement power factor
METMMXU1	PF.phsB.instCVal.mag.f	DPFB	B-Phase displacement power factor
METMMXU1	PF.phsC.instCVal.mag.f	DPFC	C-Phase displacement power factor
METMMXU1	PhV.phsA.instCVal.ang.f	VAFA	A-Phase 10-cycle average fundamental phase voltage angle
METMMXU1	PhV.phsA.instCVal.mag.f	VAFM	A-Phase 10-cycle average fundamental phase voltage magnitude
METMMXU1	PhV.phsB.instCVal.ang.f	VBFA	B-Phase 10-cycle average fundamental phase voltage angle
METMMXU1	PhV.phsB.instCVal.mag.f	VBFM	B-Phase 10-cycle average fundamental phase voltage magnitude
METMMXU1	PhV.phsC.instCVal.ang.f	VCFA	C-Phase 10-cycle average fundamental phase voltage angle
METMMXU1	PhV.phsC.instCVal.mag.f	VCFM	C-Phase 10-cycle average fundamental phase voltage magnitude
METMMXU1	TotPF.instMag.f	3DPF	Three-phase displacement power factor
METMMXU1	TotVA.instMag.f	3S_F	Fundamental apparent three-phase power
METMMXU1	TotVAr.instMag.f	3Q_F	Fundamental reactive three-phase power
METMMXU1	TotW.instMag.f	3P_F	Fundamental real three-phase power
METMMXU1	VAr.phsA.instCVal.mag.f	QA_F	A-Phase fundamental reactive power
METMMXU1	VAr.phsB.instCVal.mag.f	QB_F	B-Phase fundamental reactive power
METMMXU1	VAr.phsC.instCVal.mag.f	QC_F	C-Phase fundamental reactive power
METMMXU1	W.phsA.instCVal.mag.f	PA_F	A-Phase fundamental real power
METMMXU1	W.phsB.instCVal.mag.f	PB_F	B-Phase fundamental real power
METMMXU1	W.phsC.instCVal.mag.f	PC_F	C-Phase fundamental real power
PKDMDMDST1	A.phsA.instCVal.mag.f	IAPKD	Peak demand A-Phase current
PKDMDMDST1	A.phsB.instCVal.mag.f	IBPKD	Peak demand B-Phase current

Table 10.16 Logical Device: MET (Metering) (Sheet 3 of 3)

Logical Node	Attribute	Data Source	Comment
PKDMDMDST1	A.phsC.instCVal.mag.f	ICPKD	Peak demand C-Phase current
PKDMDMDST1	SeqA.c1.instMag.f	3I2PKD	Peak demand negative-sequence current
PKDMDMDST1	SeqA.c2.instMag.f	3I2PKD	Peak demand negative-sequence current
PKDMDMDST1	SeqA.c3.instMag.f	IGPKD	Peak demand zero-sequence current
PKDMDMDST1	TotVA.instMag.f	3UPKD	Peak demand 3-Phase apparent power
PKDMDMDST1	TotVAr.instMag.f	3QPKD	Peak demand 3-Phase reactive power
PKDMDMDST1	TotW.instMag.f	3PPKD	Peak demand 3-Phase real power
PKDMDMDST1	VA.phsA.instCVal.mag.f	UAPKD	Peak demand A-Phase apparent power
PKDMDMDST1	VA.phsB.instCVal.mag.f	UBPKD	Peak demand B-Phase apparent power
PKDMDMDST1	VA.phsC.instCVal.mag.f	UCPKD	Peak demand C-Phase apparent power
PKDMDMDST1	VAr.phsA.instCVal.mag.f	QAPKD	Peak demand A-Phase reactive power
PKDMDMDST1	VAr.phsB.instCVal.mag.f	QBPKD	Peak demand B-Phase reactive power
PKDMDMDST1	VAr.phsC.instCVal.mag.f	QCPKD	Peak demand C-Phase reactive power
PKDMDMDST1	W.phsA.instCVal.mag.f	PAPKD	Peak demand A-Phase real power
PKDMDMDST1	W.phsB.instCVal.mag.f	PBPKD	Peak demand B-Phase real power
PKDMDMDST1	W.phsC.instCVal.mag.f	PCPKD	Peak demand C-Phase real power
SEQMSQI1	SeqA.c1.instCVal.ang.f	LI1A	10-cycle average positive-sequence current (angle)
SEQMSQI1	SeqA.c1.instCVal.mag.f	LI1M	10-cycle average positive-sequence current (magnitude)
SEQMSQI1	SeqA.c2.instCVal.ang.f	L3I2A	10-cycle average negative-sequence current (angle)
SEQMSQI1	SeqA.c2.instCVal.mag.f	L3I2M	10-cycle average negative-sequence current (magnitude)
SEQMSQI1	SeqA.c3.instCVal.ang.f	LIGA	10-cycle average zero-sequence current (angle)
SEQMSQI1	SeqA.c3.instCVal.mag.f	LIGM	10-cycle average zero-sequence current (magnitude)
SEQMSQI1	SeqV.c1.instCVal.ang.f	V1A	10-cycle average positive-sequence voltage (angle)
SEQMSQI1	SeqV.c1.instCVal.mag.f	V1M	10-cycle average positive-sequence voltage (magnitude)
SEQMSQI1	SeqV.c2.instCVal.ang.f	3V2A	10-cycle average negative-sequence voltage (angle)
SEQMSQI1	SeqV.c2.instCVal.mag.f	3V2M	10-cycle average negative-sequence voltage (magnitude)
SEQMSQI1	SeqV.c3.instCVal.ang.f	3V0A	10-cycle average zero-sequence voltage (angle)
SEQMSQI1	SeqV.c3.instCVal.mag.f	3V0M	10-cycle average zero-sequence voltage (magnitude)
Functional Constraint = DC			
DMDMDST1	NamPlt.swRev	VERFID	Relay FID string
LLN0	NamPlt.swRev	VERFID	Relay FID string
METLPHD1	PhyNam.model	PARNUM	Relay part number string
METLPHD1	PhyNam.serNum	SERNUM	Relay serial number string
PKDMDMDST1	NamPlt.swRev	VERFID	Relay FID string

Synchrophasors

General synchrophasor operation is described in the *Section 18: Synchrophasors in the SEL-400 Series Relays Instruction Manual*. This section describes characteristics of synchrophasors that are unique to the SEL-421.

The SEL-421 has 6 current channels and 6 voltage channels. Current Terminals W, X and voltage terminals Y, Z are three-phase channels. The PMU combines channels W and X to create a pseudo Terminal S.

From these 12 channels, the PMU can measure as many as 20 synchrophasors; 15 phase synchrophasors, and 5 positive-sequence synchrophasors. Synchrophasors are always in primary, so set the CT and PT ratios in the group settings appropriately. Note that CTRW applies to all the channels in Terminal S.

Table 10.17 shows the voltage synchrophasor name, enable conditions and the PT ratio used to scale to the Primary values.

Table 10.17 Voltage Synchrophasor Names

Phasor Name	Phasor Enable Conditions	PT Ratio
V1YPM	PHDV*q* = V1 or ALL AND Terminal Y included	PTRY
VAYPM	PHDV*q* = PH or ALL AND Terminal Y included	PTRY
VBYPM	PHDV*q* = PH or ALL AND Terminal Y included	PTRY
VCYPM	PHDV*q* = PH or ALL AND Terminal Y included	PTRY
V1ZPM	PHDV*q* = V1 or ALL AND Terminal Z included	PTRZ
VAZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ
VBZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ
VCZPM	PHDV*q* = PH or ALL AND Terminal Z included	PTRZ

Table 10.18 shows the current synchrophasor names, enable conditions, and the CT ratio used to scale to the Primary values.

Table 10.18 Current Synchrophasor Names

Phasor Name	Phasor Enable Conditions	CT Ratio
I1SPM	PHDI*q* = I1 or ALL AND Terminal S included	CTRW
IASPM	PHDI*q* = PH or ALL AND Terminal S included	CTRW
IBSPM	PHDI*q* = PH or ALL AND Terminal S included	CTRW
ICSPM	PHDI*q* = PH or ALL AND Terminal S included	CTRW
I1WPM	PHDI*q* = I1 or ALL AND Terminal W included	CTRW
IAWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
IBWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
ICWPM	PHDI*q* = PH or ALL AND Terminal W included	CTRW
I1XPM	PHDI*q* = I1 or ALL AND Terminal X included	CTRX
IAXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX
IBXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX
ICXPM	PHDI*q* = PH or ALL AND Terminal X included	CTRX

Table 10.19 describes the order of synchrophasors inside the data packet when operating in legacy mode (LEGACY = Y).

Table 10.19 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a] (Analog Quantity Names)				Included When Global Settings Are as Follows:
Polar[b]		Rectangular[c]		
Magnitude	Angle	Real	Imaginary	
V1*m*PMM[d]	V1*m*PMA	V1*m*PMR	V1*m*PMI	PHDATAV := V1 or ALL
VA*m*PMM	VA*m*PMA	VA*m*PMR	VA*m*PMI	
VB*m*PMM	VB*m*PMA	VB*m*PMR	VB*m*PMI	PHDATAV := PH or ALL
VC*m*PMM	VC*m*PMA	VC*m*PMR	VC*m*PMI	
I1*n*PMM[e]	I1*n*PMA	I1*n*PMR	I1*n*PMI	PHDATAI := I1 or ALL
IA*n*PMM	IA*n*PMA	IA*n*PMR	IA*n*PMI	
IB*n*PMM	IB*n*PMA	IB*n*PMR	IB*n*PMI	PHDATAI := PH or ALL
IC*n*PMM	IC*n*PMA	IC*n*PMR	IC*n*PMI	

[a] Synchrophasors are included in the order shown (i.e., voltages, if selected, will always precede currents).

[b] Polar coordinate values are sent when PHFMT := P.

[c] Rectangular (real and imaginary) values are sent when PHFMT := R.

[d] Where:
m = Y if PHVOLT includes Y
m = Z if PHVOLT includes Z.

[e] Where:
n = W if PHCURR includes W
n = X if PHCURR includes X
n = S if PHCURR includes S.

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SECTION 11

Relay Word Bits

This section contains tables of the Relay Word bits available within the SEL-421 Relay. *Table 11.1* lists the Relay Word bits in alphabetic order; *Table 11.2* through *Table 11.73* list every Relay Word bit row and the bits contained within each row.

Alphabetical List

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 1 of 34)

Name	Description	Row
25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1	38
25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1	40
25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2	39
25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2	40
25ENBK1	Circuit Breaker 1 synchronism-check element enable	38
25ENBK2	Circuit Breaker 2 synchronism-check element enable	40
25W1BK1	Circuit Breaker 1 Angle 1 within Window 1	38
25W1BK2	Circuit Breaker 2 Angle 1 within Window 1	40
25W2BK1	Circuit Breaker 1 Angle 2 within Window 2	38
25W2BK2	Circuit Breaker 2 Angle 2 within Window 2	40
271P1	Undervoltage Element 1, Level 1 asserted	384
271P1T	Undervoltage Element 1, Level 1 timed out	384
271P2	Undervoltage Element 1, Level 2 asserted	384
272P1	Undervoltage Element 2, Level 1 asserted	384
272P1T	Undervoltage Element 2, Level 1 timed out	384
272P2	Undervoltage Element 2, Level 2 asserted	384
273P1	Undervoltage Element 3, Level 1 asserted	385
273P1T	Undervoltage Element 3, Level 1 timed out	385
273P2	Undervoltage Element 3, Level 2 asserted	385
274P1	Undervoltage Element 4, Level 1 asserted	385
274P1T	Undervoltage Element 4, Level 1 timed out	385
274P2	Undervoltage Element 4, Level 2 asserted	385
275P1	Undervoltage Element 5, Level 1 asserted	386
275P1T	Undervoltage Element 5, Level 1 timed out	386
275P2	Undervoltage Element 5, Level 2 asserted	386
276P1	Undervoltage Element 6, Level 1 asserted	386
276P1T	Undervoltage Element 6, Level 1 timed out	386

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 2 of 34)

Name	Description	Row
276P2	Undervoltage Element 6, Level 2 asserted	386
27APO	A-Phase undervoltage, pole-open	78
27AWI	A-Phase undervoltage condition	58
27B81	Undervoltage supervision for frequency elements	392
27BPO	B-Phase undervoltage, pole-open	78
27BWI	B-Phase undervoltage condition	58
27CPO	C-Phase undervoltage, pole-open	79
27CWI	C-Phase undervoltage condition	58
27TC1	Undervoltage Element 1, torque control	384
27TC2	Undervoltage Element 2, torque control	384
27TC3	Undervoltage Element 3, torque control	385
27TC4	Undervoltage Element 4, torque control	385
27TC5	Undervoltage Element 5, torque control	386
27TC6	Undervoltage Element 6, torque control	386
2POBK1	Two poles open Circuit Breaker 1	48
2POBK2	Two poles open Circuit Breaker 2	48
32GF	Forward ground directional element	30
32GR	Reverse ground directional element	30
32IE	32I internal enable	29
32QE	32Q internal enable	29
32QF	Forward negative-sequence overcurrent directional declaration	28
32QGE	32QG internal enable	29
32QR	Reverse negative-sequence overcurrent directional declaration	28
32SPOF	Forward open-pole directional declaration	28
32SPOR	Reverse open-pole directional declaration	28
32VE	32V internal enable	29
3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)	45
3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)	45
3PARC	Three-pole reclose initiate qualified	42
3PLSHT	Three-pole reclose last shot	43
3PO	All three poles open	78
3POBK1	Three-pole open Circuit Breaker 1	42
3POBK2	Three-pole open Circuit Breaker 2	43
3POI	Three-pole open interval timing	50
3POISC	Three-pole open interval supervision condition	50
3POLINE	Three-pole open line	43
3PRCIP	Three-pole reclaim in progress	48
3PRI	Three-pole reclose initiation (SELOGIC control equation)	42
3PS	Trip logic three-phase selected	54
3PSHOT0–3PSHOT4	Three-pole shot counter = 0–4	49
3PT	Three-pole trip	55

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 3 of 34)

Name	Description	Row
50ABC	Positive-sequence current above 50ABCP threshold	21
50FA1	Circuit Breaker 1 A-Phase current threshold exceeded	66
50FA2	Circuit Breaker 2 A-Phase current threshold exceeded	72
50FB1	Circuit Breaker 1 B-Phase current threshold exceeded	66
50FB2	Circuit Breaker 2 B-Phase current threshold exceeded	72
50FC1	Circuit Breaker 1 C-Phase current threshold exceeded	66
50FC2	Circuit Breaker 2 C-Phase current threshold exceeded	72
50FOA1	Circuit Breaker 1 A-Phase flashover current threshold exceeded	69
50FOA2	Circuit Breaker 2 A-Phase flashover current threshold exceeded	75
50FOB1	Circuit Breaker 1 B-Phase flashover current threshold exceeded	69
50FOB2	Circuit Breaker 2 B-Phase flashover current threshold exceeded	75
50FOC1	Circuit Breaker 1 C-Phase flashover current threshold exceeded	69
50FOC2	Circuit Breaker 2 C-Phase flashover current threshold exceeded	75
50G1–50G4	Level 1–4 residual overcurrent element	32
50GF	Forward zero-sequence supervisory current element	29
50GR	Reverse zero-sequence supervisory current element	29
50LCA1	Circuit Breaker 1 A-Phase load current threshold exceeded	68
50LCA2	Circuit Breaker 2 A-Phase load current threshold exceeded	74
50LCB1	Circuit Breaker 1 B-Phase load current threshold exceeded	68
50LCB2	Circuit Breaker 2 B-Phase load current threshold exceeded	74
50LCC1	Circuit Breaker 1 C-Phase load current threshold exceeded	68
50LCC2	Circuit Breaker 2 C-Phase load current threshold exceeded	74
50P1–50P4	Level 1–4 phase overcurrent element	31
50Q1–50Q4	Level 1–4 negative-sequence overcurrent element	34
50QF	Forward negative-sequence supervisory current element	29
50QR	Reverse negative-sequence supervisory current element	29
50R1	Circuit Breaker 1 residual current threshold exceeded	68
50R2	Circuit Breaker 2 residual current threshold exceeded	74
51S1	Inverse-time Overcurrent Element 1 pickup	36
51S1R	Inverse-time Overcurrent Element 1 reset	36
51S1T	Inverse-time Overcurrent Element 1 timed out	36
51S2	Inverse-time Overcurrent Element 2 pickup	36
51S2R	Inverse-time Overcurrent Element 2 reset	36
51S2T	Inverse-time Overcurrent Element 2 timed out	36
51S3	Inverse-time Overcurrent Element 3 pickup	37
51S3R	Inverse-time Overcurrent Element 3 reset	37
51S3T	Inverse-time Overcurrent Element 3 timed out	37
521_ALM	Breaker 1 status alarm	365
521CLSM	Breaker 1 closed	365
522_ALM	Breaker 2 status alarm	365
522CLSM	Breaker 2 closed	365

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 4 of 34)

Name	Description	Row
523_ALM	Breaker 3 status alarm	365
523CLSM	Breaker 3 closed	365
52AA1	Circuit Breaker 1, Pole A status	80
52AA2	Circuit Breaker 2, Pole A status	82
52AAL1	Circuit Breaker 1, Pole A alarm	80
52AAL2	Circuit Breaker 2, Pole A alarm	81
52AB1	Circuit Breaker 1, Pole B status	80
52AB2	Circuit Breaker 2, Pole B status	82
52AC1	Circuit Breaker 1, Pole C status	81
52AC2	Circuit Breaker 2, Pole C status	82
52ACL1	Circuit Breaker 1, Pole A closed	80
52ACL2	Circuit Breaker 2, Pole A closed	81
52BAL1	Circuit Breaker 1, Pole B alarm	80
52BAL2	Circuit Breaker 2, Pole B alarm	81
52BCL1	Circuit Breaker 1, Pole B closed	80
52BCL2	Circuit Breaker 2, Pole B closed	81
52CAL1	Circuit Breaker 1, Pole C alarm	80
52CAL2	Circuit Breaker 2, Pole C alarm	81
52CCL1	Circuit Breaker 1, Pole C closed	80
52CCL2	Circuit Breaker 2, Pole C closed	81
591P1	Overvoltage Element 1, Level 1 asserted	387
591P1T	Overvoltage Element 1, Level 1 timed out	387
591P2	Overvoltage Element 1, Level 2 asserted	387
592P1	Overvoltage Element 2, Level 1 asserted	387
592P1T	Overvoltage Element 2, Level 1 timed out	387
592P2	Overvoltage Element 2, Level 2 asserted	387
593P1	Overvoltage Element 3, Level 1 asserted	388
593P1T	Overvoltage Element 3, Level 1 timed out	388
593P2	Overvoltage Element 3, Level 2 asserted	388
594P1	Overvoltage Element 4, Level 1 asserted	388
594P1T	Overvoltage Element 4, Level 1 timed out	388
594P2	Overvoltage Element 4, Level 2 asserted	388
595P1	Overvoltage Element 5, Level 1 asserted	389
595P1T	Overvoltage Element 5, Level 1 timed out	389
595P2	Overvoltage Element 5, Level 2 asserted	389
596P1	Overvoltage Element 6, Level 1 asserted	389
596P1T	Overvoltage Element 6, Level 1 timed out	389
596P2	Overvoltage Element 6, Level 2 asserted	389
59TC1–59TC2	Overvoltage Element 1–2, torque control	387
59TC3–59TC4	Overvoltage Element 3–4, torque control	388
59TC5–59TC6	Overvoltage Element 5–6, torque control	389

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 5 of 34)

Name	Description	Row
59VDIF1	Circuit Breaker 1 synchronizing voltage difference less than limit	39
59VDIF2	Circuit Breaker 2 synchronizing voltage difference less than limit	41
59VP	VP within healthy voltage window	38
59VS1	VS1 within healthy voltage window	38
59VS2	VS2 within healthy voltage window	40
67G1	Level 1 residual directional overcurrent element	33
67G1T	Level 1 residual delayed directional overcurrent element	33
67G2	Level 2 residual directional overcurrent element	33
67G2T	Level 2 residual delayed directional overcurrent element	33
67G3	Level 3 residual directional overcurrent element	33
67G3T	Level 3 residual delayed directional overcurrent element	33
67G4	Level 4 residual directional overcurrent element	33
67G4T	Level 4 residual delayed directional overcurrent element	33
67P1	Level 1 phase directional overcurrent element	31
67P1T	Level 1 phase-delayed directional overcurrent element	32
67P2	Level 2 phase directional overcurrent element	31
67P2T	Level 2 phase-delayed directional overcurrent element	32
67P3	Level 3 phase directional overcurrent element	31
67P3T	Level 3 phase-delayed directional overcurrent element	32
67P4	Level 4 phase directional overcurrent element	31
67P4T	Level 4 phase-delayed directional overcurrent element	32
67Q1	Level 1 negative-sequence directional overcurrent element	34
67Q1T	Level 1 negative-sequence delayed directional overcurrent element	35
67Q2	Level 2 negative-sequence directional overcurrent element	34
67Q2T	Level 2 negative-sequence delayed directional overcurrent element	35
67Q3	Level 3 negative-sequence directional overcurrent element	34
67Q3T	Level 3 negative-sequence delayed directional overcurrent element	35
67Q4	Level 4 negative-sequence directional overcurrent element	34
67Q4T	Level 4 negative-sequence delayed directional overcurrent element	35
67QG2S	Negative-sequence and residual directional overcurrent short delay element	60
67QUBF	Forward direction supervised output from 50QUBP	23
67QUBR	Reverse direction supervised output from 50QUBP	23
79CY1	Relay in single-pole reclose cycle state	43
79CY3	Relay in three-pole reclose cycle state	43
79STRT	Relay in start state	50
81D1	Level 1 definite-time frequency element pickup	392
81D1OVR	Level 1 overfrequency element pick up	392
81D1T	Level 1 definite-time frequency element delay	392
81D1UDR	Level 1 underfrequency element pick up	392
81D2	Level 2 definite-time frequency element pickup	393
81D2OVR	Level 2 overfrequency element pick up	393

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 6 of 34)

Name	Description	Row
81D2T	Level 2 definite-time frequency element delay	393
81D2UDR	Level 2 underfrequency element pick up	393
81D3	Level 3 definite-time frequency element pickup	393
81D3OVR	Level 3 overfrequency element pick up	393
81D3T	Level 3 definite-time frequency element delay	393
81D3UDR	Level 3 underfrequency element pick up	393
81D4	Level 4 definite-time frequency element pickup	394
81D4OVR	Level 4 overfrequency element pick up	394
81D4T	Level 4 definite-time frequency element delay	394
81D4UDR	Level 4 underfrequency element pick up	394
81D5	Level 5 definite-time frequency element pickup	394
81D5OVR	Level 5 overfrequency element pick up	394
81D5T	Level 5 definite-time frequency element delay	394
81D5UDR	Level 5 underfrequency element pick up	394
81D6	Level 6 definite-time frequency element pickup	395
81D6OVR	Level 6 overfrequency element pick up	395
81D6T	Level 6 definite-time frequency element delay	395
81D6UDR	Level 6 underfrequency element pick up	395
89AL	Any disconnect alarm	332
89AL01	Disconnect 1 alarm	332
89AL02	Disconnect 2 alarm	333
89AL03	Disconnect 3 alarm	334
89AL04	Disconnect 4 alarm	335
89AL05	Disconnect 5 alarm	336
89AL06	Disconnect 6 alarm	337
89AL07	Disconnect 7 alarm	338
89AL08	Disconnect 8 alarm	339
89AL09	Disconnect 9 alarm	340
89AL10	Disconnect 10 alarm	341
89AM01	Disconnect 1 N/O auxiliary contact	332
89AM02	Disconnect 2 N/O auxiliary contact	333
89AM03	Disconnect 3 N/O auxiliary contact	334
89AM04	Disconnect 4 N/O auxiliary contact	335
89AM05	Disconnect 5 N/O auxiliary contact	336
89AM06	Disconnect 6 N/O auxiliary contact	337
89AM07	Disconnect 7 N/O auxiliary contact	338
89AM08	Disconnect 8 N/O auxiliary contact	339
89AM09	Disconnect 9 N/O auxiliary contact	340
89AM10	Disconnect 10 N/O auxiliary contact	341
89BM01	Disconnect 1 N/C auxiliary contact	332
89BM02	Disconnect 2 N/C auxiliary contact	333

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 7 of 34)

Name	Description	Row
89BM03	Disconnect 3 N/C auxiliary contact	334
89BM04	Disconnect 4 N/C auxiliary contact	335
89BM05	Disconnect 5 N/C auxiliary contact	336
89BM06	Disconnect 6 N/C auxiliary contact	337
89BM07	Disconnect 7 N/C auxiliary contact	338
89BM08	Disconnect 8 N/C auxiliary contact	339
89BM09	Disconnect 9 N/C auxiliary contact	340
89BM10	Disconnect 10 N/C auxiliary contact	341
89CBL01	Disconnect 01 close block	364
89CBL02	Disconnect 02 close block	366
89CBL03	Disconnect 03 close block	368
89CBL04	Disconnect 04 close block	370
89CBL05	Disconnect 05 close block	372
89CBL06	Disconnect 06 close block	374
89CBL07	Disconnect 07 close block	376
89CBL08	Disconnect 08 close block	378
89CBL09	Disconnect 09 close block	380
89CBL10	Disconnect 10 close block	382
89CC01	ASCII Close Disconnect 1 command	344
89CC02	ASCII Close Disconnect 2 command	346
89CC03	ASCII Close Disconnect 3 command	348
89CC04	ASCII Close Disconnect 4 command	350
89CC05	ASCII Close Disconnect 5 command	352
89CC06	ASCII Close Disconnect 6 command	354
89CC07	ASCII Close Disconnect 7 command	356
89CC08	ASCII Close Disconnect 8 command	358
89CC09	ASCII Close Disconnect 9 command	360
89CC10	ASCII Close Disconnect 10 command	362
89CCM01	Mimic Disconnect 1 close control	344
89CCM02	Mimic Disconnect 2 close control	346
89CCM03	Mimic Disconnect 3 close control	348
89CCM04	Mimic Disconnect 4 close control	350
89CCM05	Mimic Disconnect 5 close control	352
89CCM06	Mimic Disconnect 6 close control	354
89CCM07	Mimic Disconnect 7 close control	356
89CCM08	Mimic Disconnect 8 close control	358
89CCM09	Mimic Disconnect 9 close control	360
89CCM10	Mimic Disconnect 10 close control	362
89CCN01	Close Disconnect 1	344
89CCN02	Close Disconnect 2	346
89CCN03	Close Disconnect 3	348

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 8 of 34)

Name	Description	Row
89CCN04	Close Disconnect 4	350
89CCN05	Close Disconnect 5	352
89CCN06	Close Disconnect 6	354
89CCN07	Close Disconnect 7	356
89CCN08	Close Disconnect 8	358
89CCN09	Close Disconnect 9	360
89CCN10	Close Disconnect 10	362
89CIM01	Disconnect 01 close immobility timer timed out	365
89CIM02	Disconnect 02 close immobility timer timed out	367
89CIM03	Disconnect 03 close immobility timer timed out	369
89CIM04	Disconnect 04 close immobility timer timed out	371
89CIM05	Disconnect 05 close immobility timer timed out	373
89CIM06	Disconnect 06 close immobility timer timed out	375
89CIM07	Disconnect 07 close immobility timer timed out	377
89CIM08	Disconnect 08 close immobility timer timed out	379
89CIM09	Disconnect 09 close immobility timer timed out	381
89CIM10	Disconnect 10 close immobility timer timed out	383
89CIR01	Disconnect 01 close immobility timer reset	364
89CIR02	Disconnect 02 close immobility timer reset	366
89CIR03	Disconnect 03 close immobility timer reset	368
89CIR04	Disconnect 04 close immobility timer reset	370
89CIR05	Disconnect 05 close immobility timer reset	372
89CIR06	Disconnect 06 close immobility timer reset	374
89CIR07	Disconnect 07 close immobility timer reset	376
89CIR08	Disconnect 08 close immobility timer reset	378
89CIR09	Disconnect 09 close immobility timer reset	380
89CIR10	Disconnect 10 close immobility timer reset	382
89CL01	Disconnect 1 closed	332
89CL02	Disconnect 2 closed	333
89CL03	Disconnect 3 closed	334
89CL04	Disconnect 4 closed	335
89CL05	Disconnect 5 closed	336
89CL06	Disconnect 6 closed	337
89CL07	Disconnect 7 closed	338
89CL08	Disconnect 8 closed	339
89CL09	Disconnect 9 closed	340
89CL10	Disconnect 10 closed	341
89CLB01–89CLB08	Disconnect 1–8 bus-zone protection	342
89CLB09–89CLB10	Disconnect 9–10 bus-zone protection	343
89CLS01	Disconnect Close 1 output	344
89CLS02	Disconnect Close 2 output	346

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 9 of 34)

Name	Description	Row
89CLS03	Disconnect Close 3 output	348
89CLS04	Disconnect Close 4 output	350
89CLS05	Disconnect Close 5 output	352
89CLS06	Disconnect Close 6 output	354
89CLS07	Disconnect Close 7 output	356
89CLS08	Disconnect Close 8 output	358
89CLS09	Disconnect Close 9 output	360
89CLS10	Disconnect Close 10 output	362
89CRS01	Disconnect 01 close reset	364
89CRS02	Disconnect 02 close reset	366
89CRS03	Disconnect 03 close reset	368
89CRS04	Disconnect 04 close reset	370
89CRS05	Disconnect 05 close reset	372
89CRS06	Disconnect 06 close reset	374
89CRS07	Disconnect 07 close reset	376
89CRS08	Disconnect 08 close reset	378
89CRS09	Disconnect 09 close reset	380
89CRS10	Disconnect 10 close reset	382
89CSI01	Disconnect 01 close seal-in timer timed out	364
89CSI02	Disconnect 02 close seal-in timer timed out	366
89CSI03	Disconnect 03 close seal-in timer timed out	368
89CSI04	Disconnect 04 close seal-in timer timed out	370
89CSI05	Disconnect 05 close seal-in timer timed out	372
89CSI06	Disconnect 06 close seal-in timer timed out	374
89CSI07	Disconnect 07 close seal-in timer timed out	376
89CSI08	Disconnect 08 close seal-in timer timed out	378
89CSI09	Disconnect 09 close seal-in timer timed out	380
89CSI10	Disconnect 10 close seal-in timer timed out	382
89OBL01	Disconnect 01 open block	364
89OBL02	Disconnect 02 open block	366
89OBL03	Disconnect 03 open block	368
89OBL04	Disconnect 04 open block	370
89OBL05	Disconnect 05 open block	372
89OBL06	Disconnect 06 open block	374
89OBL07	Disconnect 07 open block	376
89OBL08	Disconnect 08 open block	378
89OBL09	Disconnect 09 open block	380
89OBL10	Disconnect 10 open block	382
89OC01	ASCII Open Disconnect 1 command	344
89OC02	ASCII Open Disconnect 2 command	346
89OC03	ASCII Open Disconnect 3 command	348

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 10 of 34)

Name	Description	Row
89OC04	ASCII Open Disconnect 4 command	350
89OC05	ASCII Open Disconnect 5 command	352
89OC06	ASCII Open Disconnect 6 command	354
89OC07	ASCII Open Disconnect 7 command	356
89OC08	ASCII Open Disconnect 8 command	358
89OC09	ASCII Open Disconnect 9 command	360
89OC10	ASCII Open Disconnect 10 command	362
89OCM01	Mimic Disconnect 1 open control	344
89OCM02	Mimic Disconnect 2 open control	346
89OCM03	Mimic Disconnect 3 open control	348
89OCM04	Mimic Disconnect 4 open control	350
89OCM05	Mimic Disconnect 5 open control	352
89OCM06	Mimic Disconnect 6 open control	354
89OCM07	Mimic Disconnect 7 open control	356
89OCM08	Mimic Disconnect 8 open control	358
89OCM09	Mimic Disconnect 9 open control	360
89OCM10	Mimic Disconnect 10 open control	362
89OCN01	Open Disconnect 1	344
89OCN02	Open Disconnect 2	346
89OCN03	Open Disconnect 3	348
89OCN04	Open Disconnect 4	350
89OCN05	Open Disconnect 5	352
89OCN06	Open Disconnect 6	354
89OCN07	Open Disconnect 7	356
89OCN08	Open Disconnect 8	358
89OCN09	Open Disconnect 9	360
89OCN10	Open Disconnect 10	362
89OIM01	Disconnect 01 open immobility timer timed out	365
89OIM02	Disconnect 02 open immobility timer timed out	367
89OIM03	Disconnect 03 open immobility timer timed out	369
89OIM04	Disconnect 04 open immobility timer timed out	371
89OIM05	Disconnect 05 open immobility timer timed out	373
89OIM06	Disconnect 06 open immobility timer timed out	375
89OIM07	Disconnect 07 open immobility timer timed out	377
89OIM08	Disconnect 08 open immobility timer timed out	379
89OIM09	Disconnect 09 open immobility timer timed out	381
89OIM10	Disconnect 10 open immobility timer timed out	383
89OIP	Any disconnect operation in-progress	333
89OIP01	Disconnect 1 operation in-progress	332
89OIP02	Disconnect 2 operation in-progress	333
89OIP03	Disconnect 3 operation in-progress	334

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 11 of 34)

Name	Description	Row
89OIP04	Disconnect 4 operation in-progress	335
89OIP05	Disconnect 5 operation in-progress	336
89OIP06	Disconnect 6 operation in-progress	337
89OIP07	Disconnect 7 operation in-progress	338
89OIP08	Disconnect 8 operation in-progress	339
89OIP09	Disconnect 9 operation in-progress	340
89OIP10	Disconnect 10 operation in-progress	341
89OIR01	Disconnect 01 open immobility timer reset	364
89OIR02	Disconnect 02 open immobility timer reset	366
89OIR03	Disconnect 03 open immobility timer reset	368
89OIR04	Disconnect 04 open immobility timer reset	370
89OIR05	Disconnect 05 open immobility timer reset	372
89OIR06	Disconnect 06 open immobility timer reset	374
89OIR07	Disconnect 07 open immobility timer reset	376
89OIR08	Disconnect 08 open immobility timer reset	378
89OIR09	Disconnect 09 open immobility timer reset	380
89OIR10	Disconnect 10 open immobility timer reset	382
89OPE01	Disconnect Open 1 output	344
89OPE02	Disconnect Open 2 output	346
89OPE03	Disconnect Open 3 output	348
89OPE04	Disconnect Open 4 output	350
89OPE05	Disconnect Open 5 output	352
89OPE06	Disconnect Open 6 output	354
89OPE07	Disconnect Open 7 output	356
89OPE08	Disconnect Open 8 output	358
89OPE09	Disconnect Open 9 output	360
89OPE10	Disconnect Open 10 output	362
89OPN01	Disconnect 1 open	332
89OPN02	Disconnect 2 open	333
89OPN03	Disconnect 3 open	334
89OPN04	Disconnect 4 open	335
89OPN05	Disconnect 5 open	336
89OPN06	Disconnect 6 open	337
89OPN07	Disconnect 7 open	338
89OPN08	Disconnect 8 open	339
89OPN09	Disconnect 9 open	340
89OPN10	Disconnect 10 open	341
89ORS01	Disconnect 01 open reset	364
89ORS02	Disconnect 02 open reset	366
89ORS03	Disconnect 03 open reset	368
89ORS04	Disconnect 04 open reset	370

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 12 of 34)

Name	Description	Row
89ORS05	Disconnect 05 open reset	372
89ORS06	Disconnect 06 open reset	374
89ORS07	Disconnect 07 open reset	376
89ORS08	Disconnect 08 open reset	378
89ORS09	Disconnect 09 open reset	380
89ORS10	Disconnect 10 open reset	382
89OSI01	Disconnect 01 open seal-in timer timed out	364
89OSI02	Disconnect 02 open seal-in timer timed out	366
89OSI03	Disconnect 03 open seal-in timer timed out	368
89OSI04	Disconnect 04 open seal-in timer timed out	370
89OSI05	Disconnect 05 open seal-in timer timed out	372
89OSI06	Disconnect 06 open seal-in timer timed out	374
89OSI07	Disconnect 07 open seal-in timer timed out	376
89OSI08	Disconnect 08 open seal-in timer timed out	378
89OSI09	Disconnect 09 open seal-in timer timed out	380
89OSI10	Disconnect 10 open seal-in timer timed out	382
A3PT	Assert three-pole trip	54
ACCESS	A user is logged in at Access Level B or above	207
ACCESSP	Pulsed alarm for logins to Access Level B or above	207
ACN01Q–ACN08Q	Automation Counter 1–8 output	194
ACN09Q–ACN16Q	Automation Counter 9–16 output	195
ACN17Q–ACN24Q	Automation Counter 17–24 output	196
ACN25Q–ACN32Q	Automation Counter 25–32 output	197
ACN01R–ACN08R	Automation Counter 1–8 reset	198
ACN09R–ACN16R	Automation Counter 9–16 reset	199
ACN17R–ACN24R	Automation Counter 17–24 reset	200
ACN25R–ACN32R	Automation Counter 25–32 reset	201
AFRTEXA	Automation SELOGIC control equation first execution after automation settings change	204
AFRTEXP	Automation SELOGIC control equation first execution after protection settings change, group switch, or source switch selection.	204
ALT01–ALT08	Automation Latch 1–8	182
ALT09–ALT16	Automation Latch 9–16	183
ALT17–ALT24	Automation Latch 17–24	184
ALT25–ALT32	Automation Latch 25–32	185
ALTI	Alternate current source (SELOGIC control equation)	269
ALTS2	Alternate synchronism source for Circuit Breaker 2	269
ALTV	Alternate voltage source (SELOGIC control equation)	269
ANOKA	Analog transfer OK on MIRRORED BITS Communications Channel A	229
ANOKB	Analog transfer OK on MIRRORED BITS Communications Channel B	230
APS	Trip logic A-Phase selected	54
AST01Q–AST08Q	Automation Sequencing Timer 1–8 output	186

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 13 of 34)

Name	Description	Row
AST09Q–AST16Q	Automation Sequencing Timer 9–16 output	187
AST17Q–AST24Q	Automation Sequencing Timer 17 output	188
AST25Q–AST32Q	Automation Sequencing Timer 25–32 output	189
AST01R–AST08R	Automation Sequencing Timer 1–8 reset	190
AST09R–AST16R	Automation Sequencing Timer 9–16 reset	191
AST17R–AST24R	Automation Sequencing Timer 17 reset	192
AST25R–AST32R	Automation Sequencing Timer 25–32 reset	193
ASV001–ASV008	Automation SELOGIC Variable 1–8	150
ASV009–ASV016	Automation SELOGIC Variable 9–16	151
ASV017–ASV024	Automation SELOGIC Variable 17–24	152
ASV025–ASV032	Automation SELOGIC Variable 25–32	153
ASV033–ASV040	Automation SELOGIC Variable 33–40	154
ASV041–ASV048	Automation SELOGIC Variable 41–48	155
ASV049–ASV056	Automation SELOGIC Variable 49–56	156
ASV057–ASV064	Automation SELOGIC Variable 57–64	157
ASV065–ASV072	Automation SELOGIC Variable 65–72	158
ASV073–ASV080	Automation SELOGIC Variable 73–80	159
ASV081–ASV088	Automation SELOGIC Variable 81–88	160
ASV089–ASV096	Automation SELOGIC Variable 89–96	161
ASV097–ASV104	Automation SELOGIC Variable 97–104	162
ASV105–ASV112	Automation SELOGIC Variable 105–112	163
ASV113–ASV120	Automation SELOGIC Variable 113–120	164
ASV121–ASV128	Automation SELOGIC Variable 121–128	165
ASV129–ASV136	Automation SELOGIC Variable 129–136	166
ASV137–ASV144	Automation SELOGIC Variable 137–144	167
ASV145–ASV152	Automation SELOGIC Variable 145–152	168
ASV153–ASV160	Automation SELOGIC Variable 153–160	169
ASV161–ASV168	Automation SELOGIC Variable 161–168	170
ASV169–ASV176	Automation SELOGIC Variable 169–176	171
ASV177–ASV184	Automation SELOGIC Variable 177–184	172
ASV185–ASV192	Automation SELOGIC Variable 185–192	173
ASV193–ASV200	Automation SELOGIC Variable 193–200	174
ASV201–ASV208	Automation SELOGIC Variable 201–208	175
ASV209–ASV216	Automation SELOGIC Variable 209–216	176
ASV217–ASV224	Automation SELOGIC Variable 217–224	177
ASV225–ASV232	Automation SELOGIC Variable 225–232	178
ASV233–ASV240	Automation SELOGIC Variable 233–240	179
ASV241–ASV248	Automation SELOGIC Variable 241–248	180
ASV249–ASV256	Automation SELOGIC Variable 249–256	181
ATPA–ATPC	Assert Trip A–Trip C	54
AUNRLBL	Automation SELOGIC control equation unresolved label	204

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 14 of 34)

Name	Description	Row
B1BCWAL	Circuit Breaker 1 contact wear monitor alarm	83
B1BITAL	Circuit Breaker 1 inactivity time alarm	84
B1ESOAL	Circuit Breaker 1 electrical slow operation alarm	84
B1KAIAL	Circuit Breaker 1 interrupted current alarm	84
B1MRTAL	Circuit Breaker 1 motor running time alarm	84
B1MRTIN	Motor run time contact input, Circuit Breaker 1 (SELOGIC control equation)	83
B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm	84
B1OPHA	Circuit Breaker 1 A-Phase open	77
B1OPHB	Circuit Breaker 1 B-Phase open	77
B1OPHC	Circuit Breaker 1 C-Phase open	77
B1PDAL	Circuit Breaker 1 pole discrepancy alarm	84
B1PSAL	Circuit Breaker 1 pole scatter alarm	84
B2BCWAL	Circuit Breaker 2 contact wear monitor alarm	85
B2BITAL	Circuit Breaker 2 inactivity time alarm	86
B2ESOAL	Circuit Breaker 2 electrical slow operation alarm	86
B2KAIAL	Circuit Breaker 2 interrupted current alarm	86
B2MRTAL	Circuit Breaker 2 motor running time alarm	86
B2MRTIN	Motor run time contact input, Circuit Breaker 2 (SELOGIC control equation)	85
B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm	86
B2OPHA	Circuit Breaker 2 A-Phase open	77
B2OPHB	Circuit Breaker 2 B-Phase open	77
B2OPHC	Circuit Breaker 2 C-Phase open	77
B2PDAL	Circuit Breaker 2 pole discrepancy alarm	86
B2PSAL	Circuit Breaker 2 pole scatter alarm	86
BADPASS	Invalid password attempt alarm	206
BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation	65
BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation	71
BFI3PT1	Circuit Breaker 1 extended three-pole extended circuit breaker failure initiation	65
BFI3PT2	Circuit Breaker 2 three-pole extended circuit breaker failure initiation	71
BFIA1	Circuit Breaker 1 A-Phase circuit breaker failure initiation	65
BFIA2	Circuit Breaker 2 A-Phase circuit breaker failure initiation	71
BFIAT1	Circuit Breaker 1 A-Phase extended circuit breaker failure initiation	65
BFIAT2	Circuit Breaker 2 A-Phase extended circuit breaker failure initiation	71
BFIB1	Circuit Breaker 1 B-Phase circuit breaker failure initiation	65
BFIB2	Circuit Breaker 2 B-Phase circuit breaker failure initiation	71
BFIBT1	Circuit Breaker 1 B-Phase extended circuit breaker failure initiation	65
BFIBT2	Circuit Breaker 2 B-Phase extended circuit breaker failure initiation	71
BFIC1	Circuit Breaker 1 C-Phase circuit breaker failure initiation	65
BFIC2	Circuit Breaker 2 C-Phase circuit breaker failure initiation	71
BFICT1	Circuit Breaker 1 C-Phase extended circuit breaker failure initiation	65
BFICT2	Circuit Breaker 2 C-Phase extended circuit breaker failure initiation	71

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 15 of 34)

Name	Description	Row
BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation	68
BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation	74
BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation	68
BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation	74
BFTR1	Circuit breaker failure trip, Circuit Breaker 1 (SELOGIC control equation)	70
BFTR2	Circuit breaker failure trip, Circuit Breaker 2 (SELOGIC control equation)	76
BFTRIP1	Circuit Breaker 1 failure trip output asserted	70
BFTRIP2	Circuit Breaker 2 failure trip output asserted	76
BFULTR1	Circuit breaker failure unlatch trip, Circuit Breaker 1 (SELOGIC control equation)	70
BFULTR2	Circuit breaker failure unlatch trip, Circuit Breaker 2 (SELOGIC control equation)	76
BK1BFT	Indicates Circuit Breaker 1 breaker failure trip	224
BK1CFT	Circuit Breaker 1 close failure delay timed out	46
BK1CL	Circuit Breaker 1 close command	44
BK1CLSS	Circuit Breaker 1 in close supervision state	46
BK1CLST	Circuit Breaker 1 close supervision timer timed out	46
BK1EXT	Circuit Breaker 1 closed externally	50
BK1LO	Circuit Breaker 1 in lockout state	43
BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)	48
BK1RS	Circuit Breaker 1 in ready state	43
BK2BFT	Indicates Circuit Breaker 2 breaker failure trip	224
BK2CFT	Circuit Breaker 2 close failure delay timed out	46
BK2CL	Circuit Breaker 2 close command	44
BK2CLSS	Circuit Breaker 2 in close supervision state	46
BK2CLST	Circuit Breaker 2 close supervision timer timed out	46
BK2EXT	Circuit Breaker 2 closed externally	50
BK2LO	Circuit Breaker 2 in lockout state	44
BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)	48
BK2RS	Circuit Breaker 2 in ready state	43
BLKFOA1	Circuit Breaker 1 block A-Phase flashover detection	69
BLKFOA2	Circuit Breaker 2 block A-Phase flashover detection	75
BLKFOB1	Circuit Breaker 1 block B-Phase flashover detection	69
BLKFOB2	Circuit Breaker 2 block B-Phase flashover detection	75
BLKFOC1	Circuit Breaker 1 block C-Phase flashover detection	69
BLKFOC2	Circuit Breaker 2 block C-Phase flashover detection	75
BLKLPTS	Block low-priority source from updating relay time	210
BM1CLSA	Circuit breaker monitor A-Phase close, Circuit Breaker 1 (SELOGIC control equation)	83
BM1CLSB	Circuit breaker monitor B-Phase close, Circuit Breaker 1 (SELOGIC control equation)	83
BM1CLSC	Circuit breaker monitor C-Phase close, Circuit Breaker 1 (SELOGIC control equation)	83
BM1TRPA	Circuit breaker monitor A-Phase trip, Circuit Breaker 1 (SELOGIC control equation)	83
BM1TRPB	Circuit breaker monitor B-Phase trip, Circuit Breaker 1 (SELOGIC control equation)	83
BM1TRPC	Circuit breaker monitor C-Phase trip, Circuit Breaker 1 (SELOGIC control equation)	83

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 16 of 34)

Name	Description	Row
BM2CLSA	Circuit breaker monitor A-Phase close, Circuit Breaker 2 (SELOGIC control equation)	85
BM2CLSB	Circuit breaker monitor B-Phase close, Circuit Breaker 2 (SELOGIC control equation)	85
BM2CLSC	Circuit breaker monitor C-Phase close, Circuit Breaker 2 (SELOGIC control equation)	85
BM2TRPA	Circuit breaker monitor A-Phase trip, Circuit Breaker 2 (SELOGIC control equation)	85
BM2TRPB	Circuit breaker monitor B-Phase trip, Circuit Breaker 2 (SELOGIC control equation)	85
BM2TRPC	Circuit breaker monitor C-Phase trip, Circuit Breaker 2 (SELOGIC control equation)	85
BNC_BNP	Bad jitter on BNC port and the IRIG-B signal is lost afterwards	212
BNC_OK	IRIG-B signal from BNC port is available and has sufficient quality	212
BNC_RST	Disqualify BNC IRIG-B high-accuracy time source	212
BNC_SET	Qualify BNC IRIG-B high-accuracy time source	212
BNC_TIM	A valid IRIG-B time source is detected on BNC port	213
BNCSYNC	Synchronized to a high quality BNC IRIG source	213
BPS	Trip logic B-Phase selected	54
BRKENAB	Asserted to indicate breaker control enable	208
BSYNBK1	Block synchronism check for Circuit Breaker 1	39
BSYNBK2	Block synchronism check for Circuit Breaker 2	41
BTX	Block extension picked up	60
CBADA	Unavailability threshold exceeded for MIRRORED BITS Communications Channel A	229
CBADB	Unavailability threshold exceeded for MIRRORED BITS Communications Channel B	230
CC1	Circuit Breaker 1 close command	91
CC2	Circuit Breaker 2 close command	91
CHSG	Settings group change	100
CNR1AG	Control A-Phase composite current polarized right blinder	396
CNR1BG	Control B-Phase composite current polarized right blinder	396
CNR1CG	Control C-Phase composite current polarized right blinder	397
CNR1AB	Control AB positive-sequence right blinder	398
CNR1BC	Control BC positive-sequence right blinder	398
CNR1CA	Control CA positive-sequence right blinder	398
CNR2AG	Control A-Phase Ipa polarized right blinder	396
CNR2BG	Control B-Phase Ipb polarized right blinder	396
CNR2CG	Control C-Phase Ipc polarized right blinder	396
CNR2AB	Control AB negative-sequence right blinder	398
CNR2BC	Control BC negative-sequence right blinder	398
CNR2CA	Control CA negative-sequence right blinder	398
COMPRM	Communications-assisted trip permission	53
CPS	Trip logic C-Phase selected	54
CVTBL	CCVT transient blocking logic active	18
CVTBLH	CCVT transient blocking logic active high-speed elements	18
DC1F	DC Monitor 1 fail alarm	89
DC1G	DC Monitor 1 ground fault alarm	89
DC1R	DC Monitor 1 alarm for ac ripple	89

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 17 of 34)

Name	Description	Row
DC1W	DC Monitor 1 warning alarm	89
DC2F	DC Monitor 2 fail alarm	89
DC2G	DC Monitor 2 ground fault alarm	89
DC2R	DC Monitor 2 alarm for ac ripple	89
DC2W	DC Monitor 2 warning alarm	89
DELAY	Unused	269
DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts	52
DLDB1	Dead Line Dead Bus 1	47
DLDB2	Dead Line Dead Bus 2	47
DLLB1	Dead Line Live Bus 1	47
DLLB2	Dead Line Live Bus 2	47
DOKA	Normal MIRRORED BITS Communications Channel A status	229
DOKB	Normal MIRRORED BITS Communications Channel B status	230
DOSB	Dependable out-of-step blocking asserted	25
DPFA_OK	A-Phase displacement power factor OK	27
DPFB_OK	B-Phase displacement power factor OK	27
DPFC_OK	C-Phase displacement power factor OK	27
DPF3_OK	Three-phase displacement power factor OK	27
DST	Daylight savings-time	294
DSTP	IRIG-B Daylight savings-time pending	294
DSTRT	Directional start element picked up	60
DTA	Direct transfer trip A-Phase (SELOGIC control equation)	57
DTB	Direct transfer trip B-Phase (SELOGIC control equation)	57
DTC	Direct transfer trip C-Phase (SELOGIC control equation)	57
DTR	Direct transfer trip received	53
E3PT	Three-pole trip enable	53
E3PT1	Circuit Breaker 1 three-pole trip enable	53
E3PT2	Circuit Breaker 2 three-pole trip enable	53
EAFSRC	Alternate frequency source (SELOGIC control equation)	52
ECTT	Echo conversion to trip signal	58
ECTTA	A-Phase echo conversion to trip signal (ECOMM = POTT3)	62
ECTTB	B-Phase echo conversion to trip signal (ECOMM = POTT3)	62
ECTTC	C-Phase echo conversion to trip signal (ECOMM = POTT3)	62
EKEY	Echo received permissive trip signal	58
EKEYA	A-Phase echo received permissive trip signal (ECOMM = POTT3)	62
EKEYB	B-Phase echo received permissive trip signal (ECOMM = POTT3)	62
EKEYC	C-Phase echo received permissive trip signal (ECOMM = POTT3)	62
EN	Relay enabled	0
ENX2AB	Enable AB negative-sequence reactance element	398
ENX2BC	Enable BC negative-sequence reactance element	398

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 18 of 34)

Name	Description	Row
ENX2CA	Enable CA negative-sequence reactance element	398
ENX2AG	Enable A-Phase Ipa polarized reactance element	396
ENX2BG	Enable B-Phase Ipb polarized reactance element	396
ENX2CG	Enable C-Phase Ipc polarized reactance element	396
ER	Event report trigger equation (SELOGIC control equation)	52
EVELOCK	Lock DNP events	286
F32I	Forward current polarized zero-sequence directional element	30
F32P	Forward phase directional declaration	28
F32Q	Forward negative-sequence phase directional declaration	28
F32QG	Forward negative-sequence ground directional element	30
F32V	Forward voltage polarized zero-sequence directional element	30
FAST1	fs1 > fp	39
FAST2	fs2 > fp	41
FBF1	Circuit Breaker 1 circuit breaker failure	67
FBF2	Circuit Breaker 2 circuit breaker failure	73
FBFA1	Circuit Breaker 1 A-Phase circuit breaker failure	67
FBFA2	Circuit Breaker 2 A-Phase circuit breaker failure	73
FBFB1	Circuit Breaker 1 B-Phase circuit breaker failure	67
FBFB2	Circuit Breaker 2 B-Phase circuit breaker failure	73
FBFC1	Circuit Breaker 1 C-Phase circuit breaker failure	67
FBFC2	Circuit Breaker 2 C-Phase circuit breaker failure	73
FIDEN	Fault identification logic enabled	51
FOA1	Circuit Breaker 1 A-Phase flashover detected	69
FOA2	Circuit Breaker 2 A-Phase flashover detected	75
FOB1	Circuit Breaker 1 B-Phase flashover detected	69
FOB2	Circuit Breaker 2 B-Phase flashover detected	75
FOBF1	Circuit Breaker 1 flashover detected	70
FOBF2	Circuit Breaker 2 flashover detected	76
FOC1	Circuit Breaker 1 C-Phase flashover detected	70
FOC2	Circuit Breaker 2 C-Phase flashover detected	76
FOLBK0	No follower circuit breaker	44
FOLBK1	Follower circuit breaker = Circuit Breaker 1	44
FOLBK2	Follower circuit breaker = Circuit Breaker 2	45
FOP1_01–FOP1_08	Fast-operate output control bits for Port 1, Bit 1–8	320
FOP1_09–FOP1_16	Fast-operate output control bits for Port 1, Bit 9–16	321
FOP1_17–FOP1_24	Fast-operate output control bits for Port 1, Bit 17–24	322
FOP1_25–FOP1_32	Fast-operate output control bits for Port 1, Bit 25–32	323
FOP2_01–FOP2_08	Fast-operate output control bits for Port 2, Bit 1–8	324
FOP2_09–FOP2_16	Fast-operate output control bits for Port 2, Bit 9–16	325
FOP2_17–FOP2_24	Fast-operate output control bits for Port 2, Bit 17–24	326
FOP2_25–FOP2_32	Fast-operate output control bits for Port 2, Bit 25–32	327

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 19 of 34)

Name	Description	Row
FOP3_01–FOP3_08	Fast-operate output control bits for Port 3, Bit 1–8	328
FOP3_09–FOP3_16	Fast-operate output control bits for Port 3, Bit 9–16	329
FOP3_17–FOP3_24	Fast-operate output control bits for Port 3, Bit 17–24	330
FOP3_25–FOP3_32	Fast-operate output control bits for Port 3, Bit 25–32	331
FOPF_01–FOPF_08	Fast-operate output control bits for Port F, Bit 1–8	316
FOPF_09–FOPF_16	Fast-operate output control bits for Port F, Bit 9–	317
FOPF_17–FOPF_24	Fast-operate output control bits for Port F, Bit 17–24	318
FOPF_25–FOPF_32	Fast-operate output control bits for Port F, Bit 25–32	319
FREQFZ	Assert if relay is not calculating frequency	210
FREQOK	Assert if relay is estimating frequency	210
FROKPM	Synchrophasor frequency	288
FSA	A-Phase sector fault (AG or BCG fault)	51
FSB	B-Phase sector fault (BG or CAG fault)	52
FSC	C-Phase sector fault (CG or ABG fault)	52
FSERP1–FSERP3	Fast SER enabled for Serial Port 1–3	268
FSERP5	Fast SER enabled for EN and FO ports	268
FSERPF	Fast SER enabled for Serial Port F	268
GDEM	Zero-sequence demand current picked up	90
GROUND	Indicates a ground fault	224
GRPSW	Pulsed alarm for group switches	206
HALARM	Hardware alarm	206
HALARMA	Pulse stream for unacknowledged diagnostic warnings	206
HALARML	Latched alarm for diagnostic failures	206
HALARMP	Pulsed alarm for diagnostic warnings	206
HSDGF	Ground fault, high-speed forward directional element	285
HSDGR	Ground fault, high-speed reverse directional element	285
HSDQF	Phase-to-phase fault, high-speed forward directional element	285
HSDQR	Phase-to-phase fault, high-speed reverse directional element	285
ILOP	Internal loss-of-potential from ELOP setting	51
IN101–IN107	Main Board Input 1–7	104
IN201–IN208	First optional I/O board Input 1–8 (if installed)	108
IN209–IN216	First optional I/O board Input 9–16 (if installed)	109
IN217–IN224	First optional I/O board Input 17–24 (if installed)	110
IN301–IN308	Second optional I/O board Input 1–8 (if installed)	112
IN309–IN316	Second optional I/O board Input 9–16 (if installed)	113
IN317–IN324	Second optional I/O board Input 17–24 (if installed)	114
IN401–IN408	Third optional I/O board Input 1–8 (if installed)	404
IN409–IN416	Third optional I/O board Input 9–16 (if installed)	405
IN417–IN424	Third optional I/O board Input 17–24 (if installed)	406
IN501–IN508	Fourth optional I/O board Input 1–8 (if installed)	408
IN509–IN516	Fourth optional I/O board Input 9–16 (if installed)	409

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 20 of 34)

Name	Description	Row
IN517–IN524	Fourth optional I/O board Input 17–24 (if installed)	410
IO300OK	Communications status of Interface Board 300 when installed or commissioned	403
IO400OK	Communications status of Interface Board 400 when installed or commissioned	403
IO500OK	Communications status of Interface Board 500 when installed or commissioned	403
KEY	Transmit permissive trip signal	58
KEY1	Transmit general permissive trip	59
KEY3	Transmit three-phase permissive trip	59
KEYA	Transmit A-Phase permissive trip (ECOMM = POTT3)	61
KEYB	Transmit B-Phase permissive trip (ECOMM = POTT3)	61
KEYC	Transmit C-Phase permissive trip (ECOMM = POTT3)	61
KEYD	Transmit Directional permissive trip (ECOMM = POTT, EPTDIR = Y)	61
LB_DP01–LB_DP08	Local Bit 01–08 status display (SELOGIC Equation)	308
LB_DP09–LB_DP16	Local Bit 09–16 status display (SELOGIC Equation)	309
LB_DP17–LB_DP24	Local Bit 17–24 status display (SELOGIC Equation)	310
LB_DP25–LB_DP32	Local Bit 25–32 status display (SELOGIC Equation)	311
LB_SP01–LB_SP08	Local Bit 01–08 supervision (SELOGIC Equation)	304
LB_SP09–LB_SP16	Local Bit 09–16 supervision (SELOGIC Equation)	305
LB_SP17–LB_SP24	Local Bit 17–24 supervision (SELOGIC Equation)	306
LB_SP25–LB_SP32	Local Bit 25–32 supervision (SELOGIC Equation)	307
LB01–LB08	Local Bit 1–8	92
LB09–LB16	Local Bit 9–16	93
LB17–LB24	Local Bit 17–24	94
LB25–LB32	Local Bit 25–32	95
LBOKA	Normal MIRRORED BITS Communications Channel A status while in loopback mode	229
LBOKB	Normal MIRRORED BITS Communications Channel B status while in loopback mode	230
LCBF1	Circuit Breaker 1 load current circuit breaker failure	68
LCBF2	Circuit Breaker 2 load current circuit breaker failure	74
LD_DPFA	Leading A-Phase displacement power factor	26
LD_DPFB	Leading B-Phase displacement power factor	26
LD_DPFC	Leading C-Phase displacement power factor	26
LD_DPF3	Leading three-phase displacement power factor	26
LEADBK0	No lead circuit breaker	44
LEADBK1	Lead circuit breaker = Circuit Breaker 1	44
LEADBK2	Lead circuit breaker = Circuit Breaker 2	44
LG_DPFA	Lagging A-Phase displacement power factor	26
LG_DPFB	Lagging B-Phase displacement power factor	26
LG_DPFC	Lagging C-Phase displacement power factor	26
LG_DPF3	Lagging three-phase displacement power factor	26
LINK5A	Link status of Port 5A connection	264
LINK5B	Link status of Port 5B connection	264
LINK5C	Link status of Port 5C connection	264

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 21 of 34)

Name	Description	Row
LINK5D	Link status of Port 5D connection	264
LLDB1	Live Line Dead Bus 1	47
LLDB2	Live Line Dead Bus 2	47
LNKFAIL	Link status of the active port	264
LOADTE	Load TECORR factor (SELOGIC Equation). When a rising edge is detected, the accumulated time-error value TE is loaded with the TECORR factor (preload value).	296
LOCAL	Local front-panel control	334
LOP	Loss-of-potential detected	51
LOPHA	Line A-Phase open	77
LOPHB	Line B-Phase open	77
LOPHC	Line C-Phase open	78
LPHDSIM	IEC 61850 logical node for physical device simulation	231
LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.	294
LPSECP	Leap second pending	294
M1P	Zone 1 Mho phase-distance element	18
M1PT	Zone 1 Mho phase-distance, time-delayed	19
M2P	Zone 2 Mho phase-distance element	18
M2PT	Zone 2 Mho phase-distance, time-delayed	19
M3P	Zone 3 Mho phase-distance element	19
M3PT	Zone 3 Mho phase-distance, time-delayed	19
M4P	Zone 4 Mho phase-distance element	19
M4PT	Zone 4 Mho phase-distance, time-delayed	19
M5P	Zone 5 Mho phase-distance element	19
M5PT	Zone 5 Mho phase-distance, time-delayed	19
MAB1	Zone 1 Mho A-B phase element	8
MAB1F	Zone 1 filtered Mho A-B phase element	274
MAB1H	High-speed Zone 1 Mho A-B phase element	282
MAB2	Zone 2 Mho A-B phase element	8
MAB2F	Zone 2 filtered Mho A-B phase element	274
MAB2H	High-speed Zone 2 Mho A-B phase element	282
MAB3	Zone 3 Mho A-B phase element	9
MAB3F	Zone 3 filtered Mho A-B phase element	275
MAB3H	High-speed Zone 3 Mho A-B phase element	282
MAB4	Zone 4 Mho A-B phase element	9
MAB4F	Zone 4 filtered Mho A-B phase element	276
MAB5	Zone 5 Mho A-B phase element	10
MAB5F	Zone 5 filtered Mho A-B phase element	277
MAG1	Zone 1 Mho A-Phase-to-ground element	13
MAG1F	Zone 1 filtered Mho A-Phase-to-ground element	270
MAG1H	High-speed Zone 1 Mho A-G ground element	278
MAG2	Zone 2 Mho A-Phase-to-ground element	13

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 22 of 34)

Name	Description	Row
MAG2F	Zone 2 filtered Mho A-Phase-to-ground element	270
MAG2H	High-speed Zone 2 Mho A-G ground element	278
MAG3	Zone 3 Mho A-Phase-to-ground element	14
MAG3F	Zone 3 filtered Mho A-Phase-to-ground element	271
MAG3H	High-speed Zone 3 Mho A-G ground element	278
MAG4	Zone 4 Mho A-Phase-to-ground element	14
MAG4F	Zone 4 filtered Mho C-Phase-to-ground element	272
MAG5	Zone 5 Mho A-Phase-to-ground element	15
MAG5F	Zone 5 filtered Mho A-Phase-to-ground element	273
MATHERR	SELOGIC control equation math error	202
MBC1	Zone 1 Mho B-C phase element	8
MBC1F	Zone 1 filtered Mho B-C phase element	274
MBC1H	High-speed Zone 1 Mho B-C phase element	282
MBC2	Zone 2 Mho B-C phase element	8
MBC2F	Zone 2 filtered Mho B-C phase element	274
MBC2H	High-speed Zone 2 Mho B-C phase element	282
MBC3	Zone 3 Mho B-C phase element	9
MBC3F	Zone 3 filtered Mho B-C phase element	275
MBC3H	High-speed Zone 3 Mho B-C phase element	282
MBC4	Zone 4 Mho B-C phase element	9
MBC4F	Zone 4 filtered Mho B-C phase element	276
MBC5	Zone 5 Mho B-C phase element	10
MBC5F	Zone 5 filtered Mho B-C phase element	277
MBG1	Zone 1 Mho B-Phase-to-ground element	13
MBG1F	Zone 1 filtered Mho B-Phase-to-ground element	270
MBG1H	High-speed Zone 1 Mho BG ground element	278
MBG2	Zone 2 Mho B-Phase-to-ground element	13
MBG2F	Zone 2 filtered B-Phase-to-ground Mho element asserted	270
MBG2H	High-speed Zone 2 Mho BG ground element	278
MBG3	Zone 3 Mho B-Phase-to-ground element	14
MBG3F	Zone 3 filtered Mho B-Phase-to-ground element	271
MBG3H	High-speed Zone 3 Mho BG ground element	278
MBG4	Zone 4 Mho B-Phase-to-ground element	14
MBG4F	Zone 4 filtered Mho B-Phase-to-ground element	272
MBG5	Zone 5 Mho B-Phase-to-ground element	15
MBG5F	Zone 5 filtered Mho B-Phase-to-ground element	273
MCA1	Zone 1 Mho C-A phase element	8
MCA1F	Zone 1 filtered Mho C-A phase element	274
MCA1H	High-speed Zone 1 Mho C-A phase element	282
MCA2	Zone 2 Mho C-A phase element	8
MCA2F	Zone 2 filtered Mho C-A phase element	275

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 23 of 34)

Name	Description	Row
MCA2H	High-speed Zone 2 Mho C-A phase element	282
MCA3	Zone 3 Mho C-A phase element	9
MCA3F	Zone 3 filtered Mho C-A phase element	275
MCA3H	High-speed Zone 3 Mho C-A phase element	283
MCA4	Zone 4 Mho C-A phase element	9
MCA4F	Zone 4 filtered Mho C-A phase element	276
MCA5	Zone 5 Mho C-A phase element	10
MCA5F	Zone 5 filtered Mho C-A phase element	277
MCG1	Zone 1 Mho C-Phase-to-ground element	13
MCG1F	Zone 1 filtered Mho C-Phase-to-ground element	270
MCG1H	High-speed Zone 1 Mho C-G ground element	278
MCG2	Zone 2 Mho C-Phase-to-ground element	13
MCG2F	Zone 2 filtered Mho C-Phase-to-ground element	271
MCG2H	High-speed Zone 2 Mho C-G ground element	278
MCG3	Zone 3 Mho C-Phase-to-ground element	14
MCG3F	Zone 3 filtered Mho C-Phase-to-ground element	271
MCG3H	High-speed Zone 3 Mho C-G ground element	279
MCG4	Zone 4 Mho C-Phase-to-ground element	14
MCG4F	Zone 4 filtered Mho C-Phase-to-ground element	272
MCG5	Zone 5 Mho C-Phase-to-ground element	15
MCG5F	Zone 5 filtered Mho C-Phase-to-ground element	273
NBF1	Circuit Breaker 1 no current circuit breaker failure	68
NBF2	Circuit Breaker 2 no current circuit breaker failure	74
NBK0	No circuit breakers active in reclose scheme	45
NBK1	One circuit breaker active in reclose scheme	45
NBK2	Two circuit breakers active in reclose scheme	45
NSTRT	Nondirectional start element picked up	60
OC1	Circuit Breaker 1 open command	91
OC2	Circuit Breaker 2 open command	91
OOSDET	Out-of-step condition detected	23
OSB	Out-of-step block	22
OSB1–OSB5	Block Zone 1–5 during an out-of-step condition	21
OSBA	A-Phase out-of-step block	21
OSBB	B-Phase out-of-step block	21
OSBC	C-Phase out-of-step block	21
OST	Out-of-step tripping	22
OSTI	Incoming out-of-step tripping	22
OSTO	Outgoing out-of-step tripping	22
OUT101–OUT108	Main Board Output 1–8	215
OUT201–OUT208	Optional I/O Board 1 Output 1–8	216
OUT209–OUT216	Optional I/O Board 1 Output 9–16	217

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 24 of 34)

Name	Description	Row
OUT301–OUT308	Optional I/O Board 2 Output 1–8	218
OUT309–OUT316	Optional I/O Board 2 Output 9–16	219
OUT401–OUT408	Optional I/O Board 3 Output 1–8	412
OUT409–OUT416	Optional I/O Board 3 Output 9–16	413
OUT501–OUT508	Optional I/O Board 4 Output 1–8	414
OUT509–OUT516	Optional I/O Board 4 Output 9–16	415
P5ABSW	Port 5A or 5B has just become active	400
P5ASEL	Port 5A active/inactive	265
P5BSEL	Port 5B active/inactive	265
P5CSEL	Port 5C active/inactive	265
P5DSEL	Port 5D active/inactive	265
PASSDIS	Asserted to indicate PW disable	208
PB_CLSE	Auxiliary CLOSE pushbutton	301
PB_TRIP	Auxiliary TRIP pushbutton	301
PB1–PB8	Pushbutton 1–8	214
PB1_LED–PB8_LED	Pushbutton 1–8 LED	221
PB1_PUL–PB8_PUL	Pushbutton 1–8 pulse (on for one processing interval when button is pushed)	220
PB9–PB12	Pushbutton 9–12	301
PB9_LED–PB12LED	Pushbutton 9–12 LED	302
PB9_PUL–PB12PUL	Pushbutton 9–12 pulse (on for one processing interval when button is pushed)	303
PCN01Q–PCN08Q	Protection Counter 1–8 output	142
PCN09Q–PCN16Q	Protection Counter 9–16 output	143
PCN17Q–PCN24Q	Protection Counter 17–24 output	144
PCN25Q–PCN32Q	Protection Counter 25–32 output	145
PCN01R–PCN08R	Protection Counter 1–8 reset	146
PCN09R–PCN16R	Protection Counter 9–16 reset	147
PCN17R–PCN24R	Protection Counter 17–24 reset	148
PCN25R–PCN32R	Protection Counter 25–32 reset	149
PCT01Q–PCT08Q	Protection Conditioning Timer 1–8 output	128
PCT09Q–PCT16Q	Protection Conditioning Timer 9–16 output	129
PCT17Q–PCT24Q	Protection Conditioning Timer 17–24 output	130
PCT25Q–PCT32Q	Protection Conditioning Timer 25–32 output	131
PDEM	Phase current demand picked up	90
PF3_OK	Three-phase power factor OK	27
PFA_OK	A-Phase power factor OK	27
PFB_OK	B-Phase power factor OK	27
PFC_OK	C-Phase power factor OK	27
PFRTEX	Protection SELOGIC control equation first execution	202
PHASE_A	Indicates an A-Phase fault	224
PHASE_B	Indicates a B-Phase fault	224
PHASE_C	Indicates a C-Phase fault	224

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 25 of 34)

Name	Description	Row
PLDTE	Asserts for approximately 1.5 cycles when the TEC command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.	296
PLT01–PLT08	Protection Latch 1–8	124
PLT09–PLT16	Protection Latch 9–16	125
PLT17–PLT24	Protection Latch 17–24	126
PLT25–PLT32	Protection Latch 25–32	127
PMDOK	Assert if data acquisition system is operating correctly	209
PMTEST	Synchrophasor test mode	288
PMTRIG	Trigger (SELOGIC control equation)	288
PST01Q–PST08Q	Protection Sequencing Timer 1–8 output	134
PST09Q–PST16Q	Protection Sequencing Timer 9–16 output	135
PST17Q–PST24Q	Protection Sequencing Timer 17–24 output	136
PST25Q–PST32Q	Protection Sequencing Timer 25–32 output	137
PST01R–PST08R	Protection Sequencing Timer 1–8 reset	138
PST09R–PST16R	Protection Sequencing Timer 9–16 reset	139
PST17R–PST24R	Protection Sequencing Timer 17–24 reset	140
PST25R–PST32Q	Protection Sequencing Timer 25–32 reset	141
PSV01–PSV08	Protection SELOGIC Variable 1–8	116
PSV09–PSV16	Protection SELOGIC Variable 9–16	117
PSV17–PSV24	Protection SELOGIC Variable 17–24	118
PSV25–PSV32	Protection SELOGIC Variable 25–32	119
PSV33–PSV40	Protection SELOGIC Variable 33–40	120
PSV41–PSV48	Protection SELOGIC Variable 41–48	121
PSV49–PSV56	Protection SELOGIC Variable 49–56	122
PSV57–PSV64	Protection SELOGIC Variable 57–64	123
PT	Permissive trip received	58
PTA	A-Phase permissive trip received (ECOMM = POTT3)	63
PTB	B-Phase permissive trip received (ECOMM = POTT3)	63
PTC	C-Phase permissive trip received (ECOMM = POTT3)	63
PTDRX	Directional permissive trip received (ECOMM = POTT, EPTDIR = Y)	63
PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards	400
PTP_OK	PTP is available and has sufficient quality	400
PTP_RST	Disqualify PTP high accuracy time source	400
PTP_SET	Qualify PTP high accuracy time source	400
PTP_TIM	A valid PTP time source is detected	400
PTPSYNC	Synchronized to a high quality PTP source	400
PTRX	Permissive trip received Channel 1 and Channel 2	60
PTRX1	Permissive trip received Channel 1	59
PTRX2	Permissive trip received Channel 2	59
PUNRLBL	Protection SELOGIC control equation unresolved label	202
QDEM	Negative-sequence demand current picked up	90

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 26 of 34)

Name	Description	Row
R1T	Positive-sequence resistance within Zone 7 left resistance blinder	25
R32I	Reverse current polarized zero-sequence directional element	30
R32P	Reverse phase directional declaration	28
R32Q	Reverse negative-sequence phase directional declaration	28
R32QG	Reverse negative-sequence ground directional element	30
R32V	Reverse voltage polarized zero-sequence directional element	30
R3PTE	Recloser three-pole trip enable	47
R3PTE1	Recloser three-pole trip enable Circuit Breaker 1	47
R3PTE2	Recloser three-pole trip enable Circuit Breaker 2	48
R6T	Positive-sequence resistance within Zone 6 resistance blinder	24
R7T	Positive-sequence resistance within Zone 7 resistance blinder	24
RB01–RB08	Remote Bit 1–8	99
RB09–RB16	Remote Bit 9–16	98
RB17–RB24	Remote Bit 17–24	97
RB25–RB32	Remote Bit 25–32	96
RBADA	Outage too long on MIRRORED BITS Communications Channel A	229
RBADB	Outage too long on MIRRORED BITS Communications Channel B	230
RL6	Positive-sequence resistance within Zone 6 left resistance blinder	24
RL7	Positive-sequence resistance within Zone 7 left resistance blinder	24
RMB1A–RMB8A	Channel A receive MIRRORED BITS 1–8	225
RMB1B–RMB8B	Channel B receive MIRRORED BITS 1–8	227
ROKA	Normal MIRRORED BITS Communications Channel A status while not in loopback mode	229
ROKB	Normal MIRRORED BITS Communications Channel B status while not in loopback mode	230
RR6	Positive-sequence resistance within Zone 6 right resistance blinder	24
RR7	Positive-sequence resistance within Zone 7 right resistance blinder	24
RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)	223
RST_BAT	Reset battery monitoring (SELOGIC control equation)	223
RST_BK1	Reset Circuit Breaker 1 monitor	222
RST_BK2	Reset Circuit Breaker 2 monitor	222
RST_DEM	Reset demand metering	222
RST_ENE	Reset energy metering data	222
RST_HAL	Reset hardware alarm (SELOGIC control equation)	223
RST_PDM	Reset peak demand metering	222
RSTDNPE	Reset DNP fault summary data (SELOGIC control equation)	223
RSTFLOC	Reset fault locator (SELOGIC control equation)	223
RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)	222
RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)	222
RSTMML	Reset max/min line (SELOGIC control equation)	222
RSTTRGT	Target reset (SELOGIC control equation)	223
RT1	Circuit Breaker 1 retrip	67
RT2	Circuit Breaker 2 retrip	73

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 27 of 34)

Name	Description	Row
RT3P1	Circuit Breaker 1 three-pole retrip	66
RT3P2	Circuit Breaker 2 three-pole retrip	72
RTA1	Circuit Breaker 1 A-Phase retrip	66
RTA2	Circuit Breaker 2 A-Phase retrip	72
RTB1	Circuit Breaker 1 B-Phase retrip	66
RTB2	Circuit Breaker 2 B-Phase retrip	72
RTC1	Circuit Breaker 1 C-Phase retrip	66
RTC2	Circuit Breaker 2 C-Phase retrip	72
RTCAD01–RTCAD08	RTC remote data bits, Channel A, Bit 1–8	312
RTCAD09–RTCAD16	RTC remote data bits, Channel A, Bit 9–16	313
RTCBD01–RTCBD08	RTC remote data bits, Channel B, Bit 1–8	314
RTCBD09–RTCBD16	RTC remote data bits, Channel B, Bit 9–16	315
RTCCFGA	RTC data in sequence, Channel A	290
RTCCFGB	RTC data in sequence, Channel B	290
RTCDLYA	RTC delay exceeded, Channel A	291
RTCDLYB	RTC delay exceeded, Channel B	291
RTCENA	Valid remote synchrophasors received on Channel A	291
RTCENB	Valid remote synchrophasors received on Channel B	291
RTCROK	Valid aligned RTC data available on all enabled channels	291
RTCROKA	Valid aligned RTC data available on Channel A	291
RTCROKB	Valid aligned RTC data available on Channel B	291
RTCSEQA	RTC configuration complete, Channel A	290
RTCSEQB	RTC configuration complete, Channel B	290
RTD01ST–RTD08ST	RTD status for Channel 1–8	87
RTD09ST–RTD12ST	RTD status for Channel 9–12	88
RTDCOMF	RTD communication failure	88
RTDFL	RTD device failure	88
RTDIN	State of RTD contact input	88
RTS3P1	Circuit Breaker 1 current-supervised three-pole retrip	66
RTS3P2	Circuit Breaker 2 current-supervised three-pole retrip	72
RTSA1	Circuit Breaker 1 current-supervised A-Phase retrip	67
RTSA2	Circuit Breaker 2 current-supervised A-Phase retrip	73
RTSB1	Circuit Breaker 1 current-supervised B-Phase retrip	67
RTSB2	Circuit Breaker 2 current-supervised B-Phase retrip	73
RTSC1	Circuit Breaker 1 current-supervised C-Phase retrip	67
RTSC2	Circuit Breaker 2 current-supervised C-Phase retrip	73
RXPRM	Receiver trip permission	53
SALARM	Software alarm	206
SD	Swing center voltage slope detected	25
SER_BNP	Bad jitter on serial port and the IRIG-B signal is lost afterwards	213
SER_OK	IRIG-B signal from serial Port 1 is available and has sufficient quality	212

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 28 of 34)

Name	Description	Row
SER_RST	Disqualify serial IRIG-B high-accuracy time source	212
SER_SET	Qualify serial IRIG-B high-accuracy time source	212
SER_TIM	A valid IRIG-B time source is detected on serial port	213
SERCA	Series-compensated line A-Phase output	20
SERCAB	Series-compensated line AB-Phase output	20
SERCB	Series-compensated line B-Phase output	20
SERCBC	Series-compensated line BC-Phase output	20
SERCC	Series-compensated line C-Phase output	20
SERCCA	Series-compensated line CA-Phase output	20
SERSYNC	Synchronized to a high quality serial IRIG source	213
SETCHG	Pulsed alarm for settings changes	206
SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25SFBK1	38
SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25SFBK2	40
SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz	38
SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz	40
SG1–SG6	Settings Group 1–6 active	100
SLOW1	fs1 < fp	39
SLOW2	fs2 < fp	41
SOTFE	Switch-onto-fault enable	51
SOTFT	Switch-onto-fault trip	53
SP1CLS	Single-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)	45
SP2CLS	Single-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)	45
SPARC	Single-pole reclose initiate qualified	42
SPCER1	Synchrophasor configuration error on Port 1	298
SPCER2	Synchrophasor configuration error on Port 2	298
SPCER3	Synchrophasor configuration error on Port 3	298
SPCERF	Synchrophasor configuration error on Port F	298
SPEN	Signal profiling enabled	267
SPLSHT	Single-pole reclose last shot	42
SPO	One or two poles open	78
SPOA	A-Phase open	78
SPOB	B-Phase open	78
SPOBK1	Single-pole open Circuit Breaker 1	42
SPOBK2	Single-pole open Circuit Breaker 2	42
SPOC	C-Phase open	78
SPOI	Single-pole open interval timing	50
SPOISC	Single-pole open interval supervision condition	50
SPRCIP	Single-pole reclaim in progress	48
SPRI	Single-pole reclose initiation (SELOGIC control equation)	42
SPSHOT0	Single-pole shot counter = 0	49
SPSHOT1	Single-pole shot counter = 1	49

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 29 of 34)

Name	Description	Row
SPSHOT2	Single-pole shot counter = 2	49
SPT	Single-pole trip	55
SSD	Out-of-step swing signature detected	25
STALLTE	Stall time-error calculation (SELOGIC Equation). When asserted, the time-error calculation is stalled, or frozen.	296
STOP	Stop element picked up	60
TBBK	Time between circuit breakers timing	50
TBNC	Time is based on a valid BNC IRIG-B source	211
TESTDB	Communications card database Test Bit	231
TESTDB2	Communications card database Test Bit 2	231
TESTFM	Fast meter test bit	231
TESTPUL	Pulse test bit	231
TGLOBAL	Relay calendar clock and ADC sampling synchronized to C37.118 high-accuracy IRIG-B time source	210
TIRIG	Assert while time is based on IRIG for both mark and value	209
TLED_1–TLED_8	Target LED 1–8	1
TLED_9–TLED_16	Target LED 9–16	2
TLED_17–TLED_24	Target LED 17–24	300
TMB1A–TMB8A	Channel A transmit MIRRORED BITS 1–8	226
TMB1B–TMB8B	Channel B transmit MIRRORED BITS 1–8	228
TOP	Trip during open pole timer is asserted	56
TPA	Trip A	55
TPA1	Circuit Breaker 1 Trip A	55
TPA2	Circuit Breaker 2 Trip A	56
TPB	Trip B	55
TPB1	Circuit Breaker 1 Trip B	55
TPB2	Circuit Breaker 2 Trip B	56
TPC	Trip C	55
TPC1	Circuit Breaker 1 Trip C	56
TPC2	Circuit Breaker 2 Trip C	56
TPLLEXT	Update PLL using external signal	210
TPTP	Time is based on a valid PTP source	211
TQUAL1	Time quality, binary, add 1 when asserted	294
TQUAL2	Time quality, binary, add 2 when asserted	294
TQUAL4	Time quality, binary, add 4 when asserted	294
TQUAL8	Time quality, binary, add 8 when asserted	294
TREA1–TREA4	Trigger Reason Bit 1–4 (SELOGIC Equation)	288
TRGTR	Reset all active target relay words	224
TRIP	Trip A or Trip B or Trip C	55
TRIPLED	Trip LED	0
TRPRM	Trip permission	53
TSER	Time is based on a valid Serial IRIG-B source	211

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 30 of 34)

Name	Description	Row
TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP timeout period expired	209
TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP timeout period expired	209
TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements	209
TSSW	High-priority time source switching	210
TSYNC	Assert when ADC sampling is synchronized to an IRIG-B time source	210
TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized	209
TUPDH	Assert if update source is high-accuracy time source	209
TUTC1	IRIG-B Offset hours from UTC time, binary, add 1 if asserted	293
TUTC2	IRIG-B Offset hours from UTC time, binary, add 2 if asserted	293
TUTC4	IRIG-B Offset hours from UTC time, binary, add 4 if asserted	293
TUTC8	IRIG-B Offset hours from UTC time, binary, add 8 if asserted	293
TUTCH	IRIG-B Offset half-hour from UTC time, binary, add 0.5 if asserted	293
TUTCS	IRIG-B Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise	293
UBB	Block permissive trip Receiver 1 or 2	59
UBB1	Blocks permissive trip Receiver 1	59
UBB2	Blocks permissive trip Receiver 2	59
UBOSB	Unblock out-of-step blocking	21
ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)	46
ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)	46
ULMTR1	Circuit Breaker 1 unlatch manual trip	56
ULMTR2	Circuit Breaker 2 unlatch manual trip	56
ULTR	Unlatch all protection trips	56
ULTRA	Unlatch Trip A	57
ULTRB	Unlatch Trip B	57
ULTRC	Unlatch Trip C	57
UPD_BLK	Block updating internal clock period and Master Time	212
UPD_EN	Enable updating internal clock with selected external time source	209
VB001–VB008	Virtual Bit 001–008	263
VB009–VB016	Virtual Bit 009–016	262
VB017–VB024	Virtual Bit 017–024	261
VB025–VB032	Virtual Bit 025–032	260
VB033–VB040	Virtual Bit 033–040	259
VB041–VB048	Virtual Bit 041–048	258
VB049–VB056	Virtual Bit 049–056	257
VB057–VB064	Virtual Bit 057–064	256
VB065–VB072	Virtual Bit 065–072	255
VB073–VB080	Virtual Bit 073–080	254
VB081–VB088	Virtual Bit 081–088	253
VB089–VB096	Virtual Bit 089–096	252
VB097–VB104	Virtual Bit 097–104	251
VB105–VB112	Virtual Bit 105–112	250

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 31 of 34)

Name	Description	Row
VB113–VB120	Virtual Bit 113–120	249
VB121–VB128	Virtual Bit 121–128	248
VB129–VB136	Virtual Bit 129–136	247
VB137–VB144	Virtual Bit 137–144	246
VB145–VB152	Virtual Bit 145–152	245
VB153–VB160	Virtual Bit 153–160	244
VB161–VB168	Virtual Bit 161–168	243
VB169–VB176	Virtual Bit 169–176	242
VB177–VB184	Virtual Bit 177–184	241
VB185–VB192	Virtual Bit 185–192	240
VB193–VB200	Virtual Bit 193–200	239
VB201–VB208	Virtual Bit 201–208	238
VB209–VB216	Virtual Bit 209–216	237
VB217–VB224	Virtual Bit 217–224	236
VB225–VB232	Virtual Bit 225–232	235
VB233–VB240	Virtual Bit 233–240	234
VB241–VB248	Virtual Bit 241–248	233
VB249–VB256	Virtual Bit 249–256	232
VMEMC	Polarizing memory voltage control	3
VPOLV	Polarizing voltage valid	18
WFC	Weak infeed condition detected	59
X6ABC	Impedance inside Zone 6 out-of-step	21
X6T	Positive-sequence reactance within Zone 6 reactance blinder	24
X7ABC	Impedance inside Zone 7 out-of-step	21
X7T	Positive-sequence reactance within Zone 7 reactance blinder	24
XAB1	Zone 1 quad A-B phase element	10
XAB1F	Zone 1 quad A-B phase element	274
XAB1H	High-speed Zone 1 high-speed quad A-B phase element	283
XAB2	Zone 2 quad A-B phase element	11
XAB2F	Zone 2 quad A-B phase element	275
XAB2H	High-speed Zone 2 high-speed quad A-B phase element	283
XAB3	Zone 3 quad A-B phase element	11
XAB3F	Zone 3 quad A-B phase element	275
XAB3H	High-speed Zone 3 high-speed quad A-B phase element	283
XAB4	Zone 4 quad A-B phase element	12
XAB4F	Zone 4 quad A-B phase element	276
XAB5	Zone 5 quad A-B phase element	12
XAB5F	Zone 5 quad A-B phase element	277
XAG1	Zone 1 quad A-Phase-to-ground element	16
XAG1F	Zone 1 quad A-Phase-to-ground element	270
XAG1H	High-speed Zone 1 quad A-G ground element	279

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 32 of 34)

Name	Description	Row
XAG2	Zone 2 quad A-Phase-to-ground element	16
XAG2F	Zone 2 quad A-Phase-to-ground element	271
XAG2H	High-speed Zone 2 quad A-G ground element	279
XAG3	Zone 3 quad A-Phase-to-ground element	17
XAG3F	Zone 3 quad A-Phase-to-ground element	271
XAG3H	High-speed Zone 3 high-speed quad A-G ground element	279
XAG4	Zone 4 quad A-Phase-to-ground element	17
XAG4F	Zone 4 quad A-Phase-to-ground element	272
XAG5	Zone 5 quad A-Phase-to-ground element	18
XAG5F	Zone 5 quad A-Phase-to-ground element	273
XBC1	Zone 1 quad B-C phase element	10
XBC1F	Zone 1 quad B-C phase element	274
XBC1H	High-speed Zone 1 high-speed quad B-C phase element	283
XBC2	Zone 2 quad B-C phase element	11
XBC2F	Zone 2 quad B-C phase element	275
XBC2H	High-speed Zone 2 high-speed quad B-C phase element	283
XBC3	Zone 3 quad B-C phase element	11
XBC3F	Zone 3 quad B-C phase element	276
XBC3H	High-speed Zone 3 high-speed quad B-C phase element	284
XBC4	Zone 4 quad B-C phase element	12
XBC4F	Zone 4 quad B-C phase element	276
XBC5	Zone 5 quad B-C phase element	12
XBC5F	Zone 5 quad B-C phase element	277
XBG1	Zone 1 quad B-Phase-to-ground element	16
XBG1F	Zone 1 quad B-Phase-to-ground element	270
XBG1H	High-speed Zone 1 quad B-G ground element	279
XBG2	Zone 2 quad B-Phase-to-ground element	16
XBG2F	Zone 2 quad B-Phase-to-ground element	271
XBG2H	High-speed Zone 2 quad B-G ground element	279
XBG3	Zone 3 quad B-Phase-to-ground element	17
XBG3F	Zone 3 quad B-Phase-to-ground element	272
XBG4	Zone 4 quad B-Phase-to-ground element	17
XBG4F	Zone 4 quad B-Phase-to-ground element	272
XBG5	Zone 5 quad B-Phase-to-ground element	18
XBG5F	Zone 5 quad B-Phase-to-ground element	273
XCA1	Zone 1 quad C-A phase element	10
XCA1F	Zone 1 quad C-A phase element	274
XCA1H	High-speed Zone 1 high-speed quad C-A phase element	283
XCA2	Zone 2 quad C-A phase element	11
XCA2F	Zone 2 quad C-A phase element	275
XCA2H	High-speed Zone 2 high-speed quad C-A phase element	283

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 33 of 34)

Name	Description	Row
XCA3	Zone 3 quad C-A phase element	11
XCA3F	Zone 3 quad C-A phase element	276
XCA3H	High-speed Zone 3 high-speed quad C-A phase element	284
XCA4	Zone 4 quad C-A phase element	12
XCA4F	Zone 4 quad C-A phase element	276
XCA5	Zone 5 quad C-A phase element	12
XCA5F	Zone 5 quad C-A phase element	277
XCG1	Zone 1 quad C-Phase-to-ground element	16
XCG1F	Zone 1 quad C-Phase-to-ground element	270
XCG1H	High-speed Zone 1 quad C-G ground element	279
XCG2	Zone 2 quad C-Phase-to-ground element	16
XCG2F	Zone 2 quad C-Phase-to-ground element	271
XCG2H	High-speed Zone 2 quad C-G ground element	279
XCG3	Zone 3 quad C-Phase-to-ground element	17
XCG3F	Zone 3 quad C phase-to-ground element	272
XCG4	Zone 4 quad C-Phase-to-ground element	17
XCG4F	Zone 4 quad C-Phase-to-ground element	272
XCG5	Zone 5 quad C-Phase-to-ground element	18
XCG5F	Zone 5 quad C-Phase-to-ground element	273
YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted	292
YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted	292
YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted	292
YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted	292
YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted	292
YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted	292
YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted	292
YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted	292
Z1G	Zone 1 ground-distance element	5
Z1GT	Zone 1 ground-distance, time-delayed	6
Z1P	Zone 1 phase-distance element	3
Z1PT	Zone 1 phase-distance, time-delayed	4
Z1T	Zone 1 phase- or ground-distance, time-delayed	7
Z2G	Zone 2 ground-distance element	5
Z2GT	Zone 2 ground-distance, time-delayed	6
Z2P	Zone 2 phase-distance element	3
Z2PGS	Zone 2 phase and ground short delay element	60
Z2PT	Zone 2 phase-distance, time-delayed	4
Z2T	Zone 2 phase- or ground-distance, time-delayed	7
Z3G	Zone 3 ground-distance element	5
Z3GT	Zone 3 ground-distance, time-delayed	6
Z3P	Zone 3 phase-distance element	3

Table 11.1 Alphabetic List of Relay Word Bits (Sheet 34 of 34)

Name	Description	Row
Z3PT	Zone 3 phase-distance, time-delayed	4
Z3RB	Current reversal guard asserted	58
Z3RBA	A-Phase current reversal guard asserted (ECOMM = POTT3)	61
Z3RBB	B-Phase current reversal guard asserted (ECOMM = POTT3)	61
Z3RBC	C-Phase current reversal guard asserted (ECOMM = POTT3)	61
Z3T	Zone 3 phase- or ground-distance, time-delayed	7
Z3XT	Current reversal guard timer picked up	60
Z4G	Zone 4 ground-distance element	5
Z4GT	Zone 4 ground-distance, time-delayed	6
Z4P	Zone 4 phase-distance element	3
Z4PT	Zone 4 phase-distance, time-delayed	4
Z4T	Zone 4 phase or ground-distance, time-delayed	7
Z5G	Zone 5 ground-distance element	5
Z5GT	Zone 5 ground-distance, time-delayed	6
Z5P	Zone 5 phase-distance element	3
Z5PT	Zone 5 phase-distance, time-delayed	4
Z5T	Zone 5 phase or ground-distance, time-delayed	7
ZLIN	Load-encroachment load-in element	51
ZLOAD	ZLOUT or ZLIN element picked up	51
ZLOUT	Load-encroachment load-out element	51

Row Lists

Table 11.2 Relay Word Bits: Enable and Tripping Bits

Row	Name	Description
0	EN	Relay enabled
0	TRIPLED	Trip LED
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
0	*	Reserved
1	TLED_1–TLED_8	Target LED 1–Target LED 8
2	TLED_9–TLED_16	Target LED 9–Target LED 16

Table 11.3 Relay Word Bits: Distance Elements (Sheet 1 of 4)

Row	Name	Description
3	Z1P–Z5P	Zone 1–Zone 5 phase-distance element
3	*	Reserved

Table 11.3 Relay Word Bits: Distance Elements (Sheet 2 of 4)

Row	Name	Description
3	VMEMC	Polarizing memory voltage control
3	*	Reserved
4	Z1PT–Z5PT	Zone 1–Zone 5 phase-distance, time-delayed
4	*	Reserved
4	*	Reserved
4	*	Reserved
5	Z1G–Z5G	Zone 1–Zone 5 ground-distance element
5	*	Reserved
5	*	Reserved
5	*	Reserved
6	Z1GT–Z5GT	Zone 1–Zone 5 ground-distance, time-delayed
6	*	Reserved
6	*	Reserved
6	*	Reserved
7	Z1T–Z5T	Zone 1–Zone 5 phase- or ground-distance, time-delayed
7	*	Reserved
7	*	Reserved
7	*	Reserved
8	MAB1	Zone 1 Mho A-B phase element
8	MBC1	Zone 1 Mho B-C phase element
8	MCA1	Zone 1 Mho C-A phase element
8	*	Reserved
8	MAB2	Zone 2 Mho A-B phase element
8	MBC2	Zone 2 Mho B-C phase element
8	MCA2	Zone 2 Mho C-A phase element
8	*	Reserved
9	MAB3	Zone 3 Mho A-B phase element
9	MBC3	Zone 3 Mho B-C phase element
9	MCA3	Zone 3 Mho C-A phase element
9	*	Reserved
9	MAB4	Zone 4 Mho A-B phase element
9	MBC4	Zone 4 Mho B-C phase element
9	MCA4	Zone 4 Mho C-A phase element
9	*	Reserved
10	MAB5	Zone 5 Mho A-B phase element
10	MBC5	Zone 5 Mho B-C phase element
10	MCA5	Zone 5 Mho C-A phase element
10	*	Reserved
10	XAB1	Zone 1 quad A-B phase element
10	XBC1	Zone 1 quad B-C phase element
10	XCA1	Zone 1 quad C-A phase element

Table 11.3 Relay Word Bits: Distance Elements (Sheet 3 of 4)

Row	Name	Description
10	*	Reserved
11	XAB2	Zone 2 quad A-B phase element
11	XBC2	Zone 2 quad B-C phase element
11	XCA2	Zone 2 quad C-A phase element
11	*	Reserved
11	XAB3	Zone 3 quad A-B phase element
11	XBC3	Zone 3 quad B-C phase element
11	XCA3	Zone 3 quad C-A phase element
11	*	Reserved
12	XAB4	Zone 4 quad A-B phase element
12	XBC4	Zone 4 quad B-C phase element
12	XCA4	Zone 4 quad C-A phase element
12	*	Reserved
12	XAB5	Zone 5 quad A-B phase element
12	XBC5	Zone 5 quad B-C phase element
12	XCA5	Zone 5 quad C-A phase element
12	*	Reserved
13	MAG1	Zone 1 Mho A-Phase-to-ground element
13	MBG1	Zone 1 Mho B-Phase-to-ground element
13	MCG1	Zone 1 Mho C-Phase-to-ground element
13	*	Reserved
13	MAG2	Zone 2 Mho A-Phase-to-ground element
13	MBG2	Zone 2 Mho B-Phase-to-ground element
13	MCG2	Zone 2 Mho C-Phase-to-ground element
13	*	Reserved
14	MAG3	Zone 3 Mho A-Phase-to-ground element
14	MBG3	Zone 3 Mho B-Phase-to-ground element
14	MCG3	Zone 3 Mho C-Phase-to-ground element
14	*	Reserved
14	MAG4	Zone 4 Mho A-Phase-to-ground element
14	MBG4	Zone 4 Mho B-Phase-to-ground element
14	MCG4	Zone 4 Mho C-Phase-to-ground element
14	*	Reserved
15	MAG5	Zone 5 Mho A-Phase-to-ground element
15	MBG5	Zone 5 Mho B-Phase-to-ground element
15	MCG5	Zone 5 Mho C-Phase-to-ground element
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved
15	*	Reserved

Table 11.3 Relay Word Bits: Distance Elements (Sheet 4 of 4)

Row	Name	Description
16	XAG1	Zone 1 quad A-Phase-to-ground element
16	XBG1	Zone 1 quad B-Phase-to-ground element
16	XCG1	Zone 1 quad C-Phase-to-ground element
16	*	Reserved
16	XAG2	Zone 2 quad A-Phase-to-ground element
16	XBG2	Zone 2 quad B-Phase-to-ground element
16	XCG2	Zone 2 quad C-Phase-to-ground element
16	*	Reserved
17	XAG3	Zone 3 quad A-Phase-to-ground element
17	XBG3	Zone 3 quad B-Phase-to-ground element
17	XCG3	Zone 3 quad C-Phase-to-ground element
17	*	Reserved
17	XAG4	Zone 4 quad A-Phase-to-ground element
17	XBG4	Zone 4 quad B-Phase-to-ground element
17	XCG4	Zone 4 quad C-Phase-to-ground element
17	*	Reserved
18	XAG5	Zone 5 quad A-Phase-to-ground element
18	XBG5	Zone 5 quad B-Phase-to-ground element
18	XCG5	Zone 5 quad C-Phase-to-ground element
18	CVTBLH	CCVT transient blocking logic active—high-speed elements
Note: The SEL-421-4 does not provide high-speed distance elements, so the CVTBLH Relay Word bit is unavailable.		
18	CVTBL	CCVT transient blocking logic active
18	VPOLV	Polarizing voltage valid
18	M1P–M2P	Zone 1–2 Mho phase-distance element
19	M3P–M5P	Zone 3-5 Mho phase-distance element
19	M1PT–M5PT	Zone 1–5 Mho phase-distance, time-delayed

Table 11.4 Relay Word Bits: Series-Compensated Line Logic

Row	Name	Description
20	SERCAB	Series-compensated line AB-Phase output
20	SERCBC	Series-compensated line BC-Phase output
20	SERCCA	Series-compensated line CA-Phase output
20	SERCA	Series-compensated line A-Phase output
20	SERCB	Series-compensated line B-Phase output
20	SERCC	Series-compensated line C-Phase output
20	*	Reserved
20	*	Reserved

Table 11.5 Relay Word Bits: Out-of-Step Elements (Sheet 1 of 2)

Row	Name	Description
21	X6ABC	Impedance inside Zone 6 out-of-step
21	X7ABC	Impedance inside Zone 7 out-of-step
21	50ABC	Positive-sequence current above 50ABCP threshold
21	UBOSB	Unblock out-of-step blocking
21	OSBA	A-Phase out-of-step block
21	OSBB	B-Phase out-of-step block
21	OSBC	C-Phase out-of-step block
21	OSB1	Block Zone 1 during an out-of-step condition
22	OSB2–OSB5	Block Zone 2–5 during an out-of-step condition
22	OSB	Out-of-step block
22	OSTI	Incoming out-of-step tripping
22	OSTO	Outgoing out-of-step tripping
22	OST	Out-of-step tripping
23	67QUBF	Forward direction supervised output from 50QUBP
23	67QUBR	Reverse direction supervised output from 50QUBP
23	OOSDET	Out-of-step condition detected
23	*	Reserved
23	*	Reserved
23	*	Reserved
23	*	Reserved
23	*	Reserved
24	X6T	Positive-sequence reactance within Zone 6 reactance blinder
24	R6T	Positive-sequence resistance within Zone 6 resistance blinder
24	RR6	Positive-sequence resistance within Zone 6 right resistance blinder
24	RL6	Positive-sequence resistance within Zone 6 left resistance blinder
24	X7T	Positive-sequence reactance within Zone 7 reactance blinder
24	R7T	Positive-sequence resistance within Zone 7 resistance blinder
24	RR7	Positive-sequence resistance within Zone 7 right resistance blinder
24	RL7	Positive-sequence resistance within Zone 7 left resistance blinder
25	DOSB	Dependable out-of-step blocking asserted
25	*	Reserved
25	*	Reserved
25	SSD	Out-of-step swing signature detected
25	*	Reserved
25	SD	Swing center voltage slope detected
25	*	Reserved
25	R1T	Positive-sequence resistance within Zone 7 left resistance blinder
26	LG_DPFA	Lagging A-Phase displacement power factor
26	LG_DPFB	Lagging B-Phase displacement power factor
26	LG_DPFC	Lagging C-Phase displacement power factor
26	LG_DPF3	Lagging three-phase displacement power factor

Table 11.5 Relay Word Bits: Out-of-Step Elements (Sheet 2 of 2)

Row	Name	Description
26	LD_DPFA	Leading A-Phase displacement power factor
26	LD_DPFB	Leading B-Phase displacement power factor
26	LD_DPFC	Leading C-Phase displacement power factor
26	LD_DPF3	Leading three-phase displacement power factor
26	*	Reserved
27	PFA_OK	A-Phase power factor OK
27	PFB_OK	B-Phase power factor OK
27	PFC_OK	C-Phase power factor OK
27	PF3_OK	Three-phase power factor OK
27	DPFA_OK	A-Phase displacement power factor OK
27	DPFB_OK	B-Phase displacement power factor OK
27	DPFC_OK	C-Phase displacement power factor OK
27	DPF3_OK	Three-phase displacement power factor OK
27	*	Reserved

Table 11.6 Relay Word Bits: Directional Elements

Row	Name	Description
28	F32P	Forward phase directional declaration
28	R32P	Reverse phase directional declaration
28	F32Q	Forward negative-sequence phase directional declaration
28	R32Q	Reverse negative-sequence phase directional declaration
28	32QF	Forward negative-sequence overcurrent directional declaration
28	32QR	Reverse negative-sequence overcurrent directional declaration
28	32SPOF	Forward open-pole directional declaration
28	32SPOR	Reverse open-pole directional declaration
29	50QF	Forward negative-sequence supervisory current element
29	50QR	Reverse negative-sequence supervisory current element
29	50GF	Forward zero-sequence supervisory current element
29	50GR	Reverse zero-sequence supervisory current element
29	32QE	32Q internal enable
29	32QGE	32QG internal enable
29	32VE	32V internal enable
29	32IE	32I internal enable
30	F32I	Forward current polarized zero-sequence directional element
30	R32I	Reverse current polarized zero-sequence directional element
30	F32V	Forward voltage polarized zero-sequence directional element
30	R32V	Reverse voltage polarized zero-sequence directional element
30	F32QG	Forward negative-sequence ground directional element
30	R32QG	Reverse negative-sequence ground directional element
30	32GF	Forward ground directional element
30	32GR	Reverse ground directional element

Table 11.7 Relay Word Bits: Overcurrent Elements

Row	Name	Description
31	50P1–50P4	Level 1–4 phase overcurrent element
31	67P1–67P4	Level 1–4 phase directional overcurrent element
32	67P1T–67P4T	Level 1–4 phase-delayed directional overcurrent element
32	50G1–50G4	Level 1–4 residual overcurrent element
33	67G1–67G4	Level 1–4 residual directional overcurrent element
33	67G1T–67G4T	Level 1–4 residual delayed directional overcurrent element
34	50Q1–50Q4	Level 1–4 negative-sequence overcurrent element
34	67Q1–67Q4	Level 1–4 negative-sequence directional overcurrent element
35	67Q1T–67Q4T	Level 1–4 negative-sequence delayed directional overcurrent element
35	*	Reserved
35	*	Reserved
35	*	Reserved
35	*	Reserved
36	51S1	Inverse-time Overcurrent Element 1 pickup
36	51S1T	Inverse-time Overcurrent Element 1 timed out
36	51S1R	Inverse-time Overcurrent Element 1 reset
36	*	Reserved
36	51S2	Inverse-time Overcurrent Element 2 pickup
36	51S2T	Inverse-time Overcurrent Element 2 timed out
36	51S2R	Inverse-time Overcurrent Element 2 reset
36	*	Reserved
37	51S3	Inverse-time Overcurrent Element 3 pickup
37	51S3T	Inverse-time Overcurrent Element 3 timed out
37	51S3R	Inverse-time Overcurrent Element 3 reset
37	*	Reserved
37	*	Reserved
37	*	Reserved
37	*	Reserved
37	*	Reserved

Table 11.8 Relay Word Bits: Synchronism-Check Elements (Sheet 1 of 2)

Row	Name	Description
38	59VP	VP within “healthy voltage” window
38	59VS1	VS1 within “healthy voltage” window
38	25ENBK1	Circuit Breaker 1 synchronism-check element enable
38	SFZBK1	Circuit Breaker 1 slip frequency less than 5 mHz
38	SFBK1	5 mHz ≤ Circuit Breaker 1 slip frequency < 25 SFBK1
38	25W1BK1	Circuit Breaker 1 Angle 1 within Window 1
38	25W2BK1	Circuit Breaker 1 Angle 2 within Window 2
38	25A1BK1	Circuit Breaker 1 voltages within Synchronism Angle 1
39	25A2BK1	Circuit Breaker 1 voltages within Synchronism Angle 2

Table 11.8 Relay Word Bits: Synchronism-Check Elements (Sheet 2 of 2)

Row	Name	Description
39	FAST1	fs1 > fp
39	SLOW1	fs1 < fp
39	BSYNBK1	Block synchronism check for Circuit Breaker 1
39	59VDIF1	Circuit Breaker 1 synchronizing voltage difference less than limit
39	*	Reserved
39	*	Reserved
39	*	Reserved
40	59VS2	VS2 within “healthy voltage” window
40	25ENBK2	Circuit Breaker 2 synchronism-check element enable
40	SFZBK2	Circuit Breaker 2 slip frequency less than 5 mHz
40	SFBK2	5 mHz ≤ Circuit Breaker 2 slip frequency < 25 SFBK2
40	25W1BK2	Circuit Breaker 2 Angle 1 within Window 1
40	25W2BK2	Circuit Breaker 2 Angle 2 within Window 2
40	25A1BK2	Circuit Breaker 2 voltages within Synchronism Angle 1
40	25A2BK2	Circuit Breaker 2 voltages within Synchronism Angle 2
41	FAST2	fs2 > fp
41	SLOW2	fs2 < fp
41	BSYNBK2	Block synchronism check for Circuit Breaker 2
41	59VDIF2	Circuit Breaker 2 synchronizing voltage difference less than limit
41	*	Reserved
41	*	Reserved
41	*	Reserved
41	*	Reserved

Table 11.9 Relay Word Bits: Reclosing Elements (Sheet 1 of 3)

Row	Name	Description
42	SPRI	Single-pole reclose initiation (SELOGIC control equation)
42	SPARC	Single-pole reclose initiate qualified
42	SPLSHT	Single-pole reclose last shot
42	SPOBK1	Single-pole open Circuit Breaker 1
42	SPOBK2	Single-pole open Circuit Breaker 2
42	3PRI	Three-pole reclose initiation (SELOGIC control equation)
42	3PARC	Three-pole reclose initiate qualified
42	3POBK1	Three-pole open Circuit Breaker 1
43	3POBK2	Three-pole open Circuit Breaker 2
43	3POLINE	Three-pole open line
43	3PLSHT	Three-pole reclose last shot
43	BK1RS	Circuit Breaker 1 in ready state
43	BK2RS	Circuit Breaker 2 in ready state
43	79CY1	Relay in single-pole reclose cycle state
43	79CY3	Relay in three-pole reclose cycle state

Table 11.9 Relay Word Bits: Reclosing Elements (Sheet 2 of 3)

Row	Name	Description
43	BK1LO	Circuit Breaker 1 in lockout state
44	BK2LO	Circuit Breaker 2 in lockout state
44	BK1CL	Circuit Breaker 1 close command
44	BK2CL	Circuit Breaker 2 close command
44	LEADBK0	No lead circuit breaker
44	LEADBK1	Lead circuit breaker = Circuit Breaker 1
44	LEADBK2	Lead circuit breaker = Circuit Breaker 2
44	FOLBK0	No follower circuit breaker
44	FOLBK1	Follower circuit breaker = Circuit Breaker 1
45	FOLBK2	Follower circuit breaker = Circuit Breaker 2
45	NBK0	No circuit breakers active in reclose scheme
45	NBK1	One circuit breaker active in reclose scheme
45	NBK2	Two circuit breakers active in reclose scheme
45	SP1CLS	Single-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)
45	SP2CLS	Single-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)
45	3P1CLS	Three-pole Circuit Breaker 1 reclose supervision (SELOGIC control equation)
45	3P2CLS	Three-pole Circuit Breaker 2 reclose supervision (SELOGIC control equation)
46	BK1CFT	Circuit Breaker 1 close failure delay timed out
46	BK2CFT	Circuit Breaker 2 close failure delay timed out
46	BK1CLSS	Circuit Breaker 1 in close supervision state
46	BK2CLSS	Circuit Breaker 2 in close supervision state
46	BK1CLST	Circuit Breaker 1 close supervision timer timed out
46	BK2CLST	Circuit Breaker 2 close supervision timer timed out
46	ULCL1	Unlatch closing for Circuit Breaker 1 (SELOGIC control equation)
46	ULCL2	Unlatch closing for Circuit Breaker 2 (SELOGIC control equation)
47	LLDB1	Live Line Dead Bus 1
47	LLDB2	Live Line Dead Bus 2
47	DLLB1	Dead Line Live Bus 1
47	DLLB2	Dead Line Live Bus 2
47	DLDB1	Dead Line Dead Bus 1
47	DLDB2	Dead Line Dead Bus 2
47	R3PTE	Recloser three-pole trip enable
47	R3PTE1	Recloser three-pole trip enable Circuit Breaker 1
48	R3PTE2	Recloser three-pole trip enable Circuit Breaker 2
48	BK1RCIP	Circuit Breaker 1 reclaim in progress (lockout state)
48	BK2RCIP	Circuit Breaker 2 reclaim in progress (lockout state)
48	SPRCIP	Single-pole reclaim in progress
48	3PRCIP	Three-pole reclaim in progress
48	2POBK1	Two poles open Circuit Breaker 1
48	2POBK2	Two poles open Circuit Breaker 2
48	*	Reserved

Table 11.9 Relay Word Bits: Reclosing Elements (Sheet 3 of 3)

Row	Name	Description
49	SPSHOT0	Single-pole shot counter = 0
49	SPSHOT1	Single-pole shot counter = 1
49	SPSHOT2	Single-pole shot counter = 2
49	3PSHOT0	Three-pole shot counter = 0
49	3PSHOT1	Three-pole shot counter = 1
49	3PSHOT2	Three-pole shot counter = 2
49	3PSHOT3	Three-pole shot counter = 3
49	3PSHOT4	Three-pole shot counter = 4
50	SPOI	Single-pole open interval timing
50	3POI	Three-pole open interval timing
50	79STRT	Relay in start state
50	TBBK	Time between circuit breakers timing
50	BK1EXT	Circuit Breaker 1 closed externally
50	BK2EXT	Circuit Breaker 2 closed externally
50	SPOISC	Single-pole open interval supervision condition
50	3POISC	Three-pole open interval supervision condition

Table 11.10 Relay Word Bits: Miscellaneous Elements

Row	Name	Description
51	SOTFE	Switch-onto-fault enable
51	ILOP	Internal loss-of-potential from ELOP setting
51	LOP	Loss-of-potential detected
51	ZLOAD	ZLOUT or ZLIN element picked up
51	ZLIN	Load-encroachment “load in” element
51	ZLOUT	Load-encroachment “load out” element
51	FIDEN	Fault identification logic enabled
51	FSA	A-Phase sector fault (AG or BCG fault)
52	FSB	B-Phase sector fault (BG or CAG fault)
52	FSC	C-Phase sector fault (CG or ABG fault)
52	DFAULT	Disables maximum/minimum metering and demand metering when SELOGIC control equation FAULT asserts
52	ER	Event report trigger equation (SELOGIC control equation)
52	EAFSRC	Alternate frequency source (SELOGIC control equation)
52	*	Reserved
52	*	Reserved
52	*	Reserved

Table 11.11 Relay Word Bits: Trip Logic Elements (Sheet 1 of 2)

Row	Name	Description
53	RXPRM	Receiver trip permission
53	COMPRM	Communications-assisted trip permission

Table 11.11 Relay Word Bits: Trip Logic Elements (Sheet 2 of 2)

Row	Name	Description
53	TRPRM	Trip permission
53	DTR	Direct transfer trip received
53	SOTFT	Switch-onto-fault trip
53	E3PT	Three-pole trip enable
53	E3PT1	Circuit Breaker 1 three-pole trip enable
53	E3PT2	Circuit Breaker 2 three-pole trip enable
54	APS	Trip logic A-Phase selected
54	BPS	Trip logic B-Phase selected
54	CPS	Trip logic C-Phase selected
54	3PS	Trip logic three-phase selected
54	ATPA	Assert Trip A
54	ATPB	Assert Trip B
54	ATPC	Assert Trip C
54	A3PT	Assert three-pole trip
55	TPA	Trip A
55	TPB	Trip B
55	TPC	Trip C
55	TRIP	Trip A or Trip B or Trip C
55	3PT	Three-pole trip
55	SPT	Single-pole trip
55	TPA1	Circuit Breaker 1 Trip A
55	TPB1	Circuit Breaker 1 Trip B
56	TPC1	Circuit Breaker 1 Trip C
56	TPA2	Circuit Breaker 2 Trip A
56	TPB2	Circuit Breaker 2 Trip B
56	TPC2	Circuit Breaker 2 Trip C
56	TOP	Trip during open pole timer is asserted
56	ULTR	Unlatch all protection trips
56	ULMTR1	Circuit Breaker 1 unlatch manual trip
56	ULMTR2	Circuit Breaker 2 unlatch manual trip
57	ULTRA	Unlatch Trip A
57	ULTRB	Unlatch Trip B
57	ULTRC	Unlatch Trip C
57	DTA	Direct transfer trip A-Phase (SELOGIC control equation)
57	DTB	Direct transfer trip B-Phase (SELOGIC control equation)
57	DTC	Direct transfer trip C-Phase (SELOGIC control equation)
57	*	Reserved
57	*	Reserved

Table 11.12 Relay Word Bits: Pilot Tripping Elements (Sheet 1 of 2)

Row	Name	Description
58	PT	Permissive trip received
58	Z3RB	Current reversal guard asserted
58	KEY	Transmit permissive trip signal
58	EKEY	Echo received permissive trip signal
58	ECTT	Echo conversion to trip signal
58	27AWI	A-Phase undervoltage condition
58	27BWI	B-Phase undervoltage condition
58	27CWI	C-Phase undervoltage condition
59	WFC	Weak infeed condition detected
59	KEY1	Transmit general permissive trip
59	KEY3	Transmit three-phase permissive trip
59	UBB1	Blocks permissive trip Receiver 1
59	PTRX1	Permissive trip received Channel 1
59	UBB2	Blocks permissive trip Receiver 2
59	PTRX2	Permissive trip received Channel 2
59	UBB	Block permissive trip received 1 or 2
60	PTRX	Permissive trip received Channel 1 and Channel 2
60	Z3XT	Current reversal guard timer picked up
60	Z2PGS	Zone 2 phase and ground short delay element
60	67QG2S	Negative-sequence and residual directional overcurrent short delay element
60	DSTRT	Directional start element picked up
60	NSTRT	Nondirectional start element picked up
60	STOP	Stop element picked up
60	BTX	Block extension picked up
61	Z3RBA	A-Phase current reversal guard asserted (ECOMM = POTT3)
61	Z3RBB	B-Phase current reversal guard asserted (ECOMM = POTT3)
61	Z3RBC	C-Phase current reversal guard asserted (ECOMM = POTT3)
61	KEYA	Transmit A-Phase permissive trip (ECOMM = POTT3)
61	KEYB	Transmit B-Phase permissive trip (ECOMM = POTT3)
61	KEYC	Transmit C-Phase permissive trip (ECOMM = POTT3)
61	KEYD	Transmit directional permissive trip (ECOMM = POTTZD)
61	*	Reserved
62	EKEYA	A-Phase echo received permissive trip signal (ECOMM = POTT3)
62	EKEYB	B-Phase echo received permissive trip signal (ECOMM = POTT3)
62	EKEYC	C-Phase echo received permissive trip signal (ECOMM = POTT3)
62	ECTTA	A-Phase echo conversion to trip signal (ECOMM = POTT3)
62	ECTTB	B-Phase echo conversion to trip signal (ECOMM = POTT3)
62	ECTTC	C-Phase echo conversion to trip signal (ECOMM = POTT3)
62	*	Reserved
62	*	Reserved
63	PTA	A-Phase permissive trip received (ECOMM = POTT3)

Table 11.12 Relay Word Bits: Pilot Tripping Elements (Sheet 2 of 2)

Row	Name	Description
63	PTB	B-Phase permissive trip received (ECOMM = POTT3)
63	PTC	C-Phase permissive trip received (ECOMM = POTT3)
63	PTDRX	Directional permissive trip received (ECOMM = POTTZD)
63	*	Reserved
63	*	Reserved
63	*	Reserved
63	*	Reserved

Table 11.13 Relay Word Bits: Future Breaker Open-Phase Detector

Row	Name	Description
64	*	Reserved

Table 11.14 Relay Word Bits: Breaker 1 Failure (Sheet 1 of 2)

Row	Name	Description
65	BFI3P1	Circuit Breaker 1 three-pole circuit breaker failure initiation
65	BFIA1	Circuit Breaker 1 A-Phase circuit breaker failure initiation
65	BFIB1	Circuit Breaker 1 B-Phase circuit breaker failure initiation
65	BFIC1	Circuit Breaker 1 C-Phase circuit breaker failure initiation
65	BFI3PT1	Circuit Breaker 1 extended three-pole extended circuit breaker failure initiation
65	BFIAT1	Circuit Breaker 1 A-Phase extended circuit breaker failure initiation
65	BFIBT1	Circuit Breaker 1 B-Phase extended circuit breaker failure initiation
65	BFICT1	Circuit Breaker 1 C-Phase extended circuit breaker failure initiation
66	50FA1	Circuit Breaker 1 A-Phase current threshold exceeded
66	50FB1	Circuit Breaker 1 B-Phase current threshold exceeded
66	50FC1	Circuit Breaker 1 C-Phase current threshold exceeded
66	RT3P1	Circuit Breaker 1 three-pole retrip
66	RTA1	Circuit Breaker 1 A-Phase retrip
66	RTB1	Circuit Breaker 1 B-Phase retrip
66	RTC1	Circuit Breaker 1 C-Phase retrip
66	RTS3P1	Circuit Breaker 1 current-supervised three-pole retrip
67	RTSA1	Circuit Breaker 1 current-supervised A-Phase retrip
67	RTSB1	Circuit Breaker 1 current-supervised B-Phase retrip
67	RTSC1	Circuit Breaker 1 current-supervised C-Phase retrip
67	RT1	Circuit Breaker 1 retrip
67	FBFA1	Circuit Breaker 1 A-Phase circuit breaker failure
67	FBFB1	Circuit Breaker 1 B-Phase circuit breaker failure
67	FBFC1	Circuit Breaker 1 C-Phase circuit breaker failure
67	FBF1	Circuit Breaker 1 circuit breaker failure
68	50R1	Circuit Breaker 1 residual current threshold exceeded
68	BFIN1	Circuit Breaker 1 no current circuit breaker failure initiation
68	NBF1	Circuit Breaker 1 no current circuit breaker failure

Table 11.14 Relay Word Bits: Breaker 1 Failure (Sheet 2 of 2)

Row	Name	Description
68	50LCA1	Circuit Breaker 1 A-Phase load current threshold exceeded
68	50LCB1	Circuit Breaker 1 B-Phase load current threshold exceeded
68	50LCC1	Circuit Breaker 1 C-Phase load current threshold exceeded
68	BFILC1	Circuit Breaker 1 load current circuit breaker failure initiation
68	LCBF1	Circuit Breaker 1 load current circuit breaker failure
69	50FOA1	Circuit Breaker 1 A-Phase flashover current threshold exceeded
69	50FOB1	Circuit Breaker 1 B-Phase flashover current threshold exceeded
69	50FOC1	Circuit Breaker 1 C-Phase flashover current threshold exceeded
69	BLKFOA1	Circuit Breaker 1 block A-Phase flashover detection
69	BLKFOB1	Circuit Breaker 1 block B-Phase flashover detection
69	BLKFOC1	Circuit Breaker 1 block C-Phase flashover detection
69	FOA1	Circuit Breaker 1 A-Phase flashover detected
69	FOB1	Circuit Breaker 1 B-Phase flashover detected
70	FOC1	Circuit Breaker 1 C-Phase flashover detected
70	FOBF1	Circuit Breaker 1 flashover detected
70	BFTRIP1	Circuit Breaker 1 failure trip output asserted
70	BFTR1	Circuit breaker failure trip, Circuit Breaker 1 (SELOGIC control equation)
70	BFULTR1	Circuit breaker failure unlatch trip, Circuit Breaker 1 (SELOGIC control equation)
70	*	Reserved
70	*	Reserved

Table 11.15 Relay Word Bits: Breaker 2 Failure (Sheet 1 of 2)

Row	Name	Description
71	BFI3P2	Circuit Breaker 2 three-pole circuit breaker failure initiation
71	BFIA2	Circuit Breaker 2 A-Phase circuit breaker failure initiation
71	BFIB2	Circuit Breaker 2 B-Phase circuit breaker failure initiation
71	BFIC2	Circuit Breaker 2 C-Phase circuit breaker failure initiation
71	BFI3PT2	Circuit Breaker 2 three-pole extended circuit breaker failure initiation
71	BFIAT2	Circuit Breaker 2 A-Phase extended circuit breaker failure initiation
71	BFIBT2	Circuit Breaker 2 B-Phase extended circuit breaker failure initiation
71	BFICT2	Circuit Breaker 2 C-Phase extended circuit breaker failure initiation
72	50FA2	Circuit Breaker 2 A-Phase current threshold exceeded
72	50FB2	Circuit Breaker 2 B-Phase current threshold exceeded
72	50FC2	Circuit Breaker 2 C-Phase current threshold exceeded
72	RT3P2	Circuit Breaker 2 three-pole retrip
72	RTA2	Circuit Breaker 2 A-Phase retrip
72	RTB2	Circuit Breaker 2 B-Phase retrip
72	RTC2	Circuit Breaker 2 C-Phase retrip
72	RTS3P2	Circuit Breaker 2 current-supervised three-pole retrip
73	RTSA2	Circuit Breaker 2 current-supervised A-Phase retrip
73	RTSB2	Circuit Breaker 2 current-supervised B-Phase retrip

Table 11.15 Relay Word Bits: Breaker 2 Failure (Sheet 2 of 2)

Row	Name	Description
73	RTSC2	Circuit Breaker 2 current-supervised C-Phase retrip
73	RT2	Circuit Breaker 2 retrip
73	FBFA2	Circuit Breaker 2 A-Phase circuit breaker failure
73	FBFB2	Circuit Breaker 2 B-Phase circuit breaker failure
73	FBFC2	Circuit Breaker 2 C-Phase circuit breaker failure
73	FBF2	Circuit Breaker 2 circuit breaker failure
74	50R2	Circuit Breaker 2 residual current threshold exceeded
74	BFIN2	Circuit Breaker 2 no current circuit breaker failure initiation
74	NBF2	Circuit Breaker 2 no current circuit breaker failure
74	50LCA2	Circuit Breaker 2 A-Phase load current threshold exceeded
74	50LCB2	Circuit Breaker 2 B-Phase load current threshold exceeded
74	50LCC2	Circuit Breaker 2 C-Phase load current threshold exceeded
74	BFILC2	Circuit Breaker 2 load current circuit breaker failure initiation
74	LCBF2	Circuit Breaker 2 load current circuit breaker failure
75	50FOA2	Circuit Breaker 2 A-Phase flashover current threshold exceeded
75	50FOB2	Circuit Breaker 2 B-Phase flashover current threshold exceeded
75	50FOC2	Circuit Breaker 2 C-Phase flashover current threshold exceeded
75	BLKFOA2	Circuit Breaker 2 block A-Phase flashover detection
75	BLKFOB2	Circuit Breaker 2 block B-Phase flashover detection
75	BLKFOC2	Circuit Breaker 2 block C-Phase flashover detection
75	FOA2	Circuit Breaker 2 A-Phase flashover detected
75	FOB2	Circuit Breaker 2 B-Phase flashover detected
76	FOC2	Circuit Breaker 2 C-Phase flashover detected
76	FOBF2	Circuit Breaker 2 flashover detected
76	BFTRIP2	Circuit Breaker 2 failure trip output asserted
76	BFTR2	Circuit breaker failure trip, Circuit Breaker 2 (SELOGIC control equation)
76	BFULTR2	Circuit breaker failure unlatch trip, Circuit Breaker 2 (SELOGIC control equation)
76	*	Reserved
76	*	Reserved

Table 11.16 Relay Word Bits: 52 Status and Open-Phase Detector (Sheet 1 of 2)

Row	Name	Description
77	B1OPHA	Circuit Breaker 1 A-Phase open
77	B1OPHB	Circuit Breaker 1 B-Phase open
77	B1OPHC	Circuit Breaker 1 C-Phase open
77	B2OPHA	Circuit Breaker 2 A-Phase open
77	B2OPHB	Circuit Breaker 2 B-Phase open
77	B2OPHC	Circuit Breaker 2 C-Phase open
77	LOPHA	Line A-Phase open
77	LOPHB	Line B-Phase open
78	LOPHC	Line C-Phase open

Table 11.16 Relay Word Bits: 52 Status and Open-Phase Detector (Sheet 2 of 2)

Row	Name	Description
78	SPOA	A-Phase open
78	SPOB	B-Phase open
78	SPOC	C-Phase open
78	SPO	One or two poles open
78	3PO	All three poles open
78	27APO	A-Phase undervoltage, pole-open
78	27BPO	B-Phase undervoltage, pole-open
79	27CPO	C-Phase undervoltage, pole-open
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
79	*	Reserved
80	52ACL1	Circuit Breaker 1, Pole A closed
80	52BCL1	Circuit Breaker 1, Pole B closed
80	52CCL1	Circuit Breaker 1, Pole C closed
80	52AAL1	Circuit Breaker 1, Pole A alarm
80	52BAL1	Circuit Breaker 1, Pole B alarm
80	52CAL1	Circuit Breaker 1, Pole C alarm
80	52AA1	Circuit Breaker 1, Pole A status
80	52AB1	Circuit Breaker 1, Pole B status
81	52AC1	Circuit Breaker 1, Pole C status
81	*	Reserved
81	52ACL2	Circuit Breaker 2, Pole A closed
81	52BCL2	Circuit Breaker 2, Pole B closed
81	52CCL2	Circuit Breaker 2, Pole C closed
81	52AAL2	Circuit Breaker 2, Pole A alarm
81	52BAL2	Circuit Breaker 2, Pole B alarm
81	52CAL2	Circuit Breaker 2, Pole C alarm
82	52AA2	Circuit Breaker 2, Pole A status
82	52AB2	Circuit Breaker 2, Pole B status
82	52AC2	Circuit Breaker 2, Pole C status
82	*	Reserved
82	*	Reserved
82	*	Reserved
82	*	Reserved
82	*	Reserved

Table 11.17 Relay Word Bits: Breaker Monitoring

Row	Name	Description
83	BM1TRPA	Circuit breaker monitor A-Phase trip, Circuit Breaker 1 (SELOGIC control equation)
83	BM1TRPB	Circuit breaker monitor B-Phase trip, Circuit Breaker 1 (SELOGIC control equation)
83	BM1TRPC	Circuit breaker monitor C-Phase trip, Circuit Breaker 1 (SELOGIC control equation)
83	BM1CLSA	Circuit breaker monitor A-Phase close, Circuit Breaker 1 (SELOGIC control equation)
83	BM1CLSB	Circuit breaker monitor B-Phase close, Circuit Breaker 1 (SELOGIC control equation)
83	BM1CLSC	Circuit breaker monitor C-Phase close, Circuit Breaker 1 (SELOGIC control equation)
83	B1BCWAL	Circuit Breaker 1 contact wear monitor alarm
83	B1MRTIN	Motor run time contact input, Circuit Breaker 1 (SELOGIC control equation)
84	*	Reserved
84	B1MSOAL	Circuit Breaker 1 mechanical slow operation alarm
84	B1ESOAL	Circuit Breaker 1 electrical slow operation alarm
84	B1PSAL	Circuit Breaker 1 pole scatter alarm
84	B1PDAL	Circuit Breaker 1 pole discrepancy alarm
84	B1BITAL	Circuit Breaker 1 inactivity time alarm
84	B1MRTAL	Circuit Breaker 1 motor running time alarm
84	B1KAIAL	Circuit Breaker 1 interrupted current alarm
85	BM2TRPA	Circuit breaker monitor A-Phase trip, Circuit Breaker 2 (SELOGIC control equation)
85	BM2TRPB	Circuit breaker monitor B-Phase trip, Circuit Breaker 2 (SELOGIC control equation)
85	BM2TRPC	Circuit breaker monitor C-Phase trip, Circuit Breaker 2 (SELOGIC control equation)
85	BM2CLSA	Circuit breaker monitor A-Phase close, Circuit Breaker 2 (SELOGIC control equation)
85	BM2CLSB	Circuit breaker monitor B-Phase close, Circuit Breaker 2 (SELOGIC control equation)
85	BM2CLSC	Circuit breaker monitor C-Phase close, Circuit Breaker 2 (SELOGIC control equation)
85	B2BCWAL	Circuit Breaker 2 contact wear monitor alarm
85	B2MRTIN	Motor run time contact input, Circuit Breaker 2 (SELOGIC control equation)
86	*	Reserved
86	B2MSOAL	Circuit Breaker 2 mechanical slow operation alarm
86	B2ESOAL	Circuit Breaker 2 electrical slow operation alarm
86	B2PSAL	Circuit Breaker 2 pole scatter alarm
86	B2PDAL	Circuit Breaker 2 pole discrepancy alarm
86	B2BITAL	Circuit Breaker 2 inactivity time alarm
86	B2MRTAL	Circuit Breaker 2 motor running time alarm
86	B2KAIAL	Circuit Breaker 2 interrupted current alarm

Table 11.18 Relay Word Bits: RTD Status Bits

Row	Name	Description
87	RTD01ST–RTD08ST	RTD status for Channel 1–8
88	RTDIN	State of RTD contact input
88	RTDCOMF	RTD communication failure
88	RTDFL	RTD device failure
88	*	Reserved
88	RTD09ST–RTD12ST	RTD status for Channel 9–12

Table 11.19 Relay Word Bits: Battery Monitor

Row	Name	Description
89	DC1F	DC Monitor 1 fail alarm
89	DC1W	DC Monitor 1 warning alarm
89	DC1G	DC Monitor 1 ground fault alarm
89	DC1R	DC Monitor 1 alarm for ac ripple
89	DC2F	DC Monitor 2 fail alarm
89	DC2W	DC Monitor 2 warning alarm
89	DC2G	DC Monitor 2 ground fault alarm
89	DC2R	DC Monitor 2 alarm for ac ripple

Table 11.20 Relay Word Bits: Metering Elements

Row	Name	Description
90	PDEM	Phase current demand picked up
90	QDEM	Negative-sequence demand current picked up
90	GDEM	Zero-sequence demand current picked up
90	*	Reserved
90	*	Reserved
90	*	Reserved
90	*	Reserved
90	*	Reserved

Table 11.21 Relay Word Bits: Open and Close

Row	Name	Description
91	CC2	Circuit Breaker 2 close command
91	OC2	Circuit Breaker 2 open command
91	CC1	Circuit Breaker 1 close command
91	OC1	Circuit Breaker 1 open command
91	*	Reserved
91	*	Reserved
91	*	Reserved
91	*	Reserved

Table 11.22 Relay Word Bits: Local Bits

Row	Name	Description
92	LB01–LB08	Local Bit 1–8
93	LB09–LB16	Local Bit 9–16
94	LB17–LB24	Local Bit 17–24
95	LB25–LB32	Local Bit 25–32

Table 11.23 Relay Word Bits: Remote Bits

Row	Name	Description
96	RB25–RB32	Remote Bit 25–32
97	RB17–24	Remote Bit 17–24
98	RB09–16	Remote Bit 9–16
99	RB01–RB08	Remote Bit 1–8

Table 11.24 Relay Word Bits: Settings Group Bits

Row	Name	Description
100	SG1–SG6	Settings Group 1–6 active
100	CHSG	Settings group change
100	*	Reserved

Table 11.25 Relay Word Bits: Future Breaker Failure Bits

Row	Name	Description
101–103	*	Reserved

Table 11.26 Relay Word Bits: Input Elements

Row	Name	Description
104	*	Reserved
104	IN101–IN107	Main Board Input 1–7
105–107	*	Reserved
108	IN201–IN208	First optional I/O board Input 1–8 (if installed)
109	IN209–IN216	First optional I/O board Input 9–16 (if installed)
110	IN217–IN224	First optional I/O board Input 17–24 (if installed)
111	*	Reserved
112	IN301–IN308	Second optional I/O board Input 1–8 (if installed)
113	IN309–IN316	Second optional I/O board Input 9–16 (if installed)
114	IN317–IN324	Second optional I/O board Input 17–24 (if installed)
115	*	Reserved

Table 11.27 Relay Word Bits: Protection SELogic Variables

Row	Name	Description
116	PSV01–PSV08	Protection SELogic Variable 1–8
117	PSV09–PSV16	Protection SELogic Variable 9–16
118	PSV17–PSV24	Protection SELogic Variable 17–24
119	PSV25–PSV32	Protection SELogic Variable 25–32
120	PSV33–PSV40	Protection SELogic Variable 33–40
121	PSV41–PSV48	Protection SELogic Variable 41–48
122	PSV49–PSV56	Protection SELogic Variable 49–56
123	PSV57–PSV64	Protection SELogic Variable 57–64

Table 11.28 Relay Word Bits: Protection SELOGIC Latches

Row	Name	Description
124	PLT01–PLT08	Protection Latch 1–8
125	PLT09–PLT16	Protection Latch 9–16
126	PLT17–PLT24	Protection Latch 17–24
127	PLT25–PLT32	Protection Latch 25–32

Table 11.29 Relay Word Bits: Protection SELOGIC Conditioning Timers

Row	Name	Description
128	PCT01Q–PCT08Q	Protection Conditioning Timer 1–8 output
129	PCT09Q–PCT16Q	Protection Conditioning Timer 9–16 output
130	PCT17Q–PCT24Q	Protection Conditioning Timer 17–24 output
131	PCT25Q–PCT32Q	Protection Conditioning Timer 25–32 output
132–133	*	Reserved

Table 11.30 Relay Word Bits: Protection SELOGIC Sequencing Timers

Row	Name	Description
134	PST01Q–PST08Q	Protection Sequencing Timer 1–8 output
135	PST09Q–PST16Q	Protection Sequencing Timer 9–16 output
136	PST17Q–PST24Q	Protection Sequencing Timer 17–24 output
137	PST25Q–PST32Q	Protection Sequencing Timer 25–32 output
138	PST01R–PST08R	Protection Sequencing Timer 1–8 reset
139	PST09R–PST16R	Protection Sequencing Timer 9–16 reset
140	PST17R–PST24R	Protection Sequencing Timer 17–24 reset
141	PST25R–PST32R	Protection Sequencing Timer 25–32 reset

Table 11.31 Relay Word Bits: Protection SELOGIC Counters

Row	Name	Description
142	PCN01Q–PCN08Q	Protection Counter 1–8 output
143	PCN09Q–PCN16Q	Protection Counter 9–16 output
144	PCN17Q–PCN24Q	Protection Counter 17–24 output
145	PCN25Q–PCN32Q	Protection Counter 25–32 output
146	PCN01R–PCN08R	Protection Counter 1–8 reset
147	PCN09R–PCN16R	Protection Counter 9–16 reset
148	PCN17R–PCN24R	Protection Counter 17–24 reset
149	PCN25R–PCN32R	Protection Counter 25–32 reset

Table 11.32 Relay Word Bits: Automation SELOGIC Variables

Row	Name	Description
150–181	ASV001–ASV256	Automation SELOGIC Variable 01–256

Table 11.33 Relay Word Bits: Automation SELOGIC Latches

Row	Name	Description
182	ALT01–ALT08	Automation Latch 1–8
183	ALT09–ALT16	Automation Latch 9–16
184	ALT17–ALT24	Automation Latch 17–24
185	ALT25–ALT32	Automation Latch 25–32

Table 11.34 Relay Word Bits: Automation Sequencing Timers

Row	Name	Description
186	AST01Q–AST08Q	Automation Sequencing Timer 1–8 output
187	AST09Q–AST16Q	Automation Sequencing Timer 9–16 output
188	AST17Q–AST24Q	Automation Sequencing Timer 17–24 output
189	AST25Q–AST32Q	Automation Sequencing Timer 25–32 output
190	AST01R–AST08R	Automation Sequencing Timer 1–8 reset
191	AST09R–AST16R	Automation Sequencing Timer 9–16 reset
192	AST17R–AST24R	Automation Sequencing Timer 17–24 reset
193	AST25R–AST32R	Automation Sequencing Timer 25–32 reset

Table 11.35 Relay Word Bits: Automation SELOGIC Counters

Row	Name	Description
194	ACN01Q–ACN08Q	Automation Counter 1–8 output
195	ACN09Q–ACN16Q	Automation Counter 9–16 output
196	ACN17Q–ACN24Q	Automation Counter 17–24 output
197	ACN25Q–ACN32Q	Automation Counter 25–32 output
198	ACN01R–ACN08R	Automation Counter 1–8 reset
199	ACN09R–ACN16R	Automation Counter 9–16 reset
200	ACN17R–ACN24R	Automation Counter 17–24 reset
201	ACN25R–ACN32R	Automation Counter 25–32 reset

Table 11.36 Relay Word Bits: SELOGIC Control Equation Error and Status Reporting (Sheet 1 of 2)

Row	Name	Description
202	PUNRLBL	Protection SELOGIC control equation unresolved label
202	PFRTEX	Protection SELOGIC control equation first execution
202	MATHERR	SELOGIC control equation math error
202	*	Reserved
202	*	Reserved
202	*	Reserved
202	*	Reserved
202	*	Reserved
203	*	Reserved
204	AUNRLBL	Automation SELOGIC control equation unresolved label
204	AFRTEXP	Automation SELOGIC control equation first execution after protection settings change, group switch, or source switch selection.
204	AFRTEXA	Automation SELOGIC control equation first execution after automation settings change

Table 11.36 Relay Word Bits: SELogic Control Equation Error and Status Reporting (Sheet 2 of 2)

Row	Name	Description
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
204	*	Reserved
205	*	Reserved

Table 11.37 Relay Word Bits: Alarms

Row	Name	Description
206	SALARM	Software alarm
206	HALARM	Hardware alarm
206	BADPASS	Invalid password attempt alarm
206	HALARML	Latched alarm for diagnostic failures
206	HALARMP	Pulsed alarm for diagnostic warnings
206	HALARMA	Pulse stream for unacknowledged diagnostic warnings
206	SETCHG	Pulsed alarm for settings changes
206	GRPSW	Pulsed alarm for group switches
207	*	Reserved
207	*	Reserved
207	*	Reserved
207	*	Reserved
207	*	Reserved
207	*	Reserved
207	ACCESS	A user is logged in at Access Level B or above
207	ACCESSP	Pulsed alarm for logins to Access Level B or above
208	*	Reserved
208	*	Reserved
208	*	Reserved
208	*	Reserved
208	*	Reserved
208	*	Reserved
208	PASSDIS	Asserted to indicate PW disable
208	BRKENAB	Asserted to indicate breaker control enable

Table 11.38 Relay Word Bits: Time and Date Management and Frequency Estimation (Sheet 1 of 2)

Row	Name	Description
209	TSNTPB	Asserts if time was synchronized with backup NTP server before SNTP time-out period expired
209	TSNTPP	Asserts if time was synchronized with primary NTP server before SNTP time-out period expired
209	TIRIG	Assert while time is based on IRIG for both mark and value
209	TUPDH	Assert if update source is high-accuracy time source

Table 11.38 Relay Word Bits: Time and Date Management and Frequency Estimation (Sheet 2 of 2)

Row	Name	Description
209	TSYNCA	Assert while the time mark from time source or fixed internal source is not synchronized
209	TSOK	Assert if current time source accuracy is sufficient for synchronized phasor measurements
209	PMDOK	Assert if data acquisition system is operating correctly
209	UPD_EN	Asserts when updating of the internal clock with the selected external time source is enabled
210	FREQOK	Assert if relay is estimating frequency
210	FREQFZ	Assert if relay is not estimating frequency
210	TSYNC	Asserts when the ADC sampling is synchronized to an IRIG-B time source
210	BLKLPTS	Asserts when the relay blocks a low-priority time source from updating the relay time
210	TLOCAL	Asserts when the relay internal clock and ADC sampling are synchronized to a non-C37.118 compliant high-accuracy IRIG-B time source
210	TPLLEXT	Asserts when the phase-locked loop (PLL) is updating from an external time source
210	TSSW	Asserts when high-priority time source switching is in progress
210	TGLOBAL	Asserts when the relay internal clock and ADC sampling are synchronized to a C37.118-compliant high-accuracy IRIG-B time source
211	TPTP	Time is based on a valid PTP source
211	TBNC	Time is based on a valid BNC IRIG-B source
211	TSER	Time is based on a valid Serial IRIG-B source
211	*	Reserved
212	SER_SET	Asserts when the serial IRIG-B source is the qualified high-accuracy time source
212	SER_RST	Asserts when the serial IRIG-B source is disqualified as the high-accuracy time source
212	BNC_SET	Asserts when the BNC IRIG-B source is the qualified high-accuracy time source
212	BNC_RST	Asserts when the BNC IRIG-B source is disqualified as the high-accuracy time source
212	BNC_OK	Asserts when an IRIG-B signal of sufficient quality is available from the BNC port
212	SER_OK	Asserts when an IRIG-B signal of sufficient quality is available from serial Port 1
212	UPD_BLK	Asserts when the relay blocks the updating of the internal clock period and Master Time
212	BNC_BNP	Asserts for excessive jitter on the BNC port, resulting in the loss of the IRIG-B signal
213	SER_BNP	Asserts for excessive jitter on the serial port, resulting in the loss of the IRIG-B signal
213	BNC_TIM	Asserts when a valid IRIG-B time source is detected on the BNC port
213	SER_TIM	Asserts when a valid IRIG-B time source is detected on the serial port
213	SERSYNC	Synchronized to a high quality serial IRIG-B source
213	BNCSYNC	Synchronized to a high quality BNC IRIG-B source
213	*	Reserved
213	*	Reserved
213	*	Reserved

Table 11.39 Relay Word Bits: Pushbuttons and Outputs (Sheet 1 of 2)

Row	Name	Description
214	PB1–PB8	Pushbutton 1–8
215	OUT101–OUT108	Main Board Output 1–8
216	OUT201–OUT208	Optional I/O Board 1 Output 1–8
217	OUT209–OUT216	Optional I/O Board 1 Output 9–16

Table 11.39 Relay Word Bits: Pushbuttons and Outputs (Sheet 2 of 2)

Row	Name	Description
218	OUT301–OUT308	Optional I/O Board 2 Output 1–8
219	OUT309–OUT316	Optional I/O Board 2 Output 9–16

Table 11.40 Relay Word Bits: Pushbuttons

Row	Name	Description
220	PB1_PUL–PB8_PUL	Pushbutton 1–8 pulse (on for one processing interval when button is pushed)

Table 11.41 Relay Word Bits: Pushbutton LED Bits

Row	Name	Description
221	PB1_LED–PB8_LED	Pushbutton 1–8 LED

Table 11.42 Relay Word Bits: Data Reset Bits

Row	Name	Description
222	RST_DEM	Reset demand metering
222	RST_PDM	Reset peak demand metering
222	RST_ENE	Reset energy metering data
222	RSTMML	Reset max/min line (SELOGIC control equation)
222	RSTMMB1	Reset max/min Circuit Breaker 1 (SELOGIC control equation)
222	RSTMMB2	Reset max/min Circuit Breaker 2 (SELOGIC control equation)
222	RST_BK1	Reset Circuit Breaker 1 monitor
222	RST_BK2	Reset Circuit Breaker 2 monitor
223	RST_BAT	Reset battery monitoring (SELOGIC control equation)
223	RSTFLOC	Reset fault locator (SELOGIC control equation)
223	RSTDNPE	Reset DNP fault summary data (SELOGIC control equation)
223	RST_79C	Reset recloser shot count accumulators (SELOGIC control equation)
223	RSTTRGT	Target reset (SELOGIC control equation)
223	RST_HAL	Reset warning alarm processing
223	*	Reserved
223	*	Reserved

Table 11.43 Relay Word Bits: Target Logic Bits

Row	Name	Description
224	PHASE_A	Indicates an A-Phase fault
224	PHASE_B	Indicates a B-Phase fault
224	PHASE_C	Indicates a C-Phase fault
224	GROUND	Indicates a ground fault
224	BK1BFT	Indicates Circuit Breaker 1 breaker failure trip
224	BK2BFT	Indicates Circuit Breaker 2 breaker failure trip
224	TRGTR	Reset all active target relay words
224	*	Reserved

Table 11.44 Relay Word Bits: MIRRORED BITS

Row	Name	Description
225	RMB1A–RMB8A	Channel A receive MIRRORED BITS 1–8
226	TMB1A–TMB8A	Channel A transmit MIRRORED BITS 1–8
227	RMB1B–RMB8B	Channel B receive MIRRORED BITS 1–8
228	TMB1B–TMB8B	Channel B transmit MIRRORED BITS 1–8
229	ROKA	Normal MIRRORED BITS Communications Channel A status while not in loopback mode
229	RBADA	Outage too long on MIRRORED BITS Communications Channel A
229	CBADA	Unavailability threshold exceeded for MIRRORED BITS Communications Channel A
229	LBOKA	Normal MIRRORED BITS Communications Channel A status while in loopback mode
229	ANOKA	Analog transfer OK on MIRRORED BITS Communications Channel A
229	DOKA	Normal MIRRORED BITS Communications Channel A status
229	*	Reserved
229	*	Reserved
230	ROKB	Normal MIRRORED BITS Communications Channel B status while not in loopback mode
230	RBADB	Outage too long on MIRRORED BITS Communications Channel B
230	CBADB	Unavailability threshold exceeded for MIRRORED BITS Communications Channel B
230	LBOKB	Normal MIRRORED BITS Communications Channel B status while in loopback mode
230	ANOKB	Analog transfer OK on MIRRORED BITS Communications Channel B
230	DOKB	Normal MIRRORED BITS Communications Channel B status
230	*	Reserved
230	*	Reserved

Table 11.45 Relay Word Bits: Test Bits

Row	Name	Description
231	TESTDB2	Communications card database Test Bit 2
231	TESTDB	Communications card database Test Bit
231	TESTFM	Fast meter test bit
231	TESTPUL	Pulse test bit
231	LPHDSIM	IEC 61850 logical node for physical device simulation
231	*	Reserved
231	*	Reserved
231	*	Reserved

Table 11.46 Relay Word Bits: Virtual Bits (Sheet 1 of 2)

Row	Name	Description
232	VB249–VB256	Virtual Bits 249–256
233	VB241–VB248	Virtual Bits 241–248
234	VB233–VB240	Virtual Bits 233–240
235	VB225–VB232	Virtual Bits 225–232
236	VB217–VB224	Virtual Bits 217–224
237	VB209–VB216	Virtual Bits 209–216
238	VB201–VB208	Virtual Bits 201–208

Table 11.46 Relay Word Bits: Virtual Bits (Sheet 2 of 2)

Row	Name	Description
239	VB193–VB200	Virtual Bits 193–200
240	VB185–VB192	Virtual Bits 185–192
241	VB177–VB184	Virtual Bits 177–184
242	VB169–VB176	Virtual Bits 169–176
243	VB161–VB168	Virtual Bits 161–168
244	VB153–VB160	Virtual Bits 153–160
245	VB145–VB152	Virtual Bits 145–152
246	VB137–VB144	Virtual Bits 137–144
247	VB129–VB136	Virtual Bits 129–136
248	VB121–VB128	Virtual Bits 121–128
249	VB113–VB120	Virtual Bits 113–120
250	VB105–VB112	Virtual Bits 105–112
251	VB097–VB104	Virtual Bits 097–104
252	VB089–VB096	Virtual Bits 089–096
253	VB081–VB088	Virtual Bits 081–088
254	VB073–VB080	Virtual Bits 073–080
255	VB065–VB072	Virtual Bits 065–072
256	VB057–VB064	Virtual Bits 057–064
257	VB049–VB056	Virtual Bits 049–056
258	VB041–VB048	Virtual Bits 041–048
259	VB033–VB040	Virtual Bits 033–040
260	VB025–VB032	Virtual Bits 025–032
261	VB017–VB024	Virtual Bits 017–024
262	VB009–VB016	Virtual Bits 009–016
263	VB001–VB008	Virtual Bits 001–008

Table 11.47 Relay Word Bits: Ethernet Switch (Sheet 1 of 2)

Row	Name	Description
264	LINK5A	Link status of Port 5A connection
264	LINK5B	Link status of Port 5B connection
264	LINK5C	Link status of Port 5C connection
264	LINK5D	Link status of Port 5D connection
264	LINKFAIL	Link status of the active port
264	*	Reserved
264	*	Reserved
264	*	Reserved
265	P5ASEL	Port 5A active/inactive
265	P5BSEL	Port 5B active/inactive
265	P5CSEL	Port 5C active/inactive
265	P5DSEL	Port 5D active/inactive
265	*	Reserved

Table 11.47 Relay Word Bits: Ethernet Switch (Sheet 2 of 2)

Row	Name	Description
265	*	Reserved
265	*	Reserved
265	*	Reserved
266	*	Reserved

Table 11.48 Relay Word Bits: Signal Profiling

Row	Name	Description
267	SPEN	Signal profiling enabled
267	*	Reserved
267	*	Reserved
267	*	Reserved
267	*	Reserved
267	*	Reserved
267	*	Reserved
267	*	Reserved

Table 11.49 Relay Word Bits: Fast SER Enable Bits

Row	Name	Description
268	FSERP1	Fast SER enabled for Serial Port 1
268	FSERP2	Fast SER enabled for Serial Port 2
268	FSERP3	Fast SER enabled for Serial Port 3
268	FSERPF	Fast SER enabled for Serial Port F
268	FSERP5	Fast SER enabled for EN and FO ports
268	*	Reserved
268	*	Reserved
268	*	Reserved

Table 11.50 Relay Word Bits: Source Selection Elements

Row	Name	Description
269	ALTI	Alternate current source (SELOGIC control equation)
269	ALTV	Alternate voltage source (SELOGIC control equation)
269	ALTS2	Alternate synchronism source for Circuit Breaker 2
269	DELAY	Unused
269	*	Reserved
269	*	Reserved
269	*	Reserved
269	*	Reserved

Table 11.51 Relay Word Bits: Full-Cycle Mho and Quad Ground-Distance

Row	Name	Description
270	MBG2F	Zone 2 filtered B-Phase-to-ground Mho element asserted
270	MAG2F	Zone 2 filtered Mho A-Phase-to-ground element
270	XCG1F	Zone 1 quad C-Phase-to-ground element
270	XBG1F	Zone 1 quad B-Phase-to-ground element
270	XAG1F	Zone 1 quad A-Phase-to-ground element
270	MCG1F	Zone 1 filtered Mho C-Phase-to-ground element
270	MBG1F	Zone 1 filtered Mho B-Phase-to-ground element
270	MAG1F	Zone 1 filtered Mho A-Phase-to-ground element
271	XAG3F	Zone 3 quad A-Phase-to-ground element
271	MCG3F	Zone 3 filtered Mho C-Phase-to-ground element
271	MBG3F	Zone 3 filtered Mho B-Phase-to-ground element
271	MAG3F	Zone 3 filtered Mho A-Phase-to-ground element
271	XCG2F	Zone 2 quad C-Phase-to-ground element
271	XBG2F	Zone 2 quad B-Phase-to-ground element
271	XAG2F	Zone 2 quad A-Phase-to-ground element
271	MCG2F	Zone 2 filtered Mho C-Phase-to-ground element
272	XCG4F	Zone 4 quad C-Phase-to-ground element
272	XBG4F	Zone 4 quad B-Phase-to-ground element
272	XAG4F	Zone 4 quad A-Phase-to-ground element
272	MCG4F	Zone 4 filtered Mho C-Phase-to-ground element
272	MBG4F	Zone 4 filtered Mho B-Phase-to-ground element
272	MAG4F	Zone 4 filtered Mho C-Phase-to-ground element
272	XCG3F	Zone 3 quad C-Phase-to-ground element
272	XBG3F	Zone 3 quad B-Phase-to-ground element
273	*	Reserved
273	*	Reserved
273	XCG5F	Zone 5 quad C-Phase-to-ground element
273	XBG5F	Zone 5 quad B-Phase-to-ground element
273	XAG5F	Zone 5 quad A-Phase-to-ground element
273	MCG5F	Zone 5 filtered Mho C-Phase-to-ground element
273	MBG5F	Zone 5 filtered Mho B-Phase-to-ground element
273	MAG5F	Zone 5 filtered Mho A-Phase-ground element

Table 11.52 Relay Word Bits: Full-Cycle Mho and Phase Quad Phase-Distance (Sheet 1 of 2)

Row	Name	Description
274	MBC2F	Zone 2 filtered Mho BC phase element
274	MAB2F	Zone 2 filtered Mho AB phase element
274	XCA1F	Zone 1 quad CA phase element
274	XBC1F	Zone 1 quad BC phase element
274	XAB1F	Zone 1 quad AB phase element
274	MCA1F	Zone 1 filtered Mho CA phase element

Table 11.52 Relay Word Bits: Full-Cycle Mho and Phase Quad Phase-Distance (Sheet 2 of 2)

Row	Name	Description
274	MBC1F	Zone 1 filtered Mho BC phase element
274	MAB1F	Zone 1 filtered Mho AB phase element
275	XAB3F	Zone 3 quad AB phase element
275	MCA3F	Zone 3 filtered Mho CA phase element
275	MBC3F	Zone 3 filtered Mho BC phase element
275	MAB3F	Zone 3 filtered Mho AB phase element
275	XCA2F	Zone 2 quad CA phase element
275	XBC2F	Zone 2 quad BC phase element
275	XAB2F	Zone 2 quad AB phase element
275	MCA2F	Zone 2 filtered Mho CA phase element
276	XCA4F	Zone 4 quad CA phase element
276	XBC4F	Zone 4 quad BC phase element
276	XAB4F	Zone 4 quad AB phase element
276	MCA4F	Zone 4 filtered Mho CA phase element
276	MBC4F	Zone 4 filtered Mho BC phase element
276	MAB4F	Zone 4 filtered Mho AB phase element
276	XCA3F	Zone 3 quad CA phase element
276	XBC3F	Zone 3 quad BC phase element
277	*	Reserved
277	*	Reserved
277	XCA5F	Zone 5 quad CA phase element
277	XBC5F	Zone 5 quad BC phase element
277	XAB5F	Zone 5 quad AB phase element
277	MCA5F	Zone 5 filtered Mho CA phase element
277	MBC5F	Zone 5 filtered Mho BC phase element
277	MAB5F	Zone 5 filtered Mho AB phase element

Table 11.53 Relay Word Bits: High-Speed Mho and Quad Ground-Distance (Sheet 1 of 2)

Row	Name	Description
278	MBG3H	High-speed Zone 3 Mho BG ground element
278	MAG3H	High-speed Zone 3 Mho AG ground element
278	MCG2H	High-speed Zone 2 Mho CG ground element
278	MBG2H	High-speed Zone 2 Mho BG ground element
278	MAG2H	High-speed Zone 2 Mho AG ground element
278	MCG1H	High-speed Zone 1 Mho CG ground element
278	MBG1H	High-speed Zone 1 Mho BG ground element
278	MAG1H	High-speed Zone 1 Mho AG ground element
279	XAG3H	High-speed Zone 3 high-speed quad A-G ground element
279	XCG2H	High-speed Zone 2 quad CG ground element
279	XBG2H	High-speed Zone 2 quad BG ground element
279	XAG2H	High-speed Zone 2 quad AG ground element

Table 11.53 Relay Word Bits: High-Speed Mho and Quad Ground-Distance (Sheet 2 of 2)

Row	Name	Description
279	XCG1H	High-speed Zone 1 quad CG ground element
279	XBG1H	High-speed Zone 1 quad BG ground element
279	XAG1H	High-speed Zone 1 quad AG ground element
279	MCG3H	High-speed Zone 3 Mho CG ground element
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	*	Reserved
280	XCG3H	High-speed Zone 3 quad CG ground element
280	XBG3H	High-speed Zone 3 quad BG ground element
281	*	Reserved

Table 11.54 Relay Word Bits: High-Speed Mho and Quad Phase-Distance (Sheet 1 of 2)

Row	Name	Description
282	MBC3H	High-speed Zone 3 Mho BC phase element
282	MAB3H	High-speed Zone 3 Mho AB phase element
282	MCA2H	High-speed Zone 2 Mho CA phase element
282	MBC2H	High-speed Zone 2 Mho BC phase element
282	MAB2H	High-speed Zone 2 Mho AB phase element
282	MCA1H	High-speed Zone 1 Mho CA phase element
282	MBC1H	High-speed Zone 1 Mho BC phase element
282	MAB1H	High-speed Zone 1 Mho AB phase element
283	XAB3H	High-speed Zone 3 high-speed quad AB phase element
283	XCA2H	High-speed Zone 2 high-speed quad CA phase element
283	XBC2H	High-speed Zone 2 high-speed quad BC phase element
283	XAB2H	High-speed Zone 2 high-speed quad AB phase element
283	XCA1H	High-speed Zone 1 high-speed quad CA phase element
283	XBC1H	High-speed Zone 1 high-speed quad BC phase element
283	XAB1H	High-speed Zone 1 high-speed quad AB phase element
283	MCA3H	High-speed Zone 3 Mho CA phase element
284	*	Reserved
284	*	Reserved
284	*	Reserved
284	*	Reserved
284	*	Reserved
284	*	Reserved
284	XCA3H	High-speed Zone 3 high-speed quad C–A phase element
284	XBC3H	High-speed Zone 3 high-speed quad B–C phase element
285	*	Reserved

Table 11.54 Relay Word Bits: High-Speed Mho and Quad Phase-Distance (Sheet 2 of 2)

Row	Name	Description
285	*	Reserved
285	*	Reserved
285	*	Reserved
285	HSDQR	Phase-to-phase fault, high-speed reverse directional element
285	HSDQF	Phase-to-phase fault, high-speed forward directional element
285	HSDGR	Ground fault, high-speed reverse directional element
285	HSDGF	Ground fault, high-speed forward directional element

Table 11.55 Relay Word Bits: DNP Event Lock

Row	Name	Description
286	EVELOCK	Lock DNP events
286	*	Reserved
286	*	Reserved
286	*	Reserved
286	*	Reserved
286	*	Reserved
286	*	Reserved
286	*	Reserved
287	*	Reserved

Table 11.56 Relay Word Bits: Synchrophasor SELOGIC Equations/RTC Synchrophasors Status Bits (Sheet 1 of 2)

Row	Name	Description
288	PMTRIG	Trigger (SELOGIC control equation)
288	TREA1–TREA4	Trigger Reason Bit 1–4 (SELOGIC Equation)
288	FROKPM	Synchrophasor frequency
288	PMTEST	Synchrophasor test mode
288	*	Reserved
289	*	Reserved
290	*	Reserved
290	*	Reserved
290	*	Reserved
290	*	Reserved
290	RTCSEQB	RTC configuration complete, Channel B
290	RTCSEQA	RTC configuration complete, Channel A
290	RTCCFGB	RTC data in sequence, Channel B
290	RTCCFGA	RTC data in sequence, Channel A
291	*	Reserved
291	RTCDLYB	RTC delay exceeded, Channel B
291	RTCDLYA	RTC delay exceeded, Channel A
291	RTCROK	Valid aligned RTC data available on all enabled channels
291	RTCROKB	Valid aligned RTC data available on Channel B

Table 11.56 Relay Word Bits: Synchrophasor SELogic Equations/RTC Synchrophasors Status Bits (Sheet 2 of 2)

Row	Name	Description
291	RTCROKA	Valid aligned RTC data available on Channel A
291	RTCENB	Valid remote synchrophasors received on Channel B
291	RTCENA	Valid remote synchrophasors received on Channel A

Table 11.57 Relay Word Bits: IRIG-B Control

Row	Name	Description
292	YEAR80	IRIG-B year information, binary-coded-decimal, add 80 if asserted
292	YEAR40	IRIG-B year information, binary-coded-decimal, add 40 if asserted
292	YEAR20	IRIG-B year information, binary-coded-decimal, add 20 if asserted
292	YEAR10	IRIG-B year information, binary-coded-decimal, add 10 if asserted
292	YEAR8	IRIG-B year information, binary-coded-decimal, add 8 if asserted
292	YEAR4	IRIG-B year information, binary-coded-decimal, add 4 if asserted
292	YEAR2	IRIG-B year information, binary-coded-decimal, add 2 if asserted
292	YEAR1	IRIG-B year information, binary-coded-decimal, add 1 if asserted
293	*	Reserved
293	*	Reserved
293	TUTCH	IRIG-B Offset half-hour from UTC time, binary, add 0.5 if asserted
293	TUTC8	IRIG-B Offset hours from UTC time, binary, add 8 if asserted
293	TUTC4	IRIG-B Offset hours from UTC time, binary, add 4 if asserted
293	TUTC2	IRIG-B Offset hours from UTC time, binary, add 2 if asserted
293	TUTC1	IRIG-B Offset hours from UTC time, binary, add 1 if asserted
293	TUTCS	IRIG-B Offset hours sign from UTC time, subtract the UTC offset if TUTCS is asserted, add otherwise
294	DST	Daylight saving time
294	DSTP	IRIG-B Daylight saving time pending
294	LPSEC	Direction of the upcoming leap second. During the time that LPSECP is asserted, if LPSEC is asserted, the upcoming leap second is deleted; otherwise, the leap second is added.
294	LPSECP	Leap second pending
294	TQUAL8	Time quality, binary, add 8 when asserted
294	TQUAL4	Time quality, binary, add 4 when asserted
294	TQUAL2	Time quality, binary, add 2 when asserted
294	TQUAL1	Time quality, binary, add 1 when asserted
295	*	Reserved

Table 11.58 Relay Word Bit: Time-Error Calculation (Sheet 1 of 2)

Row	Name	Description
296	LOADTE	Load TECORR factor (SELogic Equation). When a rising-edge is detected, the accumulated time-error value TE is loaded with the TECORR factor (preload value).
296	STALLTE	Stall time-error calculation (SELogic Equation). When asserted, the time-error calculation is stalled, or frozen.
296	PLDTE	Asserts for approximately 1.5 cycles when the **TEC** command is used to load a new time-error correction factor (preload value) into the TECORR analog quantity.
296	*	Reserved

Table 11.58 Relay Word Bit: Time-Error Calculation (Sheet 2 of 2)

Row	Name	Description
296	*	Reserved
296	*	Reserved
296	*	Reserved
296	*	Reserved
297	*	Reserved

Table 11.59 Relay Word Bits: Synchrophasor Configuration Error

Row	Name	Description
298	SPCER1–SPCER3	Synchrophasor configuration error on Port 1–3
298	SPCERF	Synchrophasor configuration error on Port F
298	*	Reserved
298	*	Reserved
298	*	Reserved
298	*	Reserved
299	*	Reserved

Table 11.60 Relay Word Bits: Pushbuttons, Pushbutton LEDs, and Target LEDs for New HMI

Row	Name	Description
300	TLED_17–TLED_24	Target LED 17–24
301	PB9–PB12	Pushbutton 9–12
301	*	Reserved
301	*	Reserved
301	PB_TRIP	Auxiliary TRIP pushbutton
301	PB_CLSE	Auxiliary CLOSE pushbutton
302	PB9_LED	Pushbutton 9 LED
302	PB10LED	Pushbutton 10 LED
302	PB11LED	Pushbutton 11 LED
302	PB12LED	Pushbutton 12 LED
302	*	Reserved
302	*	Reserved
302	*	Reserved
302	*	Reserved
303	PB9_PUL	Pushbutton 9 pulse (on for one processing interval when button is pushed)
303	PB10PUL	Pushbutton 10 pulse (on for one processing interval when button is pushed)
303	PB11PUL	Pushbutton 11 pulse (on for one processing interval when button is pushed)
303	PB12PUL	Pushbutton 12 pulse (on for one processing interval when button is pushed)
303	*	Reserved
303	*	Reserved
303	*	Reserved
303	*	Reserved

Table 11.61 Relay Word Bits: Local Bit Supervision

Row	Name	Description
304	LB_SP01–LB_SP08	Local Bit 01–08 supervision (SELOGIC Equation)
305	LB_SP09–LB_SP16	Local Bit 09–16 supervision (SELOGIC Equation)
306	LB_SP17–LB_SP24	Local Bit 17–24 supervision (SELOGIC Equation)
307	LB_SP25–LB_SP32	Local Bit 25–32 supervision (SELOGIC Equation)

Table 11.62 Relay Word Bits: Local Bit Status

Row	Name	Description
308	LB_DP01–LB_DP08	Local Bit 01–08 status display (SELOGIC Equation)
309	LB_DP09–LB_DP16	Local Bit 09–16 status display (SELOGIC Equation)
310	LB_DP17–LB_DP24	Local Bit 17–24 status display (SELOGIC Equation)
311	LB_DP25–LB_DP32	Local Bit 25–32 status display (SELOGIC Equation)

Table 11.63 Relay Word Bits: RTC Remote Digital Status

Row	Name	Description
312	RTCAD01–RTCAD08	RTC remote data bits, Channel A, Bit 1–8
313	RTCAD09–RTCAD16	RTC remote data bits, Channel A, Bit 9–16
314	RTCBD01–RTCBD08	RTC remote data bits, Channel B, Bit 1–8
315	RTCBD09–RTCBD16	RTC remote data bits, Channel B, Bit 9–16

Table 11.64 Relay Word Bits: Fast Operate Transmit Bits

Row	Name	Description
316	FOPF_01–FOPF_08	Fast-operate output control bits for Port F, Bit 1–8
317	FOPF_09–FOPF_16	Fast-operate output control bits for Port F, Bit 9–16
318	FOPF_17–FOPF_24	Fast-operate output control bits for Port F, Bit 17–24
319	FOPF_25–FOPF_32	Fast-operate output control bits for Port F, Bit 25–32
320	FOP1_01–FOP1_08	Fast-operate output control bits for Port 1, Bit 1–8
321	FOP1_09–FOP1_16	Fast-operate output control bits for Port 1, Bit 9–16
322	FOP1_17–FOP1_24	Fast-operate output control bits for Port 1, Bit 17–24
323	FOP1_25–FOP1_32	Fast-operate output control bits for Port 1, Bit 25–32
324	FOP2_01–FOP2_08	Fast-operate output control bits for Port 2, Bit 1–8
325	FOP2_09–FOP2_16	Fast-operate output control bits for Port 2, Bit 9–16
326	FOP2_17–FOP2_24	Fast-operate output control bits for Port 2, Bit 17–24
327	FOP2_25–FOP2_32	Fast-operate output control bits for Port 2, Bit 35–32
328	FOP3_01–FOP3_08	Fast-operate output control bits for Port 3, Bit 1–8
329	FOP3_09–FOP3_16	Fast-operate output control bits for Port 3, Bit 9–16
330	FOP3_17–FOP3_24	Fast-operate output control bits for Port 3, Bit 17–24
331	FOP3_25–FOP3_32	Fast-operate output control bits for Port 3, Bit 25–32

Table 11.65 Relay Word Bits: Bay Control Disconnect Status (Sheet 1 of 2)

Row	Name	Description
332	89AM01	Disconnect 1 N/O auxiliary contact
332	89BM01	Disconnect 1 N/C auxiliary contact
332	89CL01	Disconnect 1 closed
332	89OPN01	Disconnect 1 open
332	89OIP01	Disconnect 1 operation in-progress
332	89AL01	Disconnect 1 alarm
332	*	Reserved
332	89AL	Any disconnect alarm
333	89AM02	Disconnect 2 N/O auxiliary contact
333	89BM02	Disconnect 2 N/C auxiliary contact
333	89CL02	Disconnect 2 closed
333	89OPN02	Disconnect 2 open
333	89OIP02	Disconnect 2 operation in-progress
333	89AL02	Disconnect 2 alarm
333	*	Reserved
333	89OIP	Any Disconnect operation in-progress
334	89AM03	Disconnect 3 N/O auxiliary contact
334	89BM03	Disconnect 3 N/C auxiliary contact
334	89CL03	Disconnect 3 closed
334	89OPN03	Disconnect 3 open
334	89OIP03	Disconnect 3 operation in-progress
334	89AL03	Disconnect 3 alarm
334	*	Reserved
334	LOCAL	Local front-panel control
335	89AM04	Disconnect 4 N/O auxiliary contact
335	89BM04	Disconnect 4 N/C auxiliary contact
335	89CL04	Disconnect 4 closed
335	89OPN04	Disconnect 4 open
335	89OIP04	Disconnect 4 operation in-progress
335	89AL04	Disconnect 4 alarm
335	*	Reserved
335	*	Reserved
336	89AM05	Disconnect 5 N/O auxiliary contact
336	89BM05	Disconnect 5 N/C auxiliary contact
336	89CL05	Disconnect 5 closed
336	89OPN05	Disconnect 5 open
336	89OIP05	Disconnect 5 operation in-progress
336	89AL05	Disconnect 5 alarm
336	*	Reserved
336	*	Reserved
337	89AM06	Disconnect 6 N/O auxiliary contact

Table 11.65 Relay Word Bits: Bay Control Disconnect Status (Sheet 2 of 2)

Row	Name	Description
337	89BM06	Disconnect 6 N/C auxiliary contact
337	89CL06	Disconnect 6 closed
337	89OPN06	Disconnect 6 open
337	89OIP06	Disconnect 6 operation in-progress
337	89AL06	Disconnect 6 alarm
337	*	Reserved
337	*	Reserved
338	89AM07	Disconnect 7 N/O auxiliary contact
338	89BM07	Disconnect 7 N/C auxiliary contact
338	89CL07	Disconnect 7 closed
338	89OPN07	Disconnect 7 open
338	89OIP07	Disconnect 7 operation in-progress
338	89AL07	Disconnect 7 alarm
338	*	Reserved
338	*	Reserved
339	89AM08	Disconnect 8 N/O auxiliary contact
339	89BM08	Disconnect 8 N/C auxiliary contact
339	89CL08	Disconnect 8 closed
339	89OPN08	Disconnect 8 open
339	89OIP08	Disconnect 8 operation in-progress
339	89AL08	Disconnect 8 alarm
339	*	Reserved
339	*	Reserved
340	89AM09	Disconnect 9 N/O auxiliary contact
340	89BM09	Disconnect 9 N/C auxiliary contact
340	89CL09	Disconnect 9 closed
340	89OPN09	Disconnect 9 open
340	89OIP09	Disconnect 9 operation in-progress
340	89AL09	Disconnect 9 alarm
340	*	Reserved
340	*	Reserved
341	89AM10	Disconnect 10 N/O auxiliary contact
341	89BM10	Disconnect 10 N/C auxiliary contact
341	89CL10	Disconnect 10 closed
341	89OPN10	Disconnect 10 open
341	89OIP10	Disconnect 10 operation in-progress
341	89AL10	Disconnect 10 alarm
341	*	Reserved
341	*	Reserved

Table 11.66 Relay Word Bits: Bay Control Disconnect Bus-Zone Compliant

Row	Name	Description
342	89CLB01–89CLB08	Disconnect 1–8 bus-zone protection
343	89CLB09–89CLB10	Disconnect 9–10 bus-zone protection
343	*	Reserved
343	*	Reserved
343	*	Reserved
343	*	Reserved
343	*	Reserved
343	*	Reserved

Table 11.67 Relay Word Bits: Bay Control Disconnect Control (Sheet 1 of 3)

Row	Name	Description
344	89OC01	ASCII Open Disconnect 1 command
344	89CC01	ASCII Close Disconnect 1 command
344	89OCM01	Mimic Disconnect 1 open control
344	89CCM01	Mimic Disconnect 1 close control
344	89OPE01	Disconnect Open 1 output
344	89CLS01	Disconnect Close 1 output
344	89OCN01	Open Disconnect 1
344	89CCN01	Close Disconnect 1
345	*	Reserved
346	89OC02	ASCII Open Disconnect 2 command
346	89CC02	ASCII Close Disconnect 2 command
346	89OCM02	Mimic Disconnect 2 open control
346	89CCM02	Mimic Disconnect 2 close control
346	89OPE02	Disconnect Open 2 output
346	89CLS02	Disconnect Close 2 output
346	89OCN02	Open Disconnect 2
346	89CCN02	Close Disconnect 2
347	*	Reserved
348	89OC03	ASCII Open Disconnect 3 command
348	89CC03	ASCII Close Disconnect 3 command
348	89OCM03	Mimic Disconnect 3 open control
348	89CCM03	Mimic Disconnect 3 close control
348	89OPE03	Disconnect Open 3 output
348	89CLS03	Disconnect Close 3 output
348	89OCN03	Open Disconnect 3
348	89CCN03	Close Disconnect 3
349	*	Reserved
350	89OC04	ASCII Open Disconnect 4 command
350	89CC04	ASCII Close Disconnect 4 command
350	89OCM04	Mimic Disconnect 4 open control

Table 11.67 Relay Word Bits: Bay Control Disconnect Control (Sheet 2 of 3)

Row	Name	Description
350	89CCM04	Mimic Disconnect 4 close control
350	89OPE04	Disconnect Open 4 output
350	89CLS04	Disconnect Close 4 output
350	89OCN04	Open Disconnect 4
350	89CCN04	Close Disconnect 4
351	*	Reserved
352	89OC05	ASCII Open Disconnect 5 command
352	89CC05	ASCII Close Disconnect 5 command
352	89OCM05	Mimic Disconnect 5 open control
352	89CCM05	Mimic Disconnect 5 close control
352	89OPE05	Disconnect Open 5 output
352	89CLS05	Disconnect Close 5 output
352	89OCN05	Open Disconnect 5
352	89CCN05	Close Disconnect 5
353	*	Reserved
354	89OC06	ASCII Open Disconnect 6 command
354	89CC06	ASCII Close Disconnect 6 command
354	89OCM06	Mimic Disconnect 6 open control
354	89CCM06	Mimic Disconnect 6 close control
354	89OPE06	Disconnect Open 6 output
354	89CLS06	Disconnect Close 6 output
354	89OCN06	Open Disconnect 6
354	89CCN06	Close Disconnect 6
355	*	Reserved
356	89OC07	ASCII Open Disconnect 7 command
356	89CC07	ASCII Close Disconnect 7 command
356	89OCM07	Mimic Disconnect 7 open control
356	89CCM07	Mimic Disconnect 7 close control
356	89OPE07	Disconnect Open 7 output
356	89CLS07	Disconnect Close 7 output
356	89OCN07	Open Disconnect 7
356	89CCN07	Close Disconnect 7
357	*	Reserved
358	89OC08	ASCII Open Disconnect 8 command
358	89CC08	ASCII Close Disconnect 8 command
358	89OCM08	Mimic Disconnect 8 open control
358	89CCM08	Mimic Disconnect 8 close control
358	89OPE08	Disconnect Open 8 output
358	89CLS08	Disconnect Close 8 output
358	89OCN08	Open Disconnect 8
358	89CCN08	Close Disconnect 8

Table 11.67 Relay Word Bits: Bay Control Disconnect Control (Sheet 3 of 3)

Row	Name	Description
359	*	Reserved
360	89OC09	ASCII Open Disconnect 9 command
360	89CC09	ASCII Close Disconnect 9 command
360	89OCM09	Mimic Disconnect 9 open control
360	89CCM09	Mimic Disconnect 9 close control
360	89OPE09	Disconnect Open 9 output
360	89CLS09	Disconnect Close 9 output
360	89OCN09	Open Disconnect 9
360	89CCN09	Close Disconnect 9
361	*	Reserved
362	89OC10	ASCII Open Disconnect 10 command
362	89CC10	ASCII Close Disconnect 10 command
362	89OCM10	Mimic Disconnect 10 open control
362	89CCM10	Mimic Disconnect 10 close control
362	89OPE10	Disconnect Open 10 output
362	89CLS10	Disconnect Close 10 output
362	89OCN10	Open Disconnect 10
362	89CCN10	Close Disconnect 10
363	*	Reserved

Table 11.68 Relay Word Bits: Bay Control Disconnect Timers and Breaker Status (Sheet 1 of 5)

Row	Name	Description
364	89CBL01	Disconnect 01 close block
364	89OSI01	Disconnect 01 open seal-in timer timed out
364	89CSI01	Disconnect 01 close seal-in timer timed out
364	89OIR01	Disconnect 01 open immobility timer reset
364	89CIR01	Disconnect 01 close immobility timer reset
364	89OBL01	Disconnect 01 open block
364	89ORS01	Disconnect 01 open reset
364	89CRS01	Disconnect 01 close reset
365	89OIM01	Disconnect 01 open immobility timer timed out
365	89CIM01	Disconnect 01 close immobility timer timed out
365	521CLSM	Breaker 1 closed
365	521_ALM	Breaker 1 status alarm
365	522CLSM	Breaker 2 closed
365	522_ALM	Breaker 2 status alarm
365	523CLSM	Breaker 3 closed
365	523_ALM	Breaker 3 status alarm
366	89CBL02	Disconnect 02 close block
366	89OSI02	Disconnect 02 open seal-in timer timed out
366	89CSI02	Disconnect 02 close seal-in timer timed out

Table 11.68 Relay Word Bits: Bay Control Disconnect Timers and Breaker Status (Sheet 2 of 5)

Row	Name	Description
366	89OIR02	Disconnect 02 open immobility timer reset
366	89CIR02	Disconnect 02 close immobility timer reset
366	89OBL02	Disconnect 02 open block
366	89ORS02	Disconnect 02 open reset
366	89CRS02	Disconnect 02 close reset
367	89OIM02	Disconnect 02 open immobility timer timed out
367	89CIM02	Disconnect 02 close immobility timer timed out
367	*	Reserved
367	*	Reserved
367	*	Reserved
367	*	Reserved
367	*	Reserved
367	*	Reserved
368	89CBL03	Disconnect 03 close block
368	89OSI03	Disconnect 03 open seal-in timer timed out
368	89CSI03	Disconnect 03 close seal-in timer timed out
368	89OIR03	Disconnect 03 open immobility timer reset
368	89CIR03	Disconnect 03 close immobility timer reset
368	89OBL03	Disconnect 03 open block
368	89ORS03	Disconnect 03 open reset
368	89CRS03	Disconnect 03 close reset
369	89OIM03	Disconnect 03 open immobility timer timed out
369	89CIM03	Disconnect 03 close immobility timer timed out
369	*	Reserved
369	*	Reserved
369	*	Reserved
369	*	Reserved
369	*	Reserved
369	*	Reserved
370	89CBL04	Disconnect 04 close block
370	89OSI04	Disconnect 04 open seal-in timer timed out
370	89CSI04	Disconnect 04 close seal-in timer timed out
370	89OIR04	Disconnect 04 open immobility timer reset
370	89CIR04	Disconnect 04 close immobility timer reset
370	89OBL04	Disconnect 04 open block
370	89ORS04	Disconnect 04 open reset
370	89CRS04	Disconnect 04 close reset
371	89OIM04	Disconnect 04 open immobility timer timed out
371	89CIM04	Disconnect 04 close immobility timer timed out
371	*	Reserved
371	*	Reserved

Table 11.68 Relay Word Bits: Bay Control Disconnect Timers and Breaker Status (Sheet 3 of 5)

Row	Name	Description
371	*	Reserved
371	*	Reserved
371	*	Reserved
371	*	Reserved
372	89CBL05	Disconnect 05 close block
372	89OSI05	Disconnect 05 open seal-in timer timed out
372	89CSI05	Disconnect 05 close seal-in timer timed out
372	89OIR05	Disconnect 05 open immobility timer reset
372	89CIR05	Disconnect 05 close immobility timer reset
372	89OBL05	Disconnect 05 open block
372	89ORS05	Disconnect 05 open reset
372	89CRS05	Disconnect 05 close reset
373	89OIM05	Disconnect 05 open immobility timer timed out
373	89CIM05	Disconnect 05 close immobility timer timed out
373	*	Reserved
373	*	Reserved
373	*	Reserved
373	*	Reserved
373	*	Reserved
373	*	Reserved
374	89CBL06	Disconnect 06 close block
374	89OSI06	Disconnect 06 open seal-in timer timed out
374	89CSI06	Disconnect 06 close seal-in timer timed out
374	89OIR06	Disconnect 06 open immobility timer reset
374	89CIR06	Disconnect 06 close immobility timer reset
374	89OBL06	Disconnect 06 open block
374	89ORS06	Disconnect 06 open reset
374	89CRS06	Disconnect 06 close reset
375	89OIM06	Disconnect 06 open immobility timer timed out
375	89CIM06	Disconnect 06 close immobility timer timed out
375	*	Reserved
375	*	Reserved
375	*	Reserved
375	*	Reserved
375	*	Reserved
375	*	Reserved
376	89CBL07	Disconnect 07 close block
376	89OSI07	Disconnect 07 open seal-in timer timed out
376	89CSI07	Disconnect 07 close seal-in timer timed out
376	89OIR07	Disconnect 07 open immobility timer reset
376	89CIR07	Disconnect 07 close immobility timer reset

Table 11.68 Relay Word Bits: Bay Control Disconnect Timers and Breaker Status (Sheet 4 of 5)

Row	Name	Description
376	89OBL07	Disconnect 07 open block
376	89ORS07	Disconnect 07 open reset
376	89CRS07	Disconnect 07 close reset
377	89OIM07	Disconnect 07 open immobility timer timed out
377	89CIM07	Disconnect 07 close immobility timer timed out
377	*	Reserved
377	*	Reserved
377	*	Reserved
377	*	Reserved
377	*	Reserved
377	*	Reserved
378	89CBL08	Disconnect 08 close block
378	89OSI08	Disconnect 08 open seal-in timer timed out
378	89CSI08	Disconnect 08 close seal-in timer timed out
378	89OIR08	Disconnect 08 open immobility timer reset
378	89CIR08	Disconnect 08 close immobility timer reset
378	89OBL08	Disconnect 08 open block
378	89ORS08	Disconnect 08 open reset
378	89CRS08	Disconnect 08 close reset
379	89OIM08	Disconnect 08 open immobility timer timed out
379	89CIM08	Disconnect 08 close immobility timer timed out
379	*	Reserved
379	*	Reserved
379	*	Reserved
379	*	Reserved
379	*	Reserved
379	*	Reserved
380	89CBL09	Disconnect 09 close block
380	89OSI09	Disconnect 09 open seal-in timer timed out
380	89CSI09	Disconnect 09 close seal-in timer timed out
380	89OIR09	Disconnect 09 open immobility timer reset
380	89CIR09	Disconnect 09 close immobility timer reset
380	89OBL09	Disconnect 09 open block
380	89ORS09	Disconnect 09 open reset
380	89CRS09	Disconnect 09 close reset
381	89OIM09	Disconnect 09 open immobility timer timed out
381	89CIM09	Disconnect 09 close immobility timer timed out
381	*	Reserved
381	*	Reserved
381	*	Reserved
381	*	Reserved

Table 11.68 Relay Word Bits: Bay Control Disconnect Timers and Breaker Status (Sheet 5 of 5)

Row	Name	Description
381	*	Reserved
381	*	Reserved
382	89CBL10	Disconnect 10 close block
382	89OSI10	Disconnect 10 open seal-in timer timed out
382	89CSI10	Disconnect 10 close seal-in timer timed out
382	89OIR10	Disconnect 10 open immobility timer reset
382	89CIR10	Disconnect 10 close immobility timer reset
382	89OBL10	Disconnect 10 open block
382	89ORS10	Disconnect 10 open reset
382	89CRS10	Disconnect 10 close reset
383	89OIM10	Disconnect 10 open immobility timer timed out
383	89CIM10	Disconnect 10 close immobility timer timed out
383	*	Reserved
383	*	Reserved
383	*	Reserved
383	*	Reserved
383	*	Reserved
383	*	Reserved

Table 11.69 Under/Overvoltage Elements (Sheet 1 of 2)

Row	Name	Description
384	271P1	Undervoltage Element 1, Level 1 asserted
384	271P1T	Undervoltage Element 1, Level 1 timed out
384	271P2	Undervoltage Element 1, Level 2 asserted
384	27TC1	Undervoltage Element 1, torque control
384	272P1	Undervoltage Element 2, Level 1 asserted
384	272P1T	Undervoltage Element 2, Level 1 timed out
384	272P2	Undervoltage Element 2, Level 2 asserted
384	27TC2	Undervoltage Element 2, torque control
385	273P1	Undervoltage Element 3, Level 1 asserted
385	273P1T	Undervoltage Element 3, Level 1 timed out
385	273P2	Undervoltage Element 3, Level 2 asserted
385	27TC3	Undervoltage Element 3, torque control
385	274P1	Undervoltage Element 4, Level 1 asserted
385	274P1T	Undervoltage Element 4, Level 1 timed out
385	274P2	Undervoltage Element 4, Level 2 asserted
385	27TC4	Undervoltage Element 4, torque control
386	275P1	Undervoltage Element 5, Level 1 asserted
386	275P1T	Undervoltage Element 5, Level 1 timed out
386	275P2	Undervoltage Element 5, Level 2 asserted
386	27TC5	Undervoltage Element 5, torque control

Table 11.69 Under/Overvoltage Elements (Sheet 2 of 2)

Row	Name	Description
386	276P1	Undervoltage Element 6, Level 1 asserted
386	276P1T	Undervoltage Element 6, Level 1 timed out
386	276P2	Undervoltage Element 6, Level 2 asserted
386	27TC6	Undervoltage Element 6, torque control
387	591P1	Overvoltage Element 1, Level 1 asserted
387	591P1T	Overvoltage Element 1, Level 1 timed out
387	591P2	Overvoltage Element 1, Level 2 asserted
387	59TC1	Overvoltage Element 1, torque control
387	592P1	Overvoltage Element 2, Level 1 asserted
387	592P1T	Overvoltage Element 2, Level 1 timed out
387	592P2	Overvoltage Element 2, Level 2 asserted
387	59TC2	Overvoltage Element 2, torque control
388	593P1	Overvoltage Element 3, Level 1 asserted
388	593P1T	Overvoltage Element 3, Level 1 timed out
388	593P2	Overvoltage Element 3, Level 2 asserted
388	59TC3	Overvoltage Element 3, torque control
388	594P1	Overvoltage Element 4, Level 1 asserted
388	594P1T	Overvoltage Element 4, Level 1 timed out
388	594P2	Overvoltage Element 4, Level 2 asserted
388	59TC4	Overvoltage Element 4, torque control
389	595P1	Overvoltage Element 5, Level 1 asserted
389	595P1T	Overvoltage Element 5, Level 1 timed out
389	595P2	Overvoltage Element 5, Level 2 asserted
389	59TC5	Overvoltage Element 5, torque control
389	596P1	Overvoltage Element 6, Level 1 asserted
389	596P1T	Overvoltage Element 6, Level 1 timed out
389	596P2	Overvoltage Element 6, Level 2 asserted
389	59TC6	Overvoltage Element 6, torque control
390–391	*	Reserved

Table 11.70 Relay Word Bits: 81 Frequency Elements (Sheet 1 of 2)

Row	Name	Description
392	81D1	Level 1 definite-time frequency element pickup
392	81D1T	Level 1 definite-time frequency element delay
392	81D1OVR	Level 1 overfrequency element pickup
392	81D1UDR	Level 1 underfrequency element pickup
392	27B81	Undervoltage supervision for frequency elements
392	*	Reserved
392	*	Reserved
392	*	Reserved
393	81D2	Level 2 definite-time frequency element pickup

Table 11.70 Relay Word Bits: 81 Frequency Elements (Sheet 2 of 2)

Row	Name	Description
393	81D2T	Level 2 definite-time frequency element delay
393	81D2OVR	Level 2 overfrequency element pickup
393	81D2UDR	Level 2 underfrequency element pickup
393	81D3	Level 3 definite-time frequency element pickup
393	81D3T	Level 3 definite-time frequency element delay
393	81D3OVR	Level 3 overfrequency element pickup
393	81D3UDR	Level 3 underfrequency element pickup
394	81D4	Level 4 definite-time frequency element pickup
394	81D4T	Level 4 definite-time frequency element delay
394	81D4OVR	Level 4 overfrequency element pickup
394	81D4UDR	Level 4 underfrequency element pickup
394	81D5	Level 5 definite-time frequency element pickup
394	81D5T	Level 5 definite-time frequency element delay
394	81D5OVR	Level 5 overfrequency element pickup
394	81D5UDR	Level 5 underfrequency element pickup
395	81D6	Level 6 definite-time frequency element pickup
395	81D6T	Level 6 definite-time frequency element delay
395	81D6OVR	Level 6 overfrequency element pickup
395	81D6UDR	Level 6 underfrequency element pickup
395	*	Reserved
395	*	Reserved
395	*	Reserved
395	*	Reserved

Table 11.71 Full-Cycle Mho and Quad Distance (Sheet 1 of 2)

Row	Name	Description
396	ENX2AG	Enable A-Phase Ipa polarized reactance element
396	ENX2BG	Enable B-Phase Ipb polarized reactance element
396	ENX2CG	Enable C-Phase Ipc polarized reactance element
396	CNR2AG	Control A-Phase Ipa polarized right blinder
396	CNR2BG	Control B-Phase Ipb polarized right blinder
396	CNR2CG	Control C-Phase Ipc polarized right blinder
396	CNR1AG	Control A-Phase composite current polarized right blinder
396	CNR1BG	Control B-Phase composite current polarized right blinder
397	CNR1CG	Control C-Phase composite current polarized right blinder
398	ENX2AB	Enable AB negative-sequence reactance element
398	ENX2BC	Enable BC negative-sequence reactance element
398	ENX2CA	Enable CA negative-sequence reactance element
398	CNR1AB	Control AB positive-sequence right blinder
398	CNR1BC	Control BC positive-sequence right blinder
398	CNR1CA	Control CA positive-sequence right blinder

Table 11.71 Full-Cycle Mho and Quad Distance (Sheet 2 of 2)

Row	Name	Description
398	CNR2AB	Control AB negative-sequence right blinder
398	CNR2BC	Control BC negative-sequence right blinder
399	CNR2CA	Control CA negative-sequence right blinder

Table 11.72 Time and Date Management

Row	Name	Description
400	PTPSYNC	Synchronized to a high quality PTP source
400	PTP_TIM	A valid PTP time source is detected
400	PTP_SET	Qualify PTP high accuracy time source
400	PTP_RST	Disqualify PTP high accuracy time source
400	PTP_OK	PTP is available and has sufficient quality
400	PTP_BNP	Bad jitter on PTP signals and the PTP signal is lost afterwards
400	P5ABSW	Port 5A or 5B has just become active

Table 11.73 Remote Axion Status

Row	Name	Description
403	IO300OK	Communications status of Interface Board 300 when installed or commissioned
403	IO400OK	Communications status of Interface Board 400 when installed or commissioned
403	IO500OK	Communications status of Interface Board 500 when installed or commissioned
*	Reserved	
*	Reserved	
*	Reserved	
*	Reserved	
*	Reserved	

Table 11.74 Additional Inputs and Outputs

Row	Name	Description
404	IN401-408	Optional I/O Board 3 Input 1–8
405	IN409-416	Optional I/O Board 3 Input 9-16
406	IN417-424	Optional I/O Board 3 Input 17–24
407	*	Reserved
408	IN501-508	Optional I/O Board 4 Input 1–8
409	IN509-516	Optional I/O Board 4 Input 9-16
410	IN517-524	Optional I/O Board 4 Input 17–24
411	*	Reserved
412	OUT401-408	Optional I/O Board 3 Output 1–8
413	OUT409-416	Optional I/O Board 3 Output 9-16
414	OUT501-508	Optional I/O Board 4 Output 1–8
415	OUT509-516	Optional I/O Board 4 Output 9-16

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S E C T I O N 1 2

Analog Quantities

This section contains tables of the analog quantities available within the SEL-421 Relay.

Use *Table 12.1* and *Table 12.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC control equation relay settings. *Table 12.1* lists the analog quantities alphabetically, and *Table 12.2* groups the analog quantities by function.

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 1 of 12)

Label	Description	Unit
3DPF	Three-phase displacement power factor	NA
3I0WFA	Terminal W, zero-sequence filtered current, angle	Degrees [°] (±180°)
3I0WFI	Terminal W, zero-sequence filtered current, imaginary component	Amperes [A] (secondary)
3I0WFM	Terminal W, zero-sequence filtered current, magnitude	Amperes [A] (secondary)
3I0WFR	Terminal W, zero-sequence filtered current, real component	Amperes [A] (secondary)
3I0XFA	Terminal X, zero-sequence filtered current, angle	Degrees [°] (±180°)
3I0XFI	Terminal X, zero-sequence filtered current, imaginary component	Amperes [A] (secondary)
3I0XFM	Terminal X, zero-sequence filtered current, magnitude	Amperes [A] (secondary)
3I0XFR	Terminal X, zero-sequence filtered current, real component	Amperes [A] (secondary)
3I2D	Demand negative-sequence current	Amperes [A] (secondary)
3I2PKD	Peak demand negative-sequence current	Amperes [A] (primary)
3IA2WFA	Terminal W, negative-sequence filtered current, angle	Degrees [°] (±180°)
3IA2WFI	Terminal W, negative-sequence filtered current, imaginary component	Amperes [A] (secondary)
3IA2WFM	Terminal W, negative-sequence filtered current, magnitude	Amperes [A] (secondary)
3IA2WFR	Terminal W, negative-sequence filtered current, real component	Amperes [A] (secondary)
3IA2XFA	Terminal X, negative-sequence filtered current, angle	Degrees [°] (±180°)
3IA2XFI	Terminal X, negative-sequence filtered current, imaginary component	Amperes [A] (secondary)
3IA2XFM	Terminal X, negative-sequence filtered current, magnitude	Amperes [A] (secondary)
3IA2XFR	Terminal X, negative-sequence filtered current, real component	Amperes [A] (secondary)
3MWH3T	Total three-phase energy; Megawatt-hours	Megawatt-hour [MWh] (primary)
3MWHIN	Negative (import) three-phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
3MWHOUT	Positive (export) three-phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
3P	Three-phase real power	Megawatts [MW] (primary)
3P_F	Fundamental real power (three-phase)	Megawatts [MW] (primary)
3PD	Demand three-phase real power	Megawatts [MW] (primary)
3PF	Three-phase power factor	N/A
3PPKD	Peak demand three-phase real power	Megawatts [MW] (primary)
3PSHOT	Present value of three-pole shot counter	N/A

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 12)

Label	Description	Unit
3Q_F	Fundamental reactive three-phase power	Megavars [MVAr] (primary)
3QD	Demand three-phase reactive power	Megavars [MVAr] (primary)
3QPKD	Peak demand three-phase reactive power	Megavars [MVAr] (primary)
3S_F	Fundamental apparent three-phase power	Megavolt-amperes [MVA] (primary)
3U	Apparent three-phase power	Megavolt-amperes [MVA] (primary)
3UD	Demand three-phase apparent power	Megavolt-amperes [MVA] (primary)
3UPKD	Peak demand three-phase apparent power	Megavolt-amperes [MVA] (primary)
3V0A	10-cycle average zero-sequence voltage (angle)	Degrees [°] (±180)
3V0FIA	Zero-sequence instantaneous voltage angle	Degrees [°] (±180)
3V0FIM	Zero-sequence instantaneous voltage magnitude	Volts [V] (secondary)
3V0M	10-cycle average zero-sequence voltage (magnitude)	Kilo-volts [kV] (primary)
3V0YFA	Terminal Y, zero-sequence filtered voltage, angle	Degrees [°] (±180°)
3V0YFI	Terminal Y, zero-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3V0YFM	Terminal Y, zero-sequence filtered voltage, magnitude	Volts [V] (secondary)
3V0YFR	Terminal Y, zero-sequence filtered voltage, real component	Volts [V] (secondary)
3V0ZFA	Terminal Z, zero-sequence filtered voltage, angle	Degrees [°] (±180°)
3V0ZFI	Terminal Z, zero-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3V0ZFM	Terminal Z, zero-sequence filtered voltage, magnitude	Volts [V] (secondary)
3V0ZFR	Terminal Z, zero-sequence filtered voltage, real component	Volts [V] (secondary)
3V2A	10-cycle average negative-sequence voltage angle	Degrees [°] (±180)
3V2FIA	Negative-sequence instantaneous voltage angle	Degrees [°] (±180)
3V2FIM	Negative-sequence instantaneous voltage magnitude	Volts [V] (secondary)
3V2M	10-cycle average negative-sequence voltage magnitude	Kilo-volts [kV] (primary)
3VA2YFA	Terminal Y, negative-sequence filtered voltage, angle	Degrees [°] (±180°)
3VA2YFI	Terminal Y, negative-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3VA2YFM	Terminal Y, negative-sequence filtered voltage, magnitude	Volts [V] (secondary)
3VA2YFR	Terminal Y, negative-sequence filtered voltage, real component	Volts [V] (secondary)
3VA2ZFA	Terminal Z, negative-sequence filtered voltage, angle	Degrees [°] (±180°)
3VA2ZFI	Terminal Z, negative-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3VA2ZFM	Terminal Z, negative-sequence filtered voltage, magnitude	Volts [V] (secondary)
3VA2ZFR	Terminal Z, negative-sequence filtered voltage, real component	Volts [V] (secondary)
51P01–51P10	51 element pickup value	Amperes [A] (secondary)
51TD01–51D10	51 element time dial setting	N/A
ACN01CV–ACN32CV	Automation SELOGIC counter current value	N/A
ACN01PV–ACN32PV	Automation SELOGIC counter preset value	N/A
ACTGRP	Active group setting	N/A
AMV001–AMV256	Automation SELOGIC math variable	N/A
ANG1DIF, ANG1DIF	VSnang-VPang	Degrees [°] (±180)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 12)

Label	Description	Unit
AST01ET–AST32ET	Automation SELOGIC math sequencing timer elapsed time	Seconds (s)
AST01PT–AST32PT	Automation SELOGIC sequencing timer preset time	Seconds (s)
B1BCWPA, B1BCWPBA, B1BCWPC	Breaker contact wear (Breaker 1)	Percent
B1IAFA, B1IBFA, B1ICFA	10-cycle average fundamental phase current angle (Breaker 1)	Degrees [°] (±180)
B1IAFIM, B1IBFIM, B1ICFIM	Breaker 1 filtered instantaneous phase current magnitude	Amperes [A] (secondary)
B1IAFM, B1IBFM, B1ICFM	10-cycle average fundamental phase current magnitude (Breaker 1)	Amperes [A] (primary)
B1IARMS, B1IARMS, B1IARMS	10-cycle average rms phase-current (Breaker 1)	Amperes [A] (primary)
B1IGFIM	Breaker 1 zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
B1IMAXM	Breaker 1 maximum filtered instantaneous breaker phase current magnitude	Amperes [A] (secondary)
B21IAFA, B21IBFA, B2ICFA	10-cycle average fundamental phase current angle (Breaker 2)	Degrees [°] (±180)
B2BCWPA, B2BCWPBA, B2BCWPC	Breaker contact wear (Breaker 2)	Percent
B2IAFIM, B2IBFIM, B2ICFIM	Breaker 2 filtered instantaneous phase current magnitude	Amperes [A] (secondary)
B2IAFM, B2IBFM, B2ICFM	10-cycle average fundamental phase current magnitude (Breaker 2)	Amperes [A] (primary)
B2IARMS, B2IARMS, B2IARMS	10-cycle average rms phase-current (Breaker 2)	Amperes [A] (primary)
B2IGFIM	Breaker 2 zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
B2IMAXM	Breaker 2 maximum filtered instantaneous breaker phase current magnitude	Amperes [A] (secondary)
BNCDSJI	BNC port 100 PPS data stream jitter	μs
BNCOTJF	Fast converging BNC port ON TIME marker jitter, coarse accuracy	μs
BNCOTJS	Slow converging BNC port ON TIME marker jitter, fine accuracy	μs
BNCTBTW	Time between BNC 100 PPS pulses	μs
CTRW	Current transformer ratio, Terminal W	N/A
CTRX	Current transformer ratio, Terminal X	N/A
CUR_SRC	Current high-accuracy time source	N/A
DC1, DC2	Filtered station batt. dc voltage	Volts [V]
DC1MAX, DC2MAX	Maximum dc voltage	Volts [V]
DC1MIN, DC2MIN	Minimum dc voltage	Volts [V]
DC1NE, DC2NE	Average Negative to Ground dc voltage	Volts [V]
DC1PO, DC2PO	Average Positive to Ground dc voltage	Volts [V]
DC1RI, DC2RI	AC ripple of dc voltage	Volts [V]
DDOM	Date, day of the month (1–31)	Day
DDOW	Date, day of the week (1–SU,..., 7–SA)	Day
DDOY	Date, day of the year (1–366)	Day
DFDTP	Rate-of-change of frequency	Hertz/seconds [Hz/s]

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 4 of 12)

Label	Description	Unit
DFDTPM	Rate-of-change of frequency for synchrophasor data	Hertz/seconds [Hz/s]
DFDTPMD	Rate-of-change of frequency for synchrophasor data, delayed for RTC alignment	Hertz/seconds [Hz/s]
DLDOM	Local date, day of the month (1–31)	Day
DLDOW	Local date, day of the week (1-SU,..., 7-SA)	N/A
DLDOY	Local date, day of the year (1–366)	Day
DLMON	Local date, month (1–12)	Month
DLYEAR	Local date, year (2000–2200)	Year
DMON	Date, month (1–12)	Month
DPFA, DPFB, DPFC	Phase displacement power factor	N/A
DYEAR	Date, year (2000–2200)	Year
FLOC	Fault location	Per unit (pu)
FOSPM	Fraction of second of the synchrophasor data packet	Seconds [s]
FOSPMD	Fraction of second of the synchrophasor data packet, delayed for RTC alignment	Seconds [s]
FREQ[a]	Tracking frequency	Hertz [Hz]
FREQP[a]	Frequency for under-/overfrequency elements	Hertz [Hz]
FREQPM	Frequency for synchrophasor data	Hertz [Hz]
FREQPMD	Frequency for synchrophasor data, delayed for RTC alignment	Hertz [Hz]
I1SPMA	Positive-sequence synchrophasor current angle, Terminal S	Degrees [°] (±180)
I1SPMAD	Positive sequence synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees [°] (±180)
I1SPMI	Positive-sequence synchrophasor current imaginary component, Terminal S	Amperes [A] (primary)
I1SPMID	Positive sequence synchrophasor current imaginary component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1SPMM	Positive-sequence synchrophasor current magnitude, Terminal S	Amperes [A] (primary)
I1SPMMD	Positive sequence synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1SPMR	Positive-sequence synchrophasor current real component, Terminal S	Amperes [A] (primary)
I1SPMRD	Positive sequence synchrophasor current real component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1WPMA	Positive-sequence synchrophasor current angle, Terminal W	Degrees [°] (±180)
I1WPMAD	Positive sequence synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees [°] (±180)
I1WPMI	Positive-sequence synchrophasor current imaginary component, Terminal W	Amperes [A] (primary)
I1WPMID	Positive sequence synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMM	Positive-sequence synchrophasor current magnitude, Terminal W	Amperes [A] (primary)
I1WPMMD	Positive sequence synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMR	Positive-sequence synchrophasor current real component, Terminal W	Amperes [A] (primary)
I1WPMRD	Positive sequence synchrophasor current real component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 5 of 12)

Label	Description	Unit
I1XPMA	Positive-sequence synchrophasor current angle, Terminal X	Degrees [°] (±180)
I1XPMAD	Positive sequence synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees [°] (±180)
I1XPMI	Positive-sequence synchrophasor current imaginary component, Terminal X	Amperes [A] (primary)
I1XPMID	Positive sequence synchrophasor current imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1XPMM	Positive-sequence synchrophasor current magnitude, Terminal X	Amperes [A] (primary)
I1XPMMD	Positive sequence synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1XPMR	Positive-sequence synchrophasor current real component, Terminal X	Amperes [A] (primary)
I1XPMRD	Positive sequence synchrophasor current real component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IA1WFA	Terminal W, positive-sequence filtered current, angle	Degrees [°] (±180°)
IA1WFI	Terminal W, positive-sequence filtered current, imaginary component	Amperes [A] (secondary)
IA1WFM	Terminal W, positive-sequence filtered current, magnitude	Amperes [A] (secondary)
IA1WFR	Terminal W, positive-sequence filtered current, real component	Amperes [A] (secondary)
IA1XFA	Terminal X, positive-sequence filtered current, angle	Degrees [°] (±180°)
IA1XFI	Terminal X, positive-sequence filtered current, imaginary component	Amperes [A] (secondary)
IA1XFM	Terminal X, positive-sequence filtered current, magnitude	Amperes [A] (secondary)
IA1XFR	Terminal X, positive-sequence filtered current, real component	Amperes [A] (secondary)
IAD, IBD, ICD	Demand phase current	Amperes [A] (primary)
IAPKD, IBPKD, ICPKD	Peak demand phase current	Amperes [A] (primary)
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle, Terminal S	Degrees [°] (±180)
IASPMAD, IBSPMAD, ICSPMAD	Synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees [°] (±180)
IASPMI, IBSPMI, ICSPMI	Synchrophasor current imaginary component, Terminal S	Amperes [A] (primary)
IASPMID, IBSPMID, ICSPMID	Synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude, Terminal S	Amperes [A] (primary)
IASPMMD, IBSPMMD, ICSPMMD	Synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IASPMR, IBSPMR, ICSPMR	Synchrophasor current real component, Terminal S	Amperes [A] (primary)
IASPMRD, IBSPMRD, ICSPMRD	Synchrophasor current real component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IAWFA	A-Phase, Terminal W, filtered current, angle	Degrees [°] (±180°)
IAWFI	A-Phase Terminal W, filtered current, imaginary component	Amperes [A] (secondary)
IAWFM	A-Phase, Terminal W, filtered current, magnitude	Amperes [A] (secondary)
IAWFR	A-Phase Terminal W, filtered current, real component	Amperes [A] (secondary)
IAWM, IBWM, ICWM	Filtered instantaneous current magnitude, Terminal W	Amperes [A] (secondary)
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle, Terminal W	Degrees [°] (±180)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 6 of 12)

Label	Description	Unit
IAWPMAD, IBWPMAD, ICWPMAD	Synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees [°] (±180)
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current imaginary component, Terminal W	Amperes [A] (primary)
IAWPMID, IBWPMID, ICWPMID	Synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude, Terminal W	Amperes [A] (primary)
IAWPMMD, IBWPMMD, ICWPMMD	Synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current real component, Terminal W	Amperes [A] (primary)
IAWPMRD, IBWPMRD, ICWPMRD	Synchrophasor current real component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAXFA	A-Phase, Terminal X, filtered current, angle	Degrees [°] (±180°)
IAXFI	A-Phase Terminal X, filtered current, imaginary component	Amperes [A] (secondary)
IAXFM	A-Phase, Terminal X, filtered current, magnitude	Amperes [A] (secondary)
IAXFR	A-Phase Terminal X, filtered current, real component	Amperes [A] (secondary)
IAXM, IBXM, ICXM	Filtered instantaneous current magnitude, Terminal X	Amperes [A] (secondary)
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle, Terminal X	Degrees [°] (±180)
IAXPMAD, IBXPMAD, ICXPMAD	Synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees [°] (±180)
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current imaginary component, Terminal X	Amperes [A] (primary)
IAXPMID, IBXPMID, ICXPMID	Synchrophasor current imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude, Terminal X	Amperes [A] (primary)
IAXPMMD, IBXPMMD, ICXPMMD	Synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current real component, Terminal X	Amperes [A] (primary)
IAXPMRD, IBXPMRD, ICXPMRD	Synchrophasor current real component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IBWFA	B-Phase, Terminal W, filtered current, angle	Degrees [°] (±180°)
IBWFI	B-Phase, Terminal W, filtered current, imaginary component	Amperes [A] (secondary)
IBWFM	B-Phase, Terminal W, filtered current, magnitude	Amperes [A] (secondary)
IBWFR	B-Phase, Terminal W, filtered current, real component	Amperes [A] (secondary)
IBXFA	B-Phase, Terminal X, filtered current, angle	Degrees [°] (±180°)
IBXFI	B-Phase, Terminal X, filtered current, imaginary component	Amperes [A] (secondary)
IBXFM	B-Phase, Terminal X, filtered current, magnitude	Amperes [A] (secondary)
IBXFR	B-Phase, Terminal X, filtered current, real component	Amperes [A] (secondary)
ICWFA	C-Phase, Terminal W, filtered current, angle	Degrees [°] (±180°)
ICWFI	C-Phase, Terminal W, filtered current, imaginary component	Amperes [A] (secondary)
ICWFM	C-Phase, Terminal W, filtered current, magnitude	Amperes [A] (secondary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 7 of 12)

Label	Description	Unit
ICWFR	C-Phase, Terminal W, filtered current, real component	Amperes [A] (secondary)
ICXFA	C-Phase, Terminal X, filtered current, angle	Degrees [°] (±180°)
ICXFI	C-Phase, Terminal X, filtered current, imaginary component	Amperes [A] (secondary)
ICXFM	C-Phase, Terminal X, filtered current, magnitude	Amperes [A] (secondary)
ICXFR	C-Phase, Terminal X, filtered current, real component	Amperes [A] (secondary)
IGD	Demand zero-sequence current	Amperes [A] (primary)
IGPKD	Peak demand zero-sequence current	Amperes [A] (primary)
IN201A–IN208A	Digital input values available as floating point quantities 0.0–255.0	A/D Counts
IN201V–IN208V	Contact input A/D counts converted to calibrated voltage	V
IN301A–IN308A	Digital input values available as floating point quantities 0.0–255.0	A/D Counts
IN301V–IN308V	Contact input A/D counts converted to calibrated voltage	V
IPFIM	Filtered instantaneous polarizing current magnitude	Amperes [A] (secondary)
L3I2A	10-cycle average negative-sequence current angle (line)	Degrees [°] (±180)
L3I2FIA	Negative-sequence instantaneous current angle	Degrees [°] (±180)
L3I2FIM	Negative-sequence instantaneous current magnitude	Amperes [A] (secondary)
L3I2M	10-cycle average negative-sequence current magnitude (line)	Amperes [A] (primary)
LI1A	10-cycle average positive-sequence current angle (line)	Degrees [°] (±180)
LI1FIA	Positive-sequence instantaneous current angle	Degrees [°] (±180)
LI1FIM	Positive-sequence instantaneous current magnitude	Amperes [A] (secondary)
LI1M	10-cycle average positive-sequence current magnitude (line)	Amperes [A] (primary)
LIAFA, LIBFA, LICFA	10-cycle average fundamental current angle (line)	Degrees [°] (±180)
LIAFIA, LIBFIA, LICFIA	Filtered instantaneous current angles	Degrees [°] (±180)
LIAFIM, LIBFIM, LICFIM	Filtered instantaneous phase current magnitude	Amperes [A] (secondary)
LIAFM, LIBFM, LICFM	10-cycle average fundamental current magnitude (line)	Amperes [A] (primary)
LIARMS, LIBRMS, LICRMS	10-cycle average RMS current (line)	Amperes [A] (primary)
LIGA	10-cycle average zero-sequence current angle (line)	Degrees [°] (±180)
LIGFIA	Zero-sequence instantaneous current angle	Degrees [°] (±180)
LIGFIM	Zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
LIGM	10-cycle average zero-sequence current magnitude (line)	Amperes [A] (primary)
LIMAXM	Filtered instantaneous maximum phase current magnitude	Amperes [A] (secondary)
MAB, MBC, MCA	Mho phase-to-phase impedance calculation	Ohms (secondary)
MAGZ1, MBGZ1, MCGZ1	Zone 1 mho ground impedance calculation	Ohms (secondary)
MAGF, MBGF, MCGF	Forward mho ground calculation (excludes Zone 1)	Ohms (secondary)
MAGR, MBGR, MCGR	Reverse mho ground calculation (all reverse zones)	Ohms (secondary)
MB1A–MB7A	Channel A received MIRRORED BITS analog values	N/A
MB1B–MB7B	Channel B received MIRRORED BITS analog values	N/A
MWHAIN, MWHBIN, MWHCIN	Negative (import) phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
MWHAOUT, MWH-BOUT, MWHCOUT	Positive (export) phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 8 of 12)

Label	Description	Unit
MWHAT, MWHBT, MWHCT	Total phase energy; Megawatt-hours	Megawatt-hour [MWh] (primary)
NEW_SRC	Selected high-accuracy time source	N/A
NVS1M, NVS2M	Voltage magnitude	Volts [V] (secondary)
PA, PB, PC	Real phase power	Megawatts [MW] (primary)
PA_F, PB_F, PC_F	Fundamental real power	Megawatts [MW] (primary)
PAD, PBD, PCD	Demand phase real power	Megawatts [MW] (primary)
PAPKD, PBPKD, PCPKD	Peak demand phase real power	Megawatts [MW] (primary)
PCN01CV–PCN32CV	Protection SELOGIC counter current value	N/A
PCN01PV–PCN32PV	Protection SELOGIC counter preset value	N/A
PCT01–PCT32	Protection SELOGIC conditioning timer pickup time	Cycles
PCT01DO–PCT32DO	Protection SELOGIC conditioning timer dropout time	Cycles
PFA, PFB, PFC	Power factor (phase)	N/A
PMV01–PMV64	Protection SELOGIC math variable	N/A
PST01ET–PST32ET	Protection SELOGIC sequencing timer elapsed time	Cycles
PST01PT–PST32PT	Protection SELOGIC sequencing timer preset time	Cycles
PTPDSJI	PTP 100PPS data stream jitter in µs	µs
PTPMCC	PTP master clock class enumerated value	N/A
PTPOTJS	Slow converging PTP ON TIME marker jitter in µs, fine accuracy	µs
PTPOTJF	Fast converging PTP ON TIME marker jitter in µs, coarse accuracy	µs
PTPOFST	Raw clock offset between PTP master and relay time	ns
PTPPORT	Active PTP port number	N/A
PTPTBTW	Time between PTP 100PPS pulses in µs	µs
PTPSTEN	PTP Port State enumerated value	N/A
PTRY	Y-Potential transformer ratio setting (divided by 1000)	N/A
PTRZ	Z-Potential transformer ratio setting (divided by 1000)	N/A
QA_F, QB_F, QC_F	Fundamental reactive power (phase)	Megavars [MVAr] (primary)
QAD, QBD, QCD	Demand phase reactive power	Megavars [MVAr] (primary)
QAPKD, QBPKD, QCPKD	Peak demand phase reactive power	Megavars [MVAr] (primary)
RA001–RA256	Remote analogs	N/A
RAO01–RAO64	Remote analog output	N/A
RLYTEMP	Relay temperature (temperature of the enclosure)	°C (degrees Celsius)
RTCAA01–RTCAA08	Channel A remote synchrophasor analogs (unit depends on remote synchrophasor contents)	N/A
RTCAP01–RTCAP32	Channel A remote synchrophasor phasors (unit depends on remote synchrophasor contents)	N/A
RTCBA01–RTCBA08	Channel B remote synchrophasor analogs (unit depends on remote synchrophasor contents)	N/A
RTCBP01–RTCBP32	Channel B remote synchrophasor phasors (unit depends on remote synchrophasor contents)	N/A
RTCDFA	Rate-of-change of Channel A remote frequency (from remote synchrophasors)	Hertz/seconds [Hz/s]

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 9 of 12)

Label	Description	Unit
RTCDFB	Rate-of-change of Channel B remote frequency (from remote synchrophasors)	Hertz/seconds [Hz/s]
RTCFA	Channel A remote frequency (from remote synchrophasors)	Hertz [Hz]
RTCFB	Channel B remote frequency (from remote synchrophasors)	Hertz [Hz]
RTD01–RTD12	Instantaneous temperatures from external SEL-2600	°C (degrees Celsius)
SA_F, SB_F, SC_F	Fundamental apparent power (phase)	Megavolt-amperes [MVA] (primary)
SCV	Unfiltered swing center voltage	Per unit (pu)
SERDSJI	Serial port 100 PPS data stream jitter	µs
SEROTJF	Fast converging serial port ON TIME marker jitter, coarse accuracy	µs
SEROTJS	Slow converging serial port ON TIME marker jitter, fine accuracy	µs
SERTBTW	Time between serial 100 PPS pulses	µs
SHOT1_1	Total number of 1st shot single-pole recloses	N/A
SHOT1_2	Total number of 2nd shot single-pole recloses	N/A
SHOT1_T	Total number of single-pole reclosing shots Issued	N/A
SHOT3_1	Total number of 1st shot three-pole recloses	N/A
SHOT3_2	Total number of 2nd shot three-pole recloses	N/A
SHOT3_3	Total number of 3rd shot three-pole recloses	N/A
SHOT3_4	Total number of 4th shot three-pole recloses	N/A
SHOT3_T	Total number of three-pole recloses	N/A
SLIP1, SLIP2	Slip (fs1/2-fp)	Hertz [Hz]
SODPM	Second of day of the synchrophasor data packet	Seconds [s]
SODPMD	Second of day of the synchrophasor data packet, delayed for RTC alignment	Seconds [s]
SPSHOT	Present value of single-pole shot counter	N/A
SQUAL	IRIG-B synchronization accuracy	µs
TE	Time error	Seconds (s)
TECORR[b]	Time error correction preload value	Seconds (s)
THR	UTC time, hour (0–23)	Hour (hr)
TLHR	Local time, hour (0–23)	Hour (hr)
TLMIN	Local time, minute (0–59)	Minutes (min)
TLMSEC	Local time, milliseconds (0–999)	Milliseconds (ms)
TLNSEC	Local time, nanoseconds (0–999999)	Nanoseconds (ns)
TLODMS	Local time of day, milliseconds (0–86400000)	Milliseconds (ms)
TLSEC	Local time, seconds (0–59)	Seconds (s)
TMIN	UTC time, minute (0–59)	Minutes (min)
TMSEC	UTC time, milliseconds (0–999)	Milliseconds (ms)
TNSEC	UTC time, nanoseconds (0–999999)	Nanoseconds (ns)
TODMS	UTC time of day in milliseconds (0–86400000)	Milliseconds (ms)
TQUAL	Worst case IRIG-B clock time error	Seconds (s)
TSEC	UTC time, seconds (0–59)	Seconds (s)
TUTC	Offset from IRIG-B time to UTC time	Hour

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 10 of 12)

Label	Description	Unit
UA, UB, UC	Apparent power (phase)	Megavolt-amperes [MVA] (primary)
UAD, UBD, UCD	Demand phase apparent power	Megavolt-amperes [MVA] (primary)
UAPKD, UBPKD, UCPKD	Peak demand phase apparent power	Megavolt-amperes [MVA] (primary)
V1A	10-cycle average positive-sequence voltage angle	Degrees [°] (±180)
V1FIA	Positive-sequence instantaneous voltage angle	Degrees [°] (±180)
V1FIM	Positive-sequence instantaneous voltage magnitude	Volts [V] (secondary)
V1M	10-cycle average positive-sequence voltage magnitude	Kilo-volts [kV] (primary)
V1YPMA	Positive-sequence synchrophasor voltage angle, Terminal Y	Degrees [°] (±180)
V1YPMAD	Positive sequence synchrophasor voltage angle, Terminal Y, delayed for RTC alignment	Degrees [°] (±180)
V1YPMI	Positive-sequence synchrophasor voltage imaginary component, Terminal Y	Kilo Volts [kV] (primary)
V1YPMID	Positive-sequence synchrophasor voltage imaginary component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1YPMM	Positive-sequence synchrophasor voltage magnitude, Terminal Y	Kilo Volts [kV] (primary)
V1YPMMD	Positive-sequence synchrophasor voltage magnitude, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1YPMR	Positive-sequence synchrophasor voltage real component, Terminal Y	Kilo Volts [kV] (primary)
V1YPMRD	Positive-sequence synchrophasor voltage real component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMA	Positive-sequence synchrophasor voltage angle, Terminal Z	Degrees [°] (±180)
V1ZPMAD	Positive sequence Synchrophasor voltage angle, Terminal Z, delayed for RTC alignment	Degrees [°] (±180)
V1ZPMI	Positive-sequence synchrophasor voltage imaginary component, Terminal Z	Kilo Volts [kV] (primary)
V1ZPMID	Positive-sequence synchrophasor voltage imaginary component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMM	Positive-sequence synchrophasor voltage magnitude, Terminal Z	Kilo Volts [kV] (primary)
V1ZPMMD	Positive-sequence synchrophasor voltage magnitude, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMR	Positive-sequence synchrophasor voltage real component, Terminal Z	Kilo Volts [kV] (primary)
V1ZPMRD	Positive-sequence synchrophasor voltage real component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
VA1YFA	Terminal Y, positive-sequence filtered voltage, angle	Degrees [°] (±180°)
VA1YFI	Terminal Y, positive-sequence filtered voltage, imaginary component	Volts [V] (secondary)
VA1YFM	Terminal Y, positive-sequence filtered voltage, magnitude	Volts [V] (secondary)
VA1YFR	Terminal Y, positive-sequence filtered voltage, real component	Volts [V] (secondary)
VA1ZFA	Terminal Z, positive-sequence filtered voltage, angle	Degrees [°] (±180°)
VA1ZFI	Terminal Z, positive-sequence filtered voltage, imaginary component	Volts [V] (secondary)
VA1ZFM	Terminal Z, positive-sequence filtered voltage, magnitude	Volts [V] (secondary)
VA1ZFR	Terminal Z, positive-sequence filtered voltage, real component	Volts [V] (secondary)
VABFA, VBCFA, VCAFA	10-cycle average fundamental phase-to-phase voltage angle	Degrees [°] (±180)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 11 of 12)

Label	Description	Unit
VABFM, VBCFM, VCAFM	10-cycle average fundamental phase-to-phase voltage magnitude	Kilo-volts [kV] (primary)
VABRMS, VBCRMS, VCARMS	10-cycle average RMS phase-to-phase voltage magnitude	Kilo-volts [kV] (primary)
VAFA, VBFA, VCFA	10-cycle average fundamental phase voltage angle	Degrees [°] (±180)
VAFIA, VBFIA, VCFIA	Filtered instantaneous voltage angles	Degrees [°] (±180)
VAFIM, VBFIM, VCFIM	Filtered instantaneous phase voltage magnitude	Volts [V] (secondary)
VAFM, VBFM, VCFM	10-cycle average fundamental phase voltage magnitude	Kilo-volts [kV] (primary)
VARMS, VBRMS, VCRMS	10-cycle average RMS phase-voltage	Kilo-volts [kV] (primary)
VAYFA	A-Phase Terminal Y, filtered voltage, angle	Degrees [°] (±180°)
VAYFI	A-Phase Terminal Y, filtered voltage, imaginary component	Volts [V] (secondary)
VAYFM	A-Phase Terminal Y, filtered voltage, magnitude	Volts [V] (secondary)
VAYFR	A-Phase Terminal Y, filtered voltage, real component	Volts [V] (secondary)
VAYM, VBYM, VCYM	Filtered instantaneous voltage magnitude, Terminal Y	Volts [V] (secondary)
VAYPMA, VBYPMA, VCYPMA	Synchrophasor voltage angle, Terminal Y	Degrees [°] (±180)
VAYPMAD, VBYPMAD, VCYPMAD	Synchrophasor voltage angle, Terminal Y, delayed for RTC alignment	Degrees [°] (±180)
VAYPMI, VBYPMI, VCYPMI	Synchrophasor voltage imaginary component, Terminal Y	Kilo Volts [kV] (primary)
VAYPMID, VBYPMID, VCYPMID	Synchrophasor voltage imaginary component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAYPMM, VBYPMM, VCYPMM	Synchrophasor voltage magnitude, Terminal Y	Kilo Volts [kV] (primary)
VAYPMMD, VBYPMMD, VCYPMMD	Synchrophasor voltage magnitude, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAYPMR, VBYPMR, VCYPMR	Synchrophasor voltage real component, Terminal Y	Kilo Volts [kV] (primary)
VAYPMRD, VBYPMRD, VCYPMRD	Synchrophasor voltage real component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZFA	A-Phase, Terminal Z, filtered voltage, angle	Degrees [°] (±180°)
VAZFI	A-Phase, Terminal Z, filtered voltage, imaginary component	Volts [V] (secondary)
VAZFM	A-Phase, Terminal Z, filtered voltage, magnitude	Volts [V] (secondary)
VAZFR	A-Phase, Terminal Z, filtered voltage, real component	Volts [V] (secondary)
VAZM, VBZM, VCZM	Filtered instantaneous voltage magnitude, Terminal Z	Volts [V] (secondary)
VAZPMA, VBZPMA, VCZPMA	Synchrophasor voltage angle, Terminal Z	Degrees [°] (±180)
VAZPMAD, VBZPMAD, VCZPMAD	Synchrophasor voltage angle, Terminal Z, delayed for RTC alignment	Degrees [°] (±180)
VAZPMID, VBZPMID, VCZPMID	Synchrophasor voltage imaginary component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZPMM, VBZPMM, VCZPMM	Synchrophasor voltage magnitude, Terminal Z	Kilo Volts [kV] (primary)
VAZPMMD, VBZP-MMD, VCZPMMD	Synchrophasor voltage magnitude, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)

Table 12.1 Analog Quantities Sorted Alphabetically (Sheet 12 of 12)

Label	Description	Unit
VAZPMRD, VBZPMRD, VCZPMRD	Synchrophasor voltage real component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZYPMI, VBZPMI, VCZYPMI	Synchrophasor voltage imaginary component, Terminal Z	Kilo Volts [kV] (primary)
VAZYPMR, VBZPMR, VCZPMR	Synchrophasor voltage real component, Terminal Z	Kilo Volts [kV] (primary)
VBYFA	B-Phase, Terminal Y, filtered voltage, angle	Degrees [°] (±180°)
VBYFI	B-Phase, Terminal Y, filtered voltage, imaginary component	Volts [V] (secondary)
VBYFM	B-Phase, Terminal Y, filtered voltage, magnitude	Volts [V] (secondary)
VBYFR	B-Phase, Terminal Y, filtered voltage, real component	Volts [V] (secondary)
VBZFA	B-Phase, Terminal Z, filtered voltage, angle	Degrees [°] (±180°)
VBZFI	B-Phase, Terminal Z, filtered voltage, imaginary component	Volts [V] (secondary)
VBZFM	B-Phase, Terminal Z, filtered voltage, magnitude	Volts [V] (secondary)
VBZFR	B-Phase, Terminal Z, filtered voltage, real component	Volts [V] (secondary)
VCYFA	C-Phase, Terminal Y, filtered voltage, angle	Degrees [°] (±180°)
VCYFI	C-Phase, Terminal Y, filtered voltage, imaginary component	Volts [V] (secondary)
VCYFM	C-Phase, Terminal Y, filtered voltage, magnitude	Volts [V] (secondary)
VCYFR	C-Phase, Terminal Y, filtered voltage, real component	Volts [V] (secondary)
VCZFA	C-Phase, Terminal Z, filtered voltage, angle	Degrees [°] (±180°)
VCZFI	C-Phase, Terminal Z, filtered voltage, imaginary component	Volts [V] (secondary)
VCZFM	C-Phase, Terminal Z, filtered voltage, magnitude	Volts [V] (secondary)
VCZFR	C-Phase, Terminal Z, filtered voltage, real component	Volts [V] (secondary)
VNMAXF	Instantaneous filtered maximum phase-to-neutral voltage magnitude	Volts [V] (secondary)
VNMINF	Instantaneous filtered minimum phase-to-neutral voltage magnitude	Volts [V] (secondary)
VPM	VP voltage magnitude	Volts [V] (secondary)
VPMAXF	Instantaneous filtered maximum phase-to-phase voltage magnitude	Volts [V] (secondary)
VPMINF	Instantaneous filtered minimum phase-to-phase voltage magnitude	Volts [V] (secondary)
Z1FA	Positive-sequence instantaneous impedance angle	Degrees [°] (±180)
Z1FM	Positive-sequence instantaneous impedance magnitude	Ohms [ohm] (secondary)

[a] Measured value if the relay can track frequency, otherwise FREQ = nominal frequency setting NFREQ, and DFDT is undefined.
[b] Copy of last value set by TEC command or DNP3.

Table 12.2 Analog Quantities Sorted by Function (Sheet 1 of 13)

Labels	Description	Unit
Instantaneous Currents and Voltages (After Source Selection)		
LIAFIM, LIBFIM, LICFIM	Filtered instantaneous phase current magnitude	Amperes [A] (secondary)
LIMAXM	Filtered instantaneous maximum phase current magnitude	Amperes [A] (secondary)
IPFIM	Filtered instantaneous polarizing current magnitude	Amperes [A] (secondary)
B1IAFIM, B1IBFIM, B1ICFIM	Breaker 1 filtered instantaneous phase current magnitude	Amperes [A] (secondary)
B2IAFIM, B2IBFIM, B2ICFIM	Breaker 2 filtered instantaneous phase current magnitude	Amperes [A] (secondary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 2 of 13)

Labels	Description	Unit
B1IMAXM	Breaker 1 maximum filtered instantaneous breaker phase current magnitude	Amperes [A] (secondary)
B2IMAXM	Breaker 2 maximum filtered instantaneous breaker phase current magnitude	Amperes [A] (secondary)
VAFIM, VBFIM, VCFIM	Filtered instantaneous phase voltage magnitude	Volts [V] (secondary)
LIAFIA, LIBFIA, LICFIA	Filtered instantaneous current angles	Degrees [°] (±180)
VAFIA, VBFIA, VCFIA	Filtered instantaneous voltage angles	Degrees [°] (±180)
LI1FIM	Positive-sequence instantaneous current magnitude	Amperes [A] (secondary)
L3I2FIM	Negative-sequence instantaneous current magnitude	Amperes [A] (secondary)
LIGFIM	Zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
V1FIM	Positive-sequence instantaneous voltage magnitude	Volts [V] (secondary)
3V2FIM	Negative-sequence instantaneous voltage magnitude	Volts [V] (secondary)
3V0FIM	Zero-sequence instantaneous voltage magnitude	Volts [V] (secondary)
B1IGFIM	Breaker 1 zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
B2IGFIM	Breaker 2 zero-sequence instantaneous current magnitude	Amperes [A] (secondary)
Z1FM	Positive-sequence instantaneous impedance magnitude	Ohms [ohm] (secondary)
L3I2FIA	Negative-sequence instantaneous current angle	Degrees [°] (±180)
LIGFIA	Zero-sequence instantaneous current angle	Degrees [°] (±180)
V1FIA	Positive-sequence instantaneous voltage angle	Degrees [°] (±180)
3V2FIA	Negative-sequence instantaneous voltage angle	Degrees [°] (±180)
3V0FIA	Zero-sequence instantaneous voltage angle	Degrees [°] (±180)
LI1FIA	Positive-sequence instantaneous current angle	Degrees [°] (±180)
Z1FA	Positive-sequence instantaneous impedance angle	Degrees [°] (±180)
Real and Imaginary Analog Quantities		
IAWFR, IBWFR, ICWFR	A-Phase, B-Phase, C-Phase Terminal W, filtered current, real component	Amperes [A] (secondary)
IAXFR, IBXFR, ICXFR	A-Phase, B-Phase, C-Phase Terminal X, filtered current, real component	Amperes [A] (secondary)
IAWFI, IBWFI, ICWFI	A-Phase, B-Phase, C-Phase Terminal W, filtered current, imaginary component	Amperes [A] (secondary)
IAXFI, IBXFI, ICXFI	A-Phase, B-Phase, C-Phase Terminal X, filtered current, imaginary component	Amperes [A] (secondary)
VAYFR, VBYFR, VCYFR	A-Phase, B-Phase, C-Phase, Terminal Y, filtered voltage, real component	Volts [V] (secondary)
VAZFR, VBZFR, VCZFR	A-Phase, B-Phase, C-Phase, Terminal Z, filtered voltage, real component	Volts [V] (secondary)
VAYFI, VBYFI, VCYFI	A-Phase, B-Phase, C-Phase, Terminal Y, filtered voltage, imaginary component	Volts [V] (secondary)
VAZFI, VBZFI, VCZFI	A-Phase, B-Phase, C-Phase, Terminal Z, filtered voltage, imaginary component	Volts [V] (secondary)
IA1WFR	Terminal W, positive-sequence filtered current, real component	Amperes [A] (secondary)
IA1XFR	Terminal X, positive-sequence filtered current, real component	Amperes [A] (secondary)
IA1WFI	Terminal W, positive-sequence filtered current, imaginary component	Amperes [A] (secondary)
IA1XFI	Terminal X, positive-sequence filtered current, imaginary component	Amperes [A] (secondary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 3 of 13)

Labels	Description	Unit
VA1YFR	Terminal Y, positive-sequence filtered voltage, real component	Volts [V] (secondary)
VA1ZFR	Terminal Z, positive-sequence filtered voltage, real component	Volts [V] (secondary)
VA1YFI	Terminal Y, positive-sequence filtered voltage, imaginary component	Volts [V] (secondary)
VA1ZFI	Terminal Z, positive-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3IA2WFR	Terminal W, negative-sequence filtered current, real component	Amperes [A] (secondary)
3IA2XFR	Terminal X, negative-sequence filtered current, real component	Amperes [A] (secondary)
3IA2WFI	Terminal W, negative-sequence filtered current, imaginary component	Amperes [A] (secondary)
3IA2XFI	Terminal X, negative-sequence filtered current, imaginary component	Amperes [A] (secondary)
3VA2YFR	Terminal Y, negative-sequence filtered voltage, real component	Volts [V] (secondary)
3VA2ZFR	Terminal Z, negative-sequence filtered voltage, real component	Volts [V] (secondary)
3VA2YFI	Terminal Y, negative-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3VA2ZFI	Terminal Z, negative-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3I0WFR	Terminal W, zero-sequence filtered current, real component	Amperes [A] (secondary)
3I0XFR	Terminal X, zero-sequence filtered current, real component	Amperes [A] (secondary)
3I0WFI	Terminal W, zero-sequence filtered current, imaginary component	Amperes [A] (secondary)
3I0XFI	Terminal X, zero-sequence filtered current, imaginary component	Amperes [A] (secondary)
3V0YFR	Terminal Y, zero-sequence filtered voltage, real component	Volts [V] (secondary)
3V0ZFR	Terminal Z, zero-sequence filtered voltage, real component	Volts [V] (secondary)
3V0YFI	Terminal Y, zero-sequence filtered voltage, imaginary component	Volts [V] (secondary)
3V0ZFI	Terminal Z, zero-sequence filtered voltage, imaginary component	Volts [V] (secondary)
IAWFM, IBWFM, ICWFM	A-Phase, B-Phase, C-Phase, Terminal W, filtered current, magnitude	Amperes [A] (secondary)
IAXFM, IBXFM, ICXFM	A-Phase, B-Phase, C-Phase, Terminal X, filtered current, magnitude	Amperes [A] (secondary)
VAYFM, VBYFM, VCYFM	A-Phase, B-Phase, C-Phase, Terminal Y, filtered voltage, magnitude	Volts [V] (secondary)
VAZFM, VBZFM, VCZFM	A-Phase, B-Phase, C-Phase, Terminal Z, filtered voltage, magnitude	Volts [V] (secondary)
IA1WFM	Terminal W, positive-sequence filtered current, magnitude	Amperes [A] (secondary)
IA1XFM	Terminal X, positive-sequence filtered current, magnitude	Amperes [A] (secondary)
VA1YFM	Terminal Y, positive-sequence filtered voltage, magnitude	Volts [V] (secondary)
VA1ZFM	Terminal Z, positive-sequence filtered voltage, magnitude	Volts [V] (secondary)
3IA2WFM	Terminal W, negative-sequence filtered current, magnitude	Amperes [A] (secondary)
3IA2XFM	Terminal X, negative-sequence filtered current, magnitude	Amperes [A] (secondary)
3VA2YFM	Terminal Y, negative-sequence filtered voltage, magnitude	Volts [V] (secondary)
3VA2ZFM	Terminal Z, negative-sequence filtered voltage, magnitude	Volts [V] (secondary)
3I0WFM	Terminal W, zero-sequence filtered current, magnitude	Amperes [A] (secondary)
3I0XFM	Terminal X, zero-sequence filtered current, magnitude	Amperes [A] (secondary)
3V0YFM	Terminal Y, zero-sequence filtered voltage, magnitude	Volts [V] (secondary)
3V0ZFM	Terminal Z, zero-sequence filtered voltage, magnitude	Volts [V] (secondary)
IAWFA, IBWFA, ICWFA	A-Phase, B-Phase, C-Phase, Terminal W, filtered current, angle	Degrees [°] (±180°)
IAXFA, IBXFA, ICXFA	A-Phase, B-Phase, C-Phase, Terminal X, filtered current, angle	Degrees [°] (±180°)

Table 12.2 Analog Quantities Sorted by Function (Sheet 4 of 13)

Labels	Description	Unit
VAYFA, VBYFA, VCYFA	A-Phase, B-Phase, C-Phase, Terminal Y, filtered voltage, angle	Degrees [°] (±180°)
VAZFA, VBZFA, VCZFA	A-Phase, B-Phase, C-Phase, Terminal Z, filtered voltage, angle	Degrees [°] (±180°)
IA1WFA	Terminal W, positive-sequence filtered current, angle	Degrees [°] (±180°)
IA1XFA	Terminal X, positive-sequence filtered current, angle	Degrees [°] (±180°)
VA1YFA	Terminal Y, positive-sequence filtered voltage, angle	Degrees [°] (±180°)
VA1ZFA	Terminal Z, positive-sequence filtered voltage, angle	Degrees [°] (±180°)
3IA2WFA	Terminal W, negative-sequence filtered current, angle	Degrees [°] (±180°)
3IA2XFA	Terminal X, negative-sequence filtered current, angle	Degrees [°] (±180°)
3VA2YFA	Terminal Y, negative-sequence filtered voltage, angle	Degrees [°] (±180°)
3VA2ZFA	Terminal Z, negative-sequence filtered voltage, angle	Degrees [°] (±180°)
3I0WFA	Terminal W, zero-sequence filtered current, angle	Degrees [°] (±180°)
3I0XFA	Terminal X, zero-sequence filtered current, angle	Degrees [°] (±180°)
3V0YFA	Terminal Y, zero-sequence filtered voltage, angle	Degrees [°] (±180°)
3V0ZFA	Terminal Z, zero-sequence filtered voltage, angle	Degrees [°] (±180°)
Current and Potential Transformer Ratios		
CTRW	Current transformer ratio, Terminal W	N/A
CTRX	Current transformer ratio, Terminal X	N/A
PTRY	Y-Potential transformer ratio setting (divided by 1000)	N/A
PTRZ	Z-Potential transformer ratio setting (divided by 1000)	N/A
Instantaneous Currents and Voltages (Before Source Selection)		
IAWM, IBWM, ICWM	Filtered instantaneous current magnitude, Terminal W	Amperes [A] (secondary)
IAXM, IBXM, ICXM	Filtered instantaneous current magnitude, Terminal X	Amperes [A] (secondary)
VAYM, VBYM, VCYM	Filtered instantaneous voltage magnitude, Terminal Y	Volts [V] (secondary)
VAZM, VBZM, VCZM	Filtered instantaneous voltage magnitude, Terminal Z	Volts [V] (secondary)
10-Cycle Averaged Fundamental Current and Voltage Magnitudes		
LIAFM, LIBFM, LICFM	10-cycle average fundamental current magnitude (line)	Amperes [A] (primary)
LIAFA, LIBFA, LICFA	10-cycle average fundamental current angle (line)	Degrees [°] (±180)
LIARMS, LIBRMS, LICRMS	10-cycle average rms current (line)	Amperes [A] (primary)
LI1M	10-cycle average positive-sequence current magnitude (line)	Amperes [A] (primary)
LI1A	10-cycle average positive-sequence current angle (line)	Degrees [°] (±180)
L3I2M	10-cycle average negative-sequence current magnitude (line)	Amperes [A] (primary)
L3I2A	10-cycle average negative-sequence current angle (line)	Degrees [°] (±180)
LIGM	10-cycle average zero-sequence current magnitude (line)	Amperes [A] (primary)
LIGA	10-cycle average zero-sequence current angle (line)	Degrees [°] (±180)
B1IAFM, B1IBFM, B1ICFM	10-cycle average fundamental phase current magnitude (Breaker 1)	Amperes [A] (primary)
B2IAFM, B2IBFM, B2ICFM	10-cycle average fundamental phase current magnitude (Breaker 2)	Amperes [A] (primary)
B1IAFA, B1IBFA, B1ICFA	10-cycle average fundamental phase current angle (Breaker 1)	Degrees [°] (±180)
B21IAFA, B21IBFA, B2ICFA	10-cycle average fundamental phase current angle (Breaker 2)	Degrees [°] (±180)

Table 12.2 Analog Quantities Sorted by Function (Sheet 5 of 13)

Labels	Description	Unit
B1IARMS, B1IARMS, B1IARMS	10-cycle average rms phase-current (Breaker 1)	Amperes [A] (primary)
B2IARMS, B2IARMS, B2IARMS	10-cycle average rms phase-current (Breaker 2)	Amperes [A] (primary)
VAFM, VBFM, VCFM	10-cycle average fundamental phase voltage magnitude	Kilo-volts [kV] (primary)
VAFA, VBFA, VCFA	10-cycle average fundamental phase voltage angle	Degrees [°] (±180)
VARMS, VBRMS, VCRMS	10-cycle average rms phase-voltage	Kilo-volts [kV] (primary)
VABFM, VBCFM, VCAFM	10-cycle average fundamental phase-to-phase voltage magnitude	Kilo-volts [kV] (primary)
VABFA, VBCFA, VCAFA	10-cycle average fundamental phase-to-phase voltage angle	Degrees [°] (±180)
VABRMS, VBCRMS, VCARMS	10-cycle average rms phase-to-phase voltage magnitude	Kilo-volts [kV] (primary)
V1M	10-cycle average positive-sequence voltage magnitude	Kilo-volts [kV] (primary)
V1A	10-cycle average positive-sequence voltage angle	Degrees [°] (±180)
VNMAXF	Instantaneous filtered maximum phase-to-neutral voltage magnitude	Volts [V] (secondary)
VNMINF	Instantaneous filtered minimum phase-to-neutral voltage magnitude	Volts [V] (secondary)
VPMAXF	Instantaneous filtered maximum phase-to-phase voltage magnitude	Volts [V] (secondary)
VPMINF	Instantaneous filtered minimum phase-to-phase voltage magnitude	Volts [V] (secondary)
3V2M	10-cycle average negative-sequence voltage magnitude	Kilo-volts [kV] (primary)
3V2A	10-cycle average negative-sequence voltage angle	Degrees [°] (±180)
3V0M	10-cycle average zero-sequence voltage (magnitude)	Kilo-volts [kV] (primary)
3V0A	10-cycle average zero-sequence voltage (angle)	Degrees [°] (±180)
Apparent, Real, and Reactive Power		
PA_F, Pb_F, PC_F	Fundamental real power	Megawatts [MW] (primary)
3P_F	Fundamental real power (three-phase)	Megawatts [MW] (primary)
PA, PB, PC	Real phase power	Megawatts [MW] (primary)
3P	Three-phase real power	Megawatts [MW] (primary)
QA_F, QB_F, QC_F	Fundamental reactive power (phase)	Megavars [MVAr] (primary)
3Q_F	Fundamental reactive three-phase power	Megavars [MVAr] (primary)
SA_F, SB_F, SC_F	Fundamental apparent power (phase)	Megavolt-amperes [MVA] (primary)
3S_F	Fundamental apparent three-phase power	Megavolt-amperes [MVA] (primary)
UA, UB, UC	Apparent power (phase)	Megavolt-amperes [MVA] (primary)
3U	Apparent three-phase power	Megavolt-amperes [MVA] (primary)
DPFA, DPFB,DPFC	Phase displacement power factor	N/A
3DPF	Three-phase displacement power factor	N/A
PFA, PFB, PFC	Power factor (phase)	N/A
3PF	Three-phase power factor	N/A
Synchronizing Quantities		
VPM	VP voltage magnitude	Volts [V] (secondary)
NVS1M, NVS2M	Voltage magnitude	Volts [V] (secondary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 6 of 13)

Labels	Description	Unit
ANG1DIF, ANG1DIF	VSnang-VPang	Degrees [°] (±180)
SLIP1, SLIP2	Slip (fs1/2-fp)	Hertz [Hz]
Overcurrent Elements		
51P01–51P10	51 element pickup value	Amperes [A] (secondary)
51TD01–51D10	51 element time dial setting	N/A
Battery Monitoring		
DC1, DC2	Filtered station battery dc voltage	Volts [V]
DC1PO, DC2PO	Average positive-to-ground dc voltage	Volts [V]
DC1NE, DC2NE	Average negative-to-ground dc voltage	Volts [V]
DC1RI, DC2RI	AC ripple of dc voltage	Volts [V]
DC1MIN, DC2MIN	Minimum dc voltage	Volts [V]
DC1MAX, DC2MAX	Maximum dc voltage	Volts [V]
Demand and Peak Demand Quantities		
IAPKD, IBPKD, ICPKD	Peak demand phase current	Amperes [A] (primary)
3I2PKD	Peak demand negative-sequence current	Amperes [A] (primary)
IGPKD	Peak demand zero-sequence current	Amperes [A] (primary)
PAPKD, PBPKD, PCPKD	Peak demand phase real power	Megawatts [MW] (primary)
3PPKD	Peak demand three-phase real power	Megawatts [MW] (primary)
QAPKD QBPKD QCPKD	Peak demand phase reactive power	Megavars [MVAr] (primary)
3QPKD	Peak demand three-phase reactive power	Megavars [MVAr] (primary)
UAPKD, UBPKD, UCPKD	Peak demand phase apparent power	Megavolt-amperes [MVA] (primary)
3UPKD	Peak demand three-phase apparent power	Megavolt-amperes [MVA] (primary)
IAD, IBD, ICD	Demand phase current	Amperes [A] (primary)
3I2D	Demand negative-sequence current	Amperes [A] (primary)
IGD	Demand zero-sequence current	Amperes [A] (primary)
PAD, PBD, PCD	Demand phase real power	Megawatts [MW] (primary)
3PD	Demand three-phase real power	Megawatts [MW] (primary)
QAD, QBD, QCD	Demand phase reactive power	Megavars [MVAr] (primary)
3QD	Demand three-phase reactive power	Megavars [MVAr] (primary)
UAD, UBD, UCD	Demand phase apparent power	Megavolt-amperes [MVA] (primary)
3UD	Demand three-phase apparent power	Megavolt-amperes [MVA] (primary)
Import/Export Power Quantities		
MWHAOUT, MWHBOUT, MWHCOUT	Positive (export) phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
MWHAIN, MWHBIN, MWHCIN	Negative (import) phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
MWHAT, MWHBT, MWHCT	Total phase energy; Megawatt-hours	Megawatt-hour [MWh] (primary)
3MWHOUT	Positive (export) three-phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 7 of 13)

Labels	Description	Unit
3MWHIN	Negative (import) three-phase energy, Megawatt-hours	Megawatt-hour [MWh] (primary)
3MWH3T	Total three-phase energy; Megawatt-hours	Megawatt-hour [MWh] (primary)
MHO Calculations		
MAGZ1, MBGZ1, MCGZ1	Zone 1 mho ground impedance calculation	Ohms (secondary)
MAGF, MBGF, MCGF	Forward mho ground calculation (excludes Zone 1)	Ohms (secondary)
MAGR, MBGR, MCGR	Reverse mho ground calculation (all reverse zones)	Ohms (secondary)
MAB, MBC, MCA	Mho phase-to-phase impedance calculation	Ohms (secondary)
MIRRORED BITS		
MB1A–MB7A	Channel A received MIRRORED BITS analog values	N/A
MB1B–MB7B	Channel B received MIRRORED BITS analog values	N/A
Programming		
PMV01–PMV64	Protection SELOGIC math variable	N/A
PCT01–PCT32	Protection SELOGIC conditioning timer pickup time	Cycles
PCT01DO–PCT32DO	Protection SELOGIC conditioning timer dropout time	Cycles
PST01ET–PST32ET	Protection SELOGIC sequencing timer elapsed time	Cycles
PST01PT–PST32PT	Protection SELOGIC sequencing timer preset time	Cycles
PCN01CV–PCN32CV	Protection SELOGIC counter current value	N/A
PCN01PV–PCN32PV	Protection SELOGIC counter preset value	N/A
AMV001–AMV256	Automation SELOGIC math variable	N/A
AST01ET–AST32ET	Automation SELOGIC math sequencing timer elapsed time	Seconds (s)
AST01PT–AST32PT	Automation SELOGIC sequencing timer preset time	Seconds (s)
ACN01CV–ACN32CV	Automation SELOGIC counter current value	N/A
ACN01PV–ACN32PV	Automation SELOGIC counter preset value	N/A
Active Group Setting		
ACTGRP	Active group setting	N/A
Breaker Contact Wear		
B1BCWPA, B1BCWPBA, B1BCWPC	Breaker contact wear (Breaker 1)	Percent
B2BCWPA, B2BCWPBA, B2BCWPC	Breaker contact wear (Breaker 2)	Percent
Time and Date Management		
TODMS	UTC time of day in milliseconds (0–86400000)	Milliseconds (ms)
THR	UTC time, hour (0–23)	Hour (hr)
TMIN	UTC time, minute (0–59)	Minutes (min)
TSEC	UTC time, seconds (0–59)	Seconds (s)
TMSEC	UTC time, milliseconds (0–999)	Milliseconds (ms)
TNSEC	UTC time, nanoseconds (0–999999)	Nanoseconds (ns)
TLHR	Local time, hour (0–23)	Hour (hr)
TLMIN	Local time, minute (0–59)	Minutes (min)
TLMSEC	Local time, millisecond (0–999)	Milliseconds (ms)
TLNSEC	Local time, nanoseconds (0–999999)	Nanoseconds (ns)
TLODMS	Local time of day in milliseconds (0–86400000)	Milliseconds (ms)

Table 12.2 Analog Quantities Sorted by Function (Sheet 8 of 13)

Labels	Description	Unit
TLSEC	Local time, seconds (0–59)	Seconds (s)
DDOW	UTC date, day of the week (1–SU,..., 7–SA)	Day
DDOM	UTC date, day of the month (1–31)	Day
DDOY	UTC date, day of the year (1–366)	Day
DMON	UTC date, month (1–12)	Month
DYEAR	UTC date, year (2000–2200)	Year
Reclosing Relay		
SPSHOT	Present value of single-pole shot counter	N/A
3PSHOT	Present value of three-pole shot counter	N/A
SHOT1_1	Total number of 1st shot single-pole recloses	N/A
SHOT1_2	Total number of 2nd shot single-pole recloses	N/A
SHOT1_T	Total number of single-pole reclosing shots issued	N/A
SHOT3_1	Total number of 1st shot three-pole recloses	N/A
SHOT3_2	Total number of 2nd shot three-pole recloses	N/A
SHOT3_3	Total number of 3rd shot three-pole recloses	N/A
SHOT3_4	Total number of 4th shot three-pole recloses	N/A
SHOT3_T	Total number of three-pole recloses	N/A
Fault Location		
FLOC	Fault location	Per unit (pu)
Contact Inputs		
IN201A–IN208A	Digital input values available as floating point quantities 0.0–255.0	A/D Counts
IN301A–IN308A	Digital input values available as floating point quantities 0.0–255.0	A/D Counts
IN201V–IN208V	Contact input A/D counts converted to calibrated voltage	V
IN301V–IN308V	Contact input A/D counts converted to calibrated voltage	V
RTD		
RTD01–RTD12	Instantaneous temperatures from external SEL-2600	°C (degrees Celsius)
IRIG-B Control Function Bits for Synchrophasor Measurement		
TUTC	Offset from IRIG-B time to UTC time	Hour
TQUAL	Worst case IRIG-B clock time error	Seconds [s]
NEW_SRC	Selected high-accuracy time source	N/A
CUR_SRC	Current high-accuracy time source	N/A
SQUAL	IRIG-B synchronization accuracy	µs
BNCDSJI	BNC port 100 PPS data stream jitter	µs
BNCTBTW	Time between BNC 100 PPS pulses	µs
SERTBTW	Time between serial 100 PPS pulses	µs
BNCOTJS	Slow converging BNC port ON TIME marker jitter, fine accuracy	µs
BNCOTJF	Fast converging BNC port ON TIME marker jitter, coarse accuracy	µs
SERDSJI	Serial Port 100 PPS data stream jitter	µs
SEROTJS	Slow converging serial port ON TIME marker jitter, fine accuracy	µs
SEROTJF	Fast converging serial port ON TIME marker jitter, coarse accuracy	µs

Table 12.2 Analog Quantities Sorted by Function (Sheet 9 of 13)

Labels	Description	Unit
IEEE 1588 PTP Status		
PTPDSJI	PTP 100PPS data stream jitter in µs	µs
PTPMCC	PTP master clock class enumerated value	N/A
PTPOTJS	Slow converging PTP ON TIME marker jitter in µs, fine accuracy	µs
PTPOTJF	Fast converging PTP ON TIME marker jitter in µs, coarse accuracy	µs
PTPOFST	Raw clock offset between PTP master and relay time	ns
PTPPORT	Active PTP port number	N/A
PTPTBTW	Time between PTP 100PPS pulses in µs	µs
PTPSTEN	PTP Port State enumerated value	N/A
Time Error Connection Factor Command		
TECORR	Time error correction preload value	Seconds [s]
TE	Time error	Seconds [s]
Synchrophasor Quantities		
VAYPMM, VBYPMM, VCYPMM	Synchrophasor voltage magnitude, Terminal Y	Kilo Volts [kV] (primary)
VAZPMM, VBZPMM, VCZPMM	Synchrophasor voltage magnitude, Terminal Z	Kilo Volts [kV] (primary)
VAYPMA, VBYPMA, VCYPMA	Synchrophasor voltage angle, Terminal Y	Degrees [°] (±180)
VAZPMA, VBZPMA, VCZPMA	Synchrophasor voltage angle, Terminal Z	Degrees [°] (±180)
VAYPMR, VBYPMR, VCYPMR	Synchrophasor voltage real component, Terminal Y	Kilo Volts [kV] (primary)
VAZYPMR, VBZPMR, VCZPMR	Synchrophasor voltage real component, Terminal Z	Kilo Volts [kV] (primary)
VAYPMI, VBYPMI, VCYPMI	Synchrophasor voltage imaginary component, Terminal Y	Kilo Volts [kV] (primary)
VAZYPMI, VBZPMI, VCZYPMI	Synchrophasor voltage imaginary component, Terminal Z	Kilo Volts [kV] (primary)
V1YPMM	Positive-sequence synchrophasor voltage magnitude, Terminal Y	Kilo Volts [kV] (primary)
V1ZPMM	Positive-sequence synchrophasor voltage magnitude, Terminal Z	Kilo Volts [kV] (primary)
V1YPMA	Positive-sequence synchrophasor voltage angle, Terminal Y	Degrees [°] (±180)
V1ZPMA	Positive-sequence synchrophasor voltage angle, Terminal Z	Degrees [°] (±180)
V1YPMR	Positive-sequence synchrophasor voltage real component, Terminal Y	Kilo Volts [kV] (primary)
V1ZPMR	Positive-sequence synchrophasor voltage real component, Terminal Z	Kilo Volts [kV] (primary)
V1YPMI	Positive-sequence synchrophasor voltage imaginary component, Terminal Y	Kilo Volts [kV] (primary)
V1ZPMI	Positive-sequence synchrophasor voltage imaginary component, Terminal Z	Kilo Volts [kV] (primary)
IAWPMM, IBWPMM, ICWPMM	Synchrophasor current magnitude, Terminal W	Amperes [A] (primary)
IAXPMM, IBXPMM, ICXPMM	Synchrophasor current magnitude, Terminal X	Amperes [A] (primary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 10 of 13)

Labels	Description	Unit
IASPMM, IBSPMM, ICSPMM	Synchrophasor current magnitude, Terminal S	Amperes [A] (primary)
IAWPMA, IBWPMA, ICWPMA	Synchrophasor current angle, Terminal W	Degrees [°] (±180)
IAXPMA, IBXPMA, ICXPMA	Synchrophasor current angle, Terminal X	Degrees [°] (±180)
IASPMA, IBSPMA, ICSPMA	Synchrophasor current angle, Terminal S	Degrees [°] (±180)
IAWPMR, IBWPMR, ICWPMR	Synchrophasor current real component, Terminal W	Amperes [A] (primary)
IAXPMR, IBXPMR, ICXPMR	Synchrophasor current real component, Terminal X	Amperes [A] (primary)
IASPMR, IBSPMR, ICSPMR	Synchrophasor current real component, Terminal S	Amperes [A] (primary)
IAWPMI, IBWPMI, ICWPMI	Synchrophasor current imaginary component, Terminal W	Amperes [A] (primary)
IAXPMI, IBXPMI, ICXPMI	Synchrophasor current imaginary component, Terminal X	Amperes [A] (primary)
IASPMI, IBSPMI, ICSPMI	Synchrophasor current imaginary component, Terminal S	Amperes [A] (primary)
I1WPMM	Positive-sequence synchrophasor current magnitude, Terminal W	Amperes [A] (primary)
I1XPMM	Positive-sequence synchrophasor current magnitude, Terminal X	Amperes [A] (primary)
I1SPMM	Positive-sequence synchrophasor current magnitude, Terminal S	Amperes [A] (primary)
I1WPMA	Positive-sequence synchrophasor current angle, Terminal W	Degrees [°] (±180)
I1XPMA	Positive-sequence synchrophasor current angle, Terminal X	Degrees [°] (±180)
I1SPMA	Positive-sequence synchrophasor current angle, Terminal S	Degrees [°] (±180)
I1WPMR	Positive-sequence synchrophasor current real component, Terminal W	Amperes [A] (primary)
I1XPMR	Positive-sequence synchrophasor current real component, Terminal X	Amperes [A] (primary)
I1SPMR	Positive-sequence synchrophasor current real component, Terminal S	Amperes [A] (primary)
I1WPMI	Positive-sequence synchrophasor current imaginary component, Terminal W	Amperes [A] (primary)
I1XPMI	Positive-sequence synchrophasor current imaginary component, Terminal X	Amperes [A] (primary)
I1SPMI	Positive-sequence synchrophasor current imaginary component, Terminal S	Amperes [A] (primary)
SODPM	Second of day of the synchrophasor data packet	Seconds [s]
FOSPM	Fraction of second of the synchrophasor data packet	Seconds [s]
Synchrophasor Frequency		
FREQPM	Frequency for synchrophasor data	Hertz [Hz]
DFDTPM	Rate-of-change of frequency for synchrophasor data	Hertz/seconds [Hz/s]
Synchrophasor RTC		
VAYPMMD, VBYPMMD, VCYPMMD	Synchrophasor voltage magnitude, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZPMMD, VBZPMMD, VCZPMMD	Synchrophasor voltage magnitude, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 11 of 13)

Labels	Description	Unit
VAYPMAD, VBYPMAD, VCYPMAD	Synchrophasor voltage angle, Terminal Y, delayed for RTC alignment	Degrees [°] (±180)
VAZPMAD, VBZPMAD, VCZPMAD	Synchrophasor voltage angle, Terminal Z, delayed for RTC alignment	Degrees [°] (±180)
VAYPMRD, VBYPMRD, VCYPMRD	Synchrophasor voltage real component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZPMRD, VBZPMRD, VCZPMRD	Synchrophasor voltage real component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAYPMID, VBYPMID, VCYPMID	Synchrophasor voltage imaginary component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
VAZPMID, VBZPMID, VCZPMID	Synchrophasor voltage imaginary component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1YPMMD	Positive sequence synchrophasor voltage magnitude, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMMD	Positive sequence Synchrophasor voltage magnitude, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1YPMAD	Positive sequence synchrophasor voltage angle, Terminal Y, delayed for RTC alignment	Degrees [°] (±180)
V1ZPMAD	Positive sequence synchrophasor voltage angle, Terminal Z, delayed for RTC alignment	Degrees [°] (±180)
V1YPMRD	Positive sequence synchrophasor voltage real component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMRD	Positive sequence synchrophasor voltage real component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1YPMID	Positive sequence synchrophasor voltage imaginary component, Terminal Y, delayed for RTC alignment	Kilo Volts [kV] (primary)
V1ZPMID	Positive sequence synchrophasor voltage imaginary component, Terminal Z, delayed for RTC alignment	Kilo Volts [kV] (primary)
IAWPMMD, IBWPMMD, ICWPMMD	Synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAXPMMD, IBXPMMD, ICXPMMD	Synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IASPMMD, IBSPMMD, ICSPMMD	Synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IAWPMAD, IBWPMAD, ICWPMAD	Synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees [°] (±180)
IAXPMAD, IBXPMAD, ICXPMAD	Synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees [°] (±180)
IASPMAD, IBSPMAD, ICSPMAD	Synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees [°] (±180)
IAWPMRD, IBWPMRD, ICWPMRD	Synchrophasor current real component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAXPMRD, IBXPMRD, ICXPMRD	Synchrophasor current real component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IASPMRD, IBSPMRD, ICSPMRD	Synchrophasor current real component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IAWPMID, IBWPMID, ICWPMID	Synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAXPMID, IBXPMID, ICXPMID	Synchrophasor current imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)

Table 12.2 Analog Quantities Sorted by Function (Sheet 12 of 13)

Labels	Description	Unit
IASPMID, IBSPMID, ICSPMID	Synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMMD	Positive sequence synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1XPMMD	Positive sequence synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1SPMMD	Positive sequence synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1WPMAD	Positive sequence synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees [°] (±180)
I1XPMAD	Positive sequence synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees [°] (±180)
I1SPMAD	Positive sequence synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees [°] (±180)
I1WPMRD	Positive sequence synchrophasor current real component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1XPMRD	Positive sequence synchrophasor current real component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1SPMRD	Positive sequence synchrophasor current real component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1WPMID	Positive sequence synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1XPMID	Positive sequence synchrophasor current imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1SPMID	Positive sequence synchrophasor current imaginary component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
SODPMD	Second of day of the synchrophasor data packet, delayed for RTC alignment	Seconds [s]
FOSPMD	Fraction of second of the synchrophasor data packet, delayed for RTC alignment	Seconds [s]
FREQPMD	Frequency for synchrophasor data, delayed for RTC alignment	Hertz [Hz]
DFDTPMD	Rate-of-change of frequency for synchrophasor data, delayed for RTC alignment	Hertz/seconds [Hz/s]
RTCAP01–RTCAP32	Channel A remote synchrophasor phasors (unit depends on remote synchrophasor contents)	N/A
RTCBP01–RTCBP32	Channel B remote synchrophasor phasors (unit depends on remote synchrophasor contents)	N/A
RTCAA01–RTCAA08	Channel A remote synchrophasor analogs (unit depends on remote synchrophasor contents)	N/A
RTCBA01–RTCBA08	Channel B remote synchrophasor analogs (unit depends on remote synchrophasor contents)	N/A
RTCFA	Channel A remote frequency (from remote synchrophasors)	Hertz [Hz]
RTCFB	Channel B remote frequency (from remote synchrophasors)	Hertz [Hz]
RTCDFA	Rate-of-change of Channel A remote frequency (from remote synchrophasors)	Hertz/seconds [Hz/s]
RTCDFB	Rate-of-change of Channel B remote frequency (from remote synchrophasors)	Hertz/seconds [Hz/s]

Table 12.2 Analog Quantities Sorted by Function (Sheet 13 of 13)

Labels	Description	Unit
Protection Frequency		
DFDTP	Rate-of-change of frequency	Hertz/seconds [Hz/s]
FREQ	Tracking frequency	Hertz [Hz]
FREQP	Frequency for under-/overfrequency elements	Hertz [Hz]
Remote Analogs		
RA001–RA256	Remote analogs	N/A
RAO01–RAO64	Remote analog output	N/A
Out-Of-Step		
SCV	Unfiltered swing center voltage	Per unit (pu)
Relay Temperature		
RLYTEMP	Relay temperature (temperature of the enclosure)	°C (degrees Celsius)

APPENDIX A

Firmware, ICD File, and Manual Versions

Firmware

Determining the Firmware Version

To determine the firmware version, view the status report by using the serial port **ID** command or the front-panel **LCD View Configuration** menu option. The status report displays the Firmware Identification (FID) number.

NOTE: The SEL-421-4, -5 relays (firmware version R3xx) are incompatible with the previous SEL-421-0, -1, -2, -3 relays (firmware versions R1xx and R2xx). Do not attempt to load R3xx firmware on the previous hardware or R1xx or R2xx firmware on the new hardware.

The firmware version will be either a standard release or a point release.
A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID number.

Existing firmware:

FID=SEL-421-x-**R100**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-421-x-**R101**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-421-x-R100-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-421-x-R100-**V1**-Z001001-Dxxxxxxxx

The release date is after the D. For example, the following is firmware version number R100, release date December 10, 2003.

FID=SEL-421-x-R100-V0-Z001001-**D20031210**

Similarly, the device SELBOOT firmware revision (BFID) will be reported as:

BFID=SLBT-4XX-Rxx-Vx-Zxxxxxx-Dxxxxxxxx

Revision History

Table A.1 lists the firmware versions, revision descriptions, and corresponding instruction manual date codes.

Table A.1 Firmware Revision History (Sheet 1 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-4-R323-V0-Z024013-D20171008 SEL-421-5-R323-V0-Z024013-D20171008	➤ Added a new analog quantity, PTPMCC, to indicate the clock class of the PTP master. ➤ Enhanced memory read diagnostics. ➤ DNP3 data are now reported with a LOCAL_FORCED flag when they have been overridden through use of the TEST DB2 command. ➤ Updated IEC 61850 protocol implementation to IEC 61850 Edition 2. ➤ Modified the relay response to an MMS identify request so that it will respond with the firmware ID (FID) string. ➤ Improved MMS file services performance with successive file transfers. ➤ Enhanced wild card parsing used in MMS file transfer operations. ➤ Modified the **ID** command to display a string that uniquely identifies the IEC 61850 firmware present in the relay. ➤ Modified firmware to replace non-printable characters with question marks in settings that are sent to the front panel of the HMI. ➤ Modified firmware to allow SNTPPIP to be set to 0.0.0.0 when ESNTP = BROADCAST. ➤ The **ETH** command now shows both MAC addresses. ➤ Modified firmware to indicate an enabled or disable transition of the IEC 61850 Buffer Report Control Block (BRCB) by sending an overflow flag on the next report sent after the transition. ➤ Modified IEEE-1588 PTP power profile to be supported in Parallel Redundancy Protocol (PRP) mode. ➤ Modified firmware to only reset breaker monitor data for the breaker selected. In prior firmware, some data were being reset for all breakers. ➤ Modified firmware to avoid false GOOSE out of sequence errors while in PRP mode. ➤ Modified firmware to use only the first synchrophasor data configuration if the number of output data configurations exceeds the number of data configurations. ➤ Modified firmware to allow all settings changes when the relay is disabled.	20171008
SEL-421-4-R322-V3-Z024013-D20171021 SEL-421-5-R322-V3-Z024013-D20171021	Includes all the functions of SEL-421-4-R322-V2-Z024013-D20170810 and SEL-421-5-R322-V2-Z024013-D20170820 with the following addition: ➤ Enhanced memory read diagnostics.	20171021
SEL-421-4-R322-V2-Z024013-D20170810 SEL-421-5-R322-V2-Z024013-D20170810	Includes all the functions of SEL-421-4-R322-V1-Z024013-D20170525 and SEL-421-5-R322-V1-Z024013-D20170525 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170810
SEL-421-4-R322-V1-Z024013-D20170525 SEL-421-5-R322-V1-Z024013-D20170525	Includes all the functions of SEL-421-4-R322-V0-Z024013-D20170327 and SEL-421-5-R322-V0-Z024013-D20170327 with the following addition: ➤ Modified firmware to allow the relay to synchronize to an external time source more responsively.	20170525

Table A.1 Firmware Revision History (Sheet 2 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-4-R322-V0-Z024013-D20170327 SEL-421-5-R322-V0-Z024013-D20170327	➤ Added an event report digital setting, ERDIG, which can be set to **S** (some) or **A** (all) to allow the option for all Relay Word bits to be added to COMTRADE event reports. ➤ Added the AUTO2 option to the directional control enable setting (E32). ➤ Extended the resistance reach for Zones 4 and 5 of both the ground and phase quadrilateral distance elements. ➤ Improved Simple Network Time Protocol (SNTP) accuracy to ± 1 ms in an ideal network. ➤ Expanded the allowable reach for Zones 6 and 7 of the conventional out-of-step logic. ➤ Added time-domain link (TiDL) technology. ➤ Added digital input and digital output Relay Word bits to accommodate I/O from remote data acquisition modules. ➤ Added Zone 1 fault detector settings (Z50P1 and Z50G1) to phase- and ground-distance elements. ➤ Modified alpha voltage (VALPHA) calculation to be forced to zero when all poles are open. ➤ Enhanced frequency tracking to freeze for two cycles during toggling open-pole conditions. ➤ Modified firmware to prevent delays in periodic MMS reports. ➤ Modified firmware to allow the MMS inactivity time-out to be turned off. ➤ Enhanced the frequency tracking algorithm to update more responsively after a low frequency event.	20170327
SEL-421-4-R321-V2-Z023013-D20171021 SEL-421-5-R321-V2-Z023013-D20171021	Includes all the functions of SEL-421-4-R321-V1-Z023013-D20170820 and SEL-421-5-R321-V1-Z023013-D20170820 with the following addition: ➤ Enhanced memory read diagnostics.	20171021
SEL-421-4-R321-V1-Z023013-D20170820 SEL-421-5-R321-V1-Z023013-D20170820	Includes all the functions of SEL-421-4-R321-V0-Z023013-D20160624 and SEL-421-5-R321-V0-Z023013-D20160624 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-421-4-R321-V0-Z023013-D20160624 SEL-421-5-R321-V0-Z023013-D20160624	➤ Added EVEMOD*n* (where *n* = 1–6 for DNP LAN/WAN or empty for DNP serial) setting to force the relay to start in single- or multiple-event mode. ➤ Improved MIRRORED BITS performance under high level of GOOSE traffic. ➤ Modified DNP Object 0, Variation 242 to report the firmware V-number. ➤ Modified GOOSE subscription to update data after the messages transition from bad to good quality. ➤ Improved relay start-up time. ➤ Modified Virtual Bits to reset upon a successful CID file download. ➤ Added support for IEEE 1588-2008, Precision Time Protocol (PTP) time synchronization. ➤ Added ordering option to select Ethernet Ports 5A/5B if a customer needs PTP. ➤ Added setting EPOLDIS to enable/disable the pole discrepancy breaker status for the HMI Bay Control when the breaker type is set to single pole. EPOLDIS = Y by default, which maintains the same behavior as previous firmware.	20160624

Table A.1 Firmware Revision History (Sheet 3 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Enhanced front panel operations to show settings warnings, in addition to settings errors already displayed, during settings changes. ➤ Modified the handling of a leap year when the relay setting and clock disagree.	
SEL-421-4-R320-V2-Z022013-D20170820 SEL-421-5-R320-V2-Z022013-D20170820	Includes all the functions of SEL-421-4-R320-V1-Z022013-D20160504 and SEL-421-5-R320-V1-Z022013-D20160504 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-421-4-R320-V1-Z022013-D20160504 SEL-421-5-R320-V1-Z022013-D20160504	Includes all the functions of SEL-421-4-R320-V0-Z022013-D20160111 and SEL-421-5-R320-V0-Z022013-D20160111 with the following addition: ➤ Modified programmable digital inputs to drop out at specified setting threshold.	20160504
SEL-421-4-R320-V0-Z022013-D20160111 SEL-421-5-R320-V0-Z022013-D20160111	➤ Modified the TEST DB2 OFF command to disable the overridden remote analog output and digital values in IEC 61850 GOOSE messages. ➤ Modified the TEST DB2 functionality to override Relay Word bits that are in the Sequential Events Recorder (SER). ➤ Added two new breaker failure settings options, Y1 and Y2. ➤ Added additional synchronism-check schemes and a synchronous voltage difference setting, 25VDIF. ➤ Enhanced positive-sequence directional element (F32P) for high-resistance faults.	20160111
SEL-421-4-R319-V2-Z021013-D20170820 SEL-421-5-R319-V2-Z021013-D20170820	Includes all the functions of SEL-421-4-R319-V1-Z021013-D20160506 and SEL-421-5-R319-V1-Z021013-D20160506 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-421-4-R319-V1-Z021013-D20160506 SEL-421-5-R319-V1-Z021013-D20160506	Includes all the functions of SEL-421-4-R319-V0-Z021013-D20150504 and SEL-421-5-R319-V0-Z021013-D20150504 with the following addition: ➤ Modified programmable digital inputs to drop out at specified setting threshold.	20160506
SEL-421-4-R319-V0-Z021013-D20150504 SEL-421-5-R319-V0-Z021013-D20150504	➤ Enhanced the out-of-step blocking logic to be more dependable during single-pole open conditions. ➤ Added supervision to the quadrilateral phase and ground-distance elements for unusual unbalanced load conditions. ➤ Modified code to maintain VMEMC setting value during an upgrade. ➤ Added polarization voltage validation check to supervise quadrilateral phase-distance elements ➤ Added the option to change settings groups with IEC 61850. ➤ Added the LPHD.Sim logical node so the relay will accept GOOSE messages with the test flag asserted. ➤ Added Relay Word bits to indicate leading and lagging power factor. ➤ Added support for the stSeld attribute in IEC 61850 SBO controls. ➤ Added total energy analog quantities to the DNP3 analog input reference map, and added the imported and exported energy scaled and labeled to KW to the binary counter reference data map.	20150504

Table A.1 Firmware Revision History (Sheet 4 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added Isolated IP mode (NETMODE = ISOLATEIP) which permits IEC 61850 GOOSE messages on two ports but restricts IP traffic to just one port. ➤ Added pulsed remote bits in Automation SELOGIC. ➤ Added FRQST and PMLEGCY settings to maintain backward settings compatibility. ➤ Added aliasing capability for the phasors, analogs, and digitals in the synchrophasor data. ➤ Enhanced the report time records to save the active UTC offset (UTCOFF) value with each report. Now, when the relay collects a report, it assigns the time stamp based on the UTC time and the UTCOFF value at the time the relay stores the report. ➤ Removed the port uniqueness requirements for the PMOUDP1 and PMOUDP2 settings. ➤ Enhanced the embedded HTTP server user interface to be consistent with other SEL relays. ➤ Improved the Sequential Events Recorder (SER) resolution to 0.5 ms for level sensitive contact inputs. ➤ Modified the relay to support MMS file transfer service even if the relay contains an invalid CID file. ➤ Modified the embedded HTTP server web access to always require a valid relay Access Level 1 (ACC) password. ➤ Updated the maximum and minimum line metering data (MET M commands) to display local time for all data. ➤ Reset the port timeout on transmitted Telnet messages. ➤ Updated the profile and compressed profile commands (PRO and CPRO, respectively) to display the available analog signal profiling records regardless of the state of the signal profile enable (SPEN) setting. ➤ Changed the result of a SELOGIC control equation math error from NAN (not a number) to the previously stored valid result. ➤ Improved Port 5 functionality to disable auto-messages when the auto-messages setting is equal to no (AUTO=N). ➤ Changed the IEC 61850 Configured IED Description (CID) file to support non-Relay Word bit binary elements included in a GOOSE message. ➤ Improved dual breaker applications by allowing different CT ratios for all functions. ➤ Modified the relay to continue to send synchrophasors data after a change in port settings. ➤ Changed the Global Setting Message Format (MFRMT) so that when it is set to Fast Message (FM), the freeform settings PMAQ, PMAA, PMDG, and PMDA are hidden. ➤ Changed the Station ID label in the COMTRADE configuration (.cfg) file to prevent non-alphanumeric characters per the IEEE C37.111-1999 COMTRADE standard. ➤ Modified the firmware to prevent IP traffic from becoming unresponsive when the Parallel Redundancy Protocol (PRP) is enabled. ➤ Clarified the message generated by the relay in response to an invalid CID file. ➤ Added local time and date analog quantities. ➤ Improved relay performance during certain incorrect memory reads.	

Table A.1 Firmware Revision History (Sheet 5 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Enhanced performance to ensure that the relay does not become unresponsive when MIRRORED BITS communications is used on the front port. In previous firmware, the relay could become unresponsive on rare occasions if the front port is set to MIRRORED BITS communications protocol. ➤ Changed the minimum increment value of the Pickup and Dropout Delay of the Main Board and Interface Board Control Inputs settings (INxxxPU and INxxxDO) from 0.0625 cycles to 0.0001 cycles. ➤ Improved Close Immobility dropoff to be 60 cycles.	
SEL-421-4-R318-V0-Z020013-D20150504 SEL-421-5-R318-V0-Z020013-D20150504	**Note:** This firmware did not production release.	—
SEL-421-4-R317-V1-Z020013-D20170820 SEL-421-5-R317-V1-Z020013-D20170820	Includes all the functions of SEL-421-4-R317-V0-Z020013-D20131231 and SEL-421-5-R317-V0-Z020013-D20131231 with the following addition: ➤ Resolved an issue where certain Ethernet traffic could cause diagnostic restarts.	20170820
SEL-421-4-R317-V0-Z020013-D20131231 SEL-421-5-R317-V0-Z020013-D20131231	➤ Updated new bay screens to allow longer name lengths. ➤ Modified how 10-cycle analog quantities are initialized. ➤ Added setting EFID to enable/disable Fault Identification Logic. ➤ Added MIRRORED BITS Group Protocol Setting (MBG). ➤ Added extra directional supervision to High Speed Quadrilateral Ground- and Phase-Distance elements. This enhancement applies to the SEL-421-5 Relay only.	20131231
SEL-421-4-R316-V0-Z019013-D20130627 SEL-421-5-R316-V0-Z019013-D20130627	➤ Increased the pickup timer for the dSCV1_S comparison logic in the relay three-phase fault detector (DTF logic) to 20 cycles to ensure proper operation during very slow power swings. ➤ Added a VMEMC setting that selects between short or medium length memory voltage as the polarizing quantity in distance calculations. The relay uses the medium length memory when ESERCMP = Y to ensure proper operation during voltage inversions. This addresses an issue with revisions R313–R315 for system faults that cause voltage inversions on series-compensated lines. ➤ Provided additional current and voltage quantities to the list of analog quantities. ➤ Closed an outgoing UDP port that was reported as open by a port scanner when IEC 61850 was enabled. ➤ Corrected handling of unrecognized Ethertypes that can cause Ethernet ports to stop responding.	20130627
SEL-421-4-R315-V0-Z018013-D20130522 SEL-421-5-R315-V0-Z018013-D20130522	**Note:** This firmware did not production release.	20130522
SEL-421-4-R314-V0-Z017013-D20130222 SEL-421-5-R314-V0-Z017013-D20130222	➤ Corrected breaker inactivity time measurement in the circuit breaker report. ➤ Changed the 81UVSP default setting from 56 V to 85 V. ➤ Improved Read/Write resources to avoid communications interruptions. ➤ Improved firmware revision upgrade algorithm to avoid loss of relay settings during firmware revision upgrades. ➤ Improved memory usage by eliminating chattering binary GOOSE data. ➤ Improved diagnostic record management to avoid erroneous warnings following a firmware upgrade.	20130222

Table A.1 Firmware Revision History (Sheet 6 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-421-4-R313-V0-Z017013-D20121214 SEL-421-5-R313-V0-Z017013-D20121214	➤ Added support for MMS authentication. ➤ Added MMS file transfer. ➤ Reduced the normal time constant of the distance element polarizing voltage memory to more closely follow changes in power system frequency; the time constant automatically adapts to provide security for zero-voltage three-phase faults. ➤ Increased number of buffered and unbuffered reports to seven for MMS reporting. ➤ Added max/min voltage quantities to the 27/59 operate quantity list. ➤ Added Parallel Redundancy Protocol (PRP). ➤ Increased the number of Goose subscriptions to 128. ➤ Increased the number of binary outputs to 100 for DNP map. ➤ Changed A/D offset failures to warnings. ➤ Added setting to three-pole recloser initiate logic instead of hard coded 15 cycles. ➤ Added ALTI and ALTV indication to SER report. ➤ Added rate-of-change of frequency (DFDTP) analog value. ➤ Added the high-speed directional elements to supervise pilot tripping elements. ➤ Made mho calculation analogs available to the Event Report. ➤ Enhanced the fault identification logic to be secure during weak infeed conditions. ➤ Implemented multiple updates to the DNP3 control point operation.	20121214
SEL-421-4-R312-V0-Z016013-D20120919 SEL-421-5-R312-V0-Z016013-D20120919	➤ Changed the default Group Setting ARESE from Y to N.	20120919
SEL-421-4-R311-V0-Z016013-D20120827 SEL-421-5-R311-V0-Z016013-D20120827	➤ Added security to the ground quadrilateral element's adaptive resistance blinder.	20120827
SEL-421-4-R310-V0-Z016013-D20120223 SEL-421-5-R310-V0-Z016013-D20120223	➤ Added bay control screen panning feature. ➤ Expanded bay control power system symbols. ➤ Added user-selectable analog and digital quantities to synchrophasor data. ➤ Increased synchrophasor message capability from 1 to 5 unique data sets. ➤ Added third pass-band filter to synchrophasor filter selections. ➤ Added test-mode status indication to synchrophasor data. ➤ Added local time displayed with reference to UTC time. ➤ Added simple network time protocol (SNTP) to relays equipped with Ethernet.	20120223

Table A.1 Firmware Revision History (Sheet 7 of 7)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added web server capability to relays equipped with Ethernet. ➤ Improved relay password change management. ➤ Added mho Relay Word bits. ➤ Improved Ethernet communication when using UDP. ➤ Added Relay Word bits for relay access and main board jumper status. ➤ Added ACSELERATOR QuickSet template storage in relay nonvolatile memory. ➤ Relay will now show the DNP settings labels for DNP Maps 1–5. ➤ Added EPORT setting to relay front serial port (PORT F). ➤ Improved undervoltage supervision for frequency (81) elements. ➤ Added Ethernet card IP address to front-panel HMI relay configuration information. ➤ Increased number of analog quantities available to DNP reference map. ➤ SELBOOT was updated to S208 from S205. ➤ Added code to restart the relay in case of FPGA FAILURE. ➤ Changed the operating quantity for frequency tracking and undervoltage supervision from the positive-sequence voltage to the alpha component voltage. This change impacts the 81UVSP setting by a factor of $1.5 \bullet \sqrt{2}$ for three-phase voltages (see *Undervoltage Supervision Logic on page 5.17* for more information). ➤ Updated the DNP Fault Time values so they can no longer report incorrect time stamps. ➤ Added over- and under-voltage elements.	
SEL-421-4-R309-V0-Z014013-D20110923 SEL-421-5-R309-V0-Z014013-D20110923	➤ Improved performance of the Ethernet port. ➤ Reduced DNP current magnitude zeroing from 5% to 0.5% of I_{NOM}.	20110923
SEL-421-4-R307-V0-Z014013-D20110628 SEL-421-5-R307-V0-Z014013-D20110628	➤ Fixed the relay file system to handle all errors that can happen during FTP file transfers, including those that may occur with simultaneous relay **SHO** or **SET** commands.	20110628
SEL-421-4-R306-V0-Z014013-D20101221 SEL-421-5-R306-V0-Z014013-D20101221	➤ Corrected a problem where the relay would not accept different CTRW and CTRX ratio settings.	20101221
SEL-421-4-R305-V0-Z014013-D20100917 SEL-421-5-R305-V0-Z014013-D20100917	➤ Improved out-of-step handling during single pole-open condition.	20100917
SEL-421-4-R303-V0-Z014013-D20100520 SEL-421-5-R303-V0-Z014013-D20100520	➤ Improved the phase selection logic of the quadrilateral distance element.	20100520
SEL-421-4-R302-V0-Z013012-D20100319 SEL-421-5-R302-V0-Z013012-D20100319	➤ Corrected A-Phase analog quantity.	20100319
SEL-421-4-R301-V0-Z013012-D20100308 SEL-421-5-R301-V0-Z013012-D20100308	➤ Initial version.	20100308

SELBOOT

NOTE: All revisions of SELBOOT listed in this table are compatible with all versions of firmware available for this relay.

SELBOOT is a firmware package inside the relay that handles hardware initialization and provides the functions needed to support firmware upgrades. *Table A.4* lists the SELBOOT releases used with the SEL-421, their revision and a description of modifications. The most recent SELBOOT revision is listed first.

Table A.2 SELBOOT Revision History

SELBOOT Firmware Identification (BFID)	Summary of Revisions
SLBT-4XX-R209-V0-Z001002-D20150130	➤ Added support for a new main board variant. ➤ Fixed issue that could cause relay to disable (i.e., become unresponsive).
SLBT-4XX-R208-V0-Z001002-D20120220	➤ Added support for a new main board variant.
SLBT-4XX-R205-V0-Z001002-D20100128	➤ First revision used with SEL-421-4,-5.

ICD File

To find the ICD revision number in your relay, view the configVersion by using the serial port ID command. The configVersion is the last item displayed in the information returned from the ID command.

configVersion = ICD-451-R201-V0-Z310004-D20140321

The ICD revision number is after the R (e.g., 201) and the release date is after the D. This revision number is not related to the relay firmware revision number. The configVersion revision displays the ICD file version used to create the CID file that is loaded in the relay.

NOTE: The Z-number representation is implemented with ClassFileVersion 004. Previous ClassFileVersions do not provide an informative Z-number.

The configVersion contains other useful information. The Z-number consists of six digits. The first three digits following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 310). The second three digits represent the ICD ClassFileVersion (e.g., 004). The ClassFileVersion increments when there is a major addition or change to the IEC 61850 implementation of the relay.

Table A.3 lists the ICD file versions, a description of modifications, and the instruction manual date code that corresponds to the versions. The most recent version is listed first.

Table A.3 ICD File Revision History (Sheet 1 of 2)

configVersion[a]	Summary of Revisions	Minimum Relay Firmware	ClassFileVersion	Manual Date Code
ICD-421-R400-V0-Z323006-D20170731	➤ IEC 61850 Edition 2 Conformance. ➤ Updated ClassFileVersion to 006. ➤ Increased the default MMS inactivity timeout value to 900 seconds. ➤ Updated data set and MMS report names.	R323	006	20171008
ICD-421-R301-V0-Z322005-D20170315	➤ Added the ability to turn off the MMS inactivity timeout.	R322-V0	005	20170327
ICD-421-R300-V0-Z318005-D20150413	➤ Added support for IEC 61850 group switch, Simulated GOOSE, and stSeld.	R318	005	20150429
ICD-421-R203-V0-Z313005-D20150323	➤ Conformance enhancements.	R313	005	20150429

Table A.3 ICD File Revision History (Sheet 2 of 2)

configVersion[a]	Summary of Revisions	Minimum Relay Firmware	ClassFileVersion	Manual Date Code
ICD-421-R202-V0-Z310004-D20150323	➤ Fix for RVRS3 and RVRS4 set dirGeneral Data change true.	R310	004	20150429
ICD-421-R201-V0-Z000000-D20130430[b]	➤ Certified by KEMA for IEC 61850 Conformance.	R313	005	20130627
ICD-421-R201-V0-Z000000-D20121207[b]	➤ Added support for 128 incoming GOOSE subscriptions, MMS authentication, and user-configurable GOOSE filtering.	R313	005	20121214
ICD-421-R200-V0-Z000000-D20120220[b]	➤ SEL-421-4/-5 ICD file for firmware R310 or higher.	R310	004	20120223
ICD-421-R102-V0-Z000000-D20100118[b]	➤ SEL-421-4/-5 ICD file for firmware R300 or higher.	R300	003	20100308

configVersion Details:

ICD-[PN]-R[RN]-V[VS]-Z[FC]-D[RD] where:

[PN] = Product Name (e.g., 421)
[RN][c] = Revision Number (e.g., 102)
[VS] = Version Specifications (e.g., 9)
[FC][d] = Minimum Relay Firmware and Class File Version (e.g., 311005)
[RD] = Release Date Code (e.g., 20150219)

[a] The configVersion can be determined for the IED by performing an "ID" ASCII command from a terminal connection.
[b] The FC in this configVersion does not have a meaningful value.
[c] This is the ICD file revision number, not IED firmware revision number.
[d] FC consists of six digits. The first three following the Z represent the minimum IED firmware required to be used with the ICD (e.g., 516). The second three represent the ICD ClassFileVersion (e.g., 005).

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.4 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table A.4 Instruction Manual Revision History (Sheet 1 of 3)

Date Code	Summary of Revisions
20171021	Appendix A ➤ Updated for firmware versions R321-V2 and R322-V3.
20171008	Section 10 ➤ Updated *Table 10.15 Logical Device: PRO (Protection)* and Table 10.16 Logical Device: MET (Metering). Section 12 ➤ Updated *Table 12.1: Analog Quantities Sorted Alphabetically* and *Table 12.2: Analog Quantities Sorted by Function* for PRPMCC and PTPPORT. Appendix A ➤ Updated for firmware version R323. ➤ Updated for ICD firmware version R300.
20170820	Appendix A ➤ Updated for firmware versions R317-V1, R319-V2, R320-V2, and R321-V1.

Table A.4 Instruction Manual Revision History (Sheet 2 of 3)

Date Code	Summary of Revisions
20170810	Appendix A ➤ Updated for firmware version R322-V2.
20170525	Appendix A ➤ Updated for firmware version R322-V1.
20170428	Cover ➤ Updated copyright information. Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *Figure 2.39: SEL-2243 Power Coupler*.
20170327	Section 1 ➤ Updated *Specifications*. ➤ Modified the range of the resistance reach for quadrilateral phase-distance elements and quadrilateral ground-distance elements. ➤ Modified the range of the blinders (R1) for the conventional out-of-step elements. Section 2 ➤ Removed *Figure 2.20: IRIG-B Terminating Resistors* and the *IRIG-B Jumper* section. ➤ Added *TiDL Connections*. Section 5 ➤ Added AUTO2 to *Table 5.32: Ground Directional Element Settings*. ➤ Modified the range of the blinders (R1) for the conventional out-of-step elements in *Table 5.45: OOS Logic Relay Settings*. ➤ Modified the range of the resistance reach for quadrilateral ground-distance elements in *Table 5.51: Quadrilateral Ground-Distance Element Settings*. ➤ Modified the range of the resistance reach for quadrilateral phase-distance elements in *Table 5.56 Quadrilateral Phase-Distance Element Settings*. Section 6 ➤ Modified the range of the resistance reach for the quadrilateral distance elements in the examples. ➤ Modified the range of the blinders (R1) for the conventional out-of-step elements. Section 7 ➤ Updated *Table 7.8: Event Report Nonvolatile Storage Capability when ERDIG=S*. ➤ Added *Table 7.9: Event Report Nonvolatile Storage Capability when ERDIG=A*.
	Section 8 ➤ Added AUTO2 to *Table 8.36: Relay Configuration*. ➤ Updated ranges for RP4 and RP5 in *Table 8.38: Quadrilateral Phase-Distance Element Reach*. ➤ Updated ranges for RG4 and RG5 in *Table 8.41: Quad Ground-Distance Element Reach*. ➤ Updated ranges for X1T7, R1R7, R1R6, X1B7, X1B6, R1L7, and R1L6 in *Table 8.47: Out-of-Step Tripping/Blocking*. ➤ Updated default values in *Table 8.65: Directional Control Element*. Section 9 ➤ Added **CFG CTNOM** and **CFG NFREQ** to *Table 9.1: SEL-421 List of Commands*. Section 11 ➤ Updated *Table 11.1: Alphabetical List of Relay Word Bits*. ➤ Updated *Table 11.2: Row List of Relay Word Bits*. Section 12 ➤ Updated *Table 12.2: Analog Quantities Sorted by Function*. Appendix A ➤ Updated *Table A.1: Firmware Revision History* and *Table A.3: ICD File Revision History*.

Table A.4 Instruction Manual Revision History (Sheet 3 of 3)

Date Code	Summary of Revisions
	Command Summary ➤ Added **COM PTP**, **CFG CTNOM**, and **CFG NFREQ**.
20160615	➤ Initial version.

APPENDIX B

Converting Settings From SEL-421-0, -1, -2, -3 to SEL-421-4, -5

Because of hardware changes and feature enhancements between the SEL-421-0, -1, -2, -3 and the SEL-421-4, -5, the handling of a number of settings has changed. In particular, the replacement of the SEL-2702 Ethernet Processor with integrated Ethernet has significantly changed the handling of Ethernet related settings. This appendix describes the key differences to aid users who need to convert their settings from an SEL-421-0, -1, -2, -3 to an SEL-421-4, -5.

Relay Word Bit Changes

Relay Word bits are used in SELOGIC control equations and many other settings.

The SEL-421-4, -5 relays offer the following protection functions in addition to the proven protection elements of the SEL-421-2, -3 relays.

SEL-421-4:

- ➤ Zero-setting out-of-step (power swing) element
- ➤ Standard phase-quadrilateral distance elements

SEL-421-5:

- ➤ Zero-setting out-of-step (power swing) element
- ➤ High-speed and standard phase-quadrilateral distance elements

Table B.1 Relay Word Bit Differences

SEL-421-2, -3	SEL-421-4, -5
Z1P (setting)	Z1MP
Z2P (setting)	Z2MP
Z3P (setting)	Z3MP
Z4P (setting)	Z4MP
Z5P (setting)	Z5MP
E21P	E21MP E21XP (new setting)
TANG	TANGG TANGP (new setting)
TESTDNP	TESTDB2
CCIN001–CCIN128	VB001–VB128
CCOUT01–CCOUT32	Removed—use any visible Relay Word bit

Analog Quantity Changes

In the SEL-421-4, -5, some of the Analog Quantity names have changed. Because the SEL-421-4, -5 no longer supports two main boards there are no longer ADC-style inputs available on the main board. As a result, the quantities IN101A–IN107A and IN101V–IN107V are no longer available. Furthermore, whereas the old SEL-421 only supported synchrophasor voltage quantities on the line (Y or Z), the SEL-421-4, -5 supports synchrophasor voltage on both Y and Z. The following table shows the old line quantities and the new Y and Z quantities.

Table B.2 Analog Quantity Differences (Sheet 1 of 2)

Old Line Name	New Y Terminal Name	New Z Terminal Name
VALPMMD	VAYPMMD	VAZPMMD
VBLPMMD	VBYPMMD	VBZPMMD
VALPMM	VAYPMM	VAZPMM
VBLPMM	VBYPMM	VBZPMM
VCLPMM	VCYPMM	VCZPMM
VALPMA	VAYPMA	VAZPMA
VBLPMA	VBYPMA	VBZPMA
VCLPMA	VCYPMA	VCZPMA
VALPMR	VAYPMR	VAZPMR
VBLPMR	VBYPMR	VBZPMR
VCLPMR	VCYPMR	VCZPMR
VALPMI	VAYPMI	VAZPMI
VBLPMI	VBYPMI	VBZPMI
VCLPMI	VCYPMI	VCZPMI
V1LPMM	V1YPMM	V1ZPMM
V1LPMA	V1YPMA	V1ZPMA
V1LPMR	V1YPMR	V1ZPMR
V1LPMI	V1YPMI	V1ZPMI
VALPMMD	VAYPMMD	VAZPMMD
VBLPMMD	VBYPMMD	VBZPMMD
VCLPMMD	VCYPMMD	VCZPMMD
VALPMAD	VAYPMAD	VAZPMAD
VBLPMAD	VBYPMAD	VBZPMAD
VCLPMAD	VCYPMAD	VCZPMAD
VALPMRD	VAYPMRD	VAZPMRD
VBLPMRD	VBYPMRD	VBZPMRD
VCLPMRD	VCYPMRD	VCZPMRD
VALPMID	VAYPMID	VAZPMID
VBLPMID	VBYPMID	VBZPMID
VCLPMID	VCYPMID	VCZPMID
V1LPMMD	V1YPMMD	V1ZPMMD
V1LPMAD	V1YPMAD	V1ZPMAD

Table B.2 Analog Quantity Differences (Sheet 2 of 2)

Old Line Name	New Y Terminal Name	New Z Terminal Name
V1LPMRD	V1YPMRD	V1ZPMRD
V1LPMID	V1YPMID	V1ZPMID

The following analog quantities have changed names.

Old Name	New Name
DFDTD	DFDTPMD
DFDT	DFDTPM

Global Settings Changes

Table B.3 Global Settings Differences

Previous SEL-421 Relays	SEL-421-4, -5	Notes
IN101P	NA	The SEL-421-4, -5 does not support these inputs
IN102P	NA	
IN103P	NA	
IN104P	NA	
IN105P	NA	
IN106P	NA	
IN107P	NA	
VCOMP	VYCOMP, VZCOMP	Replaced VCOMP with VYCOMP and VZCOMP

Group Settings Changes

Table B.4 Group Settings Differences

Previous SEL-421 Relays	SEL-421-4, -5	Comments
E21P	E21MP	Renamed
Z1P	Z1MP	Renamed
Z2P	Z2MP	Renamed
Z3P	Z3MP	Renamed
Z4P	Z4MP	Renamed
Z5P	Z5MP	Renamed
TANG	TANGG	Renamed

Front-Panel Settings Changes

In the SEL-421-4, -5, the LED alias settings (T*n*LEDA) have been removed. Their equivalent functionality is available by aliasing the TLED_*n* bits using **SET T**. The only difference is that the old alias settings accept eight character aliases whereas the **SET T** aliases only accept seven characters.

Port Settings Changes

Serial Port Settings

The following table highlights key differences in the Serial Port settings between the SEL-421-1, -2, -3 and the SEL-421-4, -5.

Table B.5 Serial Port Settings Differences

Old SEL-421 Settings	New SEL-421 Settings	Notes
N/A	DNPCL	This is a new setting. It needs to be set to Y to enable control operations on a DNP port. in the old SEL-421, control was always enabled.

Ethernet Port (Port 5) Settings

In the SEL-421-1, -2, -3, Ethernet was supplied by different Ethernet hardware. This has significant impact on the settings, as described in *Table B.6*.

Table B.6 Ethernet Port Settings Differences (Sheet 1 of 2)

Old SEL-421 Settings	New SEL-421 Settings	Notes
IPADDR SUBNETM	IPADDR	This setting now operates using CIDR rules, which consolidates the old SUB-NETM setting into the IPADDR setting.
FAILOVER	NETMODE	A FAILOVER of N is equivalent to a NETMODE of FIXED. A FAILOVER of Y is equivalent to a NETMODE of FAILOVER. NETMODE also has a SWITCHED open, which enables both ports.
NETPORT	NETPORT	The old setting had choices of A, B, and D, for ports A, B, and to disable. The new setting has choices of C and D, for ports C and D.
NETASPD	NETCSPD	
NETBSPD	NETDSPD	
HOSTn IPADRn		The HOST and IPADR settings no longer exist.
T1RECV	ETELNET	
T1CBAN	TCBAN	
T1INIT		This setting no longer exists.
T1PNUM	TPORT	
T2CBAN T2RECV T2PNUM		These settings have been eliminated. They existed for access to the SEL-2702 local interface, which no longer exists.
ENDNP	EDNP	The old setting was a Y, N selection. The new setting selects the number of enabled DNP sessions, from 0 to 6. The old choice of N is equivalent to the new choice of 0 and the old choice of Y is equivalent to the new choice of 6.
DNPPNUM	DNPPNUM	The range is slightly more restrictive in the new implementation. The lowest assignable port is 1025.

Table B.6 Ethernet Port Settings Differences (Sheet 2 of 2)

Old SEL-421 Settings	New SEL-421 Settings	Notes
DNPMAP		This setting has been eliminated. Maps are now always custom.
RPADR01–RPADR06	REPADR1–REPADR6	
RPADR07–RPADR10		No longer exist.
DNIP01–DNPIP06	DNPIP1–DNPIP6	Note that HOST*n* aliases may have been used instead of actual IP addresses.
DNPIP07–DNPIP10		No longer exist.
DNPTR01–DNPTR06	DNPTR1–DNPTR6	
DNPTR07–DNPTR10		No longer exist.
DNPUP01–DNPUP06	DNPUDP1–DNPUDP6	The range is slightly more restrictive in the new implementation. The lowest assignable port is 1025.
DNPUP07–DNPUP10		No longer exist.
UNSL01–UNSL06	UNSOL1–UNSOL6	
UNSL07–UNSL10		No longer exist.
PUNSL01–PUNSL06	PUNSOL1–PUNSOL6	
PUNSL07–PUNSL10		No longer exist.
DNPMP01–DNPMP06	DNPMAP1–DNPMAP6	
DNPMP07–DNPMP10		No longer exist.
DNPCL01–DNPCL06	DNPCL1–DNPCL6	
DNPCL07–DNPCL10		No longer exist.
ECLASSA	CLASSA1–CLASSA6	Old setting allowed 0–3. New setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
ECLASSB	CLASSB1–CLASSB6	Old setting allowed 0–3. New setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
ECLASSC	CLASSC1–CLASSC6	Old setting allowed 0–3. New setting has OFF, 1–3. Old setting 0 is equivalent to new setting OFF.
DECPL	DECPLA1–DECPLA6 DECPLV1–DECPLV6 DECPLM1–DECPLM6	
ANADB	ANADBA1–ANADBA6 ANADBV1–ANADBV6 ANADBM1–ANADBM6	
16BIT	AIVAR1–AIVAR6	The old setting let one pick between 16-bit and 32-bit variations. The new settings let one pick any of the 6 valid analog input variations. The old setting of 16 is equivalent to 2 and 32 is equivalent to 1.
STIMEO	STIMEO1–STIMEO6	The new settings accept integers only.
DNPPAIR		This setting no longer exists. Selections of paired controls are now a function of configuring the map.
DNPINA	DNPINA1–DNPINA6	
NUMEVE	NUMEVE1–NUMEVE6	
ETIMEO	ETIMEO1–ETIMEO6	
URETRY	URETRY1–URETRY6	
UTIMEO	UTIMEO1–UTIMEO6	
PMOIPA1–PMOIPA2	PMOIPA1–PMOIPA2	Note that HOST*n* aliases may have been used instead of actual IP addresses.
PMOUDP1–PMOUDP2	PMOUDP1–PMOUDP2	The range is slightly more restrictive in the new implementation. The lowest assignable port is 1025

DNP3 Mapping Changes

DNP3 Settings Classes

In previous versions of DNP3, there was one map for serial DNP3, SET_D1.TXT, and five maps for Ethernet DNP3, CARD\SET_DNPn.TXT. Now there are simply five maps that can be used for serial or Ethernet DNP3: SET_Dn.TXT. When mapping from old to new, it is a good practice to drop SET_DNP5.TXT and then map the other four old DNP3 maps to the new maps, 2 through 5.

Serial DNP Map Value Changes

The previous serial DNP3 map was based on numeric references for all data. The new DNP3 mapping uses labels. The following tables show the relationships between the old numeric references and the labels.

Binary Inputs (MAPSEL = B)

For numeric references 0–799 and 800–1599, see *Table 6.11 from the SEL-421-0, -1, -2, -3 Reference Manual*. The labels from this table will work in the SEL-421-4, -5, with the exception of those noted in the Relay Word bit mapping *Table B.7*. Indexes that correspond to reserved points (*) can be treated as a fixed ‘0’ in the new map.

For numeric reference 1600–1615, see *Table 6.12 from the SEL-421-0, -1, -2, -3 Reference Manual*.

Table B.8 lists the mapping for points 1616–1639.

Table B.7 Binary Inputs Point Mapping for MAPSEL = B

Numeric Reference	Label Reference	Notes
1616	RLYDIS	
1617	STFAIL	
1618	STWARN	
1619	UNRDEV	
1620	STSET	
1621–1631	0	
1632	LDATPFW	
1633	LDBTPFW	
1634	LDCTPFW	
1635	LD3TPFW	
1636–1639	0	

Binary Inputs (MAPSEL = E)

Table B.8 lists the mapping for points 0–15.

Table B.8 Binary Inputs Point Mapping for MAPSEL = E

Numeric Reference	Label Reference	Notes
0	RLYDIS	
1	STFAIL	
2	STWARN	
3	UNRDEV	
4	STSET	
5–11	0	
12		No equivalent
13		No equivalent
14		No equivalent
15		No equivalent

References 16–265 do not have a good equivalent because they were dependent on the SER settings. For automatic remapping purposes, these references can be extracted from the SER settings. For example, reference 16 would correspond to setting SITM001, 17 to SITM002, etc.

References 266–271 are reserved and can map to hard '0'.

References 272 and above map to the Relay Word, starting at bit 0, with the exception of those noted in *Table B.8*. See *Section 11: Relay Word Bits* for the Relay Word.

Binary Outputs

Table B.9 Binary Outputs Point Mapping (Sheet 1 of 3)

Numeric Reference	Label Reference	Notes
0	RB01	
1	RB02	
2	RB03	
3	RB04	
4	RB05	
5	RB06	
6	RB07	
7	RB08	
8	RB09	
9	RB10	
10	RB11	
11	RB12	
12	RB13	
13	RB14	
14	RB15	
15	RB16	

Table B.9 Binary Outputs Point Mapping (Sheet 2 of 3)

Numeric Reference	Label Reference	Notes
16	OC1	
17	CC1	
18	OC2	
19	CC2	
20–23	NOOP	
24	RB01:RB02	
25	RB03:RB04	
26	RB05:RB06	
27	RB07:RB08	
28	RB09:RB10	
29	RB11:RB12	
30	RB13:RB14	
31	RB15:RB16	
32	OC1:CC1	
33	OC2:CC2	
34–35	NOOP	
36	RST_DEM	
37	RST_PDM	
38	RST_ENE	
39		Operated both RST_BK1 and RST_BK2
40	RSTTRGT	
41	NXTEVE	
42		Operated RST-MML, RSTMMB1, and RSTMMB2
43	NOOP	
44	RB17	
45	RB18	
46	RB19	
47	RB20	
48	RB21	
49	RB22	
50	RB23	
51	RB24	
52	RB25	
53	RB26	
54	RB27	
55	RB28	
56	RB29	
57	RB30	
58	RB31	
59	RB32	

Table B.9 Binary Outputs Point Mapping (Sheet 3 of 3)

Numeric Reference	Label Reference	Notes
60	RB17:RB18	
61	RB19:RB20	
62	RB21:RB22	
63	RB23:RB24	
64	RB25:RB26	
65	RB27:RB28	
66	RB29:RB30	
67	RB31:RB32	

Counters

Table B.10 Counters Point Mapping

Numeric Reference	Label Reference	Notes
0	ACTGRP	
1	0	
2	0	
3		No equivalent defined
4	BKR1OPA	
5	BKR1OPB	
6	BKR1OPC	
7	BKR2OPA	
8	BKR2OPB	
9	BKR2OPC	

Analog Inputs

Table B.11 Analog Inputs Point Mapping (Sheet 1 of 5)

Numeric Reference	Label Reference	Notes
0	LIAFM	
1	LIAFA	
2	LIBFM	
3	LIBFA	
4	LICFM	
5	LICFA	
6	0	
7	0	
8	B1IAFM	
9	B1IAFA	
10	B1IBFM	
11	B1IBFA	
12	B1ICFM	

Table B.11 Analog Inputs Point Mapping (Sheet 2 of 5)

Numeric Reference	Label Reference	Notes
13	B1ICFA	
14	0	
15	0	
16	B2IAFM	
17	B2IAFA	
18	B2IBFM	
19	B2IBFA	
20	B2ICFM	
21	B2ICFA	
22–35	0	
36	VAFM	
37	VAFA	
38	VBFM	
39	VBFA	
40	VCFM	
41	VCFA	
42	VPM	
43	0	
44	NVS1M	
45	0	
46	NVS2M	
47	0	
48	LIGM	
49	LIGA	
50	LI1M	
51	LI1A	
52	L3I2M	
53	L3I2A	
54–71	0	
72	3V0M	
73	3V0A	
74	V1M	
75	V1A	
76	3V2M	
77	3V2A	
78–83	0	
84	PA_F	
85	PB_F	
86	PC_F	
87	3P_F	
88	QA_F	

Table B.11 Analog Inputs Point Mapping (Sheet 3 of 5)

Numeric Reference	Label Reference	Notes
89	QB_F	
90	QC_F	
91	3Q_F	
92	DPFA	
93	DPFB	
94	DPFC	
95	3DPF	
96–99	0	
100	DC1	
101	0	
102	DC2	
103	0	
104	FREQ	
105	0	
106	MWHAIN	
107	MWHAOUT	
108	MWHBIN	
109	MWHBOUT	
110	MWHCIN	
111	MWHCOUT	
112	3MWHIN	
113	3MWHOUT	
114–121	0	
122	IAD	
123	IBD	
124	ICD	
125	IGD	
126	3I1D	
127	0	
128	PAD	
129	PBD	
130	PCD	
131	3PD	
132–143	0	
144	IAPKD	
145	IBPKD	
146	ICPKD	
147	IGPKD	
148	3I2PKD	
149	0	
150	PAPKD	

Table B.11 Analog Inputs Point Mapping (Sheet 4 of 5)

Numeric Reference	Label Reference	Notes
151	PBPKD	
152	PCPKD	
153	3PPKD	
154–165	0	
166	B1BCWPA	
167	B1BCWPB	
168	B1BCWPC	
169	B2BCWPA	
170	B2BCWPB	
171	B2BCWPC	
172–175	0	
176	FTYPE	
177	FTAR1	
178	FSLOC	
179	FCURR	
180	FFREQ	
181	FGRP	
182	FTAR2	
183	0	
184	FTIMEH	
185	FTIMEM	
186	FTIMEL	
187	0	
188	FSHOT2	
189–195	0	
196	AMV001	
197	AMV002	
198	AMV003	
199	AMV004	
200	AMV005	
201	AMV006	
202	AMV007	
203	AMV008	
204	AMV009	
205	AMV010	
206	AMV011	
207	AMV012	
208	AMV013	
209	AMV014	
210	AMV015	
211	AMV016	

Table B.11 Analog Inputs Point Mapping (Sheet 5 of 5)

Numeric Reference	Label Reference	Notes
212	AMV017	
213	AMV018	
214	AMV019	
215	AMV020	
216	AMV021	
217	AMV022	
218	AMV023	
219	AMV024	
220	AMV025	
221	AMV026	
222	AMV027	
223	AMV028	
224	AMV029	
225	AMV030	
226	AMV031	
227	AMV032	

Analog Outputs

Table B.12 Analog Outputs Point Mapping

Numeric Reference	Label Reference	Notes
0	ACTGRP	
1	TECORR	

Ethernet DNP Map Value Changes

The previous Ethernet DNP map was based on database references. The new DNP mapping uses direct data labels. The following sections describe how to get from the reference database mapping to the new direct data labels.

Binary Inputs

In the old mapping, any bit in the database could be referenced for use by DNP. Now, only Relay Word bits and a few other special bits can be used. The old reference format looked like 1:addr:bit. If *addr* is 3004h or greater, but not greater than 4000h, then the bits can be associated with the old Relay Word. Address 3004h corresponds to Relay Word 0, 3005h to Row 1, etc. The bits are simply references in the range 0–7 and match the bits within the Relay Word row. Thus, the Relay Word bits can be mapped to labels by using the old Relay Word table and correcting for any label changes.

Binary Outputs

Indexes 0–127 used to map the CCIN bits. These were general-purpose, high-speed bits, but they are no longer available. The end user will need to remap these to remote bits.

Table B.13 describes the mapping for the remaining bits.

Table B.13 Binary Outputs Mapping for DNP3 LAN/WAN (Sheet 1 of 2)

Numeric Reference	Label Reference	Notes
128	RB01	
129	RB02	
130	RB03	
131	RB04	
132	RB05	
133	RB06	
134	RB07	
135	RB08	
136	RB09	
137	RB10	
138	RB11	
139	RB12	
140	RB13	
141	RB14	
142	RB15	
143	RB16	
144	RB17	
145	RB18	
146	RB19	
147	RB20	
148	RB21	
149	RB22	
150	RB23	
151	RB24	
152	RB25	
153	RB26	
154	RB27	
155	RB28	
156	RB29	
157	RB30	
158	RB31	
159	RB32	
160	RB01:RB02	
161	RB03:RB04	
162	RB05:RB06	

Table B.13 Binary Outputs Mapping for DNP3 LAN/WAN (Sheet 2 of 2)

Numeric Reference	Label Reference	Notes
163	RB07:RB08	
164	RB09:RB10	
165	RB11:RB12	
166	RB13:RB14	
167	RB15:RB16	
168	RB17:RB18	
169	RB19:RB20	
170	RB21:RB22	
171	RB23:RB24	
172	RB25:RB26	
173	RB27:RB28	
174	RB29:RB30	
175	RB31:RB32	
176	OC1:CC1	
177	OC2:CC2	
178	89OC01:89CC01	
179	89OC02:89CC02	
180	89OC03:89CC03	
181	89OC04:89CC04	
182	89OC05:89CC05	
183	89OC06:89CC06	
184	89OC07:89CC07	
185	89OC08:89CC08	
186	89OC09:89CC09	
187	89OC10:89CC10	

Counters

In the SEL-421-0, -1, -2, -3 counters were referenced as points in the database. None of these can be directly assigned to the counter values that are now available.

Analog Inputs

In the SEL-421-0, -1, -2, -3 analog inputs were referenced as points in the database with optional type qualifiers. It is impractical to define a mapping from these points to the data that is now available.

Analog Outputs

In the SEL-421-0, -1, -2, -3 analog outputs were referenced by index: 0–255. These mapped to remote analogs: RA001–RA256. In the SEL-421-4, -5 these same remote analogs are available. So, if previously, Index 0 was referenced, the new reference is RA001. Similarly, Index 1 goes to RA002, etc.

IEC 61850 Object Changes

The SEL-421-0, -1, -2, -3 implementation of the IEC 61850 protocol suite differs slightly from the SEL-421-4, -5 implementation. *Table B.14* lists the main functional changes between the two.

Table B.14 IEC 61850 Functional Differences

Topic	SEL-421-0, -1, -2, -3	SEL-421-4, -5
ICD File Version	Version 001, 002	Version 003
Incoming GOOSE	Mappable to CCIN001–CCIN128 (binary data)	VB001–VB256 (binary data) RA001–RA256 (analog data)
Outgoing GOOSE	Relay Word bits mapped to CCOUT001 (binary data)	N/A (Relay Word bits can be sent directly without intermediate mapping; Analog outputs also available (RAO01–RAO64)
SER Time stamps	SER-quality time stamps available only for LNs included in the SER dataset	Any points in the SER list will have SER-quality time stamps. Otherwise, accuracy is within 500 ms.
Controls	Normal Security Only	Enhanced Security and Select-before-operate (SBO) available

Default datasets may be used for MMS Reports or for GOOSE message transmission. *Table B.15* lists the default dataset changes in the new ICD file version. Note that the contents of any dataset may be modified via ACSELERATOR Architect SEL-5032 Software.

Table B.15 Default Dataset Differences

Default Dataset	SEL-421-0, -1, -2, -3	SEL-421-4, -5
DSet03, DSet09	Includes LNs mapped from Relay Word Bits BK1A, BK1B, BK1C, BK2A, BK2B, BK2C	Includes LNs mapped from Relay Word Bits DC1–DC8
DSet13	CCOUT Status	Control and Annunciation

Most of the Logical Nodes and Attributes remain the same between the two implementations. *Table B.16* lists the mapping changes in the new ICD file.

Table B.16 Logical Node Mapping Differences (Sheet 1 of 2)

LD	SEL-421-1, -2, -3 Path	SEL-421-1, -2, -3 Mapping	SEL-421-4, -5 Path	SEL-421-4, -5 Mapping
PRO	BKR1PTRC2STtr$general	TRIP	BKR1PTRC2STtr$general	Set (1) if TPA1 or TPB1 or TPC1 are set
PRO	BKR2PTRC3STtr$general	TRIP	BKR2PTRC3STtr$general	Set (1) if TPA2 or TPB2 or TPC2 are set
PRO	BFR1RBRF1STStr$general	BFI3P1	BFR1RBRF1STStr$general	TRUE if (BFI3P1 OR BFIA1 OR BFIB1 OR BFIC1), FALSE otherwise
PRO	BFR2RBRF2STStr$general	BFI3P2	BFR2RBRF2STStr$general	TRUE if (BFI3P2 OR BFIA2 OR BFIB2 OR BFIC2), FALSE otherwise
CON	RBGGIO1COSPCSO09	RB09	RBGGIO2COSPCSO09	RB09
CON	RBGGIO1COSPCSO10	RB10	RBGGIO2COSPCSO10	RB10
CON	RBGGIO1COSPCSO11	RB11	RBGGIO2COSPCSO11	RB11

Table B.16 Logical Node Mapping Differences (Sheet 2 of 2)

LD	SEL-421-1, -2, -3 Path	SEL-421-1, -2, -3 Mapping	SEL-421-4, -5 Path	SEL-421-4, -5 Mapping
CON	RBGGIO1COSPCSO12	RB12	RBGGIO2COSPCSO12	RB12
CON	RBGGIO1COSPCSO13	RB13	RBGGIO2COSPCSO13	RB13
CON	RBGGIO1COSPCSO14	RB14	RBGGIO2COSPCSO14	RB14
CON	RBGGIO1COSPCSO15	RB15	RBGGIO2COSPCSO15	RB15
CON	RBGGIO1COSPCSO16	RB16	RBGGIO2COSPCSO16	RB16
CON	RBGGIO1COSPCSO17	RB17	RBGGIO3COSPCSO17	RB17
CON	RBGGIO1COSPCSO18	RB18	RBGGIO3COSPCSO18	RB18
CON	RBGGIO1COSPCSO19	RB19	RBGGIO3COSPCSO19	RB19
CON	RBGGIO1COSPCSO20	RB20	RBGGIO3COSPCSO20	RB20
CON	RBGGIO1COSPCSO21	RB21	RBGGIO3COSPCSO21	RB21
CON	RBGGIO1COSPCSO22	RB22	RBGGIO3COSPCSO22	RB22
CON	RBGGIO1COSPCSO23	RB23	RBGGIO3COSPCSO23	RB23
CON	RBGGIO1COSPCSO24	RB24	RBGGIO3COSPCSO24	RB24
CON	RBGGIO1COSPCSO25	RB25	RBGGIO4COSPCSO25	RB25
CON	RBGGIO1COSPCSO26	RB26	RBGGIO4COSPCSO26	RB26
CON	RBGGIO1COSPCSO27	RB27	RBGGIO4COSPCSO27	RB27
CON	RBGGIO1COSPCSO28	RB28	RBGGIO4COSPCSO28	RB28
CON	RBGGIO1COSPCSO29	RB29	RBGGIO4COSPCSO29	RB29
CON	RBGGIO1COSPCSO30	RB30	RBGGIO4COSPCSO30	RB30
CON	RBGGIO1COSPCSO31	RB31	RBGGIO4COSPCSO31	RB31
CON	RBGGIO1COSPCSO32	RB32	RBGGIO4COSPCSO32	RB32
ANN	CCINGGIO20STInd001–CCINGGIO20STInd128	CCIN001–CCIN128	N/A	
ANN	CCOUTGGIO21STInd01–CCOUTGGIO21STInd32	CCOUT01–CCOUT32	N/A	

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SEL-421-4, -5 Relay Command Summary

Command[a, b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
89CLOSE	Close disconnect switch *n* (*n* = 1–10)
89OPEN	Open disconnect switch *n* (*n* = 1–10)
AACCESS	Go to Access Level A (automation configuration)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	List ASCII names of Fast Meter status bits
BREAKER *n*	Display the circuit breaker report and breaker history; preload and reset breaker monitor data (*n* = 1 is BK1; *n* = 2 is BK2)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	Display Compressed ASCII breaker status report
CEVENT	Display Compressed ASCII event report
CFG CTNOM *i*	For TiDL relays, configure the nominal CT input value *i* to 1 or 5
CFG NFREQ *f*	In TiDL relays, set the nominal frequency, *f* (50 or 60)
CHISTORY	Display Compressed ASCII history report
CLOSE *n*	Close the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
COM *c*	Display relay-to-relay MIRRORED BITS communications or remote synchrophasor data (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel)
COM RTC	Display statistics for synchrophasor client channels
COM PTP	Display a report on PTP data sets and statistics
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–32)
COPY *m n*	Copy settings between instances in the same class (*m* and *n* are instance numbers; for example: *m* = 1 is Group 1; *n* = 2 is Group 2)
CPR	Display Compressed ASCII signal profiling report
CSER	Display Compressed ASCII sequential events report
CSTATUS	Display Compressed ASCII relay status report
CSUMMARY	Display Compressed ASCII summary event report
DATE	Display and set the date
DNAME X	List ASCII names of all relay digital points reported via Fast Meter
ETHERNET	Display Ethernet port (Port 5) configuration and status
EVENT	Display and acknowledge event reports
EXIT	Terminate a Telnet session
FILE	Transfer files between the relay and external software
GOOSE	Display transmit and receive GOOSE messaging information
GROUP	Display the active group number or select the active group
HELP	List and describe available commands at each access level
HISTORY	View event summaries/histories; clear event summary data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port

Command[a, b]	Description
MAC	Display the MAC addresses
MAP 1	View the relay database organization
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output configuration)
OPEN *n*	Open the circuit breaker (*n* = 1 is BK1; *n* = 2 is BK2)
PACCESS	Go to Access Level P (protection configuration)
PASSWORD *n*	Change relay passwords for access level *n*
PING	Send an ICMP echo request message to the provided IP address to confirm connectivity
PORT	Connect to a remote relay via MIRRORED BITS virtual terminal (for port number *p* = 1–3, and F)
PROFILE	Display signal profile records
PULSE OUT*nnn*	Pulse a relay control output (OUT*nnn* is a control output)
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder report
SET	Set or modify relay settings
SHOW	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC control equation errors
SUMMARY	Display a summary event report
TARGET	Display relay elements for a row in the Relay Word table
TEC	Display time-error estimate; display or modify time-error correction value
TEST DB	Test interfaces to a virtual device database
TEST DB2	Test all communications protocols, except Fast Message
TEST FM	Display or place values in metering database (Fast Meter)
TIME	Display and set the internal clock
TIME Q	Display detailed information on the relay internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW 1	View data from the Fast Message database

[a] See *Section 9: ASCII Command Reference*.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.

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[a] See *Section 9: ASCII Command Reference*.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.

SEL-400 Series Relays

Instruction Manual

20171006

SCHWEITZER ENGINEERING LABORATORIES

PM400-01

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Preface

This manual provides information and instructions for operating the SEL-400 series relays. This manual is for use by power and integration engineers and others experienced in protective relaying applications and SCADA integration. This manual describes features common to most SEL-400 series relays. Each SEL-400 series product includes its own instruction manual that describes the protection features and unique characteristics of that specific relay.

Manual Overview

This manual is a comprehensive work covering common aspects of SEL-400 series relay application and use. Read the sections that pertain to your application to gain valuable information about using SEL-400 series relays. An overview of each manual section and section topics follows.

Preface. Describes manual organization and conventions used to present information, as well as safety information.

Section 1: Introduction. Introduces SEL-400 series relay common features.

Section 2: PC Software. Explains how to use ACSELERATOR QuickSet SEL-5030 Software.

Section 3: Basic Relay Operations. Describes how to perform fundamental operations such as applying power and communicating with the relay, setting and viewing passwords, checking relay status, viewing metering data, reading event reports and Sequential Events Recorder (SER) records, operating relay control outputs and control inputs, and using relay features to make relay commissioning easier.

Section 4: Front-Panel Operations. Describes the LCD display messages and menu screens. Shows you how to use front-panel pushbuttons and read targets. Provides information about local substation control and how to make relay settings via the front panel.

Section 5: Control. Describes various control features of the relay, including circuit breaker operation, disconnect operation, remote bits, and one-line diagrams.

Section 6: Autoreclosing. Explains how to operate the two-circuit breaker multishot recloser. Describes how to set the relay for single-pole reclosing, three-pole reclosing, or both. Shows selection of the lead and follow circuit breakers.

Section 7: Metering. Provides information on viewing current, voltage, power, and energy quantities. Describes how to view other common internal operating quantities.

Section 8: Monitoring. Describes how to use the circuit breaker monitors and the substation dc battery monitors.

Section 9: Reporting. Explains how to obtain and interpret high-resolution raw data oscillograms, filtered event reports, event summaries, history reports, and SER reports. Discusses how to enter SER trigger settings.

Section 10: Testing, Troubleshooting, and Maintenance. Describes techniques for testing, troubleshooting, and maintaining the relay. Includes the list of status notification messages and a troubleshooting chart.

Section 11: Time and Date Management. Explains timekeeping principles, synchronized phasor measurements, and estimation of power system states using the high-accuracy time-stamping capability. Presents real-time load flow/power flow application ideas.

Section 12: Settings. Provides a list of all common SEL-400 series relay settings and defaults.

Section 13: SELOGIC Control Equation Programming. Describes multiple setting groups and SELOGIC control equations and how to apply these equations. Discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers. Provides a tutorial for converting older format SELOGIC control equations to new freeform equations.

Section 14: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 15: Communications Interfaces. Explains the physical connection of the relay to various communications network topologies. Describes the various software protocols and how to apply these protocols to substation integration and automation. Includes details about Ethernet IP protocols, SEL ASCII, SEL Compressed ASCII, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, and enhanced MIRRORED BITS communications.

Section 16: DNP3 Communication. Describes the DNP3 communications protocol and how to apply this protocol to substation integration and automation. Provides a Job Done example for implementing DNP3 in a substation.

Section 17: IEC 61850 Communication. Describes the IEC 61850 protocol and how to apply this protocol to substation automation and integration. Includes IEC 61850 protocol compliance statements.

Section 18: Synchrophasors. Describes the basic concepts of remote data acquisition systems. This includes both the Time-Domain Link (TiDL) remote data acquisition system, which uses SEL-2440 Axion modules to provide remote data acquisition and I/O communication, and UCA 61850-9-2LE Sampled Values.

Section 19: Remote Data Acquisition. Describes the basic concepts of remote data acquisition systems. This includes both the Time-Domain Link (TiDL) remote data acquisition system, which uses SEL-2440 Axion modules to provide remote data acquisition and I/O communication, and UCA 61850-9-2LE Sampled Values.

Appendix A: Manual Versions. Lists the current manual version and details differences between the current and previous versions.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: Cybersecurity Features. Describes the various features of the relay that impact cybersecurity.

Glossary. Defines various technical terms used in the SEL-400 series instruction manuals.

Safety Information

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols are often marked on SEL products.

	⚠CAUTION Refer to accompanying documents.	⚠ATTENTION Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d’instructions

Safety Marks

The following statements apply to this device.

General Safety Marks

⚠CAUTION There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer’s instructions. Keep battery out of reach of children.	⚠ATTENTION Une pile remplacée incorrectement pose des risques d’explosion. Remplacez seulement avec un Ray-O-Vac® no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d’utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d’incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks (Sheet 1 of 2)

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠DANGER Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.
⚠WARNING Do not look into the fiber ports/connectors.	⚠AVERTISSEMENT Ne pas regarder vers les ports ou connecteurs de fibres optiques.
⚠WARNING Do not look into the end of an optical cable connected to an optical output.	⚠AVERTISSEMENT Ne pas regarder vers l'extrémité d'un câble optique raccordé à une sortie optique.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠WARNING During installation, maintenance, or testing of the optical ports, use only test equipment qualified for Class 1 laser products.	⚠AVERTISSEMENT Durant l'installation, la maintenance ou le test des ports optiques, utilisez exclusivement des équipements de test homologués comme produits de type laser de Classe 1.
⚠WARNING Incorporated components, such as LEDs and transceivers are not user serviceable. Return units to SEL for repair or replacement.	⚠AVERTISSEMENT Les composants internes tels que les leds (diodes électroluminescentes) et émetteurs-récepteurs ne peuvent pas être entretenus par l'usager. Retourner les unités à SEL pour réparation ou remplacement.
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION Equipment damage can result from connecting ac circuits to Hybrid (high-current interrupting) control outputs. Do not connect ac circuits to Hybrid control outputs. Use only dc circuits with Hybrid control outputs.	⚠ATTENTION Des dommages à l'appareil pourraient survenir si un circuit CA était raccordé aux contacts de sortie à haut pouvoir de coupure de type "Hybrid." Ne pas raccorder de circuit CA aux contacts de sortie de type "Hybrid." Utiliser uniquement du CC avec les contacts de sortie de type "Hybrid."
⚠CAUTION Substation battery systems that have either a high resistance to ground (greater than 10 kΩ) or are ungrounded when used in conjunction with many direct-coupled inputs can reflect a dc voltage offset between battery rails. Similar conditions can exist for battery monitoring systems that have high-resistance balancing circuits or floating grounds. For these applications, SEL provides optional ground-isolated (optoisolated) contact inputs. In addition, SEL has published an application advisory on this issue. Contact the factory for more information.	⚠ATTENTION Les circuits de batterie de postes qui présentent une haute résistance à la terre (plus grande que 10 kΩ) ou sont isolés peuvent présenter un biais de tension CC entre les deux polarités de la batterie quand utilisés avec plusieurs entrées à couplage direct. Des conditions similaires peuvent exister pour des systèmes de surveillance de batterie qui utilisent des circuits d'équilibrage à haute résistance ou des masses flottantes. Pour ce type d'applications, SEL peut fournir en option des contacts d'entrée isolés (par couplage optoélectronique). De surcroît, SEL a publié des recommandations relativement à cette application. Contacter l'usine pour plus d'informations.

Other Safety Marks (Sheet 2 of 2)

⚠CAUTION If you are planning to install an INT4 I/O interface board in your relay, first check the firmware version of the relay. If the firmware version is R111 or lower, you must first upgrade the relay firmware to the newest version and verify that the firmware upgrade was successful before installing the new board. Failure to install the new firmware first will cause the I/O interface board to fail, and it may require factory service. Complete firmware upgrade instructions are provided when new firmware is ordered.	⚠ATTENTION Si vous avez l'intention d'installer une Carte d'Interface INT4 I/O dans votre relais, vérifiez en premier la version du logiciel du relais. Si la version est R111 ou antérieure, vous devez mettre à jour le logiciel du relais avec la version la plus récente et vérifier que la mise à jour a été correctement installée sur la nouvelle carte. Les instructions complètes de mise à jour sont fournies quand le nouveau logiciel est commandé.
⚠CAUTION Field replacement of I/O boards INT1, INT2, INT5, INT6, INT7, or INT8 with INT4 can cause I/O contact failure. The INT4 board has a pickup and dropout delay setting range of 0–1 cycle. For all other I/O boards, pickup and dropout delay settings (IN201PU–IN224PU, IN201DO–IN224DO, IN301PU–IN324PU, and IN301DO–IN324DO) have a range of 0–5 cycles. Upon replacing any I/O board with an INT4 board, manually confirm reset of pickup and dropout delays to within the expected range of 0–1 cycle.	⚠ATTENTION Le remplacement en chantier des cartes d'entrées/sorties INT1, INT2, INT5, INT6, INT7 ou INT8 par une carte INT4 peut causer la défaillance du contact d'entrée/sortie. La carte INT4 présente un intervalle d'ajustement pour les délais de montée et de retombée de 0 à 1 cycle. Pour toutes les autres cartes, l'intervalle de réglage du délai de montée et retombée (IN201PU–IN224PU, IN201DO– IN224DO, IN301PU–IN324PU, et IN301DO–IN324DO) est de 0 à 5 cycles. Quand une carte d'entrées/sorties est remplacée par une carte INT4, vérifier manuellement que les délais de montée et retombée sont dans l'intervalle de 0 à 1 cycle.
⚠CAUTION Do not install a jumper on positions A or D of the main board J21 header. Relay misoperation can result if you install jumpers on positions J21A and J21D.	⚠ATTENTION Ne pas installer de cavalier sur les positions A ou D sur le connecteur J21 de la carte principale. Une opération intempestive du relais pourrait résulter suite à l'installation d'un cavalier entre les positions J21A et J21D.
⚠CAUTION Insufficiently rated insulation can deteriorate under abnormal operating conditions and cause equipment damage. For external circuits, use wiring of sufficiently rated insulation that will not break down under abnormal operating conditions.	⚠ATTENTION Un niveau d'isolation insuffisant peut entraîner une détérioration sous des conditions anormales et causer des dommages à l'équipement. Pour les circuits externes, utiliser des conducteurs avec une isolation suffisante de façon à éviter les claquages durant les conditions anormales d'opération.
⚠CAUTION Relay misoperation can result from applying other than specified secondary voltages and currents. Before making any secondary circuit connections, check the nominal voltage and nominal current specified on the rear-panel nameplate.	⚠ATTENTION Une opération intempestive du relais peut résulter par le branchement de tensions et courants secondaires non conformes aux spécifications. Avant de brancher un circuit secondaire, vérifier la tension ou le courant nominal sur la plaque signalétique à l'arrière.
⚠CAUTION Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.	⚠ATTENTION Des problèmes graves d'alimentation et de terre peuvent survenir sur les ports de communication de cet appareil si des câbles d'origine autre que SEL sont utilisés. Ne jamais utiliser de câble de modem nul avec cet équipement.
⚠CAUTION Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ATTENTION Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠CAUTION Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.	⚠ATTENTION L'utilisation de commandes ou de réglages, ou l'application de tests de fonctionnement différents de ceux décrits ci-après peuvent entraîner l'exposition à des radiations dangereuses.

General Information

The *SEL-400 Series Relays Instruction Manual* uses certain conventions that identify particular terms and help you find information. To benefit fully from reading this manual, take a moment to familiarize yourself with these conventions.

Typographic Conventions

There are three ways users typically communicate with SEL-400 series relays:

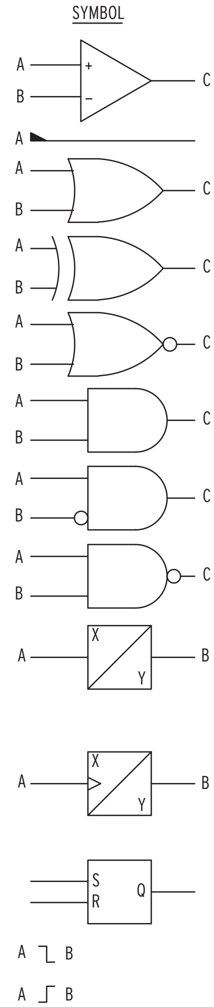
- Using a command line interface on a PC terminal emulation window
- Using the front-panel menus and pushbuttons
- Using ACSELERATOR QuickSet Software

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SUM *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
ENABLE	Relay front- or rear-panel labels and pushbuttons.
MAIN > METER	Relay front-panel LCD menus and relay responses visible on the PC screen. The > character indicates submenus.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.



NAME	FUNCTION
COMPARATOR	Input A is compared to input B. Output C asserts if A is greater than B.
INPUT FLAG	Input A comes from other logic.
OR	Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR	If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR	If neither A nor B asserts, output C asserts.
AND	Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT	If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate.
NAND	If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT	X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER	Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert for a single processing interval. Input A is ignored while the timers are running.
SET RESET FLIP FLOP	Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts.
FALLING EDGE	B asserts at the falling edge of input A.
RISING EDGE	B asserts at the rising edge of input A.

Trademarks

All brand or product names appearing in this document are the trademark or registered trademark of their respective holders. No SEL trademarks may be used without written permission.

SEL trademarks appearing in this manual are shown in the following table.

ACSELERATOR Analytic Assistant®	SEL-2407®
ACSELERATOR Architect®	SELOGIC®
ACSELERATOR QuickSet®	SEL Compass®
Best Choice Ground Directional Element®	SYNCHROWAVE®
MIRRORED BITS®	

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We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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SECTION 1

Introduction

The SEL-400 series family of relays feature high-performance protection for a variety of applications. All relays feature extensive metering, monitoring, and data recording, including high-resolution data capture and reporting.

Relays feature expanded SELOGIC control equation programming for easy and flexible implementation of custom protection and control schemes. The relays have separate protection and automation SELOGIC control equation programming areas with extensive protection and automation programming capability.

NOTE: Some SEL-400 series devices are compliant with Edition 1 of the IEC 61850 standard.

Relays provide extensive communications interfaces from standard SEL ASCII and enhanced MIRRORED BITS communications protocols to Ethernet connectivity with the optional Ethernet card. With the Ethernet card, you can employ common industry communications tools, including Telnet, FTP, DNP3 (serial and LAN/WAN), and the IEC 61850 Edition 2 standard suite of protocols.

Relays interface with ACSELERATOR QuickSet SEL-5030 Software. QuickSet assists you in setting, controlling, and acquiring data from the relays, both locally and remotely. ACSELERATOR Architect SEL-5032 Software is included with purchase of the optional Ethernet card with IEC 61850 protocol support. Architect enables you to view and configure IEC 61850 settings via a GUI.

Most relays support synchrophasor measurement. Synchrophasor measurements are available when a high-accuracy time source is connected to the relay. The relay supports the IEEE C37.118, Standard for Synchrophasors for Power Systems.

Most relays feature bay control functionality. The mimic display selected is displayed on the front-panel screen in one-line diagram format. The number of disconnects and breakers that can be controlled by the relay are a function of the selected mimic display screen. Control of the breakers and disconnects is available through front-panel pushbuttons, ASCII interface, Fast Message protocol, or SELOGIC control equations.

A simple and robust hardware design features efficient digital signal processing. Combined with extensive self-testing, these features provide relay reliability and enhance relay availability.

Common Features

Automation. Take advantage of enhanced automation features that include programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large-format front-panel LCD eliminates the need for separate panel meters. Use serial and Ethernet links to efficiently transmit key information, including metering data, protection element and control I/O status, Sequential Events Recorder (SER) reports, breaker monitor, relay summary event reports, and time synchronization. Use expanded SELOGIC control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic to speed and improve control actions.

Oscillography and Event Reporting. Record voltages, currents, and internal logic points as fast as an 8 kHz sampling rate. Phasor and harmonic analysis features allow investigation of relay and system performance.

Sequential Events Recorder (SER). Record the last 1000 entries, including setting changes, startups, and selectable logic elements.

High-Accuracy Time Stamping. Time-stamp binary COMTRADE event reports with real-time accuracy of better than 10 µs. View system state information to an accuracy of better than 1/4 of an electrical degree.

Digital Relay-to-Relay Communication. Use enhanced MIRRORED BITS communications to monitor internal element conditions between relays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

Ethernet Access. Access all relay functions with the optional Ethernet card. Interconnect with automation systems using IEC 61850 or DNP3 LAN/WAN protocols directly or through an SEL-3530 RTAC. Use File Transfer Protocol (FTP) for high-speed data collection.

Time-Domain Link (TiDL). Reduce costs with TiDL technology. With this simple-to-configure solution, the relay ac inputs and most of its digital inputs and outputs are distributed using SEL-2240 Axion modules. The Axion modules are connected to the relay through use of direct fiber connections. By placing the Axion modules near the primary equipment, you can achieve significant reductions in copper cabling while remaining cybersecure.

Parallel Redundancy Protocol (PRP). Provide seamless recovery from any single Ethernet network failure with this protocol, in accordance with IEC 62439-3. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

Increased Security. Set unique passwords for each access level. The relay divides control and settings into seven relay access levels. The relay has separate breaker, protection, automation, and output access levels, among others.

Rules-Based Settings Editor. Communicate with and set the relay using an ASCII terminal, or use the PC-based QuickSet software to configure the relay and analyze fault records with relay element response.

Settings Reduction. Show only the settings for the functions and elements you have enabled using internal relay programming.

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. The aliases are available for use in customized programming, making initial programming and maintenance easy.

SECTION 2

PC Software

This section provides information on the following topics:

SEL-400 series relays come with ACSELERATOR QuickSet SEL-5030 Software, a powerful relay settings, analysis, and measurement tool, to aid you in applying and using the relay. QuickSet reduces engineering costs for relay settings, logic programming, and system analysis. QuickSet makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more relays
  - Store and retrieve settings with Windows-based PCs
  - Upload and download relay settings files to and from relays
- Analyze events
  - Use the integrated waveform (single event reports) analysis tools
- Control the relay
  - Command relay operation through use of a GUI environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides QuickSet for easier, more efficient configuration of the relay settings. However, you do not have to use QuickSet to configure a relay; you can use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering. QuickSet gives you the advantages of rules-based settings checks, SELOGIC control equation Expression Builder, and event analysis.

QuickSet Setup

Obtaining QuickSet

QuickSet can be obtained from the Download area of the SEL website. To have the software automatically update as new relay drivers are released, download and install SEL Compass Software, and then use Compass to download and install QuickSet. When you download QuickSet within Compass, you will be asked to select which relay drivers you wish to include. Select drivers for all SEL relays that you may be required to set. If later you find that additional drivers are required, QuickSet provides an easy method to request new drivers and updates (see *Updating QuickSet on page 2.2*).

QuickSet is also available on CD upon request.

Updating QuickSet

The QuickSet software consists of a core application plus driver files for individual devices. As new device firmware versions are released, you may need to update QuickSet to add new driver files. This may be accomplished several ways:

- ➤ When the **Enable Update Notifications** check box is selected in the **Tools** > **Options** menu of SEL Compass, the Compass software will automatically check for updates on a specified schedule and facilitate the update process.
- ➤ The **Update** icon on the QuickSet startup screen starts SEL Compass and checks for updates.
- ➤ The **Install Devices** button on the Settings Editor Selection window starts SEL Compass and presents a menu of available drivers.
- ➤ **Check for updates** in the **Help** menu starts SEL Compass and checks for updates.

An Internet connection is required to add new drivers and to receive update notifications.

Serial Communication Parameters

QuickSet can communicate with a relay via any relay serial port set to SEL protocol or via Ethernet. Use the **Communication Parameters** dialog box to configure relay communications settings.

Step 1. Select the **Communication** menu on the top QuickSet toolbar.

Step 2. Click **Parameters** to open this dialog box.

Figure 2.1 shows the QuickSet **Communication Parameters** dialog box.

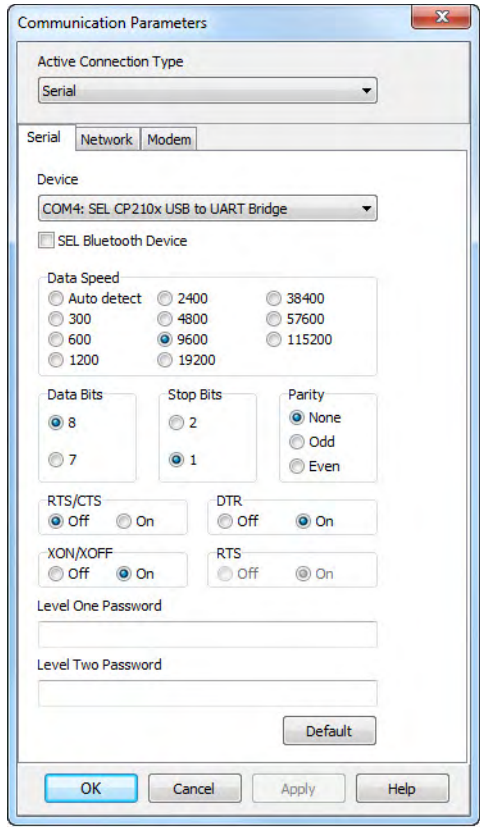

Figure 2.1 QuickSet Communication Parameters Dialog Box

You can use serial communication via relay Ports 1, 2, 3, and F (front panel). *Figure 2.1* shows the default serial port parameters (9600, 8, N, 1).

Step 1. Enter your relay Access Level One and Access Level Two passwords in the respective text boxes.

Step 2. If you choose a connection type from the **Active Connection Type** drop-down list that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

Ethernet Card

Use the optional Ethernet card for FTP and Telnet network communications.

FTP Setup

Step 1. Access the **Network** dialog box from the **Active Connection Type** drop-down menu.

Step 2. Click the **FTP File Transfer Option** button to select FTP as the network communications protocol.

Step 3. Enter the IP address of the relay Ethernet port as the Host IP address.

Step 4. Enter the FTP port number.

Step 5. Enter the relay Access Level One and Access Level Two passwords in the respective text boxes.

See *Changing the Default Passwords in the Terminal on page 3.10*.

Step 6. Use the **Save to Address Book** button to save the entered information with a Connection Name for later use.

Step 7. Set the relay Ethernet port setting **FTPSERV** to **Y**.

Telnet Setup

Step 1. Access the **Network** dialog box from the **Active Connection Type** drop-down menu.

Step 2. Click the **Telnet File Transfer Option** button to select Telnet as the network communications protocol.

The Telnet session uses the relay passwords on the **Communication Parameters** dialog box (*Figure 2.1*). See *Telnet on page 15.13* for more information on Telnet.

Terminal Window

The terminal window provides an ASCII interface on which you can communicate with the relay. This is a basic terminal emulation. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Step 1. Click the QuickSet **Communication** menu.

Step 2. Click **Terminal** to start the terminal window.

Another convenient method to start the terminal is to press **<Ctrl+T>**.

Terminal Logging

When you select the **Terminal Logging** check box in the **Communication** menu, QuickSet records communications events and errors in a log.

Step 1. Click **Communication > Logging > Connection Log** to view the log.

Step 2. Clear the log by selecting **Communication > Logging > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

QuickSet uses a relay database to save relay settings. QuickSet contains sets of all settings files for each relay that you specify in the **Database Manager**. Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Database Manager** menu to retrieve a relay database from computer memory.

Relay Database

The default relay database file already configured in QuickSet is **Relay.rdb**. This database contains example settings files for the SEL products with which you can use QuickSet.

Step 1. Open the **Database Manage**r to access the database.

a. Click **File** in the QuickSet top toolbar.

b. Select and click the **Database Manager** menu item. You will see a dialog box similar to *Figure 2.2*.

Step 2. If you wish, you can enter descriptions of the database and/or relay in the **Database Description** and/or **Settings Description** text boxes.

A relay description would consist of special operating characteristics that describe the relay settings including the protection scheme settings and communications settings.

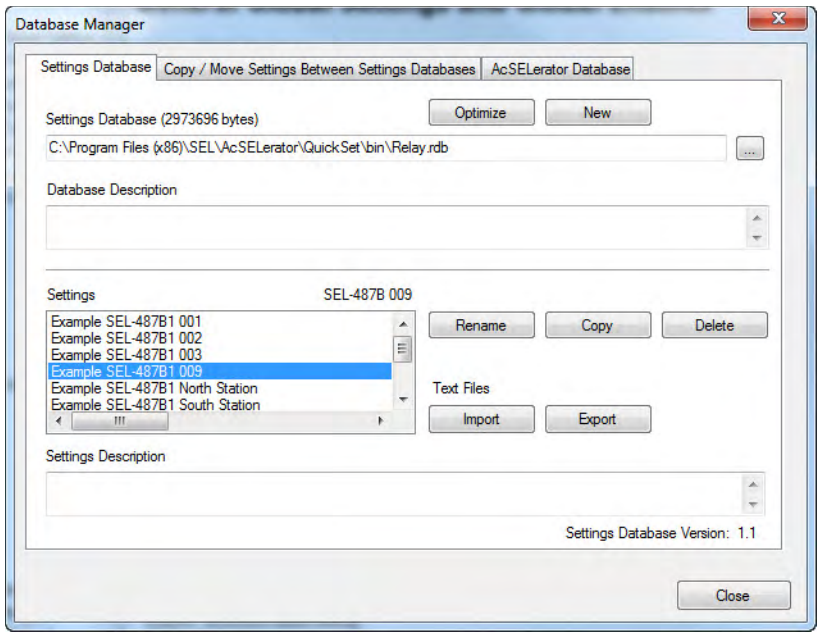

Figure 2.2 QuickSet Database Manager Relay Database

Step 3. Highlight one of the relays listed in **Settings**.

Step 4. Click **Copy** to create a new collection of relay settings.

QuickSet prompts you to provide a new name.

Copy/Move Relays Between Databases

You can create multiple relay databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

Step 1. Select the **Copy/Move Relays Between Settings Databases** tab to access the dialog box shown in *Figure 2.3*.

Step 2. Click the ellipsis next to **Settings Database B** to open a relay database.

Step 3. Navigate to the desired database location.

Step 4. Click **Open**.

For example, **Relay2.rdb** is the B relay database in *Figure 2.3*.

Step 5. Highlight a relay in the A database.

Step 6. Select **Copy** or **Move**.

Step 7. Click the **>** button to create a new relay in the B database.

Reverse this process to take relays from the B database to the A database.

Copy creates an identical relay that appears in both databases. **Move** removes the relay from one database and places the relay in another database.

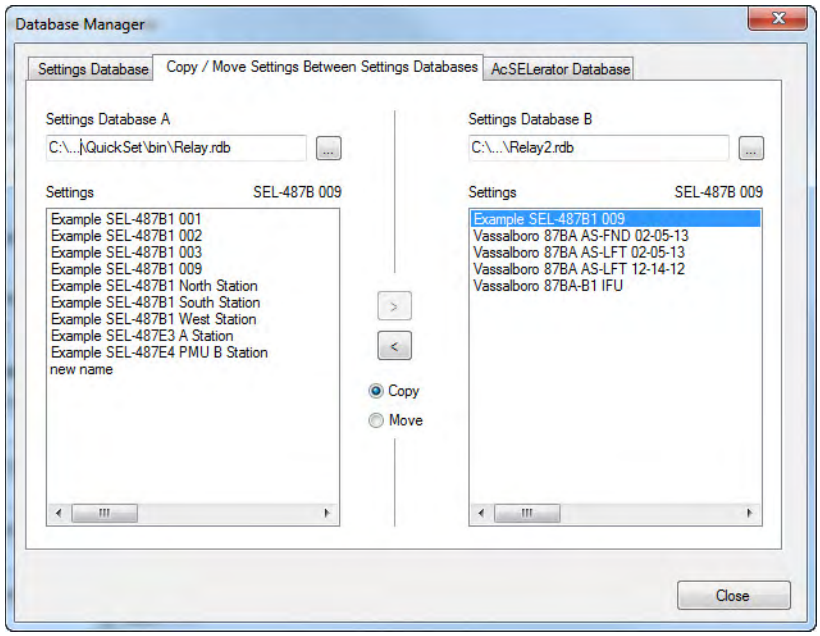

Figure 2.3 QuickSet Database Manager Copy/Move

Create a New Database

Step 1. To create and copy an existing database of relays to a new database, select the **File > Database Manager** menu.

Step 2. Select **Copy/Move Relays Between Databases** on the **Database Manager** dialog box.

QuickSet opens the last active database and assigns it as Database A (see *Figure 2.3*).

Step 3. Click on the ellipsis next to **Settings Database B**.

QuickSet prompts you for a file location.

Step 4. Type a new database name.

Step 5. Click **Open**.

Step 6. Answer **Yes**.

The program creates a new empty database.

Step 7. Load relays into the new database as in *Copy/Move Relays Between Databases on page 2.5*.

Drivers

Relay settings folders in QuickSet are closely associated with the QuickSet relay driver that you used to create the settings. The relay settings and the QuickSet drivers must match.

Step 1. Use one of the following methods to view the relay FID (firmware identification) number to determine the active QuickSet drivers.

➢ Enter Access Level 1 and use the **STATUS** command from the serial port terminal emulation window.

➢ Type **ID <Enter>** in the computer emulation software window (**<Ctrl+T>** from QuickSet).

Step 2. Locate and record the Z-number in the FID string.

The Z-number helps determine the proper QuickSet relay settings driver version when creating or editing relay settings files.

Step 3. View the QuickSet settings driver information at the bottom of the **Settings Editor** window.

The first portion of the Z-number is the QuickSet settings driver version number (see *Figure 2.4*).

Step 4. Compare the QuickSet driver number and the relay FID number.

This QuickSet driver Z-number and the corresponding part of the relay FID must match.

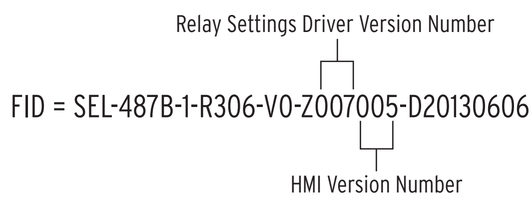

Figure 2.4 QuickSet Software Driver Information in the FID String

Use the first portion of the Z-number (Z001XXX, for example) to determine the correct **Settings Editor** version to select.

Step 5. View the top of the **Settings Editor** window to check the **Settings Editor** driver number (see *Figure 2.5*).

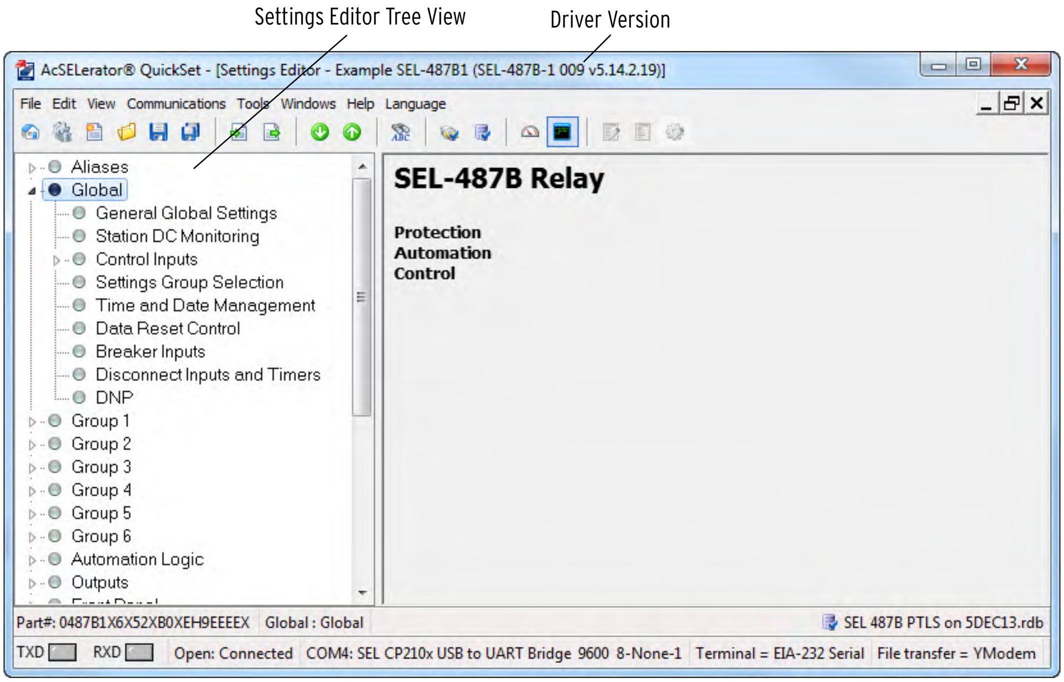

Figure 2.5 Relay Settings Driver Version Number

As SEL develops new drivers, you can update your existing QuickSet with specific relay drivers for each SEL product that uses QuickSet. Use SEL Compass (selinc.com/products/compass/) to download the latest QuickSet drivers.

QuickSet Main Menu

The main menu provides the following options and submenu options. Selected submenu options are explained in detail in *Table 2.1*.

Table 2.1 QuickSet Submenu Options (Sheet 1 of 2)

File	➤ New—Create new settings for a connected device or offline. ➤ Open—Open existing settings stored in a Relay Database (RDB) file. ➤ Close—Close settings instance that is open in the QuickSet window. ➤ Save/Save As—Save settings instance that is open in the QuickSet window to the active Relay Database (RDB) file. ➤ Print Device Settings—Print standard or custom settings reports. ➤ Read—Read settings from a connected device and display the settings in the QuickSet window. ➤ Send—Send settings instance that is open in the QuickSet window to a connected device. ➤ Active Database—Change which Relay Database (RDB) file is used for the Open and Save/Save As commands. ➤ Database Manager—Open Database Manager to create a new Relay Database (RDB) file, copy settings within the active Relay Database (RDB) file, add descriptions to settings within the database, and copy and move settings between different databases. ➤ Exit—Quit the QuickSet software.

Table 2.1 QuickSet Submenu Options (Sheet 2 of 2)

Edit	➤ Copy—Copy settings from one Settings Group to another. ➤ Search—Search for a text string within the settings instance. ➤ Compare—Compare the settings instance that is open in the QuickSet window to another settings instance in the Relay Database file. ➤ Merge—Merge the settings instance that is open in the QuickSet window with another settings instance in the Relay Database file. ➤ Part Number—Change the current part number for the settings instance that is open in the QuickSet window.
Communications	➤ Connect—Request QuickSet to attempt to connect to a device using the current Connection Parameters. ➤ Parameters—Modify the Communications Parameters, including connection type (Serial, Network, or Modem), PC port numbers, speed, and settings, device passwords, IP addresses, ports, and file transfer options, and modem phone numbers and speeds. ➤ Network Address Book—Select from a list of Ethernet-connected devices. Add or modify devices by specifying the Connection Name, IP Address, Telnet Port Number, User ID, and Password. ➤ Terminal—Open terminal window to issue ASCII commands directly to a connected relay. ➤ Logging—Initiate terminal logging to record terminal communications. View and clear the connection log.
Tools	➤ Settings—Convert settings between settings versions. Import and export settings from and to text files. ➤ HMI—Open HMI for connected device and manage custom HMI Device Overviews. ➤ Events—Collect event and view reports from connected devices. ➤ Options—Control QuickSet options, including Setting Comments, Event Viewer, and Terminal Options. ➤ Firmware Loader—Upgrade relay firmware.
Help	➤ Access program and settings help.

Create and Manage Relay Settings

QuickSet enables you to create settings for one or more relays. You can store existing relay settings downloaded from relays with QuickSet, creating a library of relay settings (see *Database Manager on page 2.4*). You can then modify and upload these settings from your settings library to a relay. QuickSet makes setting the relay easy and efficient.

Relay Part Number

The relay part number determines the settings that QuickSet displays and the functions that the software controls. When configuring QuickSet to control a particular relay, you should confirm that the QuickSet part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Relay Part Number

Step 1. Select the QuickSet **Edit** menu.

Step 2. Click **Part Number** in the drop down menu, as shown in *Figure 2.6*.

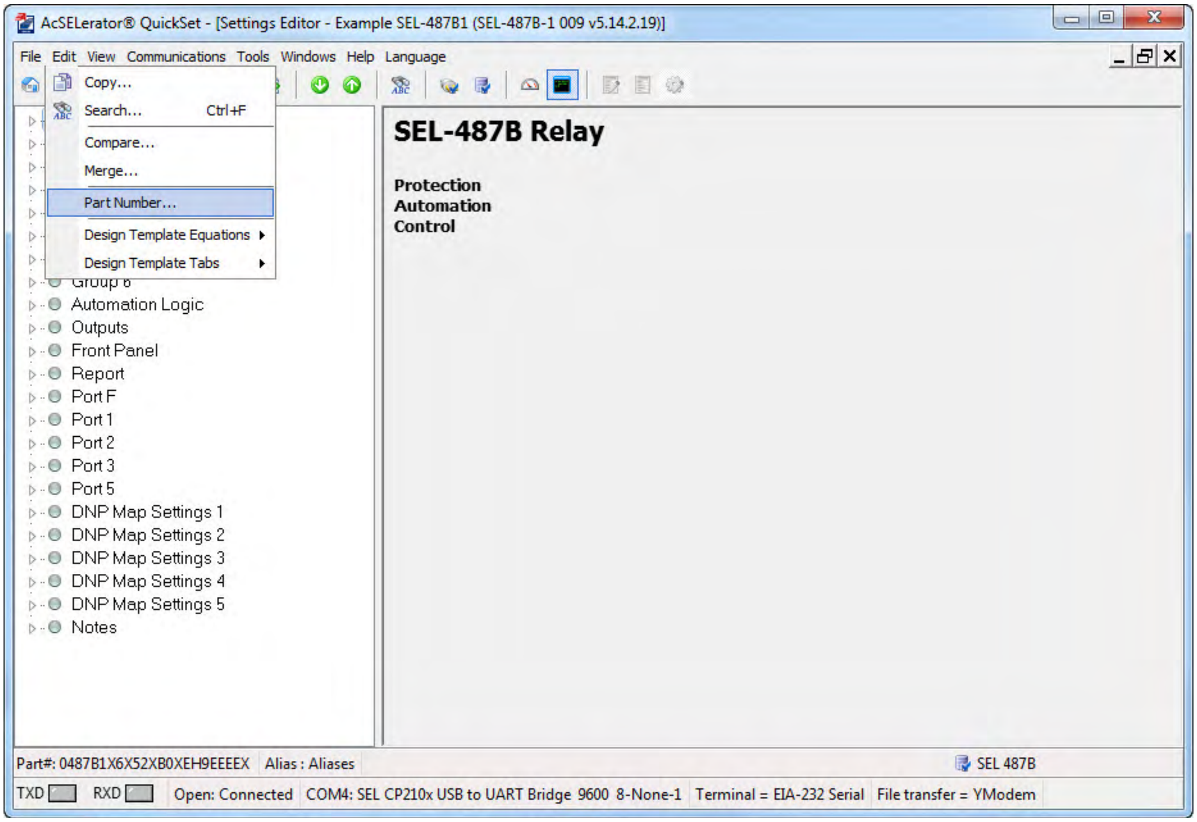

Figure 2.6 Retrieving the Device Part Number

You will see the **Device Part Number** dialog box, similar to the one shown in *Figure 2.7* for the SEL-487B.

Step 3. Use the arrows inside the text boxes to match corresponding portions of the **Device Part Number** dialog box to your relay. Alternatively, click **Edit** in the lower left corner of the **Device Part Number** screen and paste in the desired part number.

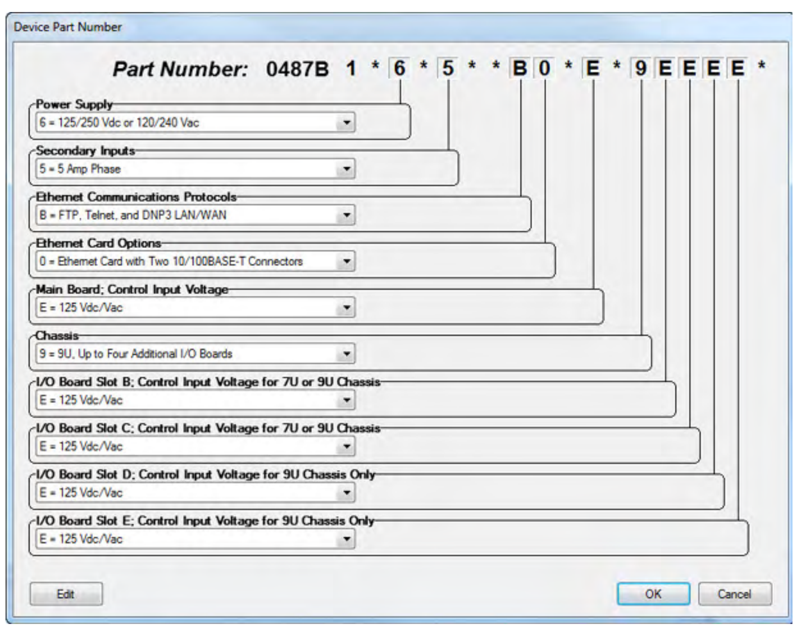

Figure 2.7 Setting the Relay Part Number in QuickSet

Remote Data Acquisition Settings

NOTE: The relay must be configured using the **CFG CTNOM *n*** command before the settings are transferred to the relay to avoid erasing the transferred settings. The commands used to set the nominal current in the relay will default all settings after the commands are issued. Changing the SECINC, CURSTU, or CURWXY settings in QuickSet will not change the rest of the settings in QuickSet back to default but will provide an error if any of the current settings are now out of range. In addition, when the relay is connected to QuickSet, the software reads the configuration of the relay and appropriately updates this setting automatically; however, this setting must work offline and develop settings when not connected to the relay.

In relays that support remote data acquisition, such as Time-Domain Link (TiDL), there are configurable settings that are specific to those applications. These settings are needed to help configure QuickSet and control attributes such as setting ranges, defaults, and functionality. These settings are not part of the actual relay firmware, and therefore are not sent to the relay at the time the settings transfer. SECINC is one of these configurable settings. SECINC determines the nominal current input for the remotely connected SEL-2240 Axion units used in TiDL applications for remote data acquisition. In the relay, the user issues an ASCII command, **CFG CTNOM *n***, to set the relay firmware to the correct nominal current being received from the remote TiDL Axion units. Once the command has been used to set the nominal current value from the remote data acquisition units, use QuickSet to set SECINC (see *Figure 2.8*) to that same nominal value to adjust all QuickSet setting ranges to the appropriate scales.

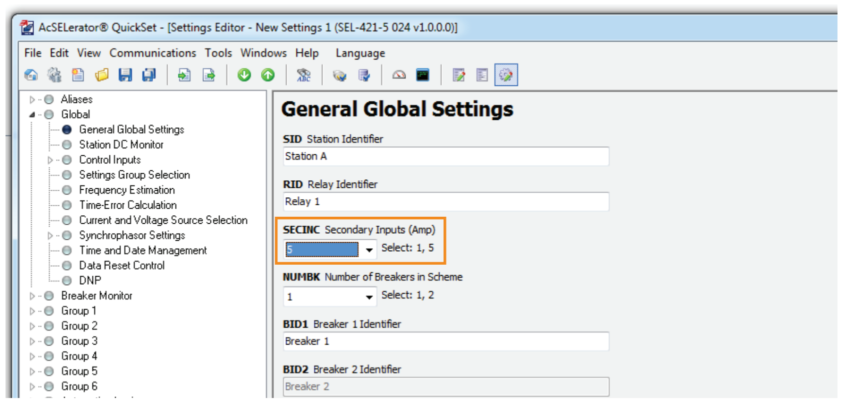

Figure 2.8 SECINC Setting

Some relays, such as the SEL-487E, have multiple setting combinations. The QuickSet settings for the SEL-487E, CURSTU and CURWXY, are shown in *Figure 2.9*. and are used instead of SECINC. For more information on the settings options, review the **CFG CTNOM** command operation in *Section 2: Installation* of the product-specific instruction manual.

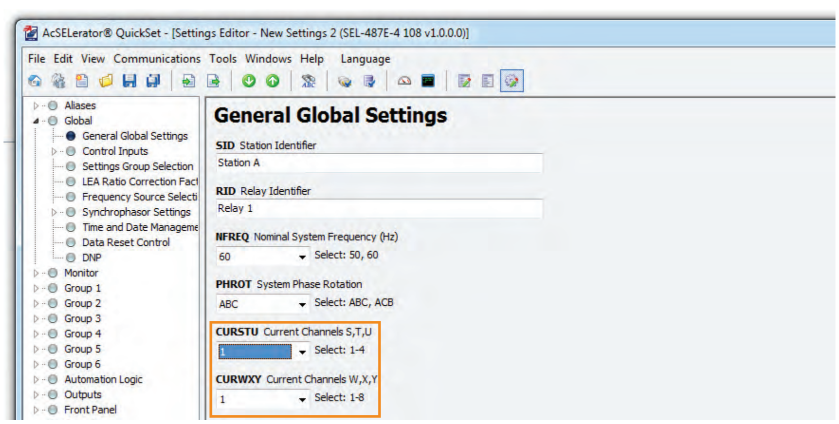

Figure 2.9 SEL-487E Nominal Current Selection

If at the time the relay settings are transferred, the QuickSet settings SECINC, CURSTU, or CURWXY do not match the nominal current set in the relay by the **CFG CTNOM** command, the settings transfer is rejected and an error message is displayed.

For relays that do not support remote data acquisition, the SECINC setting is grayed out in QuickSet (see *Figure 2.10*). Settings CURSTU and CURWXY are also grayed out in the SEL-487E.

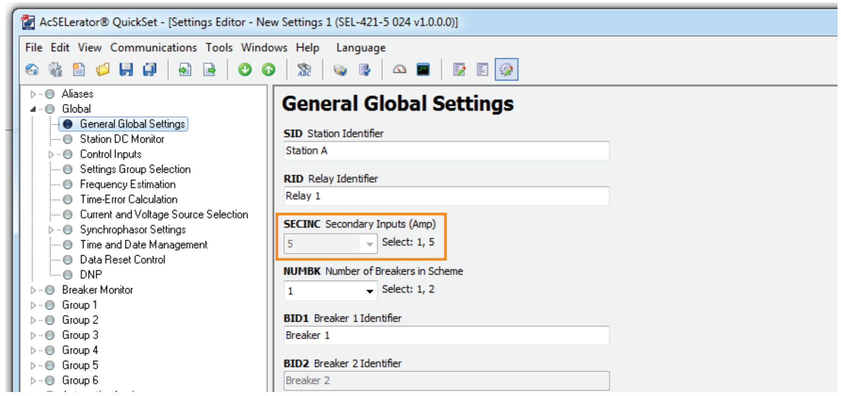

Figure 2.10 SECINC Disabled

Settings Overview

QuickSet arranges relay settings in easy-to-understand categories (for an explanation of settings organization, see *Making Simple Settings Changes on page 3.15*). These categories of collected settings help you quickly set the relay. *Figure 2.11* is an example of relay settings categories in the **Settings Editor** tree view.

QuickSet shows all of the settings categories in the settings tree view. When you enable and disable settings categories, the tree view remains constant, but when you click on the tree view to access the settings in a disabled category, the disabled settings are dimmed. For example try the following steps:

Step 1. Select **Global > Station DC Monitoring** and observe that the settings are dim.

Step 2. To enable the Station DC Monitor settings, select the **Global > General Global Settings/Enables** branch of the settings tree view.

Step 3. Change the **EDCMON Station DC Battery Monitor** setting to **Y**.

Step 4. *Figure 2.11* through *Figure 2.13* illustrates this feature of QuickSet.

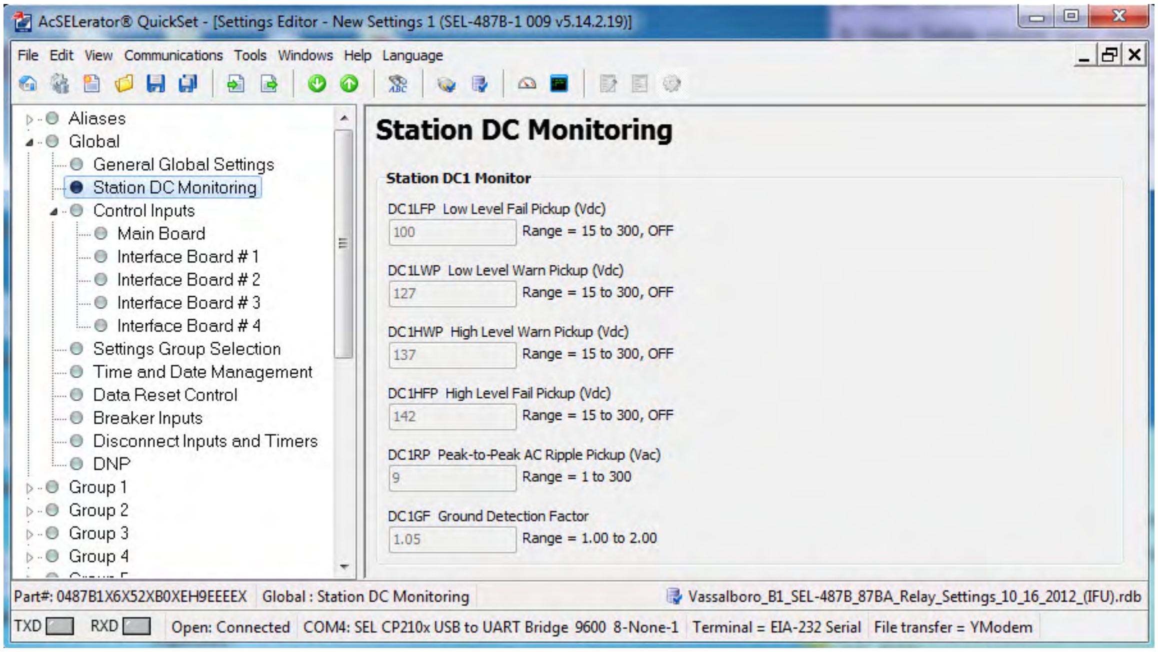

Figure 2.11 Station DC Settings

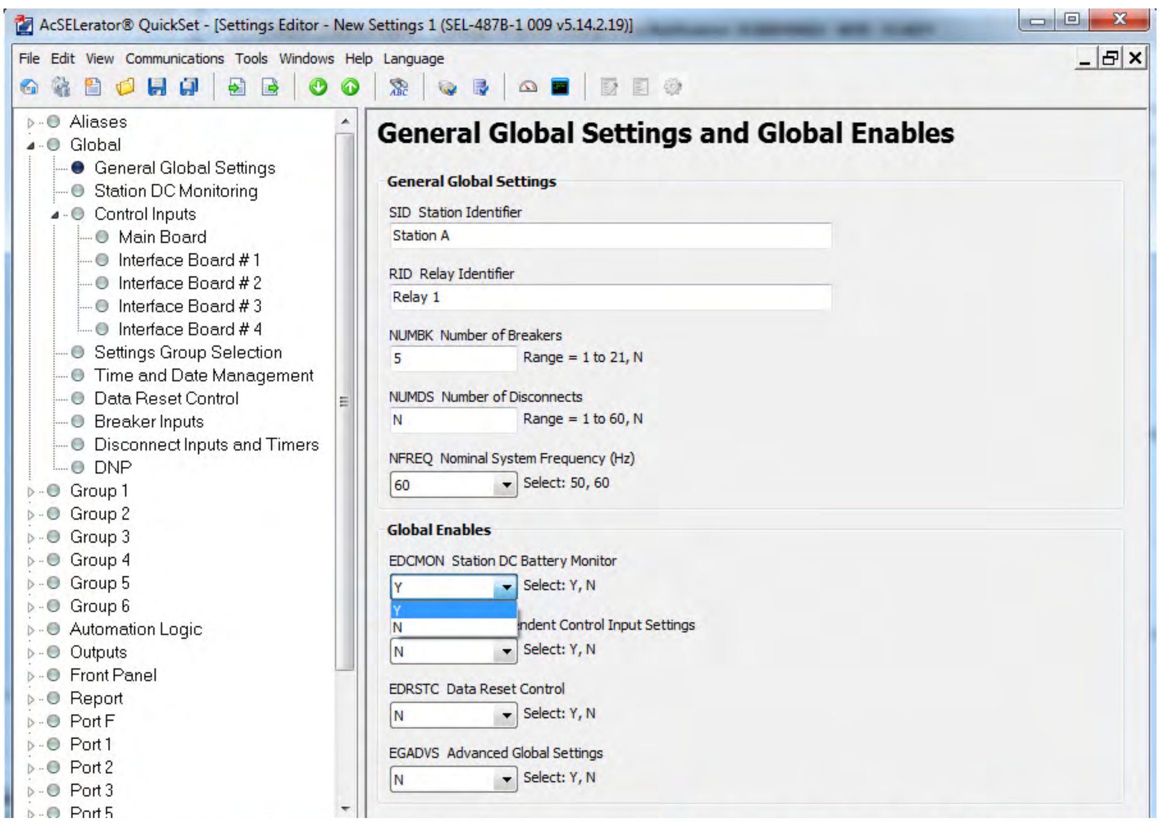

Figure 2.12 Enable EDCMON in Global Settings

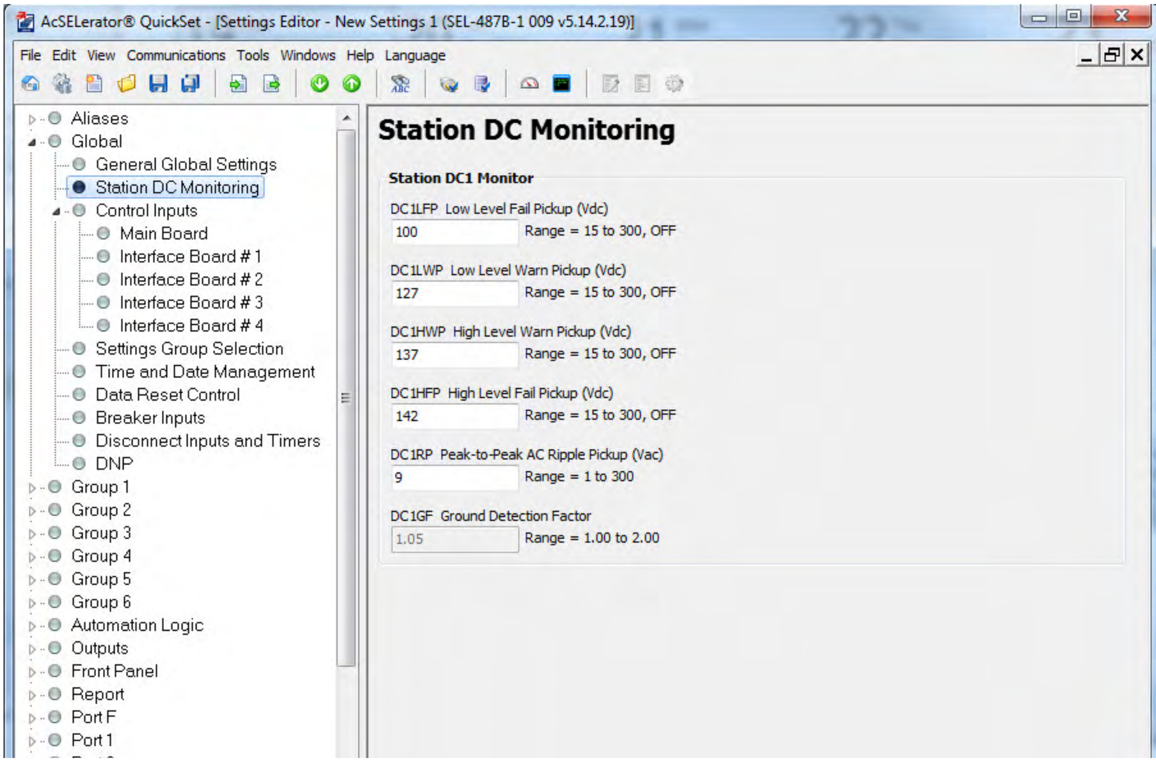

Figure 2.13 DC Monitor Settings Enabled

Settings Editor

Use the **Settings Editor** to enter relay settings. *Figure 2.14* illustrates the important features of the editor. These features include the QuickSet settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Settings Editor**.

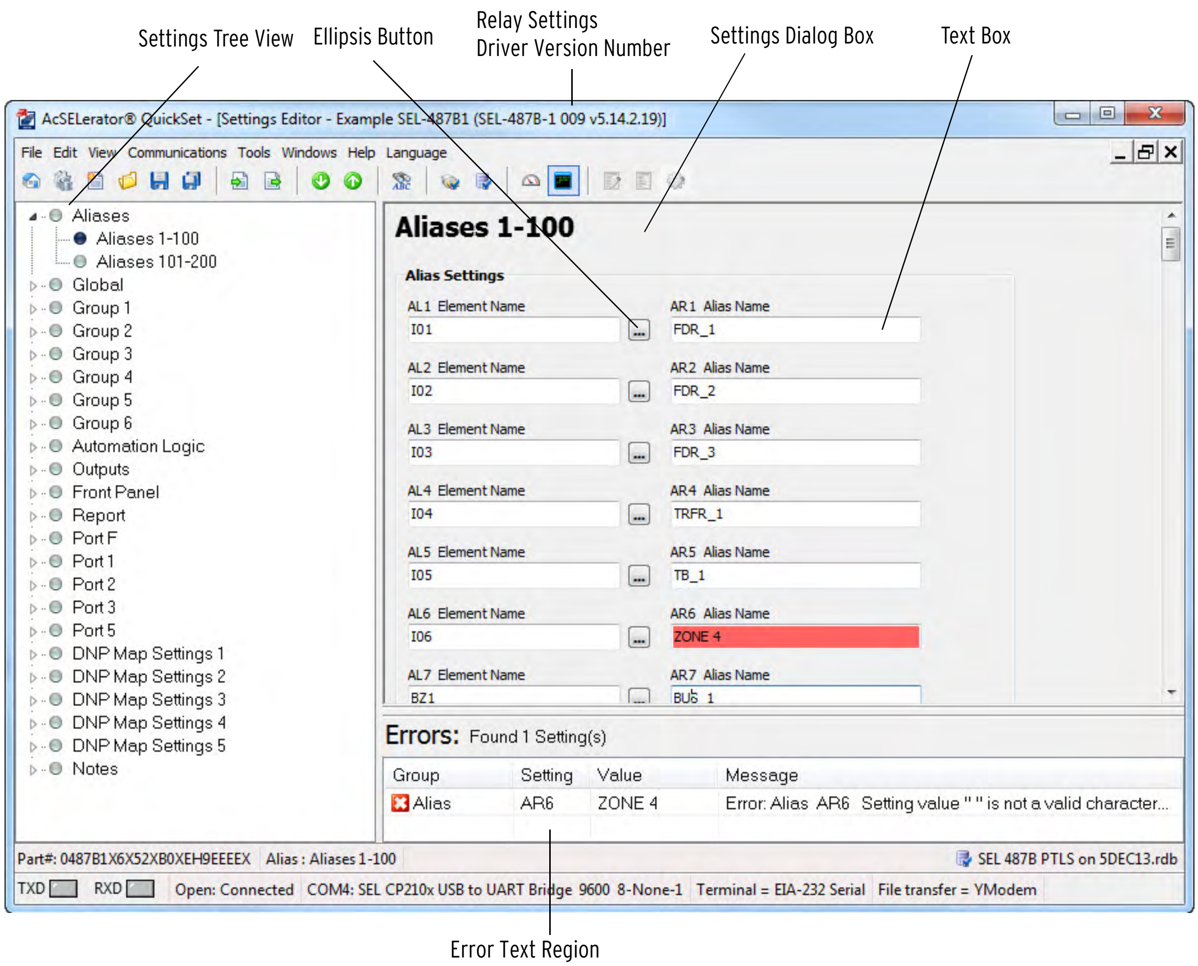

Figure 2.14 QuickSet Settings Editor

Entering Settings

Step 1. Click the arrows to expand the **Settings Tree View** (see *Figure 2.14*).

Step 2. Click the circle buttons to select the settings class, instance, and category that you want to change.

Step 3. Use the **<Tab>** key to move to the setting text book and from setting to setting when entering and editing.

Step 4. The right-click mouse button allows access to two special functions when you are editing settings: **Previous Value** and **Default Value**. It also allows the user to **Add a Comment** to the selected setting or **Search for Selected Text**.

Step 5. Use the following methods to edit the settings from QuickSet.

- ➢ Restore previous values. Right click the mouse over the setting and select **Previous Value**.
- ➢ Restore default values. Right click in the setting dialog box and select **Default Value**.

  If you enter a setting that is out of range or has an error, an error message appears at the bottom of the **Settings Editor** window. To correct the error, proceed to *Step 6*.

Step 6. Correct settings errors.

a. Double-click on the error listing in the **Settings Editor** window.

b. Enter a valid input for the setting where the error appears.

Ellipsis Button

QuickSet includes a feature called an **ellipsis button** (see *Figure 2.15*).

Figure 2.15 Ellipsis Button

The ellipsis button is a square button with three dots, as shown in *Figure 2.16*. Use the ellipsis button to build expressions or assist with entering settings in the relay. Whether the ellipsis button is an expression builder or a setting assistant depends on the selected relay function and is preprogrammed in the relay. For example, *Figure 2.16* shows the **ellipsis button** as a setting assistant, entering settings for the SER.

Step 1. Enter the SER settings by clicking on the **Report > SER Settings** in the **Tree View**.

Step 2. Click on the **SITM1 SER Points and Alias, Point 1** ellipsis button, which makes the **R1-SITM1** window available.

Step 3. Click on the Relay Word bit ellipsis button in the **R1-SITM1** window.

The software displays a list of Relay Word bits available in the relay that you can select to enter in the SER report.

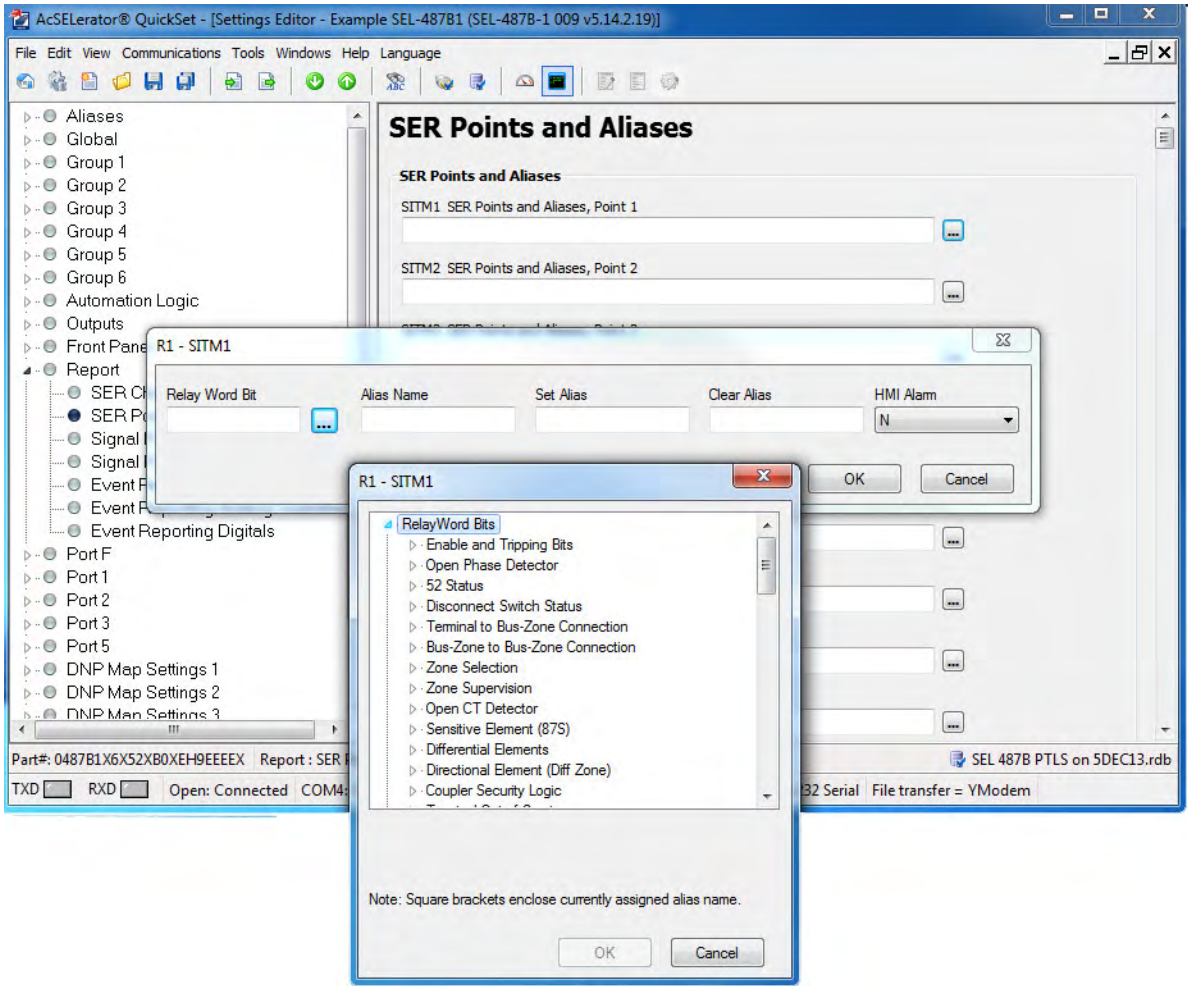

Figure 2.16 Location of Ellipsis Button

Expression Builder

The ellipsis button also allows access to an expression builder. SELOGIC control equations are a powerful means for customizing relay performance. Creating these equations can be difficult because of the large number of relay elements (Relay Word bits) and analog quantities in the relay. QuickSet simplifies this process with the expression builder, a rules-based editor for programming SELOGIC control equations. The expression builder organizes relay elements, analog quantities, and SELOGIC control equation variables and focuses your equation decision making.

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. (The LVALUE is fixed for all settings except Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equation settings—see *Fixed SELOGIC Control Equations on page 13.6*.) *Figure 2.17* shows the two sides of the **Expression Builder**, with the SELOGIC control equation that you are constructing at the top of the dialog box. Note the dark vertical line and the equals sign (**:=**) separating the equation's left and right sides.

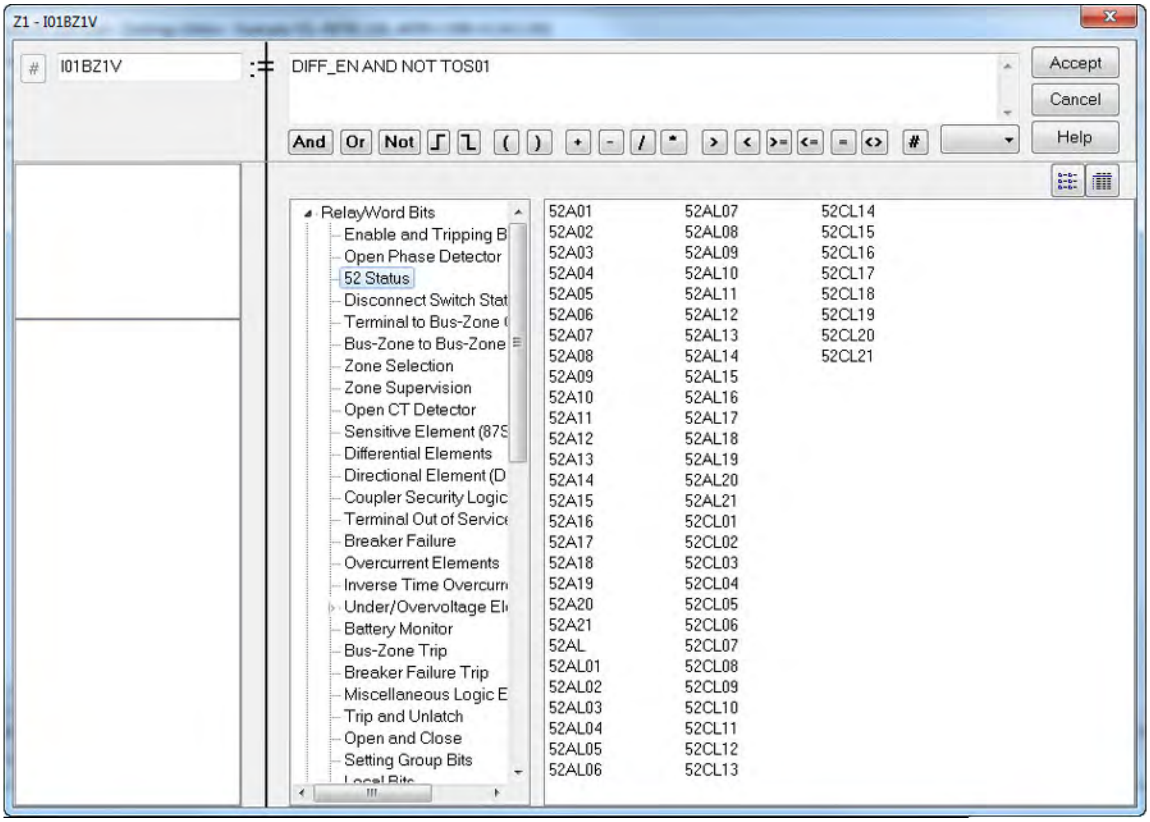

Figure 2.17 QuickSet Expression Builder

Using the Expression Builder

Step 1. For Protection Free-Form SELOGIC and Automation Free-Form SELOGIC control equations, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**.

QuickSet shows Relay Word bits available for use in compiling expressions. The program shows the relay elements for each type of SELOGIC control equation (e.g., Boolean Variables, Math Variables).

On the right side of the equation (RVALUE), you can select broad categories of relay elements, analog quantities, counters, timers, latches, Boolean variables, and math variables.

Step 2. Select a category in the RVALUE tree view.

The Expression Builder displays all elements for that category in the list box at the bottom right side. Directly underneath the right side of the equation, you can choose operations to include in the RVALUE. These operations include basic logic functions, rising and falling edge triggers, expression compares, and math functions. For more information on programming SELOGIC control equations, see *Section 13: SELOGIC Control Equation Programming*.

QuickSet HMI

Use the QuickSet human-machine interface (HMI) feature to view real-time relay information in a graphical format. Use the virtual relay front panel to read metering and targets (see *Figure 2.18*) for a representative example.

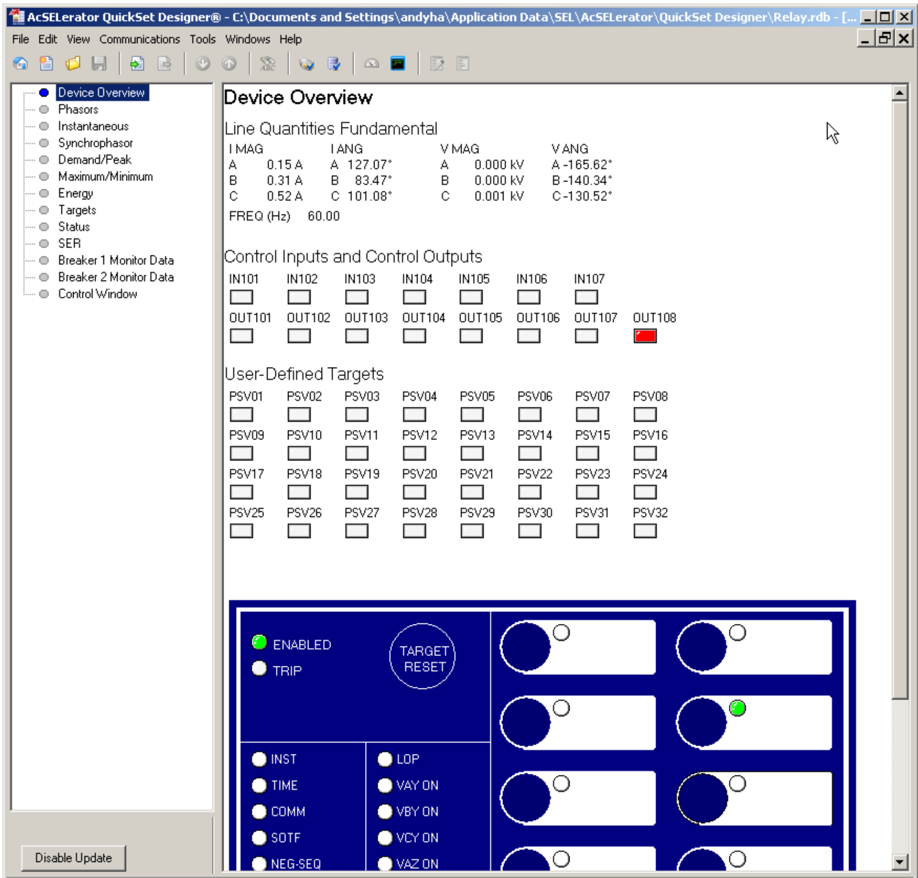

Figure 2.18 Virtual Relay Front Panel

Open the QuickSet HMI

Select **Tools > HMI > HMI** in the QuickSet menu bar. QuickSet opens the HMI window and downloads the interface data. The HMI can also be accessed using the HMI icon.

QuickSet HMI Features

Table 2.2 lists typical functions in the HMI tree view and a brief explanation of each function. The specific options available for any specific relay depend on the features available in that relay.

Table 2.2 QuickSet HMI Tree View Functions (Sheet 1 of 2)

Function	Description
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel
Contact I/O	View status of contact inputs and contact outputs

Table 2.2 QuickSet HMI Tree View Functions (Sheet 2 of 2)

Function	Description
Phasors	A graphical and textual representation of phase and sequence voltages and currents.
Time and Communications	View for Time Quality, MIRRORED BITS Channel A or B, RTC Channel. PTP, or Sampled Values status.
Fundamental Metering	A table of instantaneous voltages, currents, powers, and frequency.
Zone Metering	View active Zone meter reports.
Differential Metering	View differential currents of all active zones.
Unbalance Metering	View the differential and unbalanced metering data.
Synchrophasor	A table of synchrophasor data.
Demand/Peak	A table showing demand and peak demand values. This display also allows demand and peak demand values to be reset.
Min/Max	A table showing maximum/minimum metering quantities. This display also allows maximum/minimum metering quantities to be reset.
Energy	A table showing energy import/export. This display also allows energy values to be reset.
Temperature	View the temperature measurements received from the SEL-2600A.
Protection Math Variables	View the protection math variable values.
Automation Math Variables	View the automation math variable values.
MIRRORED BITS Communications	View the MIRRORED BITS communications analog quantities.
Through Faults	View the through-fault data.
Thermal Monitoring	View the most recent saved thermal report of the transformer(s) monitored by the device.
Breaker *n* Monitoring (*n* can be S,T,U,W, or X)	View a comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times.
Analog Signal Profile	View the Signal Profile data for as many as 20 user-selectable analog values.
VSSI Report	View the voltage sag, swell, and interruption report.
Targets	View Relay Word bits in a row/column format.
Status	A list of relay status conditions.
LDP	View load profile data.
SER	Sequential Events Recorder (SER) data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display.
SSI	View voltage Sag, Swell, and Interruption data.
Breaker Monitor Data	A table showing the latest circuit breaker monitor data.
Control Window	Metering and records reset buttons, trip and close control, output pulsing, target reset, time and date set, group switch, and remote bit control.

The flashing LED representation in the lower left of the QuickSet window indicates an active data update via the communications channel (see *Figure 2.18*). Click the button marked **Disable Update** to suspend HMI use of the communications channel.

HMI Device Overview

Select the **Device Overview** branch to display an overview of the relay operation. This view includes a summary of information from many of the other HMI branches, including fundamental metering, contact input/output status, and front-panel LED status.

The **Device Overview** colors and text can be customized. White LED symbols indicate a deasserted condition and LED symbols with any other color indicate an asserted condition. Click an LED symbol to change its assert color.

HMI Control Window

Select the **Control Window** branch to reset metering values, clear event records, trip and close reclosers/breakers, pulse output contacts, and set and clear remote bits (see *Figure 2.19*) for a representative example.

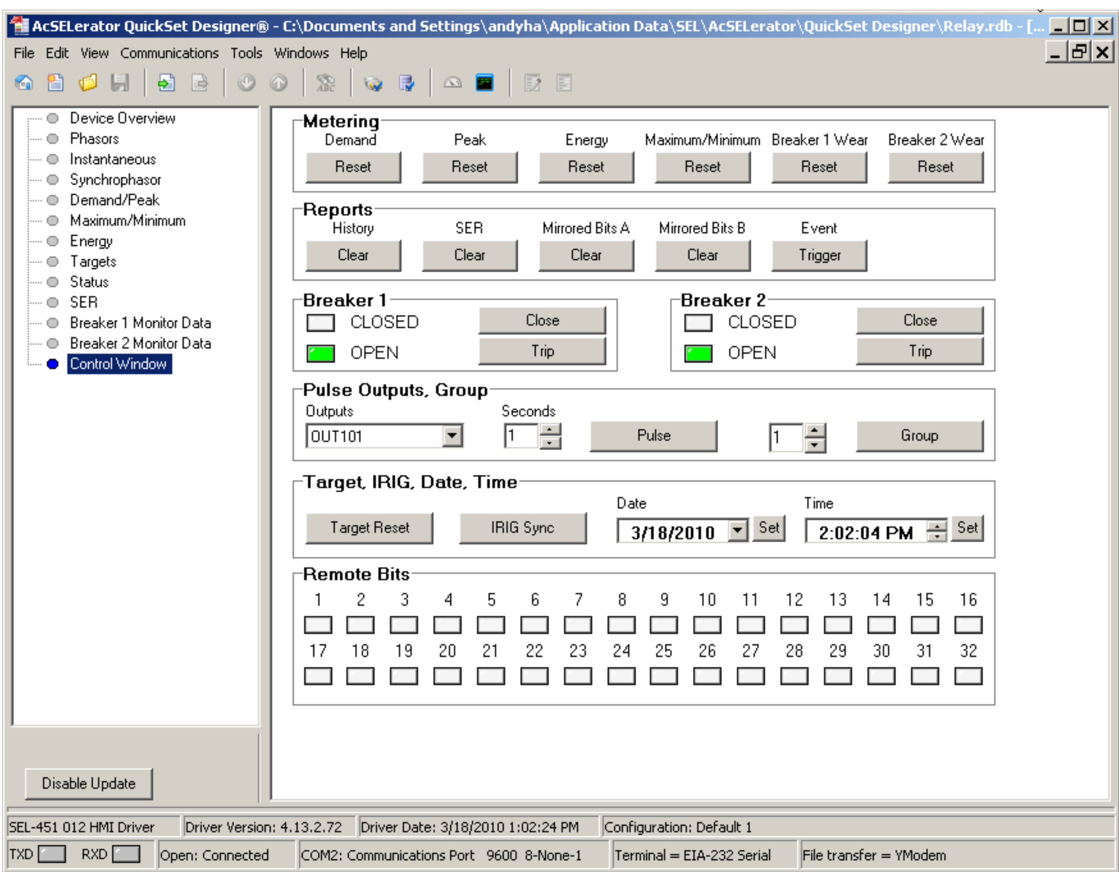

Figure 2.19 Control Window

Other HMI Branches

The remaining HMI branches display metering, targets, status, reporting, and monitoring information.

HMI Configurations

Customized **Device Overviews** can be saved as HMI Configurations. To save the current configuration, select **Tools > HMI > Save Configuration** to save the configuration under the current name, or **Tools > HMI > Save Configuration As** to specify a configuration name.

HMI configurations are identified by relay type and a configuration name. To use an existing configuration, select **Tools > HMI > Select Configuration**. To view available configurations, select **Tools > HMI > Manage Configurations**. To make an existing configuration the default configuration for a given relay type, select the configuration in the **Manage Configurations** window, select **Edit**, and select the **Default** check box.

Analyze Events

QuickSet has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that relays store to evaluate the performance of a protection system.

Event Waveforms

Relays record power system events for all trip situations and for other operating conditions programmed with SELOGIC control equations.

The relays provide two types of event data captures:

- Event report oscillography that uses filtered sample-per-cycle data
- Unfiltered (raw) data

Use QuickSet to view event report oscillograms, phasor diagrams, harmonic analysis, and settings.

Read History

You can retrieve event files stored in the relay and transfer these files to a computer. To download event files from the relay, open the QuickSet **Tools > Events** menu on the QuickSet toolbar and click **Get Event Files**. The **Event History** dialog box will appear (similar to *Figure 2.20*).

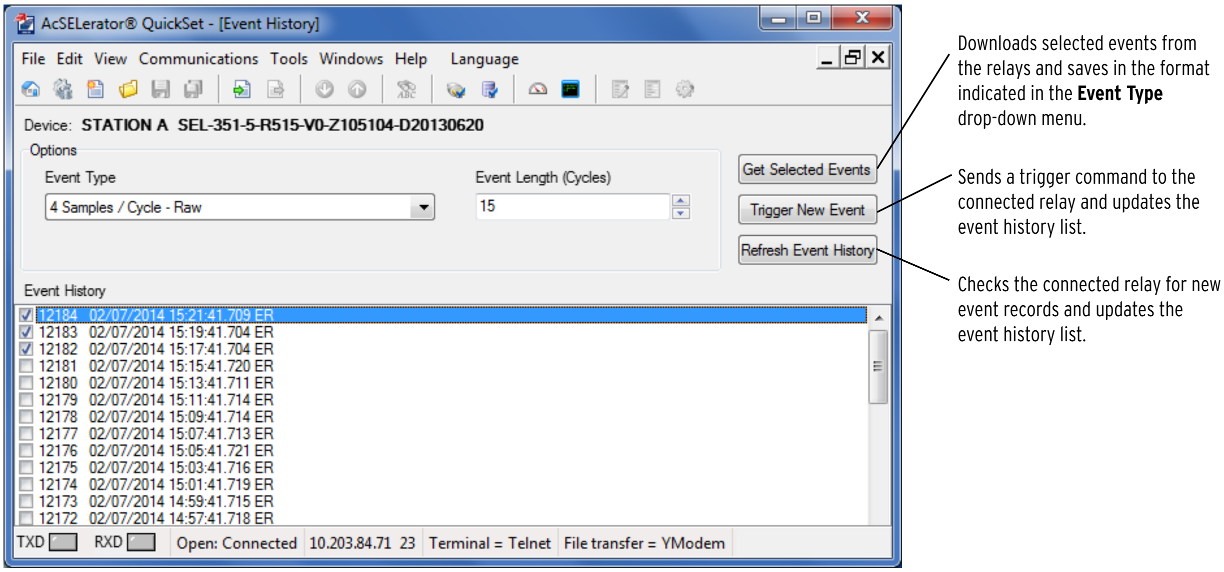

Figure 2.20 Retrieving an Event History

Get Event

Highlight the event you want to view and click the **Get Selected Event** button. The **Event Options** dialog box allows selection of Event Type and Event Length. When downloading is complete, QuickSet asks for a location to save the file on your computer. Select **Tools > Events> View Event Files** and select an event file to view events saved on your computer. QuickSet displays the **Event Waveform** dialog box and the event oscillogram (see *Figure 2.21* and *Figure 2.22*).

When viewing the event oscillogram, use keyboard function keys to measure the time of oscillogram occurrences. These function keys and related functions help in event analysis.

- **<F2>**: go to trigger
- **<F3>**: Cursor 1
- **<F4>**: Cursor 2

The display shows the time difference between Cursor 1 and Cursor 2.

To see high-accuracy time-stamp information on the event oscillogram, click the **Pref** button at the bottom of the oscillogram, select **Time** (under **Time Units**, **Starting/Ending Row**), and click **OK**. Click on any point in a graph to observe the **Event Time** in microseconds of that data point at the bottom of the oscillogram.

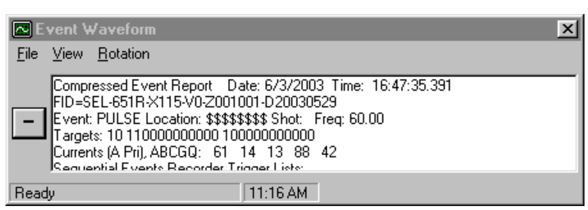

Figure 2.21 Event Waveform Window

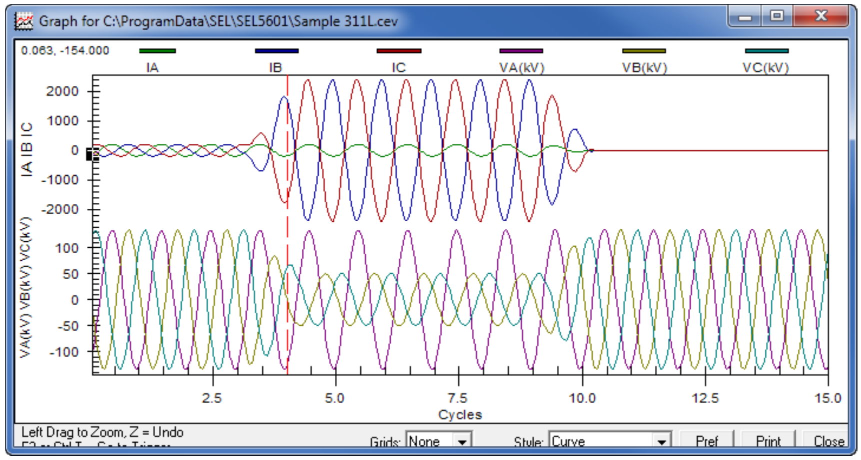

Figure 2.22 Sample Event Oscillogram

Other event displays are available through the **Event Waveform** dialog box. Select the **View** menu and click **Phasors**, as shown in *Figure 2.23*, to view a sample-by-sample phasor display. The phasor display should be similar to *Figure 2.24*.

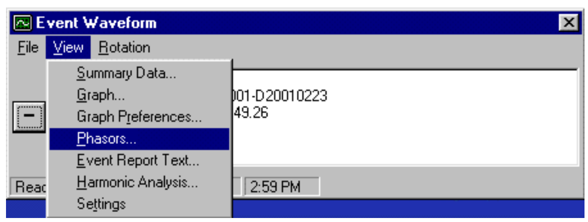

Figure 2.23 Retrieving Event Report Waveforms

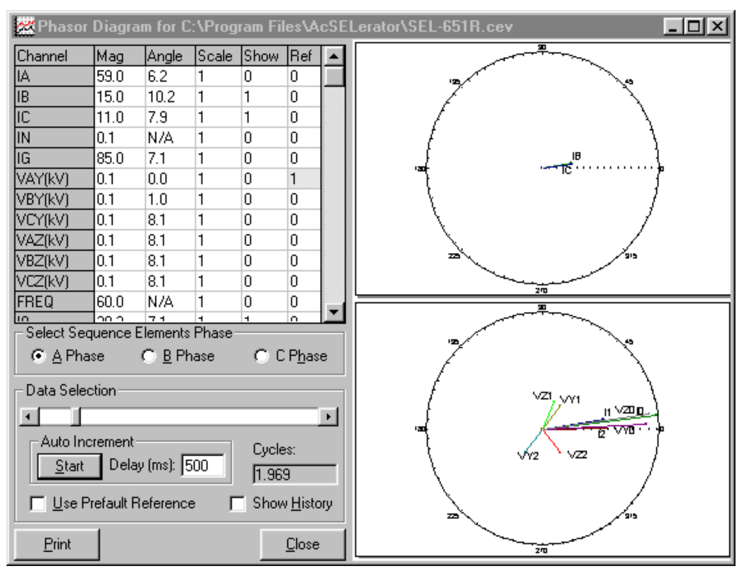

Figure 2.24 Sample Phasors Event Waveform Screen

QuickSet also presents a harmonic analysis of power system data for raw data event captures. From the **View** menu, click **Harmonic Analysis**. The window will be similar to *Figure 2.25*. On the left side of the **Harmonic Analysis** screen, choose the relay voltage and current channels to monitor for harmonic content. Click the arrows of the **Data Scroll** box or the **# Cycles** box to change the data analysis range.

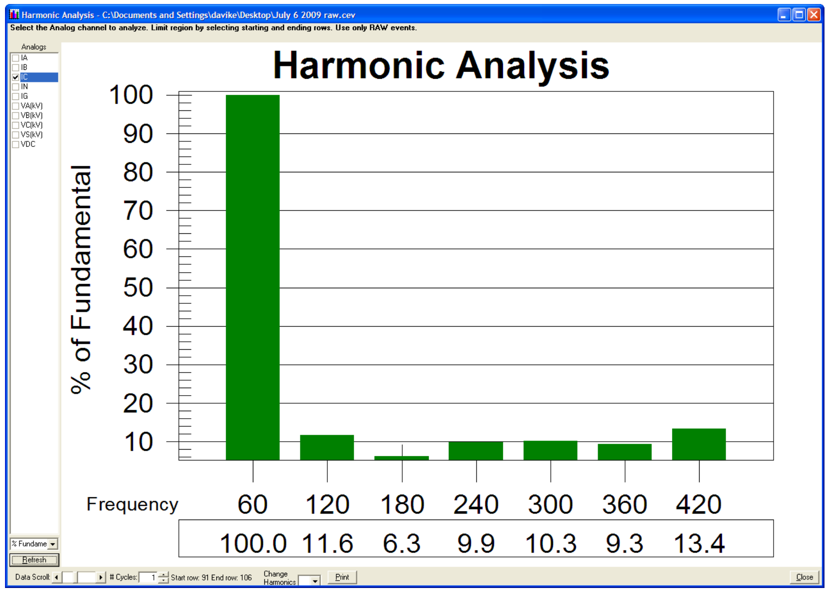

Figure 2.25 Sample Harmonic Analysis Event Waveform Screen

Click **Summary Data** on the **View** menu to see event summary information and to confirm that you are viewing the correct event. *Figure 2.26* shows a sample QuickSet **Event Report Summary** screen.

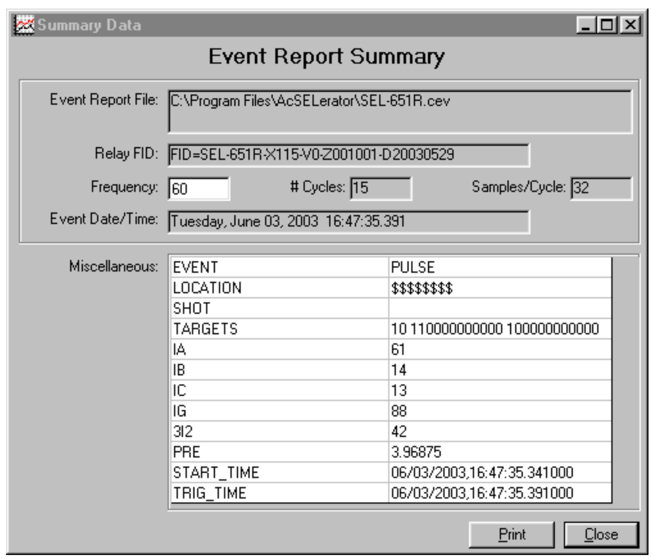

Figure 2.26 Sample Event Report Summary Screen

Click **Relay Settings** on the **View** menu to view the relay settings that were active at the time of the event. *Figure 2.27* shows a sample CEV-type event **Settings** screen.

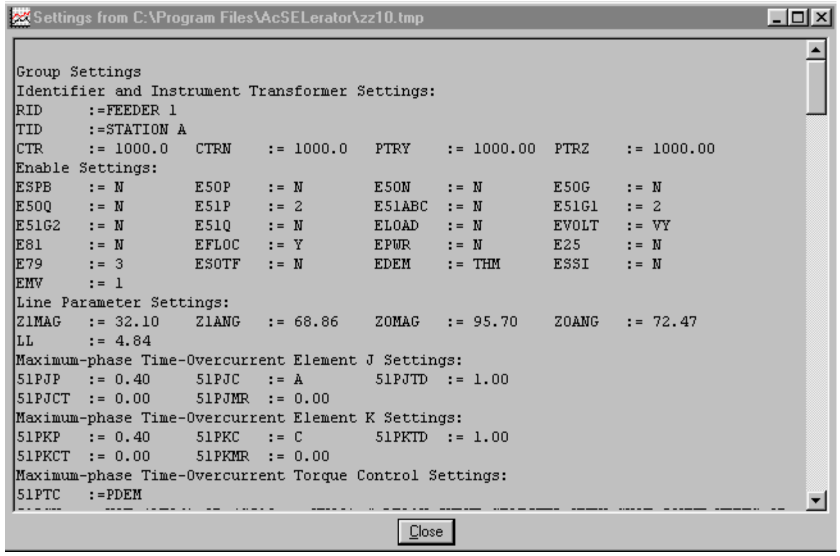

Figure 2.27 Sample Event Waveform Settings Screen

Aligning Events

There are times when it is desirable to look at data from multiple device event reports simultaneously. This is especially valuable with the SEL-487B when a set of three relays are acting as single-phase relays on a single system. Once you have the event reports retrieved and saved, you can view them together using the following procedure.

Step 1. In ACSELERATOR Analytic Assistant SEL-5601 Software, select **File > Combine Time-Synchronized Events** files to combine the three event reports into one event, as shown in *Figure 2.28*.

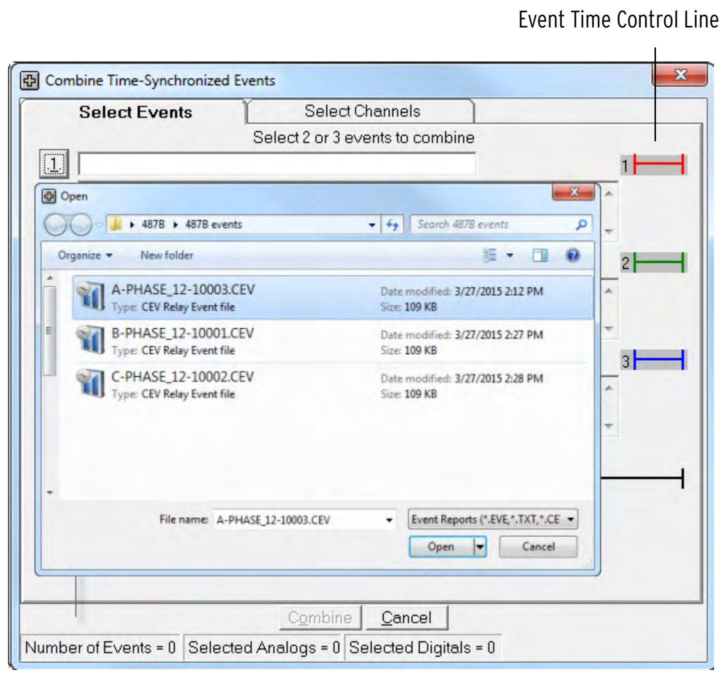

Figure 2.28 Combine Time-Synchronized Events Submenu Screen

Three placeholders are available for as many as three events. Next to each placeholder is a color-coded horizontal line called an event time control line. These event time control lines also appear at the bottom of the screen where they show the relative overall time relationship between the events, the trigger time of each event, and the number of cycles of each event. The event time control lines are color-coded, with red (Event 1) on top, green (Event 2) in the center, and blue (Event 3) at the bottom. A flashing arrow points to a button for Event 1.

Step 2. Click the button for Event 1.

The software selects the directory where you last stored an event report.

Step 3. Click the event you want to analyze.

Step 4. Click the **Open** button, as shown in *Figure 2.29*.

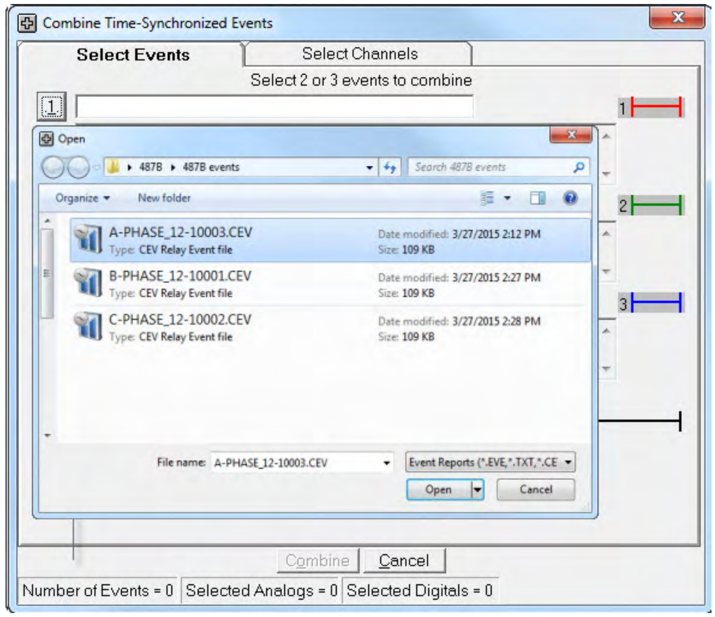

Figure 2.29 Selection of the First Event Report

The software reads the selected event report and places the event report in the first placeholder, as shown in *Figure 2.30*.

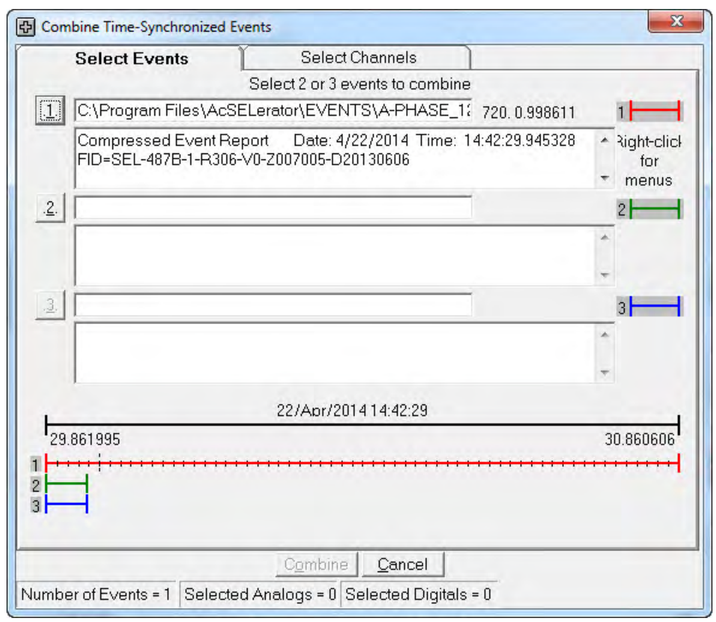

Figure 2.30 First Event of the Analysis

Notice that the actual event control line of the first events now appears at the bottom of the screen and becomes the reference time position. All other events must overlap the reference time position by at least one data point. The software positions the subsequent events relative to the position of the first event.

If the subsequent event does not overlap the first event by at least one data point, the software does not allow the events to be combined.

Step 5. Click on the button for Event 2 and repeat the steps described for selecting Event 1.

Step 6. Repeat the steps for Event 3. *Figure 2.31* shows the screen after reading all three events.

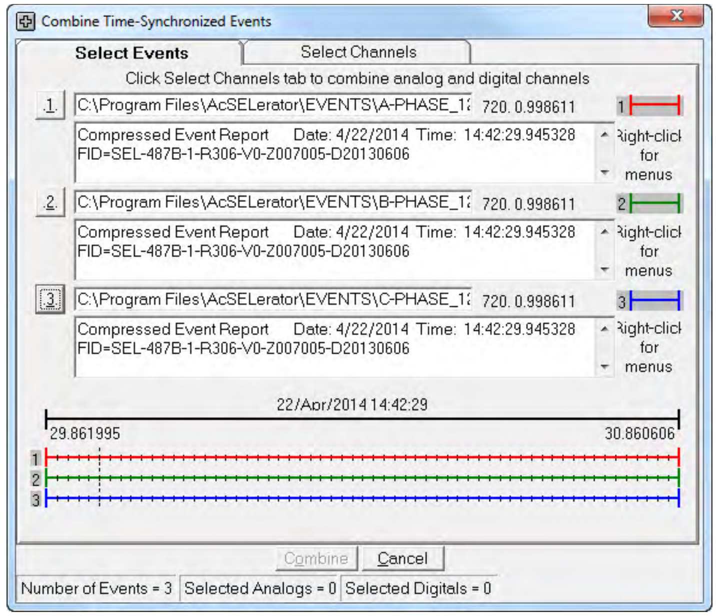

Figure 2.31 Screen After Reading All Three Events

The information displayed at the bottom of the screen shows that we have opened three events, but have not yet selected any analog channels or digital Relay Word bits from these events.

Step 7. Click on the **Select Channels** tab to select analog channels and digital Relay Word bits. *Figure 2.32* shows the screen for selecting the channels.

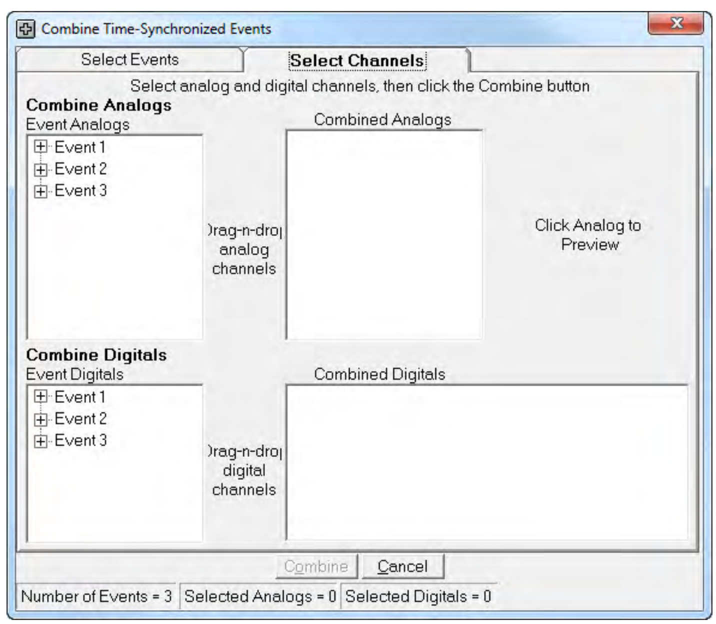

Figure 2.32 Screen for Selecting Analog Channels and Digital Relay Word Bits

The three events appear in the window labeled **Event Analogs**.

Step 8. Click the **+** of Event 1 to see a list of the analog channels in the event report.

Step 9. Click **1_FDR_1(A)**, the first analog channel in the list.

Step 10. A trace of channel **1_ FDR _1** appears on the right hand window next to the **Combined Analogs** list.

Step 11. Right-click on channel **1_ FDR _1**.

Step 12. Hold the mouse button down.

Step 13. Drag the cursor to the **Combined Analogs** window.

Alternatively, press the **<A>** key to add the selected channel to the list.

Step 14. Release the mouse button to complete the transfer of channel 1_ FDR _1 from the **Event Analogs** window to the **Combine Analogs** window.

Alternatively, select the channels to be removed and press the **<Delete>** key.

Drag and drop is similarly supported for digital channels.

Step 15. Select a channel.

Step 16. Drop the selection into the **Event Analogs** or **Event Digitals** window to remove channels from the **Combined Analogs** or **Combined Digitals** windows.

Figure 2.33 shows the screen with **Analog Channel** 1_ FDR _1 from Event Report 1, **2_ FDR _1** from Event Report 2, and **3_ FDR _1** from Event Report 3 selected for analysis and appearing in the **Combined Analogs** window.

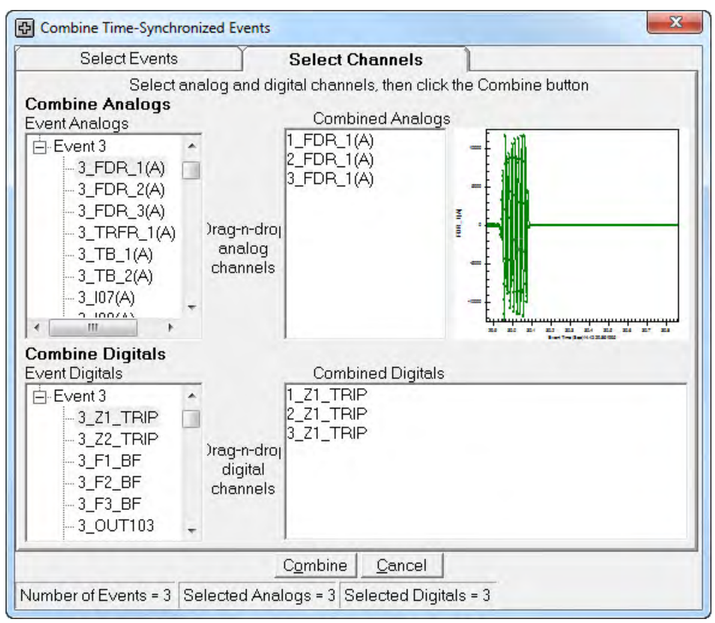

Figure 2.33 Selection of Analog Channels and Digital Relay Word Bits

Figure 2.33 also shows the differential element from each event report: **Relay Word bit 1_Z1_TRIP** from Event Report 1, **Relay Word bit**, **2_ Z1_TRIP** from Event Report 2, and **Relay Word bit**, **3_ Z1_TRIP** from Event Report 3.

Step 17. Click on the **Combine** button to create a single, combined report comprising the selected analog and digital selections from three individual event reports.

Step 18. On the graph preference form, select the values of interest from the **Analogs** window.

Step 19. Drop these selections in any one of the six available **Axis** windows.

You can select as many as 12 analog channels.

Figure 2.34 shows an example after selecting all three analog channels on Axis 1 for analysis.

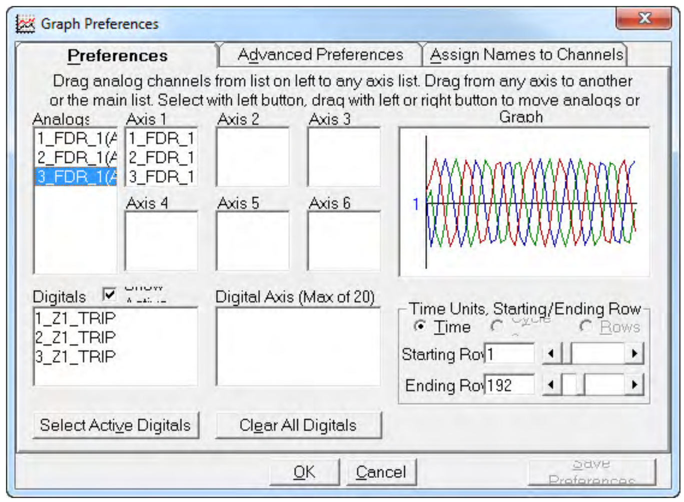

Figure 2.34 Data From Three Separate Event Reports Combined in a Single Report

Step 20. Click **OK** to view the report.

The software displays the three traces on the same graph, as shown in *Figure 2.35*.

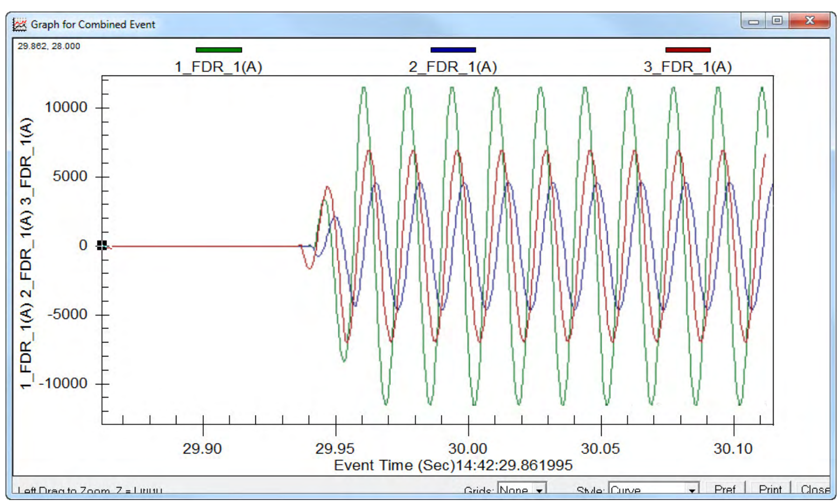

Figure 2.35 Traces of the Three Analog Channels

QuickSet Help

Various forms of QuickSet help are available as shown in *Table 2.3*. Press **<F1>** to open a context-sensitive help file with the appropriate topic as the default. Other ways to access help are shown in *Table 2.3*.

Table 2.3 Accessing QuickSet Help

Help	Description
General ACSELERATOR QuickSet	Select **Help > Contents** from the main menu bar.
HMI Application	Select **Help > HMI Help** from the main menu bar.
Relay Settings	Select **Help > Settings Help** from the from the main menu bar.
Database Manager	Select **Help** from the bottom of the **Database Manager** window.
Communications Parameters	Select **Help** from the bottom of the **Communications Parameters** window.

SECTION 3

Basic Relay Operations

SEL-400 series relays are power tools for power system protection and control. Understanding basic relay operation principles and methods will help you use the relay effectively. This section presents the fundamental knowledge you need to operate the relay, organized by task. These tasks help you become familiar with the relay and include the following:

Perform these tasks to gain a good understanding of relay operation, be able to confirm that the relay is properly connected, and be more effective when using the relay. To work through the examples in this section, you need to install the relay either in a final installation or in a laboratory configuration. See *Section 2: Installation* in the product-specific instruction manual for more information.

Inspecting a New Relay

NOTE: Do not connect power to the relay until you have completed your inspection of the relay. See the product-specific Installation section for details on applying power. Failure to follow these instructions can lead to equipment damage.

The following items are included in your shipment from SEL:

- Relay
- CD-ROM containing the electronic version of the entire Relay Manual and the Customer Label Templates
- CD-ROM containing the ACSELERATOR QuickSet SEL-5030 Software program
- Configurable Front-Panel Label Kit
- SEL Contact Card

If any item is missing or damaged, please contact your distributor or SEL immediately.

Initial Inspection

Perform the following initial inspection when the relay arrives:

Step 1. Remove the protective wrapping from the relay.

Step 2. Observe the outside of the front cover and the rear panel.

Step 3. Check that no significant scratches or dents are evident on any outer surface.

Step 4. Confirm that all terminal strips on the rear panel are secure.

Perform the following steps and use care when cleaning the relay:

Step 1. Use a mild soap or detergent solution and a damp cloth to clean the relay chassis.

Be careful cleaning the front and rear panels because a permanent plastic sheet covers each panel; do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any relay surface.

Step 2. Allow the relay to air dry, or wipe dry with a soft dry cloth.

Verify Relay Configuration

When you first inspect the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. Examine the serial number label on the relay rear panel. *Figure 3.1* shows a sample rear-panel serial number label.

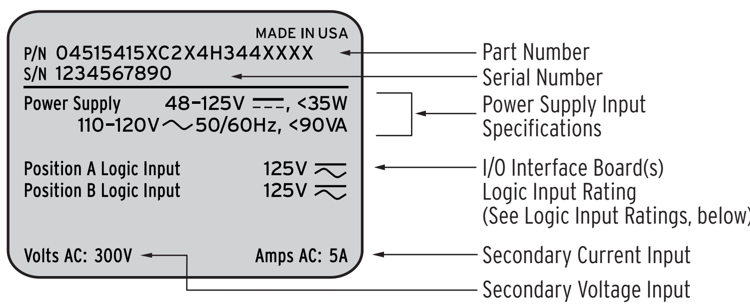

Figure 3.1 Sample Relay Serial Number Label

NOTE: Do not use this page for ordering a relay. For ordering information, refer to the relay Model Option Table available at selinc.com, or contact your SEL Sales Representatives.

Figure 3.1 shows a serial number label for an SEL-451 with additional I/O in a 4U horizontal chassis. This example serial number label is for a 5 A-per-phase secondary CT input relay. For information on CT and PT inputs, Do not use this page for ordering a relay. For ordering information, refer to the SEL-451 Model Option Table available at selinc.com/products/, or contact your SEL Sales Representatives.

The power supply specification in Figure 4.1 indicates that this relay is equipped with a power supply that accepts a nominal 48–125 Vdc input. This power supply also accepts a 110–120 Vac input. Refer to the serial number label affixed to the back of your relay to determine the power supply voltage you should apply to the relay power supply input terminals. As this label indicates, the voltage source should be capable of providing at least 35 W for dc inputs and 90 VA for ac inputs. See *Section 1: Introduction and Specifications* in the product-specific instruction manual for more information on power supply specifications.

The serial number label does not list power system phase rotation and frequency ratings, because you can use relay settings to configure these parameters. The factory defaults are ABC phase rotation and 60 Hz nominal frequency. See *Making Settings Changes in Initial Global Settings on page 3.20* for details on setting these parameters.

Logic Input Ratings

The serial number label in *Figure 3.1* only lists control input voltages for I/O Interface Boards that have optoisolated inputs, which is determined at ordering time. The other types of control inputs (Direct Coupled) have settable pickup voltages, and do not appear on the serial number label. See *Control Input Assignment on page 3.69* for more information.

Establishing Communication

Once you have applied the correct power input successfully, you are ready to operate the relay. Use the relay front panel and the communications ports to communicate with the relay.

Front-panel control of relay functions involves use of a menu system that you access through the LCD and the six navigational pushbuttons shown in *Figure 3.2*. For complete instructions on using the front-panel menu system, see *Front-Panel Menus and Screens on page 4.14*.

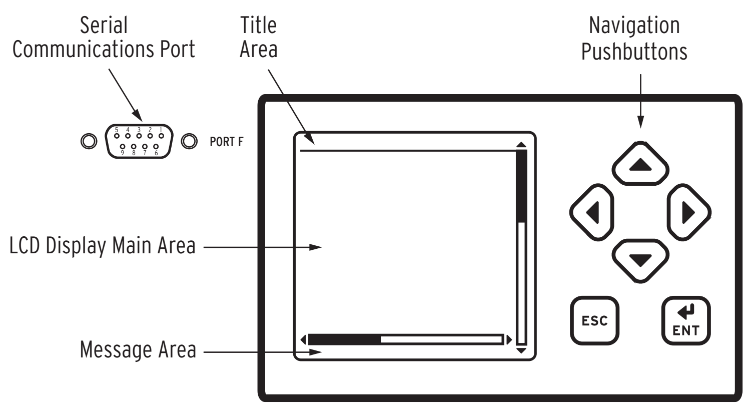

Figure 3.2 PORT F, LCD Display, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as PORT F, also shown in *Figure 3.2*. A design philosophy for all SEL relays is that an ASCII or open terminal is all that you need to communicate with the relay. Many off-the-shelf computer programs provide terminal emulation. These programs are inexpensive and widely available.

Use the cable connections appropriate for your terminal configuration. See *Section 15: Communications Interfaces* for more information on communications ports.

All ASCII commands you send to the relay must terminate with a carriage return or carriage return/line feed; the terminal emulation program appends the necessary carriage return when you press **<Enter>**.

You can truncate commands to the first three characters: EVENT 1 becomes EVE 1. Use upper- and lowercase characters without distinction, except in passwords, which are case sensitive. For a list of ASCII commands see *Section 14: ASCII Command Reference*.

Help

When you are using a terminal, you can access built-in relay help for each ASCII command. Relay help is access-level sensitive; you see only the ASCII commands for the present access level when you type **HELP <Enter>**. For in-depth information on a particular ASCII command, enter the command name after typing **HELP**. For example, for help on the **EVENT** ASCII command, type **HELP EVE <Enter>**.

When you are using QuickSet, press **<F1>** to get help, or select the **Help** menu from the QuickSet toolbars. The help information in QuickSet gives detailed information and sample screens in a GUI format.

Making an EIA-232 Serial Port Connection

The following steps use any popular computer terminal emulation software and SEL serial cables to connect to the relay.

Use an SEL-C234A cable to connect a 9-pin computer serial port to the relay. Use an SEL-C227A cable to connect a 25-pin computer serial port to the relay. For computers with USB ports, use an SEL-C662 USB-to-serial cable to connect to the relay. See *Section 15: Communications Interfaces* for further information on serial communications connections. These and other cables are available from SEL. Contact the factory or your local distributor for more information.

Step 1. Use the serial cable to connect the computer to the relay via PORT F on the relay front panel.

Step 2. Apply power to both the computer and to the relay.

Step 3. Start the computer terminal emulation program.

Step 4. Set your computer terminal emulation program serial communications parameters.

The default relay communications port settings are listed in *Table 3.1*.

Also set the terminal program to emulate either VT100 or VT52 terminals. These terminal emulations work best with SEL relays.

Table 3.1 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	SEL
SPEED	Data speed (300 to 57600, SYNC)	9600
DATABIT	Data bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

Step 5. To check the communications link, press **<Enter>** to confirm that you can communicate with the relay.

You will see the Access Level 0 = prompt at the left side of your computer screen (column 1).

If you do not see the prompt, check the cable connections and confirm the settings in your terminal emulation program match the default communications parameters shown in *Table 3.1*.

Step 6. Type **QUIT <Enter>** to view the relay report header.

You will see a computer screen display similar to that shown in *Figure 3.3*. (Text that you type is emphasized in bold letters.)

If you see jumbled characters, change the terminal emulation type in the computer terminal program.

```
=QUIT <Enter>

Relay 1                                     Date: 04/16/2004  Time: 00:01:05.209
Station A                                   Serial Number: 2001001234

=
```

Figure 3.3 Report Header

When you communicate with the relay at the Access Level 0 = prompt, you are in security Access Level 0. You cannot view or control relay functions at this level.

Higher access levels are password-protected and allow increased control over relay operation. For more information on access levels and password protection, see *Changing the Default Passwords in the Terminal on page 3.10*.

Making an Ethernet Telnet Connection

Factory-default settings for the Ethernet ports disable all Ethernet protocols, including PING. Enable the Telnet protocol with the SET P 5 command using any of the serial ports. Command **SET P 5** accesses settings for all Ethernet ports on the relay.

Make the following settings using the **SET P 5** command:

- EPORT = Y
- IPADDR = IP Address assigned by network administrator in CIDR notation
- DEFRTR = Default router gateway IP Address assigned by network administrator
- NETMODE = SWITCHED
- ETELNET = Y

NOTE: Telnet works with other NETMODE settings also, but NETMODE = SWITCHED is easiest to begin communications.

Leave all other settings at their default values.

Connect an Ethernet cable between your PC or a network switch and any Ethernet port on the relay. Verify that the amber Link LED illuminates on the connected relay port. Many computers and most Ethernet switches support autocrossover, so nearly any Cat 5 Ethernet cable with RJ45 connectors, such as an SEL-C627 cable, will work. When the computer does not support auto crossover, use a crossover cable, such as an SEL-C628 cable. For fiber-optic Ethernet ports, use an SEL-C808 cable (62.5/125 µm multimode fiber-optic cable). If your relay is equipped with dual Ethernet ports, connect to either port. Use a Telnet client or QuickSet on the host PC to communicate with the relay. During Ethernet transmit or receive activity, the green Activity LED blinks on the relay Ethernet port. To terminate a Telnet session, use the command **EXI <Enter>** from any access level.

Making an Ethernet Web Server (HTTP) Connection

When Port 5 setting EHTTP = Y, the relay serves read-only webpages displaying certain settings, metering, and status reports. The relay-embedded HTTP server has been optimized and tested to work with the most popular web browsers, but should work with any standard web browser. As many as four users can access the embedded HTTP server simultaneously.

To begin using the embedded read-only HTTP server, launch your web browser, and browse to http://IPADDR, where IPADDR is the Port 5 setting IPADDR (e.g., http://192.168.1.2). The relay responds with a login screen as shown in *Figure 3.4*.

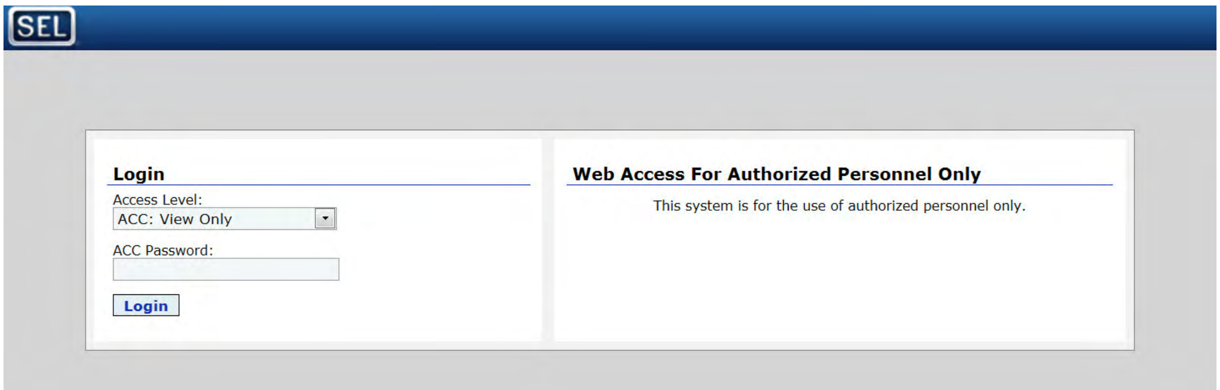

Figure 3.4 HTTP Server Login Screen

Choose **ACC** for the username, type in the relay Access Level 1 password, and click **Submit**. The only username allowed is ACC. The relay responds with the homepage shown in *Figure 3.5*. While you remain logged in to the relay, the webpage displays the approximate time as determined by the relay time-of-day clock, and increments the displayed time once per second based on the clock contained in your PC.

Once the user is logged in, the HTTP server displays the Meter webpage. This page will refresh within five seconds and includes all metering options available and enabled on the relay.

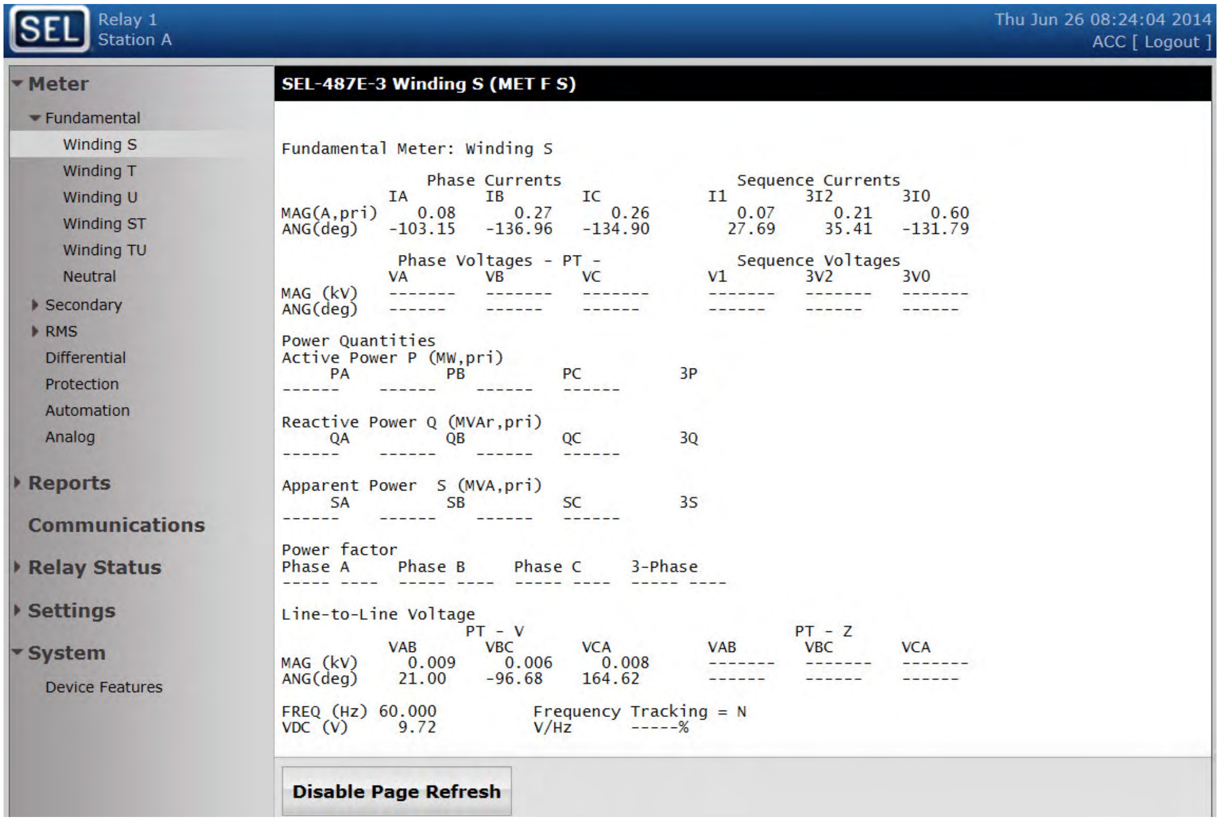

Figure 3.5 Example HTTP Server Meter Page

Click on any menu selection in the left pane to navigate through the available webpages.

Access Levels and Passwords

NOTE: Perform the password change steps described in *Changing the Default Passwords in the Terminal on page 3.10*.

It is extremely important that you change the factory-default passwords programmed in the relay. Setting unique passwords for the relay access levels increases the security of your substation and the power system.

This subsection begins with information on the access level/password system in SEL-400 relays and includes an example of changing the default passwords.

Access Levels

Access levels control whether you can perform different operations within the relay. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 3.6* presents an overview of the general access level structure in the relay.

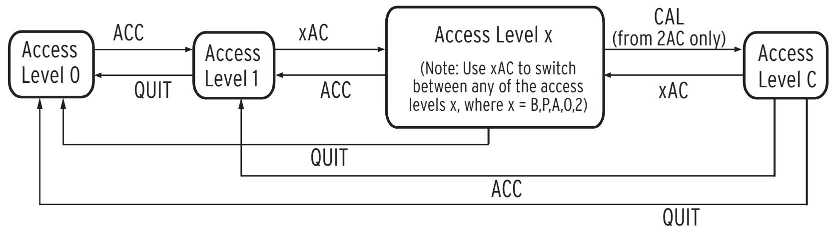

Figure 3.6 Access Level Structure

Access Level 0 is the least secure and most limited access level, and Access Level 2 is the most secure level at which you have total relay functionality (Level C is reserved for SEL factory operations. Only go to level C to change the level C password or under the direction of an SEL employee). For example, from Access Level 1, you can view settings, but you cannot change settings unless you are at a higher access level.

Table 3.2 lists access levels and operator functions for the relay.

Table 3.2 SEL-400 Series Relay Access Levels

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1.
1	=>	View data and status information.
B	==>	Access Level 1 functions plus breaker control and data.
P	P=>	Access Level B functions plus protection settings.
A	A=>	Access Level B functions plus automation settings.
O	O=>	Access Level B functions plus output settings.
2	=>>	Perform all relay access level functions.
C	==>>	SEL factory-specific functions. For a list of commands available, contact SEL.

The relay performs command interpretation and execution according to your validated access level. Each access level has a password that the relay must verify before you can control the relay at that level. *Table 3.3* lists the access level commands with corresponding passwords.

Table 3.3 Access Level Commands and Passwords

Access Level	Command	Factory-Default Password
0	QUIT	(None)
1	ACCESS	OTTER
B	BACCESS	EDITH
P	PACCESS	AMPERE
A	AACCESS	VOLTA
O	OACCESS	WATT
2	2ACCESS	TAIL
C	CAL	Sel-1

Communications Ports Access Levels

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Entrance to the higher security levels is sequential. You must first enter a correct password to move from Access Level 0 to Access Level 1.

To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1. For example, to go to the O (Output) Access Level from Access Level 1, type **OAC <Enter>**. At the `Password: ?` prompt, type your Access Level O password.

To enter level C, you must enter a correct password from Access Level 2.

Use the relay **QUIT** command from any access level to return the relay to Access Level 0. To reestablish control at a previous access level from Access Level 1, you must use the access level commands and passwords to log in to that previous access level.

When a connection with the relay times out, the relay reduces the access level to Access Level 0 for that communications port connection.

The MAXACC port setting can be used to limit the maximum access level permitted on a port. This can be useful to restrict what remote users can do.

Front-Panel Access Levels

The lowest access level for the front panel is Access Level 1. To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1.

The front-panel LCD displays a password prompt when you attempt to control the relay at any access level higher than Access Level 1. (For more information on entering passwords from the front panel, see *PASSWORD on page 14.42*.)

The front-panel `MAIN MENU` item `RESET ACCESS LEVEL` returns the relay to Access Level 1. In addition, when the front-panel inactivity timer times out (indicated by the `ROTATING DISPLAY` on the front-panel LCD), the relay returns the front-panel access level to Access Level 1.

ACCESS Command

NOTE: You can shorten relay commands to the first three letters of the full command. *Section 14: ASCII Command Reference* for more information.

Enter the **ACCESS (ACC)** command to change to Access Level 1. Passwords are case sensitive; you must enter a password exactly as set.

If you enter the password correctly, the relay moves to Access Level 1 and the Access Level 1 => prompt appears. If you are at a higher access level (B, P, A, O, and 2), you can reduce the access level to Access Level 1 by entering the **ACC** command. The relay performs no password validation to reduce the present access level.

Higher Access Level Commands

Enter the commands in *Table 3.3* to enter access levels above Access Level 1. For example, enter the **2ACCESS (2AC)** command to change to Access Level 2.

If you are presently at Access Level 1, B, P, A, or O, typing **2AC <Enter>** causes the relay to prompt you to type the Access Level 2 password. If the present level is Access Level 0, the relay responds with `Invalid Access Level`. The relay pulses alarm Relay Word bit SALARM when entering Access Level B, P, A, O, and 2 from a lower access level.

If an incorrect password is entered three times, the relay asserts the BADPASS and SALARM Relay Word bits for one second and displays on a communications terminal screen the following error message:

```
WARNING: ACCESS BY UNAUTHORIZED PERSONS STRICTLY PROHIBITED
```

In addition, you cannot make further access level entry attempts for 30 seconds. The relay terminates the communications connection after the third failed attempt when you use Ethernet via an Ethernet card, DNP3 (Distributed Network Protocol version 3.0), or MIRRORED BITS communications virtual terminal mode. For more information on these protocols, see *Section 15: Communications Interfaces* and *Section 16: DNP3 Communication*.

If your connection to the relay has an inactivity time-out (in the **SET P** port settings), the relay automatically closes the communications connection and changes to Access Level 0 when the time-out occurs.

Passwords

Valid passwords are character sequences of as many as twelve characters. Valid password characters are any printable ASCII character. HMI password entry is limited to upper- and lowercase letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel. Passwords are case-sensitive.

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

It is important that you change all of the passwords from their default values. This will protect you from unauthorized access.

Use strong passwords. Strong passwords contain a mix of the valid password characters in a combination that does not spell common words in any portion of the password.

Changing the Default Passwords in the Terminal

Step 1. Confirm that the relay is operating (see *Establishing Communication on page 3.3*).

Step 2. Establish communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4* to learn how to use a terminal to communicate with the relay).

Step 3. Enter Access Level C (level 2 is sufficient except when changing the level C password).

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password **OTTER** and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

NOTE: Passwords are case sensitive; you must enter passwords exactly as set.

d. At the password prompt, type **TAIL <Enter>**.

e. You will see the Access Level 2 =>> prompt.

f. Type **CAL <Enter>**.

g. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

Step 4. To set a new password for Access Level 2, type the following:

PAS 2 <Enter>.

Step 5. Before you can change to a new password, the relay prompts you to first confirm the existing password. Enter the existing password and press **<Enter>**.

```
Old Password:  ?**** <Enter>
```

Step 6. The relay prompts you for the new password, and a confirmation of the new password, as follows:

```
New Password:  ?**** <Enter>
Confirm New Password:  ?**** <Enter>
Password Changed
CAUTION: This password can be strengthened. Strong Pass-
words do not include a name, date, acronym or word. They
consist of the maximum allowable characters, with at least
one special character, number, lower-case letter, and
upper-case letter. A change in password is recommended.
```

Notice that the new password is not displayed. After the confirmation, the new password is in effect. The relay will issue a weak password warning if the new password does not include at least one special character, number, lowercase letter, and uppercase letter.

Step 7. Set new passwords for each access level.

In a similar manner as the previous step, create new strong passwords for each access level.

Step 8. Commit these passwords to memory, permanently record your new passwords, and store this permanent record in a secure location.

To eliminate password verification for an access level, enter **DISABLE** in place of the new password. This action will disable the password of that level; therefore, the relay does not check for a password upon entering that access level.

If you forget a password or encounter difficulty changing the default passwords, you can temporarily disable password verification. See *Section 2: Installation* in the product specific instruction manual for information on the password disable jumper.

Checking Relay Status

With continual self-testing, the relay monitors the internal operation of all circuits to verify optimal performance of relay functions. If an internal circuit, protection algorithm, or automation algorithm enters an out-of-tolerance operating range, the relay reports a status warning. In the unlikely event that an internal failure occurs, the relay reports a status failure. For more information on relay status, see *Relay Self-Tests on page 10.15*.

You can check relay status through a communications port by using a terminal, terminal emulation computer program, or QuickSet. In addition, you can use the relay front panel to view status information.

Checking Relay Status Using the Terminal

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

Step 1. Enter Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **STA <Enter>**. The relay returns a status terminal screen similar to that in *Figure 3.7*.

```
=>STA <Enter>
Relay 1                                                Date: mm/dd/yyyy
   Time:07:02:50.776
Station A                                              Serial Number: 000000000
FID=SEL-451-1-Rxxx-V0-Zxxxxxx-Dyyyymmdd                  CID=0x9aed

Failures
  No Failures
Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors
Relay Enabled
=>
```

Figure 3.7 Relay Status

Step 3. Type **STA A <Enter>** to view all relay status entries.

For more information on relay status report items, see *STATUS on page 14.50*.

Checking Relay Status in QuickSet

You can use QuickSet to check relay status. Use the **HMI > Meter Control** menu to view status conditions.

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Section 2: PC Software*).

Step 1. Configure the communications port.

a. Start QuickSet.

NOTE: The DTR parameter has no effect on communications with the relay.

b. On the top toolbar, click **Communications > Parameters**.

You will see the **Communication Parameters** dialog box similar to that shown in *Figure 3.8*.

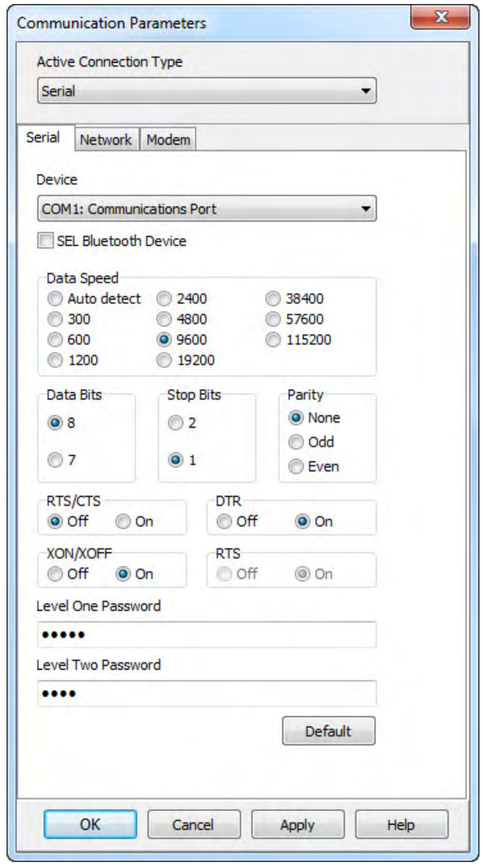

Figure 3.8 QuickSet Communication Parameters and Password Entry

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are 9600, 8, 1, None, and Off, respectively.

d. Click **OK** to update the QuickSet communications parameters and connect to the relay.

e. Confirm that the Communications Status bar at the bottom of the QuickSet window says `Connected`.

Step 2. Confirm that you have loaded the correct passwords in QuickSet.

a. Enter your Access Level 1 password in the Level One Password text box, and your Access Level 2 password in the Level Two Password text box.

b. Click **OK** to accept changes and close the dialog box.

Step 3. Click **Tools** in the top toolbar and select the **HMI** menu to start the QuickSet operator interface.

Step 4. Click the **Status** button of the HMI tree view (see *Figure 3.9*).

QuickSet displays the relay status with a display similar to that in *Figure 3.9*.

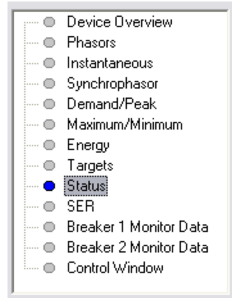

Figure 3.9 Retrieving Relay Status in QuickSet

Checking Relay Status From the Front Panel

Use the front-panel display and navigation pushbuttons to check relay status. See *Section 4: Front-Panel Operations* for information on using the relay front panel.

Step 1. Apply power to the relay, and note that the LCD shows a sequence of screens called the ROTATING DISPLAY.

(If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **ENT** pushbutton to display the MAIN MENU as shown in *Figure 3.10*.

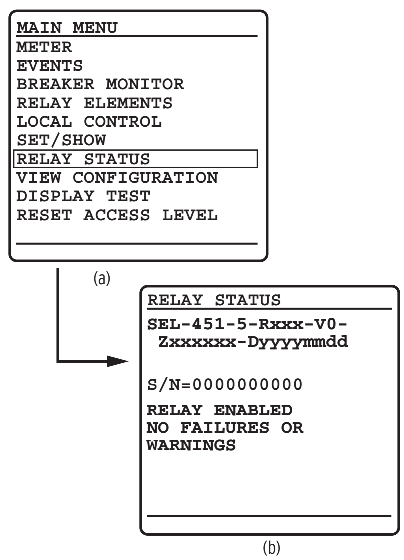

Figure 3.10 Checking Relay Status From the Front-Panel LCD

Step 3. View the relay status.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the RELAY STATUS action item (see *Figure 3.10*).

b. Press the **ENT** pushbutton.

You will see the RELAY STATUS screen (the second screen of *Figure 3.10*).

Step 4. Press the **ESC** pushbutton to return to the MAIN MENU.

Step 5. Press **ESC** pushbutton again to return to the ROTATING DISPLAY.

For more information on the front-panel screen presentations and the items in the RELAY STATUS screens, see *Relay Status on page 4.29*.

Making Simple Settings Changes

⚠WARNING
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The relay settings structure makes setting the relay easy and efficient. Settings are grouped logically, and relay elements that are not used in your selected protection scheme are hidden. QuickSet uses a similar method to focus your attention on the active settings. Unused relay elements and inactive settings are dimmed (grayed) in the QuickSet menus. See *Section 2: PC Software* for more information on QuickSet.

Settings Structure

SEL-400 series relays use a settings structure that assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

- Class
- Instance
- Category
- Setting

Examine *Figure 3.11* to understand the settings structure in a typical relay. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Settings classes and related instances for the SEL-451, which are typical of SEL-400 series relays, are listed in *Table 3.4*. See *Section 8: Settings* of the product-specific instruction manual for details on the classes and instances for a given relay.

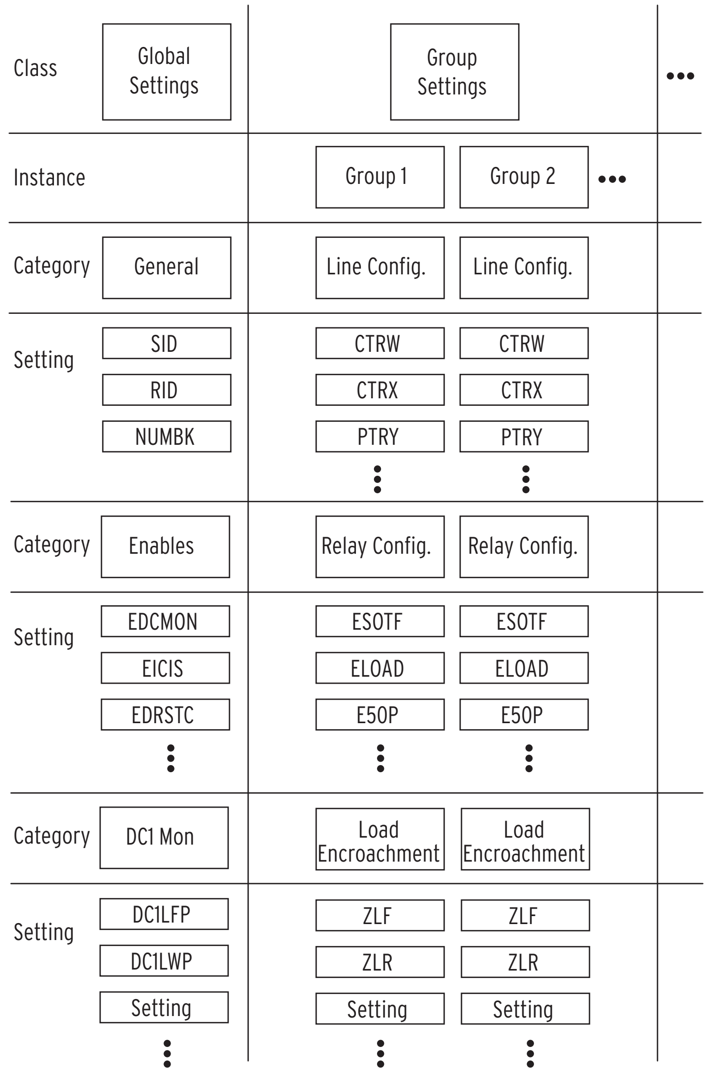

Figure 3.11 Example Relay Settings Structure Overview

Table 3.4 SEL-451 Settings Classes and Instances (Sheet 1 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Global	Relay-wide applications settings	Global		SET G	P, A, O, 2
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	SET 1, SET S 1 • • • SET 6, SET S 6	P, 2
Breaker Monitor	Circuit breaker monitoring settings	Breaker Monitor		SET M	P, 2
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5	Front-panel port PORT 1 settings • • • PORT 3 settings Communications card settings	SET P F SET P 1 • • • SET P 3 SET P 5	P, A, O, 2
Report	Report settings	Report		SET R	P, A, O, 2

Table 3.4 SEL-451 Settings Classes and Instances (Sheet 2 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Front Panel	Front-panel HMI settings	Front Panel		SET F	P, A, O, 2
Protection SELOGIC control equations	Protection-related SELOGIC control equations	Group 1 • • • Group 6	Group 1 protection SELOGIC control equations • • • Group 6 protection SELOGIC control equations	SET L 1 • • • SET L 6	P, 2
Automation SELOGIC control equations	Automation-related SELOGIC control equations	Block 1 • • • Block 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP3	Direct Network Protocol data remapping	Map 1 • • • Map 5		SET D 1 • • • SET D 5	P, A, O, 2
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communication transmit equations	Output		SET O	O, 2
Bay	Bay control settings	Bay		SET B	P, 2
Alias	Set aliases	Analog or digital quantities		SET T	P, A, O, 2
Notes	Freeform programming to leave notes in the relay	Notes	100 lines	SET N	P, A, O, 2

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 3.4*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**. Conversely, the Port settings command has five instances (PORT F, PORT 1, PORT 2, PORT 3, and PORT 5). To access the PORT 1 settings, type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym S attached to the command; you can enter **SET 1** or **SET S 1** for Group 1 settings, **SET 2** or **SET S 2** for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Alias Settings

Although the relay provides extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names in order to improve the readability of the program.

Rename, or assign as many as 200 alias names to any Relay Word bit or analog quantity in the relay. The maximum length of an alias is seven characters. Valid characters are 0–9, A–Z (only uppercase), and _ (underscore), and must contain at least one alphabetic character. Ensure that no Relay Word bit or analog quantity appears more than once in the alias settings. Each alias name must be unique, i.e., you cannot use the name of an existing Relay Word bit or analog quantity. If you remove the alias name, all settings that referenced that alias revert to the original name.

Use the **SHO T** command to view the default settings, as shown in *Figure 3.12*.

```
=>>SHO T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
=>>
```

Figure 3.12 Default Alias Settings

Making Text-Edit Mode Alias Changes

Assign the alias name THETA to math variable PMV01 and the alias TAN to math variable PMV02. These variables are then used in calculating the tangent of theta, using their alias names in the equation.

Step 1. Prepare to control the relay at Access Level 2.

a. Type **ACC <Enter>** at a communications terminal.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the =>> prompt.

Step 2. Type **SET T <Enter>** to access the alias settings.

Figure 3.13 shows a representative computer terminal screen.

Step 3. Type **> <Enter>** for the relay to display the first line that you can edit.

Step 4. Type **PMV01,THETA <Enter>** at the Line 2 `?` settings prompt to set the alias for PMV01.

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the `?` settings prompt.

Step 5. Type **PMV02,TAN <Enter>** at the Line 3 `?` settings prompt to set the alias for PMV02.

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the `?` settings prompt.

Step 6. Type **END <Enter>** to end the settings session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y, N) ?` prompt. At the end of the readback information, just before the `Save settings (Y, N) ?` prompt, you can verify the new display point information.

Step 7. Type **Y <Enter>** to save the new settings.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
?   <Enter>
2:
?  PMV01,THETA <Enter>
3:
?  PMV02,TAN <Enter>

4:
?  END <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
2: PMV01,"THETA"
3: PMV02,"TAN"

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.13 Using Text-Edit Mode Line Editing to Set Aliases

Use the alias names, instead of the Relay Word bits, in SELOGIC control equation programming. *Figure 3.14* shows an example of an alias used in protection logic programming.

```
=>>SET L <Enter>
Protection 1
1: PLT01S := PB1_PUL AND NOT PLT01 #GROUND ENABLED
?  > <Enter>
15:
?  THETA:=IO1FA <Enter>

16:
?  TAN:=SIN(THETA)/COS(THETA) <Enter>
17:
?  END <Enter>
Protection 1
.
.
.

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.14 Using Text-Edit Mode Line Editing to Set Protection Logic

Changing Settings Using the Terminal

When you change settings (with any **SET** command) from a terminal, the relay shows the setting category, prompt, present value, and action prompt.

Figure 3.15 shows two settings examples: multiple-line settings (SID and RID) and an in-line setting (NUMBK) for relay Global settings from Access Level P (protection). The relay prompts you for input by presenting an action prompt. You have many options for navigating the settings at the ? prompt.

Table 3.5 lists the operations possible from a settings action prompt.

```
==>SET G <Enter>
Global

General Global Settings                                        Category

Station Identifier (40 characters)                             Prompt
SID := "Station A"                                             Present Value
? <Enter>                                                      Action Prompt
Relay Identifier (40 characters)
RID := "Relay 1"
? <Enter>
Number of Breakers in Scheme (1,2)      NUMBK   := 1     ? <Enter>
              Prompt                          Present    Action
                                               Value     Prompt
```

Figure 3.15 Components of SET Commands

Table 3.5 Actions at Settings Prompts

Action	Relay Response
<Enter>	Accept setting and move to the next setting; if at the last setting, exit settings.
[*value*] <Enter>	Enter the given *value* and move to the next setting if valid; if at the last setting, exit settings.
^ <Enter>	Move to the previous setting; if at the top of settings, stay at the present setting.
< <Enter>	Move to the top of the previous settings category; if at the top of settings, stay at the present setting.
> <Enter>	Move to the top of the next settings category; if in the last category, exit settings.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort the editing session without saving changes.

When you exit settings entry from the **SET** commands, the relay responds with `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay writes the new settings to nonvolatile storage. If you answer **N <Enter>**, the relay discards any settings changes you have made.

Making Settings Changes in Initial Global Settings

You must configure SEL-400 series relays for specific conditions found in the power system where you are connecting the relay. For example, in most SEL-400 series relays you must set the nominal frequency and phase rotation.

The procedure in the following steps assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page 3.4* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords. See *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords.

This example jumps to a Global setting that is not at the beginning of the Global settings list. Thus, you enter **SET G**, the setting name, and **<Enter>**. To start at the beginning of the Global settings, simply type **SET G <Enter>** without a settings name.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Type **SET G NFREQ <Enter>** (this sets the nominal system frequency using the **NFREQ** setting, which has options of 50 Hz and 60 Hz).

The relay responds with a terminal screen display similar to that shown in *Figure 3.16*.

```
=>>SET G NFREQ <Enter>
Global

General Global Settings

Nominal System Frequency (50,60 Hz)                NFREQ   := 60     ? <Enter>
System Phase Rotation (ABC,ACB)                    PHROT   := ABC    ? <Enter>
Date Format (MDY,YMD,DMY)                          DATE_F  := MDY    ? YMD <Enter>
Fault Condition Equation (SELogic Equation)
FAULT := 51S1 OR 51S2 OR 50P1
?  END <Enter>
.
.
.

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.16 Example Global Settings

Step 3. Accept the default settings.

a. For a 60 Hz system, press **<Enter>** to accept the NFREQ existing value of 60 (Hz).

The relay presents the next setting, which is the PHROT (phase rotation) setting.

b. Type **<Enter>** to accept the ABC phase rotation default.

Step 4. Set the date format:

The relay can report dates in three formats: MDY, YMD, and DMY (where M = month, D = date, and Y = year).

a. For this procedure, type **YMD <Enter>**.

At each setting in turn, the relay presents the settings prompt, name, present value, and action prompt.

Note that SELOGIC control equation settings, such as FAULT in *Figure 3.16*, can appear on multiple lines.

b. If you make a mistake or want to go backward through the settings, type the ^ character (on most computer keyboards, this is a shifted numeral 6) and **<Enter>**.

Refer to *Table 3.5* for this and other navigational aids.

Step 5. End the settings session.

a. Type **END <Enter>** at the `FAULT` action prompt.

(The Fault SELOGIC control equation remains unchanged.)

The relay next scrolls a readback of all the Global settings, eventually displaying the following prompt:

`Save settings (Y,N) ?`

(In *Figure 3.16*, a vertical ellipsis represents the relay information during readback.)

b. Examine the settings readback to verify your new settings.

c. Answer **Y <Enter>** to save your new settings.

The TERSE Option

You can avoid viewing the entire class settings summary the relay displays when you type **END <Enter>** midway through a settings class or instance.

On slow data speed links, waiting for the complete settings readback can clog your automation control system or take too much of your time for a few settings changes. Eliminate the settings readback by appending **TERSE** to the **SET** command.

Text-Edit Mode Line Editing

Some relay settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name. See *Making Text-Edit Mode Settings Changes on page 3.22* for an example of a text-edit mode setting.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 3.6* lists the commands for text-edit mode.

NOTE: To begin an entry with one of these keywords, especially in notes settings, put the string in quotes: e.g. "END OF REPORT".

Table 3.6 Actions at Text-Edit Mode Prompts

Action	Relay Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE [*n*] <Enter>	Delete the present line and subsequent lines for a total of *n* lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort editing session without saving changes.

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

Making Text-Edit Mode Settings Changes

The procedure in the following steps familiarizes you with basic text-edit mode line editing.

Example 3.1 Text-Edit Mode Line Editing

Set Display Point 1 through Display Point 3 to show the status of Circuit Breaker 1, Circuit Breaker 2, and the operational state (on or off) of the transformer cooling fans near the circuit breaker bay where you have installed the relay. See *Display Points on page 4.10* for information on programming display points.

For this example, use inputs IN101, IN102, and IN105. You can use other inputs for your particular application.

This procedure assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10*) to change the default access level passwords.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Step 2. Access the display point settings.

a. Type **SET F <Enter>** to modify the front-panel settings.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the **Display Points** category.

Figure 3.17 shows a representative terminal screen. The relay displays the first line that you can edit. For the case of display points, the line number is the display point number.

Step 3. At the Line 1 settings `?` prompt, type the following to create Display Point 1:

IN101,CB1,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt (see *Figure 3.17*).

Step 4. At the Line 2 settings `?` prompt, type the following to create Display Point 2:

IN102,CB2,CLOSED,OPEN <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `3:` followed by the settings `?` prompt (see *Figure 3.17*).

Step 5. At the `Display Points` prompt, use the text-edit mode line editing commands to list the active display points. Type the following:

LIST <Enter>

After showing the active display points, the relay returns to Line 3 followed by the settings `?` prompt.

Example 3.1 Text-Edit Mode Line Editing (Continued)

NOTE: Use quotation marks when entering alias strings that contain spaces or punctuation marks, as shown in the IN105 sample, Step 6.

Step 6. Type the following to create Display Point 3:

IN105,“5 MVA XFMR Fans”,ON,OFF <Enter>

The relay verifies that this is a valid entry, then responds with the next line prompt `4:` followed by the settings `?` prompt (see *Figure 3.17*).

Step 7. Type **END <Enter>** to end the editing session.

The relay scrolls a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (A vertical ellipsis in *Figure 3.17* represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save the new settings.

```
Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”


1:
? IN101,CB1,CLOSED,OPEN <Enter>
2:
? IN102,CB2,CLOSED,OPEN <Enter>
3:
? LIST <Enter>
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S

3:
? IN105,“5 MVA XFMR Fans”,ON,OFF <Enter>
4:
? END <Enter>
              .
              .
              .

Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S
              .
              .
              .

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.17 Using Text-Edit Mode Line Editing to Set Display Points

This procedure proposes connecting the transformer bank fan sensor to relay input IN105. In the **SET G** (GLOBAL) command, verify that the debounce time settings IN105PU and IN105DO are correct for your fan-running sensor. To access separate input parameters, you must first enable independent control input settings with setting EICIS. To change the input conditioning, enter the following settings:

EICIS := **Y** Enable Independent Control Input Settings (Y, N)

IN105PU := **0.3750** Pickup Delay for Contact Input IN105 (0.0000–5 cyc)

IN105DO := **0.3750** Dropout Delay for Contact Input IN105 (0.0000–5 cyc)

Use the appropriate interface hardware to connect the fan-running sensor to IN105. Choose any relay input that conforms to your requirements.

Example 3.2 Leaving a Note in the Relay

For this example, assume you are testing a line, but you will be away for a few days. You want to leave your colleague, Marius, a note telling him where you left the drawings and settings. Use the Notes function in the relay to leave the note, as shown in *Figure 3.18*. All relevant procedures in this section assume that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords to change the default access level passwords. Furthermore, *Step 1* below applies to all relevant tests, and is not repeated for each test.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the Notes settings.

a. Type **SET N <Enter>** to access the Notes settings.

b. At the Line 1 settings `?` prompt, type the Line 1 text shown in *Figure 3.18* (as many as 70 characters without wrap), and press **<Enter>**.

The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 3. At the Line 2 settings `?` prompt, type the Line 2 text shown in *Figure 3.18*.

Because there are more than 70 characters, the relay rejects the entry.

Re-enter the text, but keep the number of characters at 70 or fewer.

Step 4. After the last entry, type **END <Enter>**.

This tells the relay that you have completed the setting change.

Step 5. Type **Y <Enter>** at the prompt `Save settings (Y,N)` to save the settings.

```
=>>SET N <Enter>
Notes
1:
? Marius, this is the relay for CARR substation <Enter>
2:
? The Sacramento line drawings and setting sheets are in the top drawer in the sub\
station. <Enter>
Note cannot exceed 70 chars

2:
? The Sacramento line drawings and settings are in the <Enter>
3:
? top drawer in the substation. <Enter>
4:
? END <Enter>
Notes
1: Marius, this is the relay for CARR substation
2: The Sacramento line drawings and settings are in the
3: top drawer in the substation.

Save settings (Y,N) ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
```

Figure 3.18 Leave a Note in the Relay

To read the note, type **SHO N <Enter>**, as shown in *Figure 3.19*.

```
=>>SHO N <Enter>
Notes
1: Marius, this is the relay for CARR substation
2: Capacitor Bank 1 drawings and settings are in the
3: top drawer in the substation.
=>>
```

Figure 3.19 Read a Note in the Relay

Example 3.3 Deleting a Display Point

This example shows you how to delete a previously used display point. In the **SET F** command, at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set and delete the display points. This procedure shows two previously programmed display points that indicate on the front-panel LCD the status of Circuit Breaker 1 and Circuit Breaker 2. Relay control inputs IN101 and IN102 are the Relay Word bits for the Circuit Breaker 1 and Circuit Breaker 2 display points, respectively (see *Making Text-Edit Mode Settings Changes on page 3.22*). You can use other inputs for your particular application.

The procedure in the following steps assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10*).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Example 3.3 Deleting a Display Point (Continued)

Step 2. Access the `Display Points and Aliases` prompt.

a. Enter the **SET F** command.

b. Advance through the front-panel settings (repeatedly type **>** and then **<Enter>**) until you reach the `Display Points and Aliases` category.

Figure 3.20 shows a representative terminal screen. The relay displays the first line that you can edit. For display points, the line number is the display point number.

```
Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”
1: IN101,"CB1","CLOSED","OPEN",S
?  LIST <Enter>
1: IN101,"CB1","CLOSED","OPEN",S
2: IN102,"CB2","CLOSED","OPEN",S
3: IN105,"5 MVA XFMR Fans","ON","OFF",S

1: IN101,"CB1","CLOSED","OPEN",S
?  <Enter>
2: IN102,"CB2","CLOSED","OPEN",S
?  DELETE <Enter>
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  LIST <Enter>

1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
?  END <Enter>
              .
              .
              .

Display Points
(Boolean) : RWB Name, “Label”, “Set String”, “Clear String”, “Text Size”
(Analog) : Analog Quantity Name, “User Text and Formatting”, “Text Size”
1: IN101,"CB1","CLOSED","OPEN",S
2: IN105,"5 MVA XFMR Fans","ON","OFF",S
              .
              .
              .

Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.20 Using Text-Edit Mode Line Editing to Delete a Display Point

Step 3. List the present display points.

a. Type **LIST <Enter>** at the Display Points `?` prompt.

b. After showing the active display points, the relay returns to Line 1 followed by the settings `?` prompt.

Step 4. Type **<Enter>** once to proceed to the Line 2 present value and settings `?` prompt.

Step 5. Type **DELETE <Enter>** to delete Display Point 2.

Step 6. Type **LIST <Enter>** to examine the remaining display points.

Former Display Point 2 is eliminated, and Display Point 3 moves up to position 2.

The relay returns to Line 2 followed by the settings `?` prompt.

Example 3.3 Deleting a Display Point (Continued)

Step 7. Type **END <Enter>** to end the settings process.

The relay next scrolls a readback of all the Front-Panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 3.20*, a vertical ellipsis represents this scrolling readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can verify the new display point information.

Step 8. Answer **Y <Enter>** to save your new settings.

Settings in QuickSet

You can use QuickSet to develop settings for the relay offline. QuickSet automatically checks interrelated settings and alerts you to out-of-range settings. Upload the offline QuickSet settings to the relay via the communications ports. See *Checking Relay Status in QuickSet on page 3.12* for an introductory tutorial on using QuickSet.

You can also use QuickSet as a terminal program to interact in real time with the relay. For an introduction to QuickSet and all of features of this software, see *Section 2: PC Software*.

Making Initial Global Settings in QuickSet

QuickSet makes setting the relay an easy task. The purpose of the procedure in the following steps is to familiarize you with reading, modifying, and sending settings with QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet; see *Section 2: PC Software* and *Checking Relay Status in QuickSet on page 3.12*.

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. In the **File** menu, click **Read** to read the present configuration in the relay.

The relay sends all configuration and settings data to QuickSet.

Step 3. Select **Global** settings.

a. Click the arrow next to the **Global** branch of the left-hand QuickSet tree structure shown in *Figure 3.21*.

b. Click **General Global Settings**.

You will see the **Global Settings** window (see *Figure 3.21*).

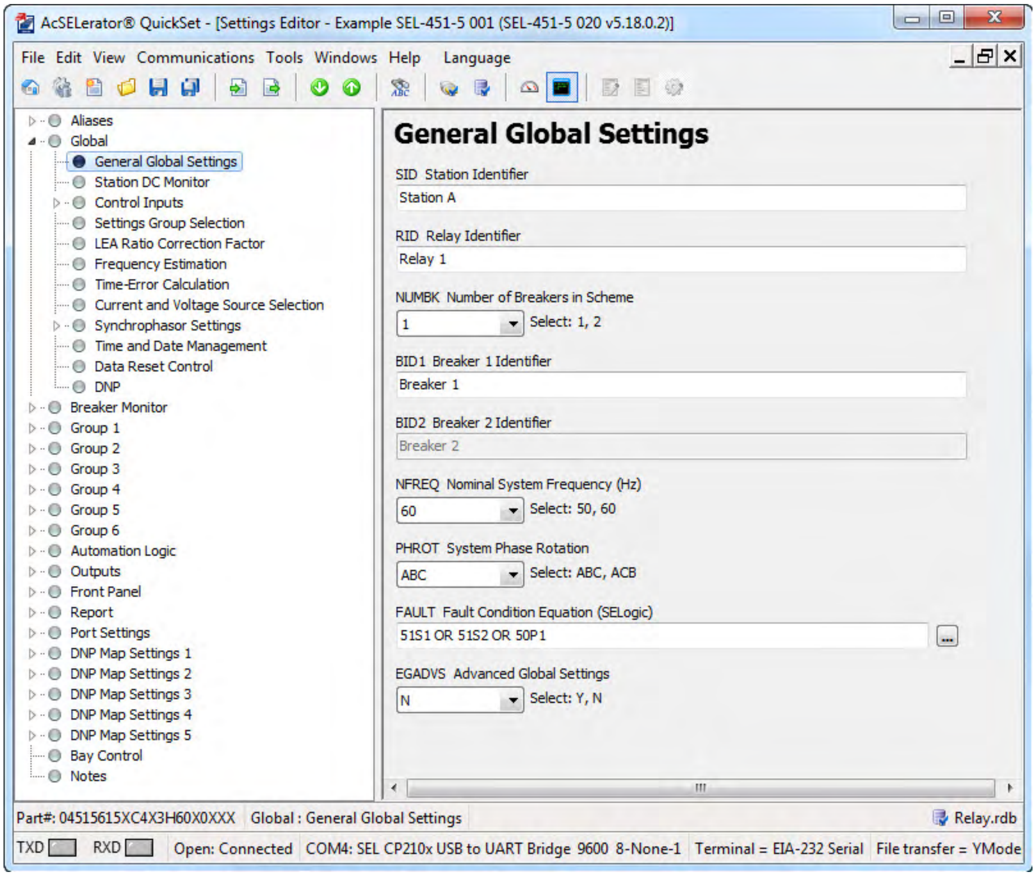

Figure 3.21 QuickSet Global Settings Window

Step 4. Change settings.

a. Click the button for the correct option for NFREQ and PHROT to specify your system frequency and phase rotation.

When you tab or click to the next field, the relay validates the new setting.

b. The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**.

➢ Right-click in the setting dialog box and select **Previous Value** if you want to revert to the setting value before you made a change.

➢ Right-click in the setting dialog box and select **Default Value** if you want to restore the factory-default setting value.

Step 5. Save the new settings in QuickSet.

a. In the **File** menu, click **Save**.

b. Specify a Settings Name.

c. Click **OK**.

Step 6. Upload the new settings to the relay.

a. On the **File** menu, click **Send**.

QuickSet prompts you for the settings class or instance you want to send to the relay, as shown in the first dialog box of *Figure 3.22*.

b. Click the check box for **Global**.

c. Click **OK**.

QuickSet responds with the second dialog box shown in *Figure 3.22*.

If you see no error message, the new settings are loaded in the relay.

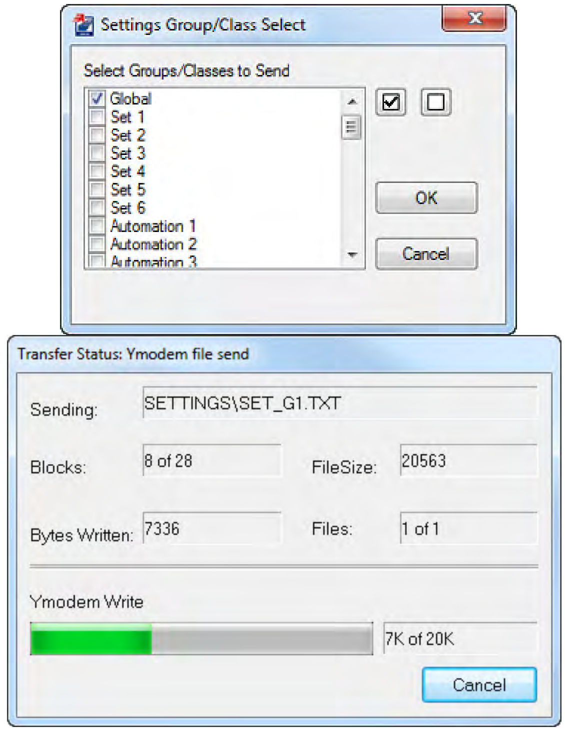

Figure 3.22 Uploading Global Settings to the Relay

Settings From the Front Panel

You can use the relay front panel to enter some of the relay settings. The relay presents the settings in order from class to instance (if applicable) to category to the particular setting, in a manner similar to setting the relay using a terminal.

Use the LCD and the adjacent navigation pushbuttons to enter each character of the setting in sequence. This can be a laborious process for some settings (e.g., long SELOGIC control equations). However, if you need to make a quick correction or have no faster means to make settings, settings functions are available at the front panel. For more information on making settings changes from the front panel, see *Set/Show on page 4.25*.

Entering DATE and TIME From the Front Panel

The purpose of the procedure in the following steps is to familiarize you with entering data from the relay front panel.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the relay front-panel display shows a sequence of LCD screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **ENT** pushbutton to display the MAIN MENU of *Figure 3.23*.

Step 3. View the settings screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the SET/SHOW action item (see *Figure 3.23*).

b. Press the **ENT** pushbutton.

You will see the SET/SHOW submenu (the second screen in *Figure 3.23*).

Step 4. View the date/time screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the DATE/TIME action item (*Figure 3.23*, second screen).

b. Press the **ENT** pushbutton.

The relay next displays the DATE/TIME submenu (the third screen of *Figure 3.23*).

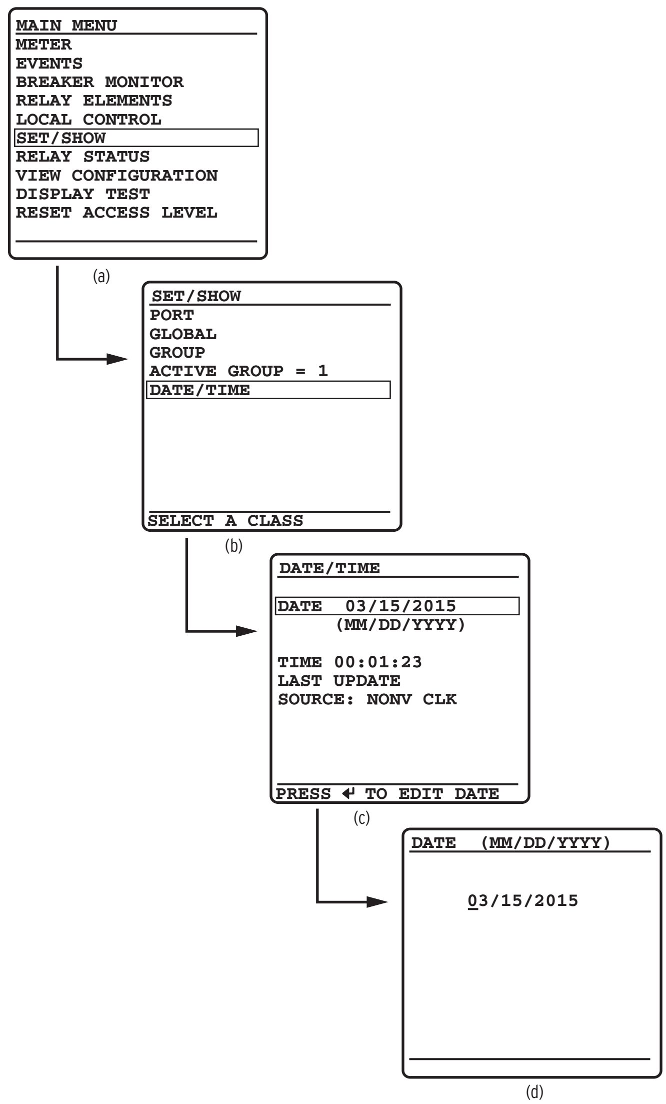

Figure 3.23 DATE and TIME Settings From Front-Panel LCD

Step 5. Set the date.

a. Press the **ENT** pushbutton.

The relay shows the last screen of *Figure 3.23*, the DATE edit screen.

b. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to increase and decrease the date position numbers.

Step to the next or previous position by using the **Left Arrow** and **Right Arrow** pushbuttons.

c. When finished adjusting the new date, press **ENT**.

The relay returns the display to the DATE/TIME submenu. Note that the relay reports the TIME SOURCE as FP DATE (front-panel date).

Step 6. Press **ESC** repeatedly to normalize the front-panel display.

Changing a Relay Setting From the Front Panel

The purpose of the procedure in the following steps is to provide additional practice at entering relay settings from the front panel. In this example, you change the PORT F front-panel communications port settings.

Step 1. View the MAIN MENU.

a. If you have been using the front panel (as in the previous example), press the **ESC** key repeatedly until you see the MAIN MENU.

b. If the relay is displaying the ROTATING DISPLAY, press the **ENT** pushbutton to display the MAIN MENU.

Figure 3.24(a) shows the MAIN MENU at the beginning of the front-panel settings process.

Step 2. View the settings screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the SET/SHOW action item, as shown in *Figure 3.24(a)*.

b. Press the **ENT** pushbutton. You will see the SET/SHOW submenu screen, as shown in *Figure 3.24(b)*.

Step 3. Select PORT F.

a. Highlight PORT and press the **ENT** pushbutton.

The relay displays the PORT instances screen, as shown in *Figure 3.24(c)*.

b. Choose the port you want to configure by using the **Up Arrow** and **Down Arrow** navigation pushbuttons to move the screen arrow.

For this example, select PORT F and press **ENT**.

Step 4. View the **Communications Settings** category screen.

a. The relay displays the Port F category screen, as shown in *Figure 3.24(d)*. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to select the settings category.

b. For this example, highlight **Communications Settings** and press **ENT**.

The relay displays the Communications Settings screen, as shown in *Figure 3.24(e)*.

Step 5. Change settings.

a. Highlight the SPEED setting.

b. Press **ENT**.

(The relay possibly requires a password here; see *Passwords on page 3.10* and *Section 4: Front-Panel Operations*.)

The LCD displays the SPEED selection submenu that has all the possible choices for serial data speeds.

The highlighted selection in *Figure 3.24(f)* indicates the default setting of 9600 (bps).

c. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to select a different speed.

d. Once you have selected a data speed, press the **ENT** pushbutton.

NOTE: Once you have changed communications parameters, you must change the corresponding parameters in your terminal emulation program to communicate with the relay via a communications port.

Step 6. End the settings session.

a. The relay returns to the previous category settings list screen. Press **ESC** to return to the categories screen where you see the Save Settings item at the bottom of the screen.

b. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight Save Settings and press **ENT**.

c. Highlight YES, and then press **ENT**.

The relay validates the setting and returns to the PORT screen, as shown in *Figure 3.24(c)*.

Step 7. Press **ESC** repeatedly to return to the MAIN MENU.

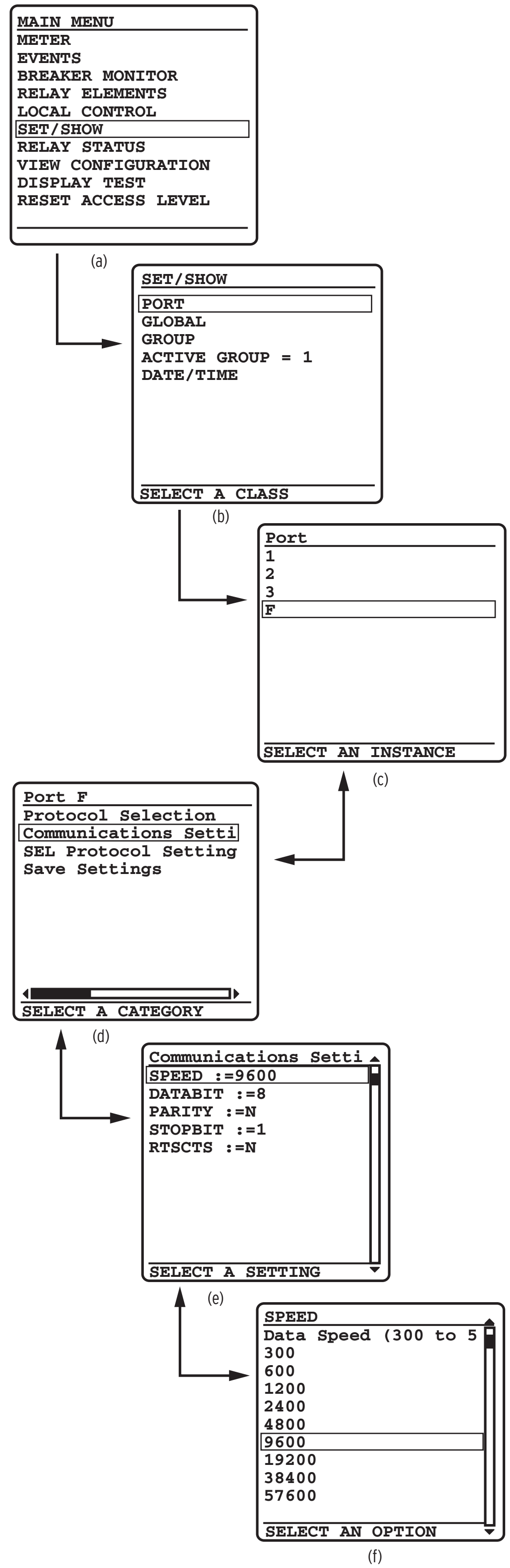

Figure 3.24 SET/SHOW Menus

Examining Metering Quantities

SEL-400 series relays feature high-accuracy power system metering. You can view fundamental and rms quantities by using a communications terminal, QuickSet, or the front panel. For more information on relay metering, see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual.

View Metering Using the Terminal

The procedure in the following steps shows how to use a terminal or terminal emulation computer program to view power system metering. In this example, you connect specific voltages and currents for a 5 A, 60 Hz relay. Scale these quantities appropriately for your particular relay.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). Step 1 through Step 7 are necessary if you have not yet configured the relay and want to test metering using a test source. If the relay is already connected to the system, you may jump to Step 8 to view the system metering information.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Set the relay to a nominal operation mode.

a. Use a terminal to perform the initial Global settings relay setup in *Making Settings Changes in Initial Global Settings on page 3.20*.

b. Set the relay for 60 Hz operation, ABC phase rotation.

Step 3. Some SEL-400 series relays support voltage and current source selection. In these relays, configure the source selection appropriate for metering testing. The following shows how to do this in an SEL-451 (see *Figure 3.25*). Use the terminal to set Global setting ESS := 1.

a. Type **SET G ESS TERSE <Enter>**.

b. Type **1 <Enter>**.

c. Type **END <Enter>** to finish this settings session.

d. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET G ESS TERSE <Enter>
Global

Current and Voltage Source Selection

Current and Voltage Source Selection (Y,N,1,2,3,4)      ESS   := N    ? 1 <Enter>
Line Current Source (IW,COMB)                           LINEI := IW   ? END <Enter>


Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.25 Setting ESS in the Terminal

Step 4. Set CT and PT ratios. The specific CT and PT configuration settings depends on the relay. The following shows a typical set of configuration choices. Use the terminal to set Group 1 setting CTRW := 200 (the CT W-input ratio), and PTRY := 2000.0 (the PT Y-input ratio).

a. Type **SET CTRW TERSE <Enter>**.

b. If the CTRW setting is not 200, type **200 <Enter>**.

c. Proceed as shown in *Figure 3.26* to PTRY and change PTRY to 2000.0, if needed.

d. Type **END <Enter>** to finish this settings session.

e. Answer **Y <Enter>** to the save settings prompt.

```
=>>SET CTRW TERSE <Enter>
Group 1

Line Configuration

Current Transformer Ratio - Input W (1-50000)       CTRW   := 120    ?200 <Enter>
Current Transformer Ratio - Input X (1-50000)       CTRX   := 120    ? <Enter>
Potential Transformer Ratio - Input Y (1.0-10000)   PTRY   := 180.0  ?2000.0 <Enter>
PT Nominal Voltage (L-L) - Input Y (60-300 V,sec)   VNOMY  := 115    ?END <Enter>


Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 3.26 Setting CTRW and PTRY in the Terminal

Step 5. Turn the relay off.

Step 6. Connect analog inputs. The specific connections depend on the relay. The following illustrates a typical set of voltage and current connections.

a. If three voltage sources and three current sources are available, connect the sources to the relay as shown in *Figure 3.27*.

If three voltage sources and two current sources are available, use the connection diagram of *Figure 3.28*.

b. Apply 67 V per phase (line-to-neutral) in ABC phase rotation.

c. Apply 2.0 A per phase, in phase with the applied phase voltages.

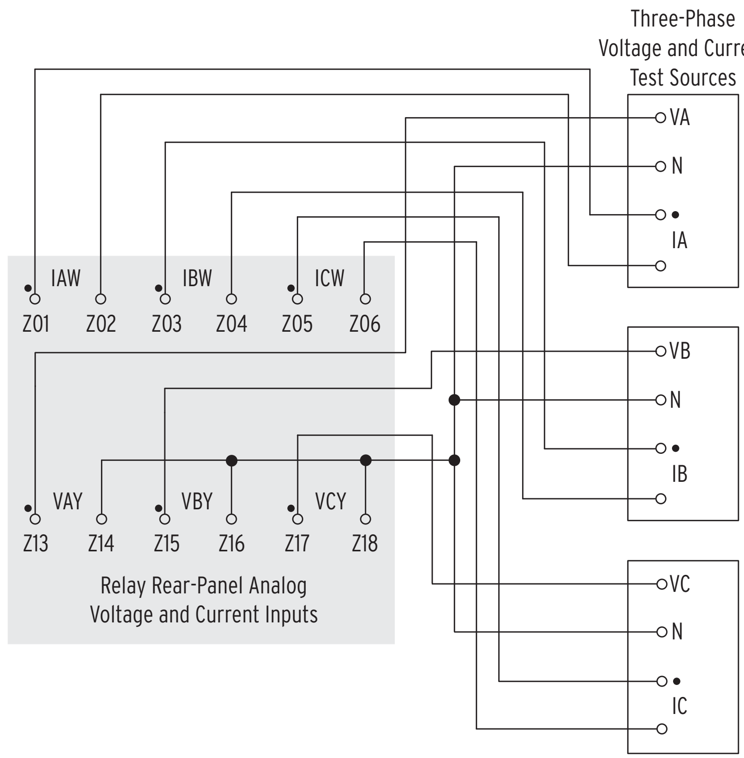

Figure 3.27 Test Connections Using Three Voltage Sources/Three Current Sources

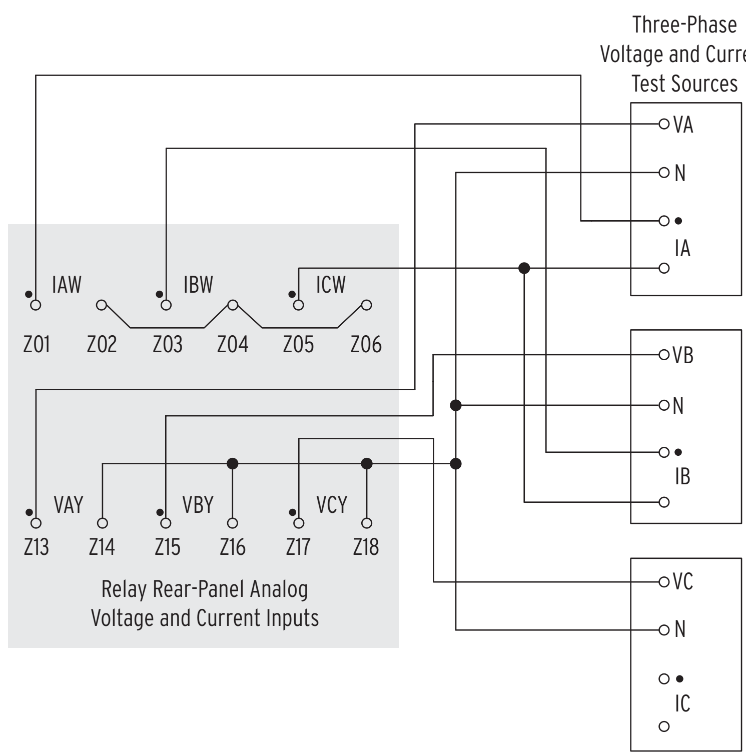

Figure 3.28 Test Connections Using Two Current Sources for Three-Phase Faults and METER Test

Step 7. Turn the relay on.

Step 8. View metering.

a. Type **ACC <Enter>** to log in to the relay at Access Level 1.

b. Type the password and press **<Enter>**.

c. Type **MET <Enter>**.

The relay displays the fundamental frequency (50 Hz or 60 Hz) metering information in a manner similar to that shown in *Figure 3.29*.

```
=>>MET <Enter>

Relay 1                                    Date: 02/26/2015  Time: 01:35:05.221
Station A                                  Serial Number: 0000000000

                     Phase Currents
                IA        IB        IC
I MAG (A)      398.882   399.041   398.784
I ANG (DEG)     -1.18   -120.97    119.21

                     Phase Voltages              Phase-Phase Voltages
                VA        VB        VC          VAB       VBC       VCA
V MAG (kV)     133.994   133.986   133.953     231.903   231.815   232.450
V ANG (DEG)     -0.17   -120.02    120.18       29.91    -89.92    150.01

                   Sequence Currents (A)        Sequence Voltages (kV)
                I1        3I2       3I0         V1        3V2       3V0
MAG            398.901     2.159     2.588     133.977     0.692     0.713
ANG (DEG)       -0.98    -62.68   -115.80        0.00    -53.25   -120.79

                  A            B            C            3P
P (MW)          53.44        53.46        53.41        160.31
Q (MVAR)         0.95         0.89         0.91          2.75
S (MVA)         53.45        53.47        53.42        160.33
POWER FACTOR     1.00         1.00         1.00          1.00
                  LAG          LAG          LAG           LAG

FREQ (Hz)      60.00       VDC1(V)   125.00   VDC2(V)    48.00

=>>
```

Figure 3.29 Terminal Screen MET Metering Quantities

The metering quantities of *View Metering Using the Terminal on page 3.35* are the fundamental line quantities. Other variants of the **MET** command give different relay metering quantities. See *Section 8: Metering, Monitoring, and Reporting* of the product-specific instruction manual for more information on the specific metering options available in a specific relay.

View Metering Using QuickSet

Use the procedures in the following steps to examine the relay metering with the QuickSet HMI.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Checking Relay Status in QuickSet on page 3.12* and *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for details on how to do this.

Step 2. Set the relay to a nominal operation mode. Perform the initial Global settings relay setup of *Making Initial Global Settings in QuickSet on page 3.28* to set the relay for 60-Hz operation, ABC phase rotation.

Step 3. Set a basic voltage and current configuration.

a. In the QuickSet **Settings** tree view, click the drop down arrow next to **Global** to expand the **Global** branch (see *Figure 3.30*).

b. Click the **Current and Voltage Source Selection** branch.

You will see the **Current and Voltage Source Selection** dialog box as shown in *Figure 3.30*.

c. Choose **1** from the drop-down menu under **ESS Current and Voltage Source Selection**.

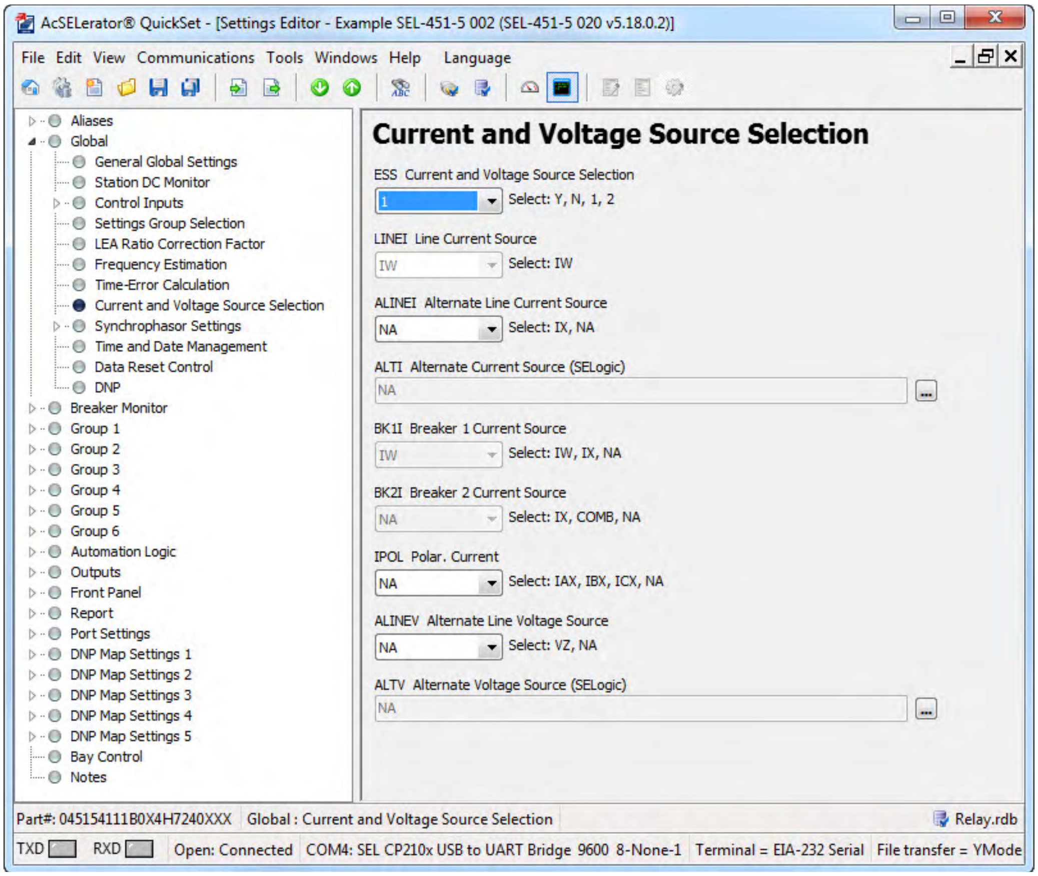

Figure 3.30 Global Alternate Source Selection Settings in QuickSet

Step 4. Set PT and CT ratios.

a. In the QuickSet **Settings** tree view, click the drop down arrow next to **Group 1** to expand this branch (see *Figure 3.31*).

b. Click the drop down arrow next to **Set 1**.

c. Click **Line Configuration**.

You will see the **Line Configuration** window similar to *Figure 3.31*.

d. Enter setting **CTRW Current Transformer Ratio - Input W** as **200**, and the **PTRY Potential Transformer Ratio - Input Y** as **2000**.

e. Save the settings and send the **Group 1** settings if you change the settings (see Step 6 and Step 7).

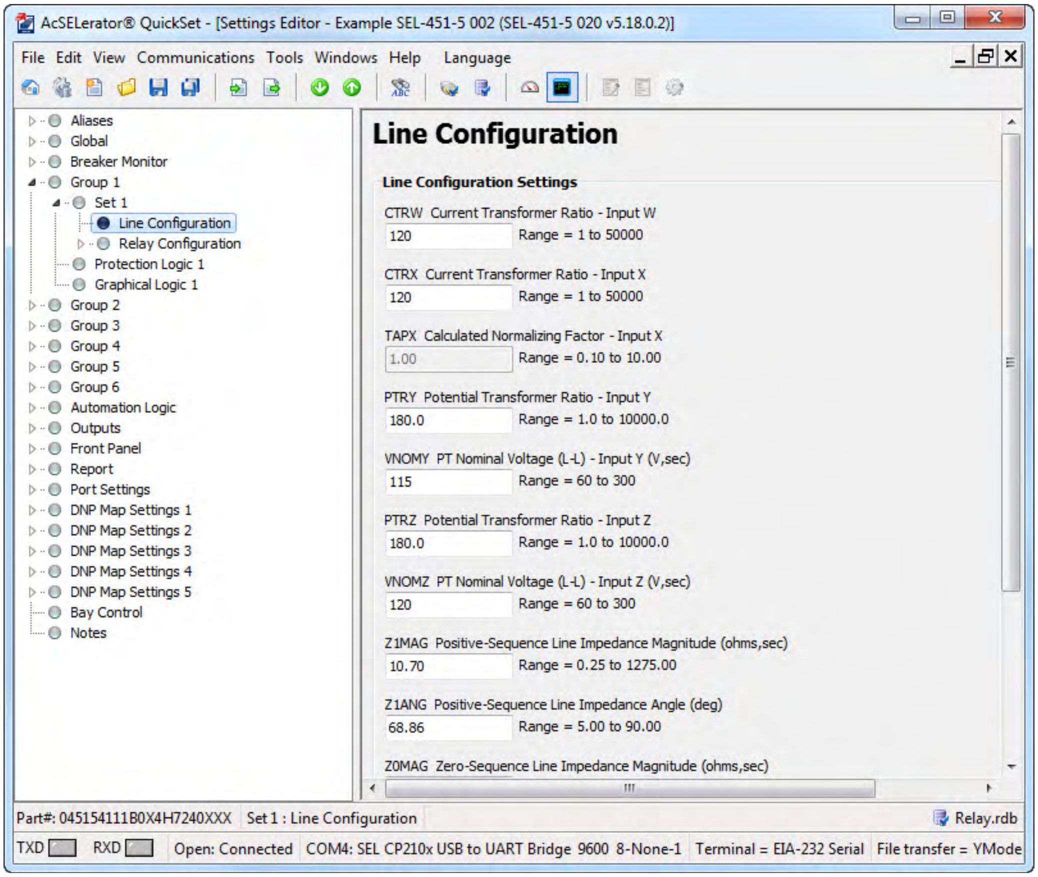

Figure 3.31 Group 1 Terminal Configuration Settings in QuickSet

Step 5. Start the QuickSet operator interface.

Step 6. In the top toolbar select **Tools** > **HMI** > **HMI** to start the GUI.

Step 7. Click the **Phasors** button of the HMI tree view (see *Figure 3.32*) to view phasors.

QuickSet displays fundamental line metering quantities with a display similar to *Figure 3.33*. (The test setup is adjusted for an approximately 30-degree lagging current.)

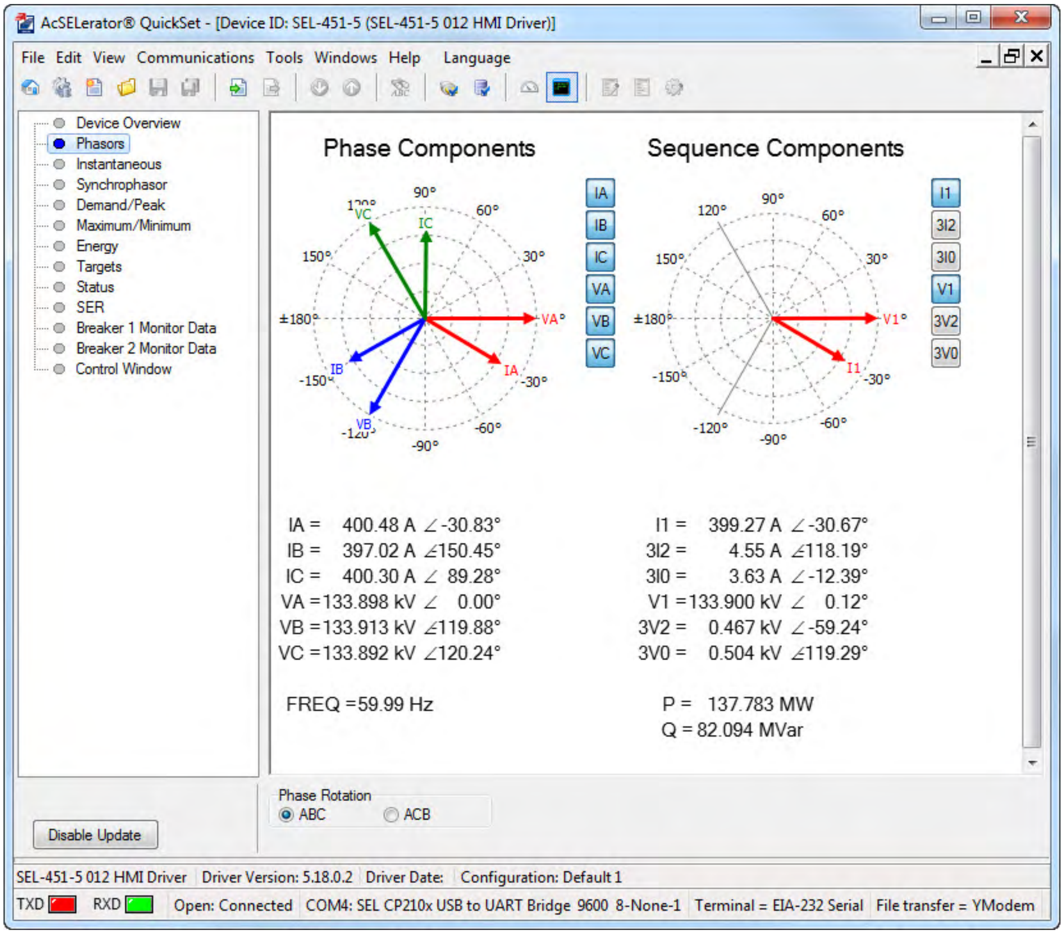

Figure 3.32 HMI Phasors View in QuickSet

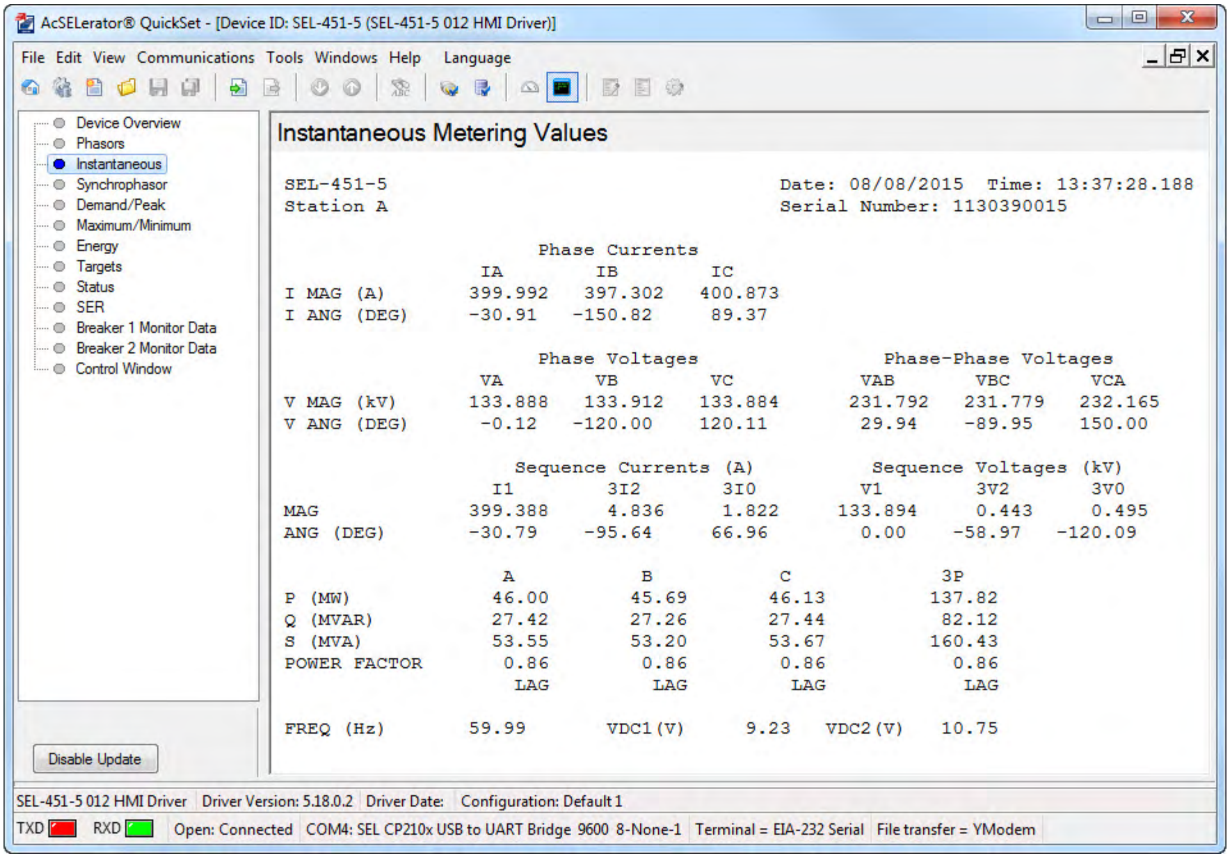

Figure 3.33 Instantaneous Metering Quantities in QuickSet HMI

Step 8. Click the **Instantaneous** button of the HMI tree view to see metering information similar to *Figure 3.33*.

View Metering From the Front Panel

In most SEL-400 series relays, you can use the front-panel display and navigation pushbuttons to view the metering quantities of the relay (see *Meter on page 4.16* for more information on viewing metering on the relay front panel). The screens in this procedure are for an SEL-451 with one circuit breaker, and this example assumes that you have not enabled the demand metering or synchronism-check features.

Step 1. Prepare to use the front panel by applying power to the relay.

Note that the LCD shows a sequence of screens called the ROTATING DISPLAY. (If you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 2. Press the **ENT** pushbutton to display the MAIN MENU at the top of *Figure 3.34*.

Step 3. View the metering selection screen.

a. Highlight the METER action item (see the first screen of *Figure 3.34*).

b. Press the **ENT** pushbutton.

The relay displays the METER submenu (the second screen in *Figure 3.34*).

Step 4. View the metering screens.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the FUNDAMENTAL METER action item, as shown in *Figure 3.34(b)*.

b. Press the **ENT** pushbutton.

The relay displays the first FUNDAMENTAL METER screen, shown in *Figure 3.34(c)*.

c. Use the **Up Arrow** and **Down Arrow** navigation pushbuttons to move among the fundamental line quantities metering screens.

Step 5. Press the **ESC** pushbutton repeatedly to return to the MAIN MENU.

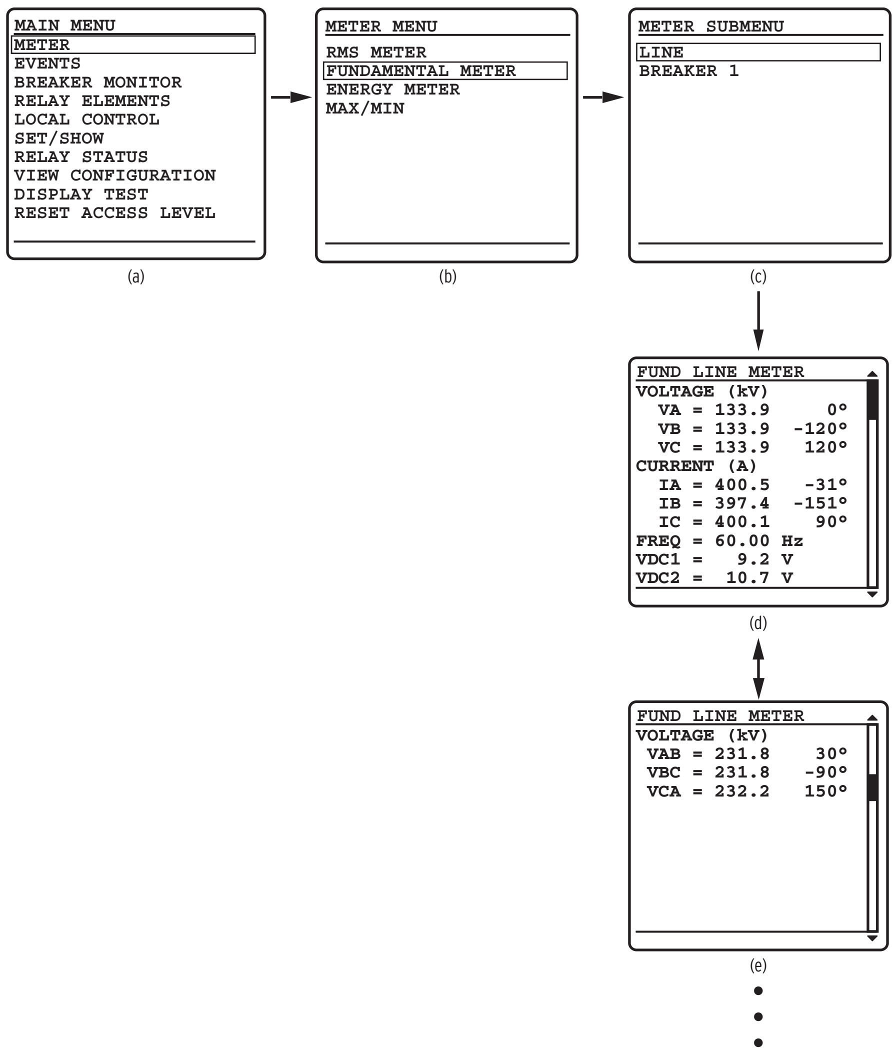

Figure 3.34 Front-Panel Screens for METER

Examining Relay Elements

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements.

View Relay Elements in the Terminal

The procedure in the following steps shows you how to view a change in state for the SEL-451 50P1 Phase-Instantaneous Overcurrent element from a communications port.

Table 3.7 Phase Instantaneous Overcurrent Pickup

Setting	Description	Default
50P1P	Level 1 Pickup (OFF, 0.25–100 A secondary)	15.00

For this procedure, you must have a serial terminal or computer with terminal emulation software and a variable current source for relay testing.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords and enter higher relay access levels).

Step 1. Type **ACC <Enter>** at a communications terminal.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 4. Type **TAR 50P1 <Enter>** to view the initial element status.

The relay returns a target terminal screen similar to that shown in *Figure 3.35*.

```
=>TAR 50P1 <Enter>
50P1  50P2  50P3  50P4  67P1  67P2  67P3  67P4
0     0     0     0     0     0     0     0
=>
```

Figure 3.35 Sample Targets Display on a Serial Terminal

Step 5. View the element status change.

a. Type **TAR 50P1 1000 <Enter>** (this command causes the relay to repeat the **TAR 50P1** command 1000 times). For more information on the **TAR** command see *Section 14: ASCII Command Reference*.

b. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

c. Type **<Ctrl+X>** to stop the relay from presenting the target display before completion of the 1000 target repeats.

View Relay Elements From the Front-Panel LCD

You can use the front-panel display and navigation pushbuttons to check Relay Word bit elements. See *Section 4: Front-Panel Operations* for more information on using the relay front panel.

This procedure uses the SEL-451 50P1 Phase-Instantaneous Overcurrent element.

Step 1. Display the MAIN MENU.

Step 2. If the relay LCD is in the ROTATING DISPLAY, press the **ENT** pushbutton to display the MAIN MENU similar to that in *Figure 3.36*.

Step 3. Press the **Down Arrow** navigation pushbutton to highlight the RELAY ELEMENTS action item, as shown in *Figure 3.36(a)*.

Step 4. Press the **ENT** pushbutton.

You will see a RELAY ELEMENTS screen, as shown in *Figure 3.36(b)*.

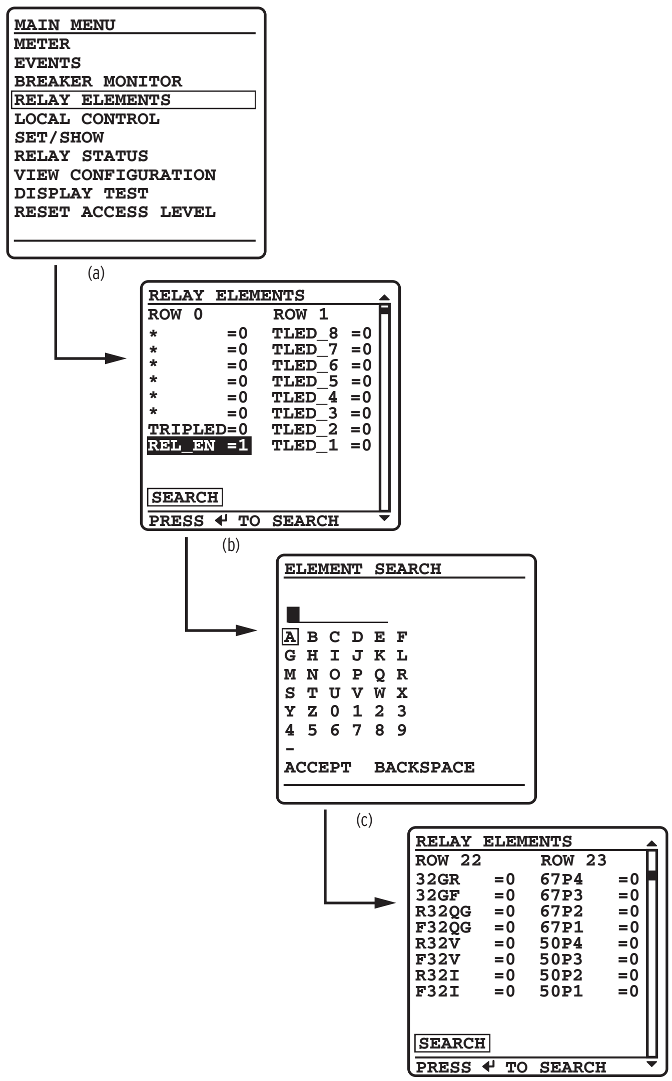

Figure 3.36 Viewing Relay Word Bits From the Front-Panel LCD

Step 5. Display the 50P1 Relay Word bit on the front-panel LCD screen.

a. Press **ENT** to go to the ELEMENT SEARCH submenu of *Figure 3.36(c)*.

b. Use the navigation keys to highlight 5 and then press **ENT** to enter the character 5 in the text input field.

c. Enter the 0, P, and 1 characters in the same manner.

d. Highlight ACCEPT and press **ENT**.

The relay displays the LCD screen containing the 50P1 element, as shown *Figure 3.36(d)*.

Step 6. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 7. View the target status change.

a. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

b. Observe the 50P1 target on the front-panel display.

You will see the 50P1 element status change to 1 when the input current exceeds the 50P1P setting threshold.

Step 8. Press **ESC** to return to the MAIN MENU.

View Relay Elements Using the Front-Panel LED

The procedure in the following steps shows you how to use a front-panel LED to view a change-in-state for the SEL-451 50P1 Phase-Instantaneous Overcurrent element.

In this example, use QuickSet to configure the relay. You must have a computer that is communicating with the relay and running QuickSet (see *Making Settings Changes in Initial Global Settings on page 3.20*). In addition, you need a variable current source suitable for relay testing.

Step 1. Prepare to control the relay with QuickSet by establishing communication, checking passwords, and reading relay settings.

Step 2. Set a pushbutton LED SELOGIC control equation.

a. Expand the **Front Panel** branch of the **Settings** tree view and click **Pushbuttons** (see *Figure 3.37*).

QuickSet displays the **Pushbuttons** dialog box similar to that shown in *Figure 3.37*.

b. Click in the **PB6_LED** text box and type **50P1**.

c. Tab or click to any other text box.

QuickSet checks the validity of the setting.

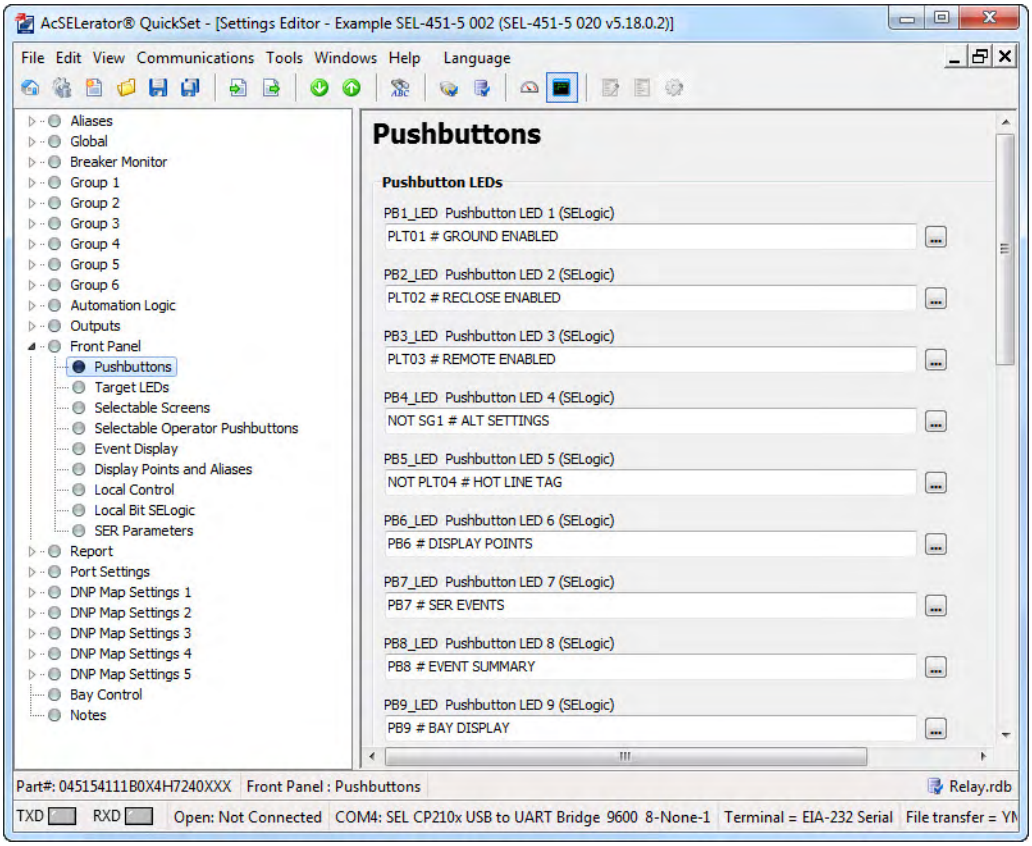

Figure 3.37 Setting Pushbutton LED Response in QuickSet

Step 3. Click **File > Save** to save the new settings in QuickSet.

Step 4. Upload the new settings to the SEL-451.

a. Click **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the Group Select dialog box of *Figure 3.38*.

b. Click the check box for **Front Panel**.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box shown in *Figure 3.38*.

If you see no error message, the new settings are loaded in the relay.

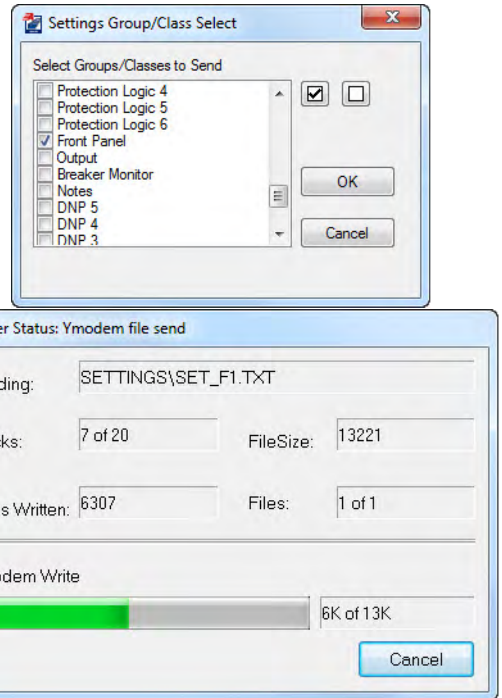

Figure 3.38 Uploading Front-Panel Settings to the Relay

Step 5. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 6. View the target status change.

a. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay.

b. Observe the LED next to Pushbutton 6 on the SEL-451 front panel.

You will see the LED illuminate when the input current exceeds the 50P1P setting threshold.

Reading Oscillograms, Event Reports, and SER

SEL-400 series relays have great capabilities for storing and reporting power system events. These include high-resolution oscillography with sampling as high as 8 kHz, event reports that encompass important variables in the power system, and the SER that reports changing power system conditions and relay operating states.

You can view oscillograms taken from high-resolution raw data or from filtered event report data. Each type of presentation gives you a unique view of the power system. High-resolution oscillograms are useful for viewing system transients and dc artifacts outside the relay filter system; event report oscillograms give you a picture of the quantities that the relay used in the protection algorithms.

The examples listed in this subsection give step-by-step procedures to acquaint you with these features. *Section 9: Reporting* provides a complete discussion of these relay features.

Generating an Event

To view high-resolution raw data oscillograms and event reports, you must generate a relay event. High-resolution oscillography and event reports use the same event triggering methods. The relay uses multiple sources to initiate a data capture, including any of the following: Relay Word bit TRIP asserts, SELOGIC control equation ER (event report trigger), or the **TRI** command. (Factory-default setup does not include the **PUL** command as an event report trigger. You can add the **PUL** command by entering the Relay Word bit TESTPUL in the ER SELOGIC control equation.)

You can use an event trigger to initiate capturing power system data. The procedure in the following steps shows how to use the QuickSet HMI to generate the **TRI** command, which triggers an event capture. In this example, the relay uses default parameters to record the event. These parameters are at a sampling rate (SRATE) of 2000 samples per second (2 kHz), a pretrigger or prefault recording length (PRE) of 0.1 seconds, and an event report length (LER) of 0.5 seconds. See *Duration of Data Captures and Event Reports on page 9.7* for complete information on changing these default settings to match your application.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Checking Relay Status in QuickSet on page 3.12* and *Section 2: PC Software*). In addition, you should perform the steps described in *View Metering Using the Terminal on page 3.35* to connect secondary test voltages and currents, and to set the relay to meter these quantities correctly.

Step 1. Connect voltage and current sources to the relay secondary voltage and secondary current inputs (use the connections of *View Metering Using the Terminal on page 3.35* and *Figure 3.27* or *Figure 3.28*).

Step 2. Apply power to the relay, start QuickSet, and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

NOTE: The Trigger New Event button in the Event History dialog box may also be used (see *Figure 3.42*).

Step 3. In the top toolbar menu, select **Tools > HMI > HMI** to start the QuickSet operator interface.

Step 4. Click **Control Window** in the HMI tree view (see *Figure 3.39*).

QuickSet displays the Control Window similar to that shown in *Figure 3.40*.

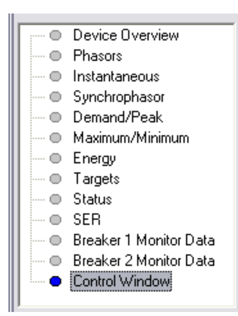

Figure 3.39 QuickSet HMI Tree View

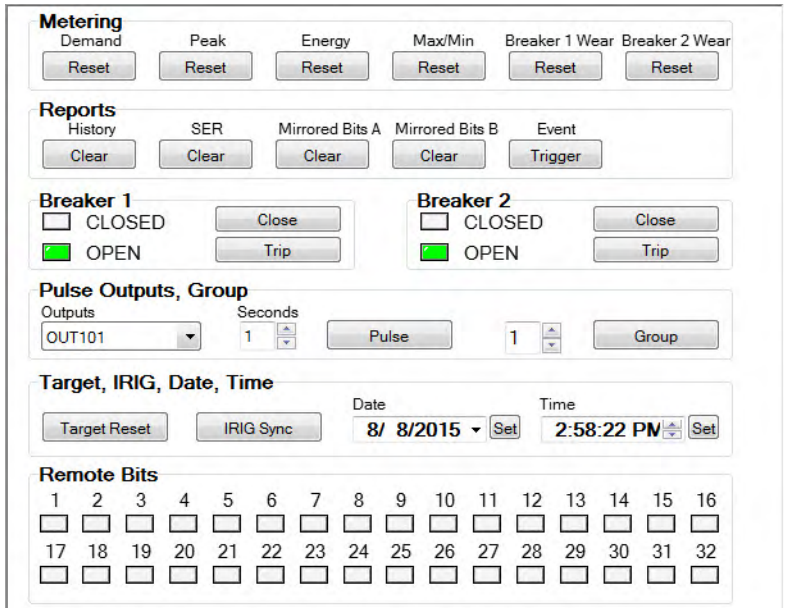

Figure 3.40 QuickSet HMI Control Window

Step 5. Trigger an Event.

a. Click the **Event Trigger** box to trigger an event.

QuickSet displays a prompt in a dialog box similar to that in *Figure 3.41*.

b. Click **Yes** to trigger an event.

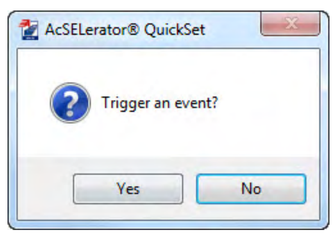

Figure 3.41 Event Trigger Prompt in QuickSet

Reading the Event History

The relay has multiple convenient methods for checking whether you successfully captured power system data. The following describes how to view the event history data with QuickSet and how to examine the history data through use of the ASCII terminal interface.

Reading the Event History in QuickSet

The procedure in the following steps shows how to use the QuickSet HMI to gather relay event history information. See *Event History on page 9.27* for more information on event history.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see

Changing the Default Passwords in the Terminal on page 3.10 to change the default access level passwords). You should also be familiar with QuickSet (see *Checking Relay Status in QuickSet on page 3.12* and *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. To view the event history report, open the QuickSet **Tools** menu and click **Events > Get Event Files**.

You will see the **Relay Event History** dialog box similar to that shown in *Figure 3.42*.

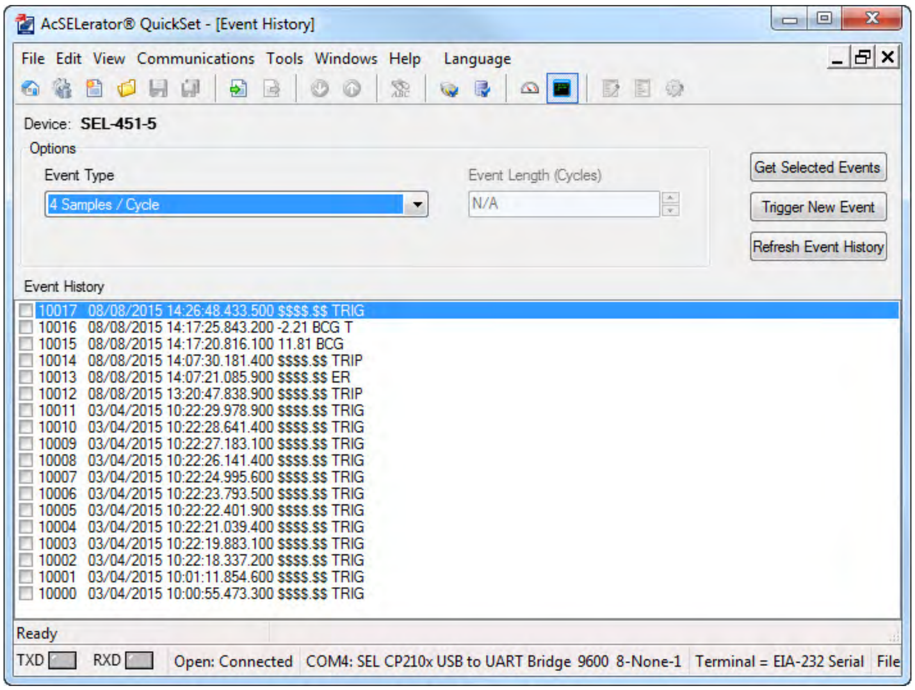

Figure 3.42 Relay Event History Dialog Box

Reading the Event History in the Terminal

The procedure in the following steps shows how to use the relay **HIS** command to confirm that you captured power system data with an event trigger. This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **HIS <Enter>** to examine the event history

You will see a screen display similar to *Figure 3.43*.

```
=>HIS <Enter>

Relay 1                                    Date: 03/03/2015  Time: 17:27:44.140
Station A                                  Serial Number: 0000000000

#       DATE        TIME     EVENT  LOCAT   CURR GRP TARGETS
10024 03/03/2015 08:33:29.201 TRIP  $$$$.$$     0  1
10023 03/02/2015 15:41:35.777 ER    $$$$.$$     0  1
10022 03/02/2015 15:41:35.227 ER    $$$$.$$     0  1
10021 03/02/2015 15:41:34.577 ER    $$$$.$$     0  1
10020 03/02/2015 15:41:34.152 ER    $$$$.$$     0  1
10019 03/02/2015 15:41:32.702 ER    $$$$.$$     0  1
10018 02/24/2015 15:22:19.496 TRIG  $$$$.$$     1  3

10017 02/24/2015 15:22:17.705 TRIG  $$$$.$$     1  3
10016 02/23/2015 17:42:56.581 TRIG  $$$$.$$     1  3
10015 02/20/2015 19:23:41.369 BCG      0.02  3442  3
10014 02/20/2015 17:14:40.056 CA T     7.28  2449  3  TIME A_FAULT C_FAULT

=>
```

Figure 3.43 Sample HIS Command Output in the Terminal

For more information on the event history, see *Event History on page 9.27*.

Viewing High-Resolution Oscillograms

Once you have successfully generated an event, you can view high-resolution oscillograms and event report oscillograms about this event. When gathered from a field-installed relay, this information helps you assess power system operating conditions. In addition, when you first install the relay, this reporting information helps you confirm that you have connected the relay correctly.

The relay provides high-resolution oscillography data in the binary COMTRADE file format (IEEE/ANSI standard C37.111-1999). File transfer is the only mechanism for retrieving high-resolution COMTRADE data from the relay.

The SEL-5601 SYNCHROWAVE Event is a program you can use to view COMTRADE data. Many third-party software suppliers can provide you with programs to display and manipulate COMTRADE files.

Retrieving High-Resolution COMTRADE Data in the Terminal

The relay recorded the event triggered in *Generating an Event on page 3.49*. The procedure in the following steps shows you how to retrieve the high-resolution raw oscillography data for this event.

Perform the steps listed in *Generating an Event on page 3.49* before executing the instructions in this example. For this procedure, you must use a communications terminal emulation computer program capable of file transfers.

If you need help finding a terminal emulation program, contact the SEL factory or your local Technical Service Center.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the contents of the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 3.44*.

The relay shows three high-resolution oscillography files with the file extensions .HDR, .CFG, and .DAT for each event.

This procedure uses HR_10014 as the number of the event that you recently triggered; use the event number corresponding to your triggered event.

```
=>FILE DIR EVENTS <Enter>
C4_10014.TXT                R   02/20/2004 17:14:40
C8_10014.TXT                R   02/20/2004 17:14:40
CHISTORY.TXT                R
E4_10014.TXT                R   02/20/2004 17:14:40
E8_10014.TXT                R   02/20/2004 17:14:40
HISTORY.TXT                 R

HR_10014.CFG                R   02/20/2004 17:14:40
HR_10014.DAT                R   02/20/2004 17:14:40
HR_10014.HDR                R   02/20/2004 17:14:40
=>
```

Figure 3.44 EVENTS Folder Files

Step 3. Type **FILE READ EVENTS HR_10014.* <Enter>** to ready the relay to transfer the HR_10014.HDR, HR_10014.CFG, and HR_10014.DAT files to your computer.

Step 4. Download the files. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- Specify the destination file location in your computer file storage system and file name.
- Select the transfer type as **YModem** (if this transfer type is not already enabled).
- Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

When these files have transferred successfully, you have the entire COMTRADE file for the high-resolution raw data capture.

Step 5. Use ACSELERATOR Analytic Assistant SEL-5601 Software, SYNCHROWAVE Event, QuickSet, or other COMTRADE-capable programs to play back high-resolution raw data oscillograms of the high-resolution raw data capture files you just transferred.

Retrieving High-Resolution COMTRADE Data in QuickSet

The procedure in the following steps shows how to use QuickSet to view the event that you triggered in *Generating an Event on page 3.49*. You can use this procedure to view other events stored in the relay.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Checking Relay Status in QuickSet on page 3.12* and *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. Open the QuickSet **Tools** menu and click **Events > Get Event Files** to view the Event History. Select **COMTRADE** from the **Event Type** list and then click **Refresh Event History**.

You will see the **Event History** dialog box similar to that shown in *Figure 3.45*.

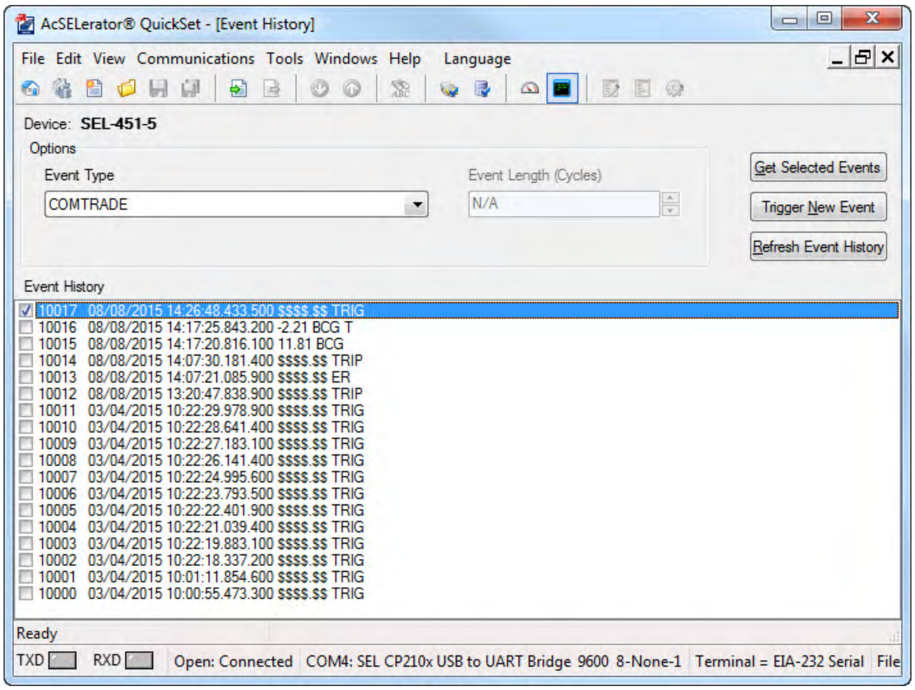

Figure 3.45 Relay Event History Dialog Box in QuickSet

Step 3. Get the event.

a. Highlight the event you want to view and click **Get Selected Events**.

b. After getting the event QuickSet prompts you to save the event file (.DAT) in a directory.

c. Click **Tools > Events** and select the saved event file (.dat).

d. Press **Open**.

QuickSet then presents the window similar to that in *Figure 3.46* and the sample event oscillogram of *Figure 3.47*.

NOTE: QuickSet provides the option to choose which Event Viewer program will open the event files by default. Under the Tools menu, go to Options and select your preference of Event Viewer under the Main tab.

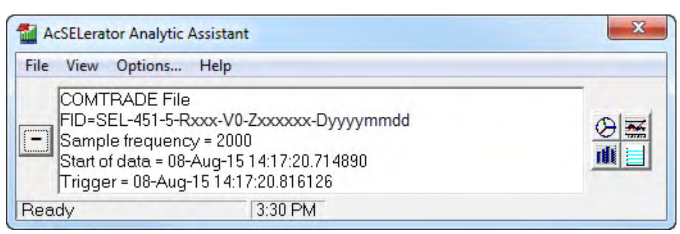

Figure 3.46 QuickSet Event Waveform Window

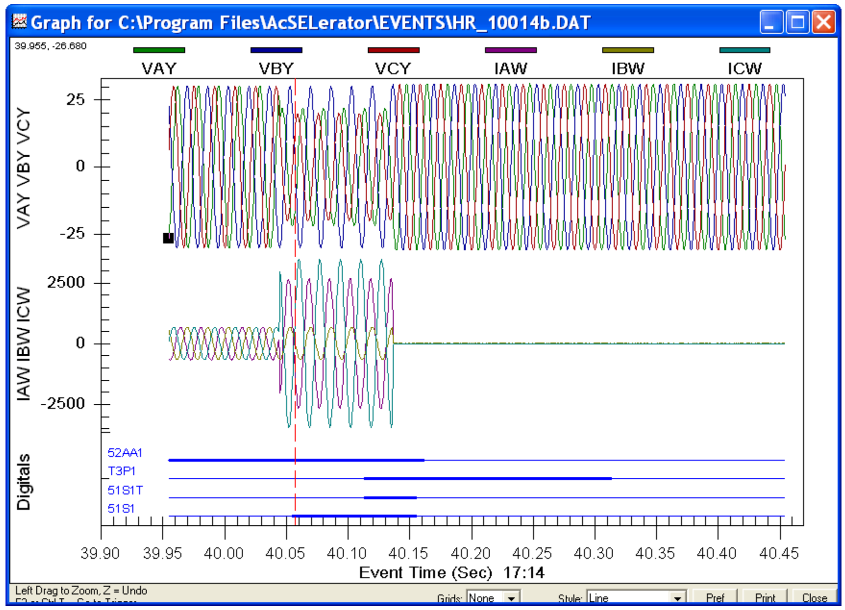

Figure 3.47 Sample Event Oscillogram

You can also examine a phasors display, an event harmonic analysis display, and the event summary from the **Event Waveform View** menu. See *Section 9: Reporting* for more information.

Viewing Event Report Data

Examine relay event reports to inspect the operating quantities the relay used at each triggered event. Unlike the raw data samples/second high-resolution oscillography files, these reports contain the filtered samples/cycle data the relay uses to make protection decisions. Event reports are useful for determining why the relay operated for a particular set of power system conditions. For more information on event reports, see *Event Report on page 9.14*.

The relay recorded the event triggered in *Generating an Event on page 3.49*. The procedure in the following steps shows you how to retrieve the event report data files for this event. Perform the steps listed in *Generating an Event on page 3.49* before executing the instructions in this example. For this procedure, you must use a terminal program capable of Ymodem protocol file transfer.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR EVENTS <Enter>** to view the events file directory.

The relay lists file names for recently recorded events in a manner similar to that shown in *Figure 3.44*.

In the figure, the relay shows two event report files: E4_10014.TXT and E8_10014.TXT, and two Compressed ASCII event report files: C4_10014.TXT and C8_10014.TXT.

Step 3. Type **FILE READ EVENTS C8_10014.TXT <Enter>** to transfer the Compressed ASCII event report file to your computer.

Step 4. Download the file. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **YModem** (if not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When this file has transferred successfully, use Analytic Assistant or SYNCHROWAVE Event to play back the event report oscillograms of the 8-samples/cycle event report file you just transferred.

Viewing SER Records

The relay SER records relay operating changes and relay element states. In response to an element change of state, the SER logs the element, the element state, and a time stamp. Program the relay elements that the relay stores in the SER records, thus capturing significant system events such as an input/output change of state, element pickup/dropout, recloser state changes, etc.

The relay stores the latest 1000 entries to a nonvolatile record. Use the relay communications ports or QuickSet to view the SER records. For more information on the SER, see *Section 9: Reporting*.

The latest 200 SER events are viewable from the front panel. For more information, see *Section 4: Front-Panel Operations*.

Setting the SER and Examining an SER Record in QuickSet

The procedure in the following steps shows you how to use QuickSet to program relay elements into the SER. Also, use these procedures to review SER records with QuickSet.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. Download the present configuration in the relay by clicking **File > Read**.

The relay sends all configuration and settings data to QuickSet.

Step 3. Click the **Report** branch of the QuickSet **Settings** tree view structure (see *Figure 3.48*) to view the SER settings entry screen.

You will see the SER Points and Aliases window similar to *Figure 3.49*.

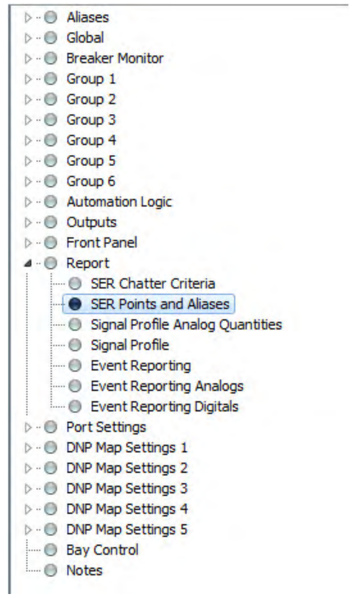

Figure 3.48 Selecting SER Points and Aliases Settings in QuickSet

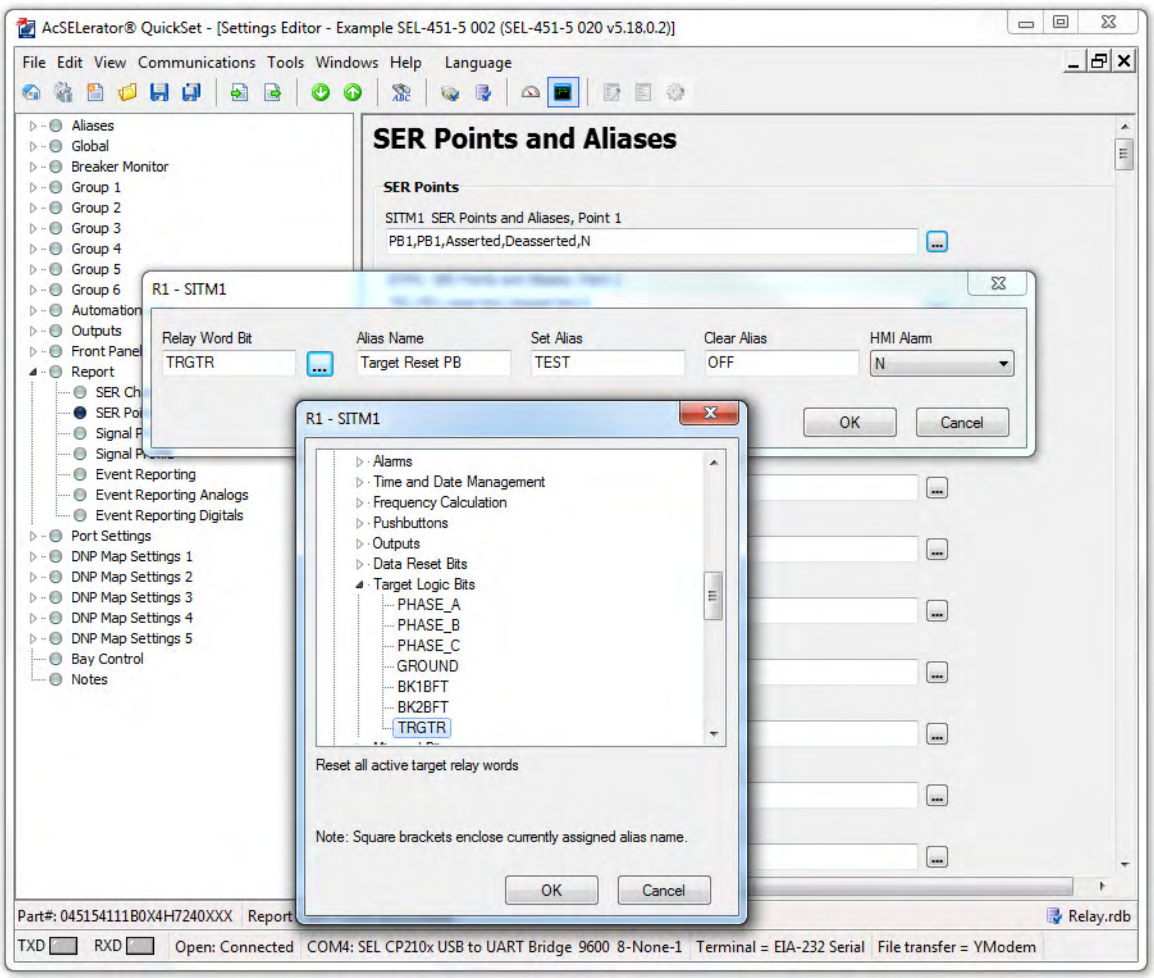

Figure 3.49 SER Points and Aliases Settings in QuickSet

Step 4. Enter SER settings.

a. For this example, open the entry form by clicking the ... button beside the **SITM1 SER Points and Aliases**, **Point 1** entry field. We will change this SER point to report the operation of the **Target Reset** pushbutton.

b. Click the ... button beside the **Relay Word Bit** entry field.

c. Select Target Logic Bits, and then double-click on TRGTR to copy the TRGTR name into the **Relay Word Bit** field. This also copies TRGTR to the Reporting Name (or alias) field.

d. Type **Target Reset PB** in the **Alias Name** field.

e. Type **TEST** in the **Set Alias** field.

f. Type **OFF** in the **Clear Alias** field.

g. Click **OK**.

Step 5. Click **File > Save** to save the new settings in QuickSet.

Step 6. Upload the new settings to the relay.

a. Click **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the first dialog box of *Figure 3.50*.

b. Click the **Report** check box.

c. Click **OK**.

QuickSet responds with the second dialog box of *Figure 3.50*.

If you see no error message, the new settings are loaded in the relay.

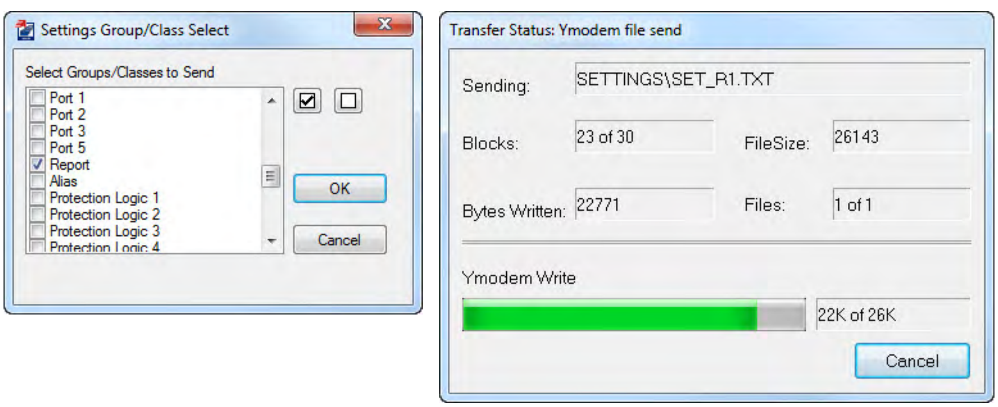

Figure 3.50 Uploading Report Settings to the Relay

Step 7. Press and release the front-panel **TARGET RESET** pushbutton to generate an SER record.

Step 8. View the SER report.

a. Start the QuickSet operator interface.

b. In the top toolbar **Tools** menu, click **HMI > HMI**.

c. Click the **SER** button of the HMI tree view (see *Figure 3.51*).

QuickSet displays the SER records with a display similar to *Figure 3.52*.

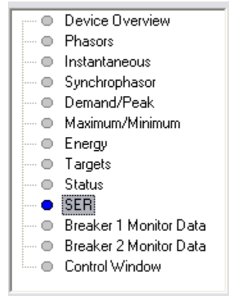

Figure 3.51 Retrieving SER Records With QuickSet

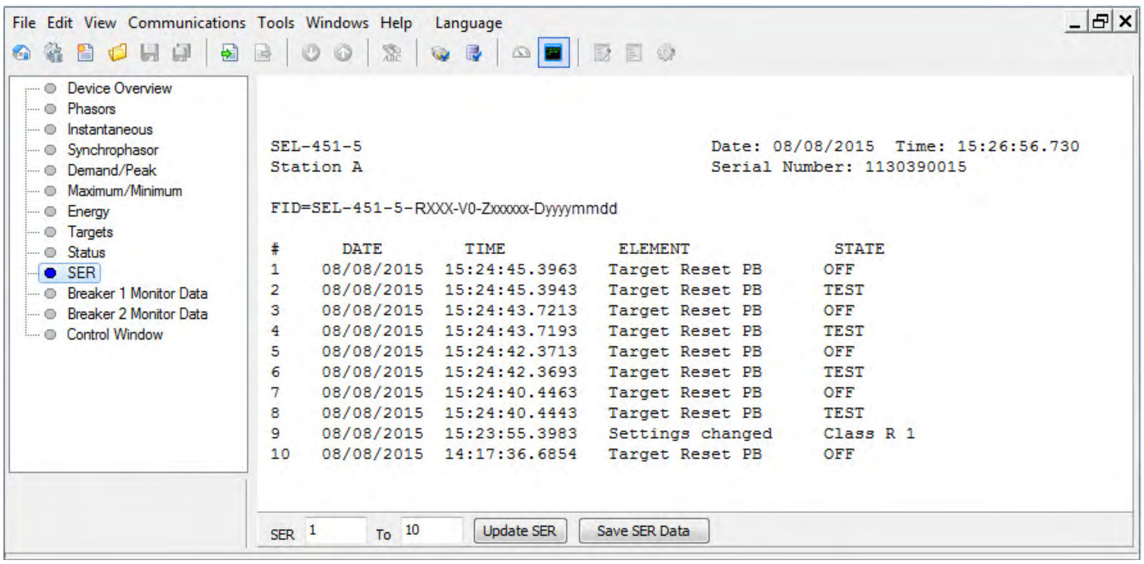

Figure 3.52 SER Records in the QuickSet HMI

The relay lists the SER records in chronological order from top to bottom as shown in *Figure 3.52*. In addition, the relay numbers each record with the most recent record as number 1; new events are usually more important for determining the effects of recently occurring power system events.

For each application of power to the relay, the SER reports a “Power-up” indication and the active settings group. A properly operating relay immediately goes to the enabled state, an event that causes the SER to report another SER record. The SER reports the **TARGET RESET** button when you press the pushbutton and it remains asserted for one processing interval.

Setting the SER and Examining the SER Record in the Terminal

The procedure in the following steps shows how to use a terminal connected to a relay communications port to set an element in the SER. Use text edit mode line editing to enter the SER settings (see *Text-Edit Mode Line Editing on page 3.22*). Also included is a procedure for viewing the SER report with a terminal.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Enter SER trigger data.

a. Type **SET R TERSE <Enter>** to access the **Report** settings (see *Figure 3.53*).

b. Press **<Enter>** to move past the **SER Chatter Criteria** setting.

c. At the `SER Points ?` prompt line, type the following:

TRGTR,"TARGET RESET PB",TEST,OFF,N <Enter>.

At the next line, type **END <Enter>**.

d. The relay prompts you to save the new setting; type **Y <Enter>**.

```
=>>SET R TERSE <Enter>
Report
SER Chatter Criteria
Automatic Removal of Chattering SER Points (Y,N)   ESERDEL := N   ? <Enter>


SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)
1:
? TRGTR,"TARGET RESET PB",TEST,OFF,N <Enter>
2:
? END <Enter>

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 3.53 Setting an SER Element: Terminal

Step 3. Press and release the front-panel TARGET RESET pushbutton to generate an SER record.

Step 4. Type **SER <Enter>** (at the Access Level 1 prompt or higher) to view the SER report.

The relay presents a screen similar to the SER display of *Figure 3.52*.

Downloading an SER Report File

The procedure in the following steps shows you how to retrieve the SER report stored in the relay as a file. For this procedure, you must use a terminal emulation program with file transfer capability.

Step 1. Prepare to monitor the relay at Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 2. Type **FILE DIR REPORTS <Enter>** to view the events file directory.

The terminal lists the file names for standard reports as shown in *Figure 3.54*.

Step 3. Prepare the relay to download the SER report.

a. Type **FILE READ REPORTS SER.TXT <Enter>**.

b. If you want the Compressed ASCII file, type the following:

FILE READ REPORTS CSER.TXT <Enter>

```
=>FILE DIR REPORTS <Enter>
BRE_1.TXT                    R
BRE_2.TXT                    R
BRE_S1.TXT                   R
BRE_S2.TXT                   R
CBRE.TXT                     R
CHISTORY.TXT                 R
CPRO.TXT                     R
CSER.TXT                     R
HISTORY.TXT                  R
PRO.TXT                      R
SER.TXT                      R
=>
```

Figure 3.54 Example Reports File Structure

Step 4. Download the SER report. Perform the steps necessary for your terminal emulation program to receive a file.

Typically, these are the file transfer steps:

NOTE: Transferring SER files (or CSER files) with the **FILE READ REPORTS SER.TXT** command, performs an **SER CV** command as part of the transfer. SER CV clears the SER information from the present port. With the SER information cleared, there are no data available for subsequent SER or CSER transfers from the same port.

- ➢ Specify the destination file location in your computer file storage system and file name.
- ➢ Select the transfer type as **YModem** (if not already enabled).
- ➢ Click **Receive**.

You will usually see a confirmation message when the file transfer is complete.

Step 5. When the SER.txt file has transferred successfully, use a word-processing program to view the contents of the file.

You will see the SER records in a format similar to *Figure 3.52*.

Operating the Relay Inputs and Outputs

SEL-400 series relays give you great ability to perform control actions at bay and substation locations via the relay control outputs. The control outputs close and open circuit breakers, switch disconnects, and operate auxiliary station equipment such as fans and lights. The relay reads data from the power system and interfaces with external signals (contact closures and data) through the control inputs. This subsection is an introduction to operating the control outputs and control inputs. For more information on connecting and applying the control outputs and control inputs, see *Section 2: Installation* in the product-specific instruction manual.

Control Output

The relay features standard, hybrid (high-current interrupting), and high-speed high-current interrupting control outputs that you can use to control circuit breakers and other devices in an equipment bay or substation control house.

Pulsing a Control Output in the Terminal

When first connecting the relay, or at any time that you want to test relay control outputs, perform the following procedure. The procedure in the following steps shows how to use a communications terminal to pulse the control output contacts. Perform the steps in this example to become familiar with relay control and serial communication. For more information on the **PULSE** command, see *PULSE on page 14.45*.

This example assumes that you have successfully established communication with the relay; see *Making an EIA-232 Serial Port Connection on page 3.4* for a step-by-step procedure. In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

NOTE: To pulse an output, the circuit breaker control enable jumper must be installed on the main board.

Step 1. Prepare to control the relay at Access Level B.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **BAC <Enter>**.

d. Type the correct password to go to Access Level B.

You will see the Access Level B ==> prompt.

Step 2. Attach an indicating device (ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104.

This output is a standard control output and is not polarity-sensitive.

Step 3. Perform the pulse operation.

a. Type **PULSE OUT104 <Enter>**.

The relay confirms your request to pulse an output with a prompt such as that shown in *Figure 3.55*.

b. Type **Y <Enter>** at the prompt.

You will see or hear the indicating device turn on for a second and then turn off.

```
==>PULSE OUT104 <Enter>
Pulse contact OUT104 for 1 seconds(Y/N)       ? Y <Enter>
==>
```

Figure 3.55 Terminal Display for PULSE Command

You can also pulse an output for longer than the default one-second period. If you enter a number after the **PULSE** command, that number specifies the duration in seconds for the pulse. For example, if you enter **PULSE OUT104 3 <Enter>**, the relay pulses OUT104 for three seconds.

Pulsing a Control Output on the Front Panel

The procedure in the following steps shows you how to use the front-panel display and navigation pushbuttons to check for proper operation of the relay control outputs. See *Section 4: Front-Panel Operations* for information on using the relay front panel.

Step 1. Attach an indicating device (an ohmmeter with a beep sounder or a test set) to the terminals for control output OUT104.

This output is a standard control output and is not polarity-sensitive.

Step 2. View the front-panel display.

After applying power to the relay, note that the LCD shows a sequence of screens called the ROTATING DISPLAY.

(Also, if you do not operate the front panel for a certain period, the relay will enter front-panel time-out mode and you will see the sequential screens of the ROTATING DISPLAY.)

Step 3. Press the **ENT** pushbutton to view the MAIN MENU, similar to that in *Figure 3.56(a)*.

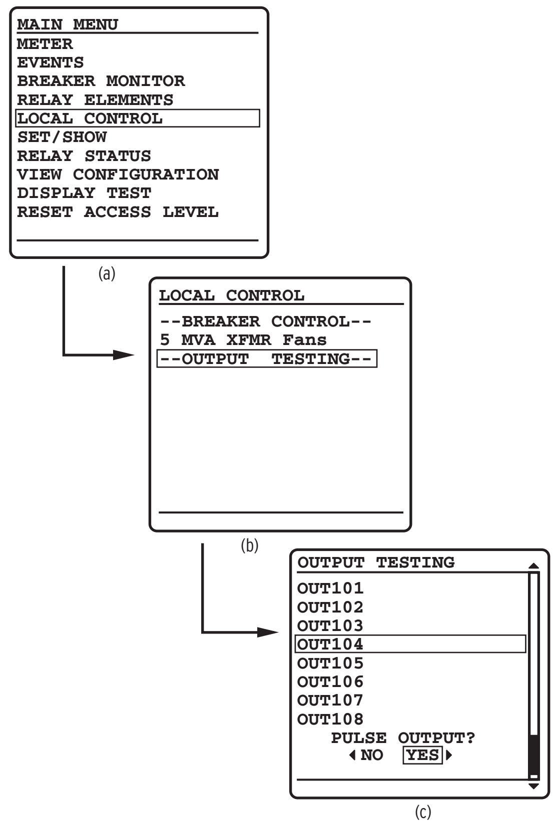

Figure 3.56 Front-Panel Menus for Pulsing OUT104

Step 4. View the LOCAL CONTROL screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the LOCAL CONTROL action item, as shown in *Figure 3.56(a)*.

b. Press the **ENT** pushbutton.

You will see the LOCAL CONTROL submenu as shown in *Figure 3.56(b)*.

Step 5. View the OUTPUT TESTING screen.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight the --OUTPUT TESTING-- action item, as shown in *Figure 3.56(b)*.

b. Press the **ENT** pushbutton.

The relay displays the OUTPUT TESTING submenu, as shown in *Figure 3.56(c)*.

Step 6. Command the relay to pulse the control output.

a. Press the **Up Arrow** and **Down Arrow** navigation pushbuttons to highlight `OUT104` as shown in *Figure 3.56(c)*.

b. Press the **Right Arrow** navigation pushbutton to highlight `YES` under `PULSE OUTPUT?`

c. Press the **ENT** pushbutton.

The relay detects your request for a function at an access level for which you do not yet have authorization. Whenever this condition occurs, the relay displays the password access screen as shown in *Figure 3.57*.

```
PASSWORD REQUIRED
█
A B C D E F G H
I J K L M N O P
Q R S T U V W X
Y Z a b c d e f
g h i j k l m n
o p q r s t u v
w x y z 0 1 2 3
4 5 6 7 8 9 _ .
ACCEPT  BACKSPACE
```

Figure 3.57 Password Entry Screen

Step 7. Input a password and pulse the output.

a. Enter a valid Access Level B, P, A, O, or 2 password.

(The front panel is always at Access Level 1, so you do not enter the Access Level 1 password.)

Enter a valid password by using the navigation pushbuttons to select, in sequence, the alphanumeric characters that correspond to your password.

b. Press the **ENT** pushbutton at each password character.

(If you make a mistake, highlight the `BACKSPACE` option and press **ENT** to reenter a character or characters.)

c. After entering all password characters, press the **Up Arrow** or **Down Arrow** pushbuttons to highlight `ACCEPT`, and press **ENT**.

The relay pulses the output, and you will see the indicating device turn on for a second and then turn off.

Controlling a Relay Control Output With a Local Bit in the Terminal

In this example, you set Local Bit 3 to start the transformer cooling fans near the breaker bay where you have installed the SEL-451. Thus, you can use the LCD screen and navigation pushbuttons to toggle relay Local Bit 3 to control the state of the cooling fans. Relay Word bit LB_SP03 provides supervision for Local Bit 3. Relay Word bit LB_SP03 must be asserted for successful Local Bit 3 operations. For more information on local bits, see *Local Control Bits on page 4.22*.

The procedure in the following steps proposes connecting the transformer bank fan control to relay output **OUT105**. You can choose any relay output that conforms to your requirements.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Access the local control settings.

a. Type **SET F <Enter>**.

b. Repeatedly type **>** and then **<Enter>** to advance through the front-panel settings until you reach the **Local Control** category.

Figure 3.58 shows a representative terminal screen.

```
Local Control
(Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable)

1:
? LIST <Enter>
1:
? LB03,"5 MVA XFMR Fans",ON,OFF,N <Enter>
2:
? END <Enter>
           .
           .
           .
Local Control
(Local Bit, Local Label, Local Set State, Local Clear State, Pulse Enable)

1: LB03,"5 MVA XMFR Fans","ON","OFF",N
Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
 =>>
```

Figure 3.58 Using Text-Edit Mode Line Editing to Set Local Bit 3

Step 3. Type **LIST <Enter>** at the `Local Control ?` prompt to list the active control points.

This example assumes that you are using no local bits, so the relay returns you to Line 1 followed by the settings `?` prompt.

Step 4. Type **LB03,“5 MVA XFMR Fans”,ON,OFF,N <Enter>** at the Line `?` prompt.

The relay checks that this is a valid entry and responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 5. End the settings session.

a. Type **END <Enter>**.

The relay displays a readback of all the front-panel settings, eventually displaying the `Save settings (Y,N) ?` prompt. (In *Figure 3.58* a vertical ellipsis represents the readback.)

At the end of the readback information, just before the `Save settings (Y,N) ?` prompt, you can see the new local bit information.

b. Type **Y <Enter>** to save your new settings.

Step 6. Set OUT105 to respond to Local Bit 3.

a. Type **SET O OUT105 <Enter>** (see *Figure 3.59*).

b. At the `?` prompt, type **LB03 <Enter>**.

c. At the next `?` prompt, type **END <Enter>**.

d. When prompted to save settings, type **Y <Enter>**.

```
=>>SET O OUT105 <Enter>
Output
Main Board
OUT105 :== NA
? LB03 <Enter>
OUT106 := NA
? END <Enter>
Output

Main Board
OUT101 := T3P1 #BREAKER 1 TRIP
OUT102 := T3P1 #EXTRA BREAKER 1 TRIP
OUT103 := BK1CL #BREAKER 1 CLOSE
OUT104 := NA
OUT105 := LB03
OUT106 := NA
OUT107 := NA
OUT108 := NOT (HALARM OR SALARM)

Save settings (Y,N) ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.59 Setting Control Output OUT105 in the Terminal

Step 7. Test the connection and programming.

a. Use the appropriate interface hardware to connect the fan control start circuit to OUT105.

b. At the relay front-panel MAIN MENU, select LOCAL CONTROL and press the **ENT** pushbutton as shown in *Figure 3.60(a)*.

c. Select 5 MVA XFMR Fans on the LOCAL CONTROL screen as shown in *Figure 3.60(b)*.

d. Press **ENT** to see the 5 MVA XFMR Fans as shown in *Figure 3.60(c)*.

e. Highlight 1 ON and press **ENT**.

The graphical local control handle moves to the 1 position. At this time, the transformer fans will begin running.

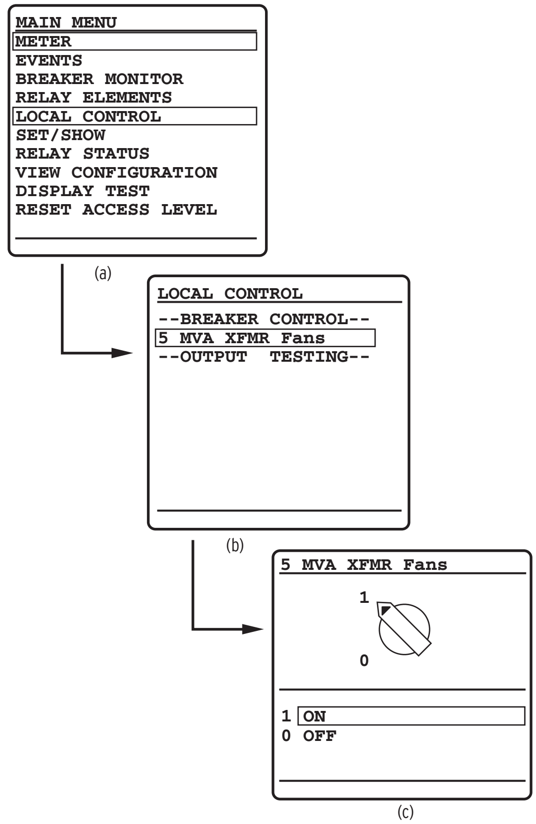

Figure 3.60 Front-Panel LOCAL CONTROL Screens

Setting Outputs for Tripping and Closing

To actuate power system circuit breakers, you must configure the control outputs to operate the trip bus and close bus. The relay uses internal logic and SELOGIC control equations to activate the control outputs.

Trip Output Signals

All SEL-400 series relays are capable of three-pole tripping and some are capable of single-pole tripping. There are many Relay Word bits (e.g., T3P1, T3P2, and 3PT) that you can program to drive control outputs to trip circuit breakers. See *Section 5: Protection* in the product-specific instruction manual for complete information on tripping equations and settings. For target illumination at tripping, see *Section 4: Front-Panel Operations*.

Close Output Signals

Some SEL-400 series relays feature an automatic recloser for single-circuit breaker and two-circuit breaker applications, with as many as four autoreclose shots. See *Section 6: Autoreclosing* for more information.

Assigning Control Outputs for Tripping and Closing

The procedure in the following steps shows a method for setting the relay to operate the trip bus and the close bus at a typical substation. This procedure assigns a close output at OUT106. This example is specific to the SEL-451 relay, but similar configuration changes can be made in all SEL-400 series relays.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. Click **File > Read**.

The relay sends all configuration and settings data to QuickSet.

Step 3. Access the **Main Board** output settings.

a. Expand the **Outputs** branch of the Settings tree view.

b. Click **Main Board** (see *Figure 3.61*).

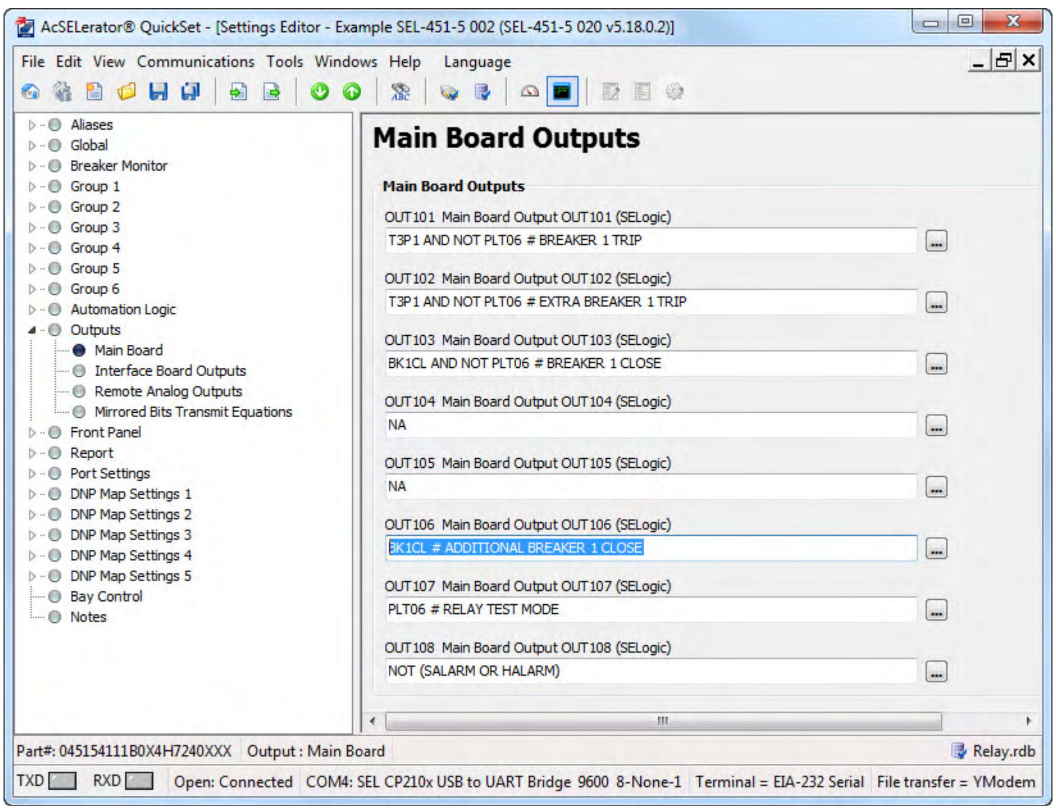

Figure 3.61 Assigning an Additional Close Output in QuickSet

Step 4. Assign a control output for the close bus.

a. In the **Main Board Outputs** dialog box, click the **OUT106** text box and type the following:

BK1CL #ADDITIONAL BREAKER 1 CLOSE

(The # indicates that a comment follows.)

b. Click or tab to another text box.

QuickSet checks that your entry is valid.

Step 5. Click **File > Save** to save the new settings in QuickSet.

Step 6. Upload the new settings to the relay.

a. Click **File > Send**.

QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Outputs** as shown in the first dialog box shown in *Figure 3.62*.

c. Click **OK**.

QuickSet responds with the second dialog box of *Figure 3.62*.

If you see no error message, the new settings are loaded in the relay.

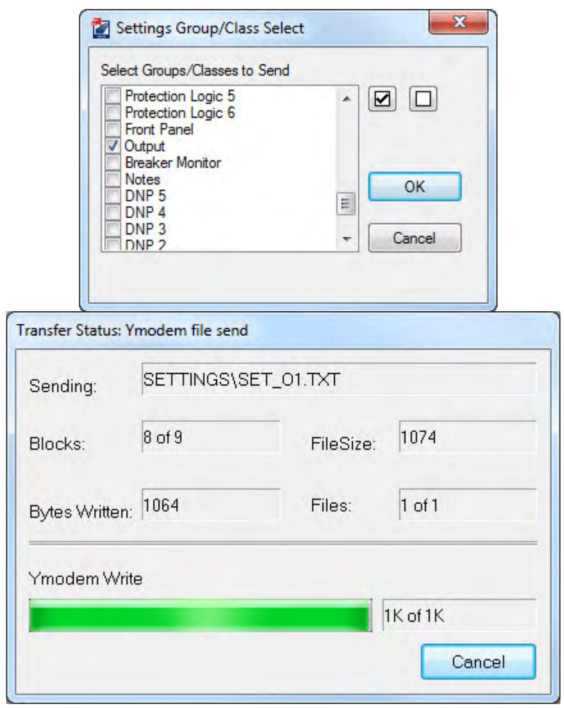

Figure 3.62 Uploading Output Settings to the SEL-451

Control Input Assignment

Most SEL-400 series relays have control inputs on the main board (IN101–IN107), and on one or more optional I/O interface boards (IN201–IN2xx, IN301–IN3xx, etc.), if so equipped.

There are two types of input circuitry: direct-coupled and optoisolated. *Table 3.8* lists the main differences between the two types of control inputs. Only the SEL-421 and SEL-451 are available with interface boards that support direct-coupled inputs. All SEL-400 series relays support optoisolated inputs.

Table 3.8 Control Input Characteristics

	Direct-Coupled	**Optoisolated**
Pickup characteristics:	Pickup voltage can be selected via Global settings. Can have different pickup voltages on each input.	Pickup voltage is determined by hardware: one of six voltage levels determined at time of factory order. All pickup voltages are the same on each I/O interface board.
Polarity- sensitive:	Yes (will not respond to reverse polarity signals). A + polarity mark is printed over the positive terminals.	No (will respond to signals of either polarity). No polarity mark. AC signal detection is possible.[a]
Where found:	INT1, INT5, and INT6 I/O Interface Boards (available in SEL-421 and SEL-451 relays)	SEL-400 Series Main Board (IN101–IN107) All other interface boards

[a] With appropriate debounce settings (see *Section 2: Installation* of the product-specific instruction manual).

The default value for Global setting EICIS (Enable Independent Control Input Settings) is N, which hides all individual control input settings and only presents some overall settings that will apply to all control inputs. Set EICIS := Y to gain full access to the individual control input settings.

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A) in the Terminal

This is a step-by-step procedure to configure a control input that reflects the state of the circuit breaker auxiliary (52A) NO (normally open) contact. A common relay input is from circuit breaker auxiliary contacts; the relay monitors the 52A contacts to detect the closed/open status of the circuit breaker. Perform the following steps to connect three-pole circuit breaker auxiliary contacts to the relay. This example was created using an SEL-451. Refer to the product-specific instruction manual for the correct Relay Word bit names for each product.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords).

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the => prompt.

c. Type **2AC <Enter>**.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

Step 2. Configure the relay to read the circuit breaker auxiliary contact.

a. Type **SET M <Enter>** (see *Figure 3.63*).

These settings are the breaker monitor settings.

b. Type **<Enter>** to bypass the Breaker 1 Monitoring enable, and **<Enter>** again to bypass the Breaker 2 Monitoring enable (NUMBK := 2 in this example).

The relay displays the 52AA1 SELOGIC control equation action prompt.

c. Type **IN101 <Enter>** at the ? prompt to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

   Press **<Enter>** until the relay displays the 52AA2 SELOGIC control equation action prompt.

d. Type **IN102 <Enter>** at the ? prompt to specify input IN102 as the control input that represents the close/open state of Circuit Breaker 2.

Step 3. End the settings process. The relay next scrolls a readback of all the Global settings, eventually displaying the `Save settings (Y,N) ?` prompt.

a. In the readback information, just before the `Save settings (Y,N) ?` prompt, confirm the new control input information.

b. Answer **Y <Enter>** to save your new settings.

```
=>>SET M <Enter>
Breaker Monitor
Breaker Configuration
Breaker 1 Monitoring (Y,N) EB1MON  := N ? <Enter>
Breaker 2 Monitoring (Y,N) EB2MON  := N ? <Enter>
Breaker 1 Inputs

N/O Contact Input -BK1 (SELogic Equation)
52AA1 := NA
?  IN101 <Enter>
Breaker 2 Inputs
N/O Contact Input -BK2 (SELogic Equation)
52AA2 := NA
?  IN102 <Enter>
Breaker Monitor

Breaker Configuration
EB1MON  := N        EB2MON  := N
Breaker 1 Inputs
52AA1   := IN101
Breaker 2 Inputs
52AA2   := IN102
Save settings (Y,N)  ? Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
=>>
```

Figure 3.63 Setting 52AA1 in the Terminal

Setting a Control Input for Circuit Breaker Auxiliary Contacts (52A) in QuickSet

The procedure in the following steps shows how to program the relay control input IN101 to read the state of circuit breaker auxiliary contacts. This example uses a single three-pole tripping breaker. Modify the procedure listed here for your application.

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). You should also be familiar with QuickSet (see *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. On the **File** menu, click **Read**.

The relay sends all configuration and settings data to QuickSet.

Step 3. Access the **Control Inputs** settings.

a. Click the arrow next to the **Global** branch of the **Settings** tree view.

b. Click the arrow next to the **Control Inputs** branch of the **Settings** tree view (see *Figure 3.64*).

Step 4. Set **EICIS Independent Control Input Settings** to **Y**.

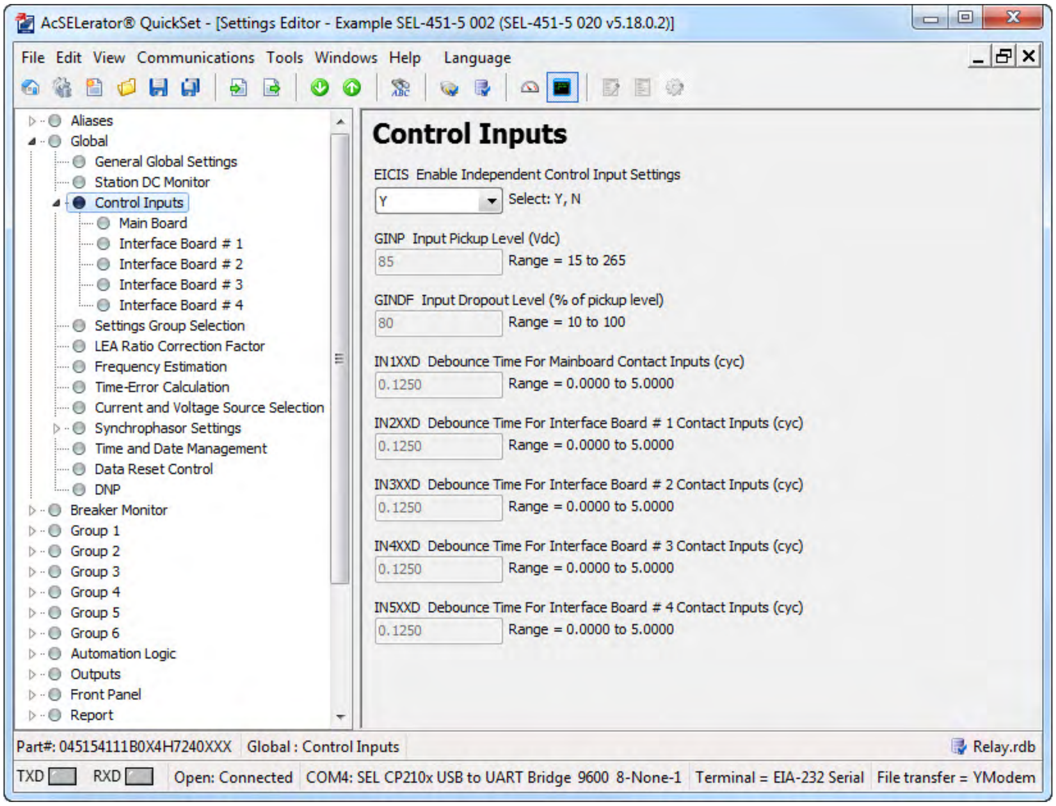

Figure 3.64 Accessing Control Inputs Settings in QuickSet

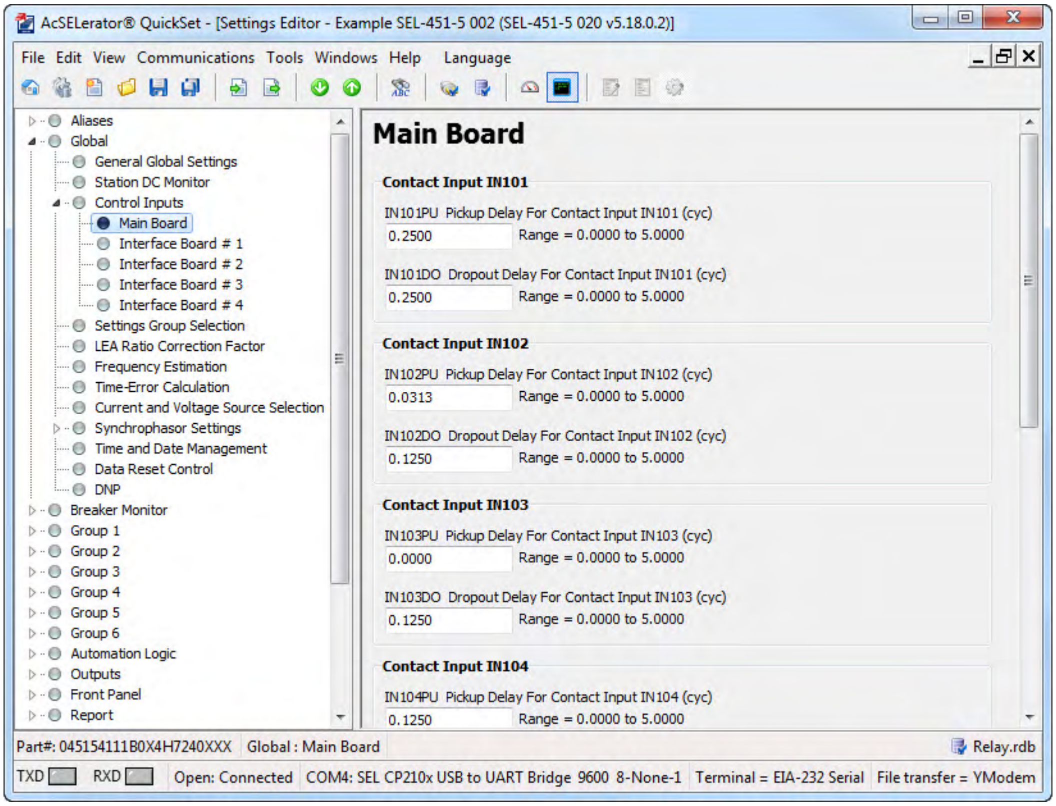

Figure 3.65 Control Input Pickup and Dropout Delay Settings in QuickSet

Step 5. Set the control input IN101 debounce time.

For this example, assume that the auxiliary contacts are slow and noisy; you must provide a slightly longer debounce time for these contacts.

a. Double-click the mouse cursor (or press **<Tab>**) to highlight **IN101PU Pickup Delay for Contact Input**.

b. Delete the present setting by pressing **<Delete>**.

c. Type **0.25 <Enter>**.

d. Similarly change the **IN101DO Input IN101 Dropout Delay** to **0.25**.

The relay checks the new value and enters the value in the QuickSet database.

Step 6. Configure the relay to read the circuit breaker auxiliary contact.

a. Expand the **Breaker Monitor** branch of the **Settings** tree view by clicking the **+** button (see *Figure 3.66*).

b. In the tree view, click **Breaker 1** to select circuit breaker monitor settings for Circuit Breaker 1.

c. Set the 52AA1 SELOGIC control equation by clicking in the text box labeled **52AA1 N/O Contact Input**.

d. Type **IN101**, and then click or **<Tab>** to another field to specify input IN101 as the control input that represents the close/open state of Circuit Breaker 1.

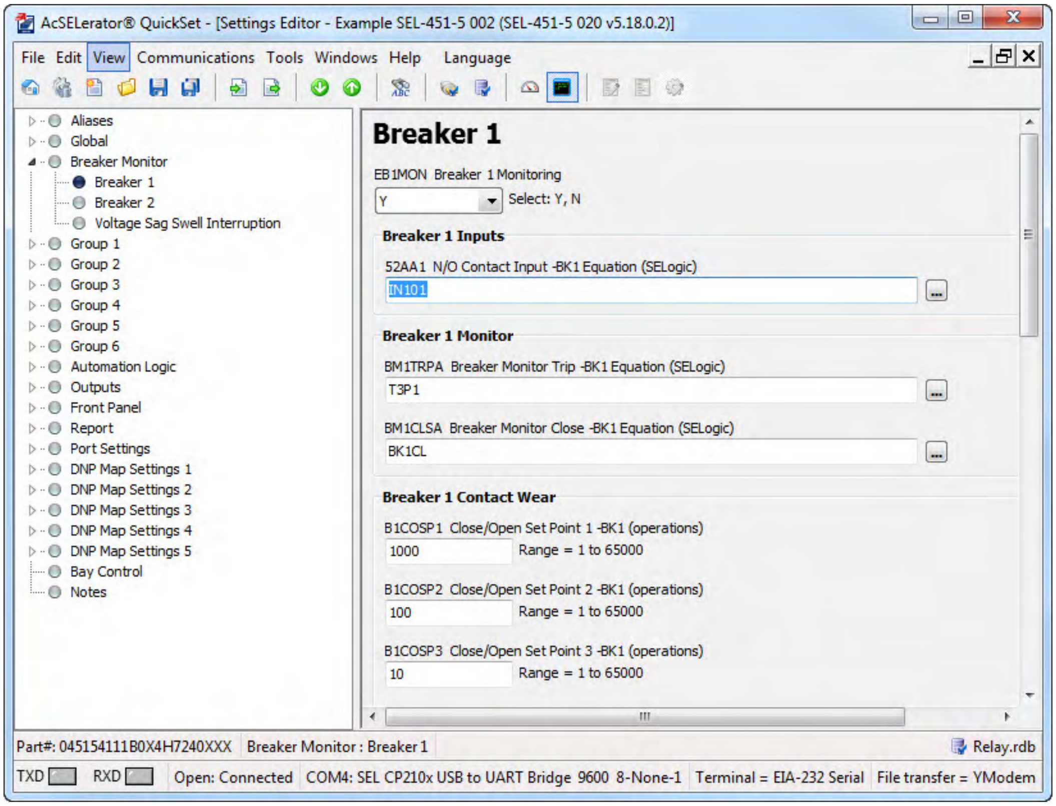

Figure 3.66 Setting 52AA1 in QuickSet

Step 7. Click **File > Save** to save the new settings in QuickSet.

Step 8. Upload the new settings to the SEL-451.

a. Click **File > Send**.

QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Select the **Global** check box and the **Breaker Monitor** check box.

c. Click **OK**.

d. QuickSet responds with a Transfer Status dialog box.

If you see no error message, the new settings are loaded in the relay.

Special Considerations for TiDL

In Time-Domain Link (TiDL) systems, IN301–IN324, OUT301–OUT316, IN401–IN424, OUT401–OUT416, IN501–IN524, and OUT501–OUT516 are provided by remotely connected Axion modules. (See the installation section of the product-specific instruction manual for details on how these are configured and mapped internally.) Within the relay, the inputs behave just like local inputs. They will be accurately time-tagged in SER. Similarly, the outputs will behave like local outputs, except that the communications channel will add a slight time delay to the operating time (less than one millisecond).

The one difference to consider is that it is possible to lose communication with a remote Axion, which will cause all of the mapped inputs and outputs to stop updating. There are special Relay Word bits to indicate this loss of communication: IO300OK, IO400OK, and IO500OK. Use these bits to condition the operation of the corresponding inputs to sustain appropriate operation when there is a loss of communication. You may also want to map these bits to an alarm so someone is notified of the loss of communication.

Configuring Timekeeping

The relay features high-accuracy timekeeping when supplied with an IRIG-B or Ethernet PTP signal. When the supplied clock signal is sufficiently accurate, most SEL-400 series relays can act as a phasor measurement unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record COMTRADE event report data using the high-accuracy time stamp. See *Oscillography on page 9.9* and *Time-Synchronized Triggers on page 11.9* for details on these applications.

IRIG-B and PTP

The relay has two input connectors that accept IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of Serial Port 1, and the IRIG-B BNC connector. In relays with Ethernet, Precision Time Protocol (PTP) can also be used to provide high-accuracy time. See *Section 11: Time and Date Management* for more information on using IRIG-B and PTP.

Monitoring High-Accuracy Time Source Status

The purpose of the procedure in the following steps is to show one method for deriving the TIME Q Time Source information from Relay Word bits TSOK and TIRIG when using an IRIG Time Source. The TSOK Relay Word bit is at logical 1 when the relay is in HIRIG time mode. For this application example, use a protection SELOGIC variable (PSV) to monitor timekeeping status.

PSV02 asserts when the relay is synchronized to the HIRIG source. A departure from this condition asserts the relay alarm output (OUT108 for this application example).

This example assumes that you have successfully established communication with the relay (see *Making an EIA-232 Serial Port Connection on page 3.4*). In addition, you must be familiar with relay access levels and passwords (see *Changing the Default Passwords in the Terminal on page 3.10* to change the default access level passwords). Also, you should be familiar with QuickSet (see *Section 2: PC Software*).

Step 1. Start QuickSet and establish a connection with the relay. See Step 1 and Step 2 of *Checking Relay Status in QuickSet on page 3.12* for detailed steps.

Step 2. Read the present configuration in the relay. Click **File > Read**.

The relay sends all configuration and settings data to QuickSet.

Step 3. Access the protection free-form SELOGIC settings.

a. Click the arrow next to **Group 1** in the **Settings** tree view.

b. Click the **Protection Logic 1** settings (see *Figure 3.67*).

Step 4. Enter the two lines of SELOGIC control equation programming in the **Protection Free-Form Logic Settings** shown in *Figure 3.67*.

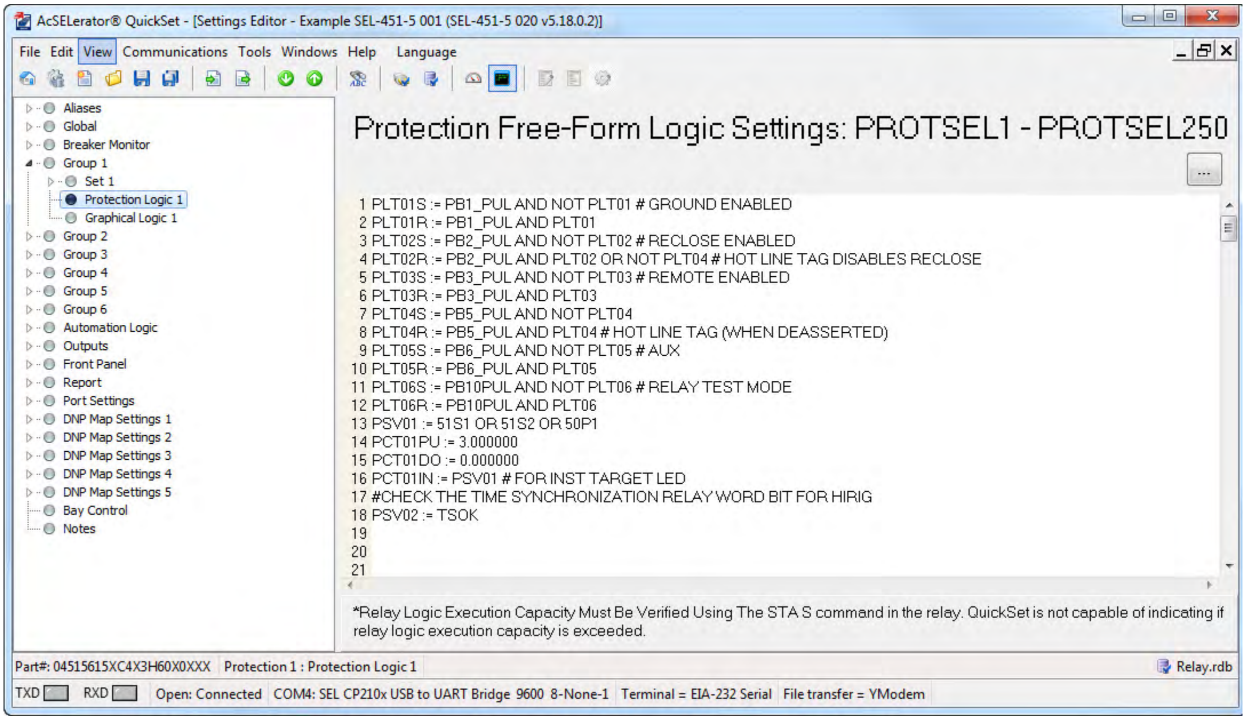

Figure 3.67 Programming a PSV to Monitor HIRIG in QuickSet

Step 5. Configure a control output to alarm a loss of HIRIG mode.

a. In the **Settings** tree view, click **Outputs** and then click **Main Board** (see *Figure 3.68*).

b. In the **OUT108 Main Board Outputs** text box, enter the OR NOT PSV02 condition to the preexisting OUT108 := NOT (SALARM OR HALARM) equation, as shown in *Figure 3.68*.

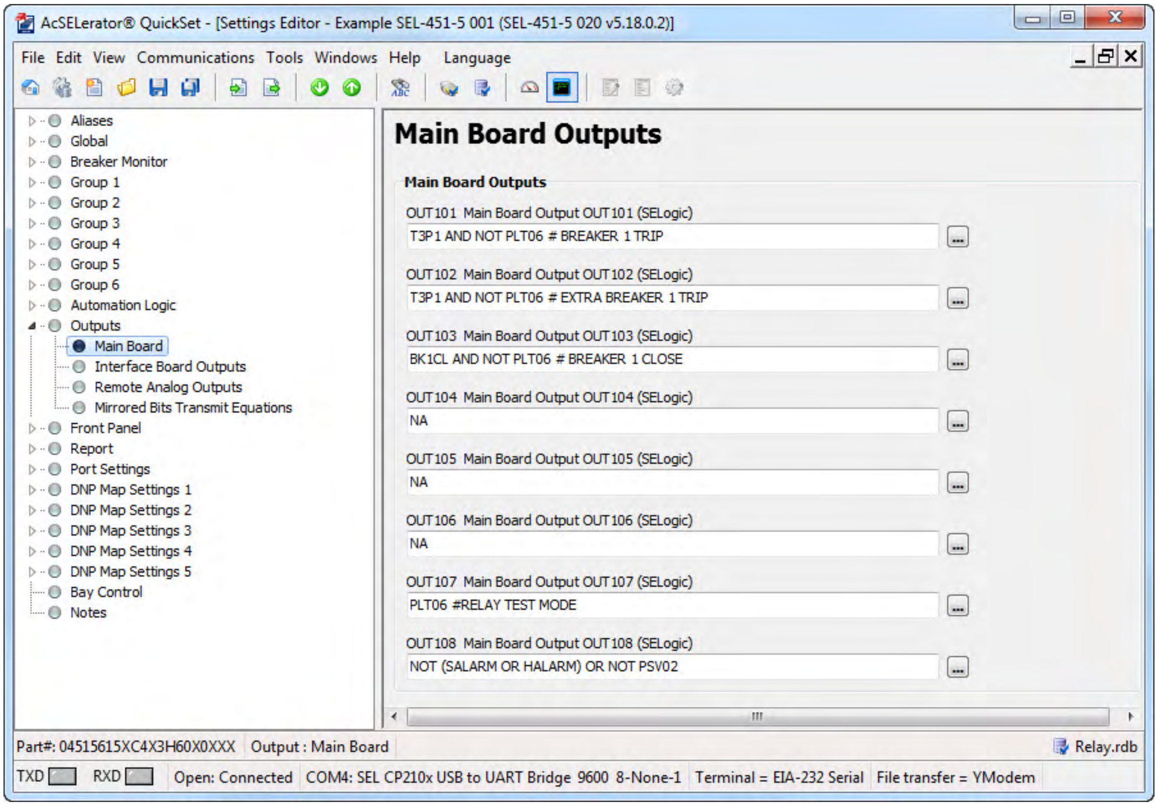

Figure 3.68 Setting OUT108 in QuickSet

Step 6. Click **File > Save** to save the new settings in QuickSet.

Step 7. Upload the new settings to the relay.

a. Click **File > Send**.

QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Select the **Group 1** check box and the **Output** check box, as shown in the first dialog box of *Figure 3.62*.

c. Click **OK**.

QuickSet responds with a display similar to the second dialog box shown in *Figure 3.62*.

If you see no error message, the new settings are loaded in the relay.

To confirm that you have prepared an out-of-synchronization/loss-of-HIRIG mode alarm, disconnect the IRIG-B input. The relay alarm will activate.

Readying the Relay for Field Application

Before applying the relay in your power system, set the relay for your particular field application. Be sure to modify the relay factory-default settings for your power system conditions to enable relay features to help you protect and control your system.

This procedure is a guide to help you ready the relay for field application. If you are unfamiliar with the steps in this procedure, see the many relay usage examples presented in this section. This is a suggested procedure; modify the procedure as necessary to conform to your standard company practices.

Step 1. Open the appropriate low-voltage breaker(s) and remove fuses to verify removal of control power and ac signals from the relay.

Step 2. Isolate the relay TRIP control output.

Step 3. Perform point-to-point continuity checks on the circuits associated with the relay to verify the accuracy and correctness of the ac and dc connections.

Step 4. Apply power to the relay.

The green ENABLED LED on the front panel will illuminate.

Step 5. Use an SEL-C234A cable to connect a serial terminal to the relay.

Step 6. Start the terminal (usually a PC with terminal emulation software).

Step 7. Establish communication with the relay at Access Level 0.

Step 8. Proceed to Access Level 2 (see *Changing the Default Passwords in the Terminal on page 3.10*).

Step 9. Change the default passwords (see *Changing the Default Passwords in the Terminal on page 3.10*).

Step 10. Set the DATE and TIME (see *Making Simple Settings Changes on page 3.15*).

Step 11. Use test sources to verify relay ac connections (see *Examining Metering Quantities on page 3.35*).

Step 12. Verify control input connections.

Step 13. Verify control output connections.

Step 14. Perform protection element tests.

Step 15. Set the relay (see *Making Simple Settings Changes on page 3.15, Section 12: Settings,* and *Section 6: Protection and Protection Application Examples* in the product-specific instruction manual.

Step 16. Connect the relay for tripping/closing duty.

Step 17. From Access Level 2, use a communications terminal to issue applicable commands (listed in *Table 3.9*) to clear the relay data buffers.

Table 3.9 Communications Port Commands That Clear Relay Buffers

Communications Port Command	Task Performed
MET RD	Reset demand meter data
MET RP	Reset peak demand meter data
MET RE	Reset energy meter data
MET RM	Reset maximum/minimum meter data
HIS CA	Reset event report and history buffers
SER CA	Reset Sequential Events Recorder data

Step 18. Connect the secondary voltage and current inputs.

Step 19. Use the **MET** command or the QuickSet HMI to view relay metering to confirm secondary connections (see *Examining Metering Quantities on page 3.35*).

SECTION 4

Front-Panel Operations

The relay front panel makes power system data collection and system control quick and efficient. Using the front panel, you can analyze power system operating information, view and change relay settings, and perform relay control functions. The relay features a straightforward menu-driven control structure presented on the front-panel LCD. Front-panel targets and other LED indicators provide a quick look at relay operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

➤ Reading metering
➤ Inspecting targets
➤ Accessing settings
➤ Controlling relay operations

This section describes features found in many, but not necessarily all, SEL-400 series relays. See the relay-specific instruction manuals to determine which front-panel features are supported in that relay. This section includes the following:

Front-Panel Layout

Some SEL-400 series relays come with a front panel with 16 target LEDs and 8 operator pushbuttons. Others come with 24 target LEDs and 12 operator pushbuttons. Refer to the product-specific instruction manual to see which displays are available for any specific relay. *Figure 4.1*, *Figure 4.2*, and *Figure 4.3* show what these front panel options look like in the SEL-451 and the SEL-487E relays. Some relays are also available with direct action pushbuttons for breaker control, which is illustrated in *Figure 4.2*.

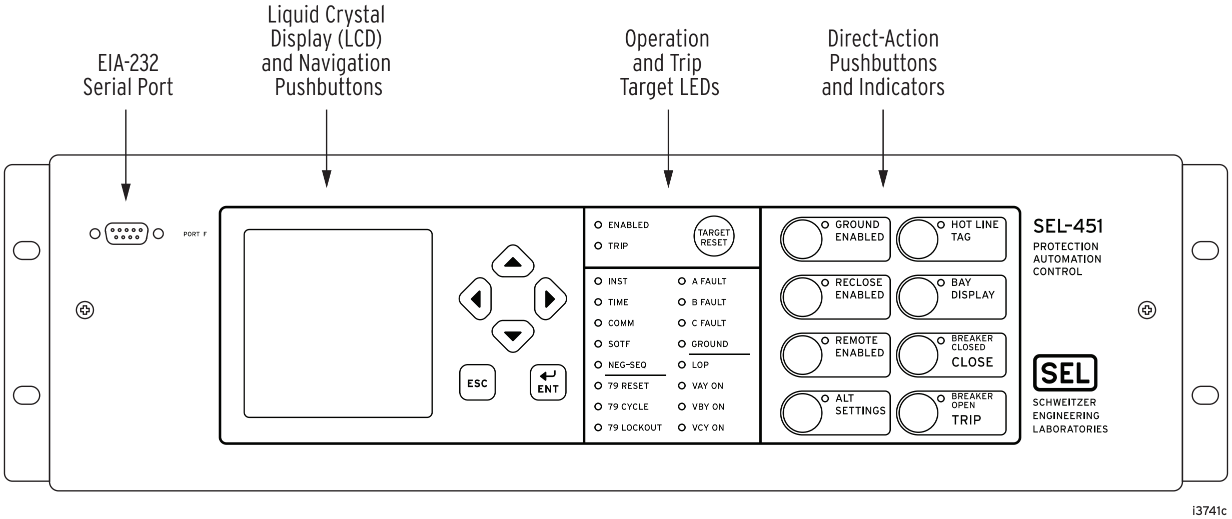

Figure 4.1 SEL-451 Front Panel (8-Pushbutton Model)

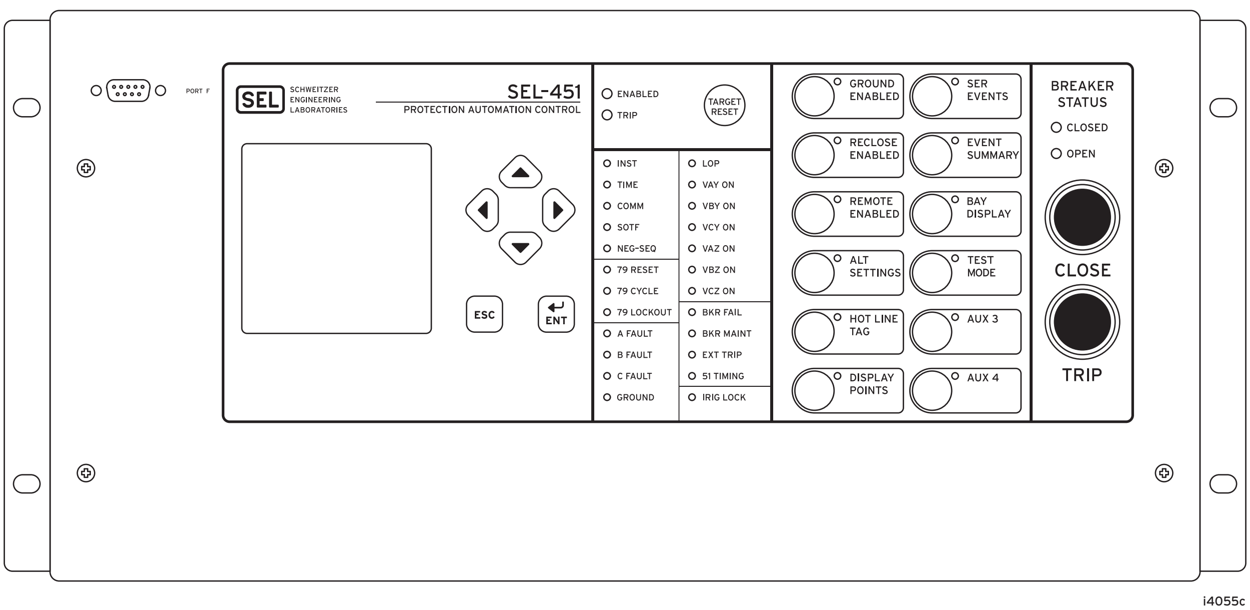

Figure 4.2 SEL-451 Front Panel (12-Pushbutton Model) with Optional Auxiliary Trip/Close Buttons

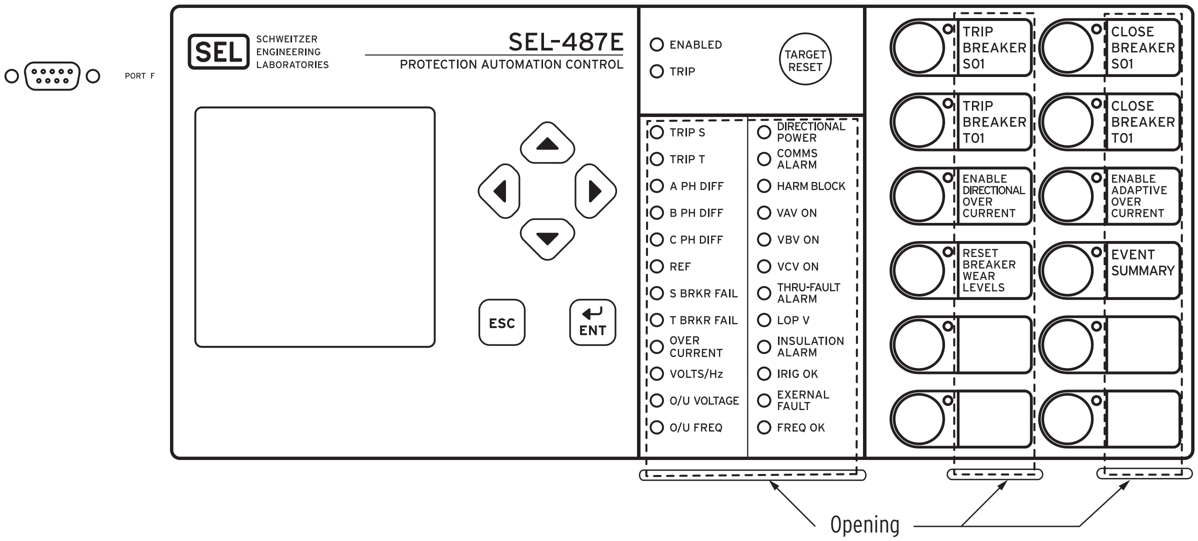

Figure 4.3 SEL-487E Front Panel

A 128 x 128 pixel LCD shows relay operating data including event summaries, metering, settings, and relay self-test information.

Six navigation pushbuttons adjacent to the LCD window control the relay menus and information screens. Sequentially rotating display screens provide important power system metering parameters; you can easily change this ROTATING DISPLAY to suit your particular onsite monitoring needs. Use a simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access relay metering, control, and settings.

Front-panel LEDs (light emitting diodes) indicate the relay operating status. You can confirm that the relay is operational by viewing the **ENABLED** LED. The relay illuminates the **TRIP** LED target to indicate a tripping incident. The relay is factory programmed for particular relay elements to illuminate the other target LEDs. You can program these target LEDs to show the results of the most recent relay trip event. The asserted and deasserted colors for the LEDs are programmable.

Select relay models feature auxiliary **TRIP/CLOSE** pushbuttons. These pushbuttons are electrically isolated from the rest of the relay.

The relay front panel features large operator control pushbuttons with annunciator LEDs that facilitate local control. Factory-default settings associate specific relay functions with these direct-action pushbuttons and LEDs. Using SELOGIC control equations or front-panel settings PB*n*_HMI, you can readily change the default direct-action pushbutton functions and LED indications to fit your specific control and operational needs. Change the pushbutton and pushbutton LED labels with the slide-in labels adjacent to the pushbuttons. The asserted and deasserted colors for the LEDs are programmable in 12-pushbutton models.

The relay front panel includes an EIA-232 serial port (labeled **PORT F**) for connecting a communications terminal or using the ACSELERATOR QuickSet SEL-5030 Software program. Use the common EIA-232 open ASCII communications protocol to communicate with the relay via front-panel **PORT F**. Other communications protocols available with the front-panel port are MIRRORED BITS communications, and DNP3. For more information on communications protocols and **PORT F**, see *Section 15: Communications Interfaces*.

Front-Panel LCD

The LCD is the prominent feature of the relay front panel. *Figure 4.4* shows the following areas contained in the LCD:

- Title area
- Main area
- Message area
- Scroll bars

The scroll bars are present only when a display has multiple screens.

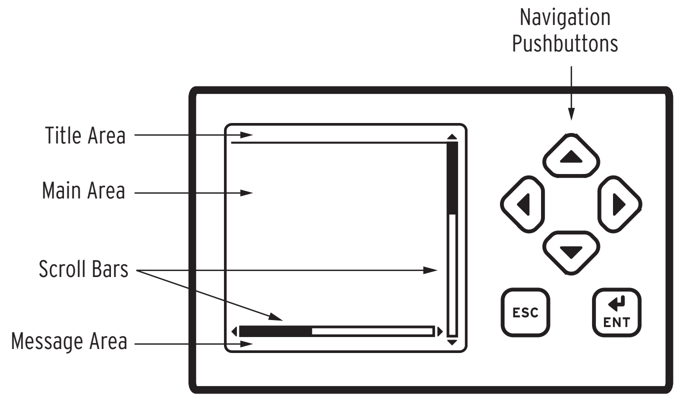

Figure 4.4 LCD Display and Navigation Pushbuttons

Front-Panel Inactivity Time-Out

An LCD backlight illuminates the screen when you press any front-panel pushbutton. This backlight extinguishes after a front-panel inactivity time-out period. You can control the duration of the time-out with relay setting FP_TO, listed in *Table 4.1*.

To set FP_TO, use the SET F (set front panel) settings from any communications port or use the Front Panel branch of the QuickSet Settings tree view. The maximum backlight time is 60 minutes (FP_TO = 60). When the front panel times out, the relay displays an automatic ROTATING DISPLAY, described later in this section under *Screen Scrolling on page 4.5*.

Table 4.1 Front-Panel Inactivity Time-Out Setting

Name	Description	Range	Default
FP_TO	Front-panel display time-out	OFF, 1–60 minutes	15 minutes

Navigating the Menus

The relay front panel presents a menu system for accessing metering, settings, and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 4.4*) to navigate these front-panel menus.

The navigation pushbutton names and functions are the following:

- **ESC**—Escape pushbutton
- **ENT**—Enter pushbutton
- **Left Arrow**, **Right Arrow**, **Up Arrow**, and **Down Arrow**—Navigation pushbuttons

Menus show lists of items that display information or control the relay. A rectangular box around an action or choice indicates the menu item you have selected. This rectangular box is the menu item highlight.

Figure 4.5 shows an example of RELAY ELEMENTS highlighted in an example MAIN MENU. When you highlight a menu item, pressing the **ENT** pushbutton selects the highlighted item.

```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 4.5 RELAY ELEMENTS Highlighted in Example MAIN MENU

The **Up Arrow** pushbutton and **Down Arrow** pushbutton scroll the highlight box to the previous or next menu selection, respectively. When there is more than one screen of menu items, pressing the **Up Arrow** while at the first menu item causes the display to show the previous set of full-screen menu items, with the last menu item highlighted. Pressing the **Down Arrow** while at the bottom menu item causes the display to show the next set of full-screen menu items, with the first menu item highlighted.

Pressing the **ESC** pushbutton reverts the LCD display to the previous screen. Pressing **ESC** repeatedly returns you to the MAIN MENU. If a status warning, alarm condition, or event condition is active (not acknowledged or reset), the relay displays the full-screen status warning, alarm screen, or trip event screen in place of the MAIN MENU.

Screen Scrolling

SEL-400 series relays have two screen scrolling modes: autoscrolling mode and manual-scrolling mode. After front-panel time-out, the LCD presents each of the display screens in this sequence:

- One-line diagram (if applicable)
- Any active (filled) alarm points screens
- Any active (filled) display points screens
- Other enabled screens

See the product-specific instruction manual for the details of the other screens that are supported and how they are enabled.

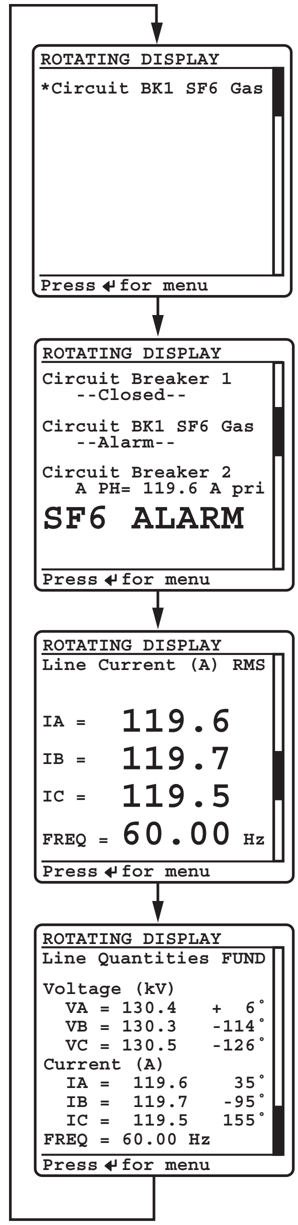

Figure 4.6 Sample ROTATING DISPLAY

Figure 4.6 illustrates an example rotating display sequence. The active alarm points are the first screens in the ROTATING DISPLAY (see *Alarm Points on page 4.7*). Each alarm points screen shows as many as 11 alarm conditions. The relay can present a maximum of six alarm points screens.

The active display points are the next screens in the ROTATING DISPLAY after alarm points (see *Display Points on page 4.10*). Each display points screen shows as many as 11 enabled display points (with 96 display points, the relay can present a maximum of nine display points screens). If a display point does not have text to display, the screen space for that display point is maintained.

Autoscrolling Mode

Autoscrolling mode shows each screen for a user-configurable period of time. Front Panel setting SCROLD defines the period of time for which each screen is shown. When you first apply power to the relay, the LCD shows the autoscrolling ROTATING DISPLAY. With SCROLD := OFF, the screen remains on the first screen in the rotating display order; automatic rotation of additional screens is disabled.

The autoscrolling ROTATING DISPLAY also appears after a front-panel inactivity time-out (see *Front-Panel Inactivity Time-Out on page 4.4*). The relay retrieves data prior to displaying each new screen. The relay does not update screen information during the display interval. At any time during autoscrolling mode, pressing **ENT** takes you to the MAIN MENU. Pressing any of the four navigation pushbuttons switches the display to manual-scrolling mode.

Manual-Scrolling Mode

In manual-scrolling mode, you can use the directional navigation arrow pushbuttons to select the next or previous screen. Pressing the **Down Arrow** or **Right Arrow** pushbuttons switches the display to the next screen; pressing the **Up Arrow** or **Left Arrow** pushbuttons switches the display to the previous screen.

In manual-scrolling mode, the display shows arrows at the top and bottom of the vertical scroll bar. The screen arrows indicate that you can navigate between the different screens at will. The relay retrieves data prior to displaying each new screen. Unlike the autoscrolling mode, the relay continues to update screen information while you view it in the manual-scrolling mode. To return to autoscrolling mode, press **ESC** or wait for a front-panel time-out.

Alarm Points

You can display messages on the front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 4.7 shows a sample alarm points screen. The relay is capable of displaying as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. While you navigate the HMI menu structure, the relay does not automatically display the alarm points. Instead, ALARM EVENT displays in the footer. When you escape the HMI menu structure, the relay will display the alarm points screen.

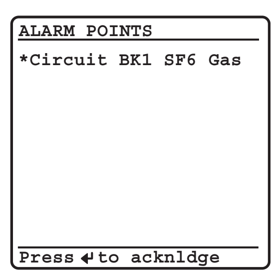

Figure 4.7 Sample Alarm Points Screen

The alarm point setting is an element of the SER settings. To enable an alarm point, enable the HMI alarm parameter of the SER Point Settings listed in *Table 4.2*. The format for entering the SER point data is the following comma-delimited string:

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Names can contain any valid ASCII character. Enclose the name within quotation marks. See *Example 4.1* for particular information on the format for entering SER point data.

Table 4.2 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element
Reporting Name	20-character maximum ASCII string
SET State Name (logical 1)	20-character maximum ASCII string
CLR State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y, N

If you enter a Relay Word bit that does not match a valid relay element, the relay displays: `Unknown relay word reference`. If you enter an alias or name that is too long, the relay displays: `Alias label too long`.

The relay displays alarm points in a similar fashion as the SER. As many as 19 characters of the given alias are displayed, with one character reserved for the "*." The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted in order to be displayed; after the corresponding element deasserts, the asterisk is removed, but the alias is not. The relay displays alarm points in reverse chronological order, just as in the SER, with the most recently asserted alarm displayed on the top. Deasserted alarms may be removed from the display with user acknowledgment, as shown in *Example 4.1*.

Example 4.1 Creating an Alarm Point

Alarm points screens provide operator feedback about the status of system conditions. An alarm points screen contains 11 alarm points; this example demonstrates a method to set the alarm point message that is shown in *Figure 4.7*. This example is based on the Relay Word bit IN101 asserting when circuit breaker 1 is in an alarm condition.

In the Report settings (SET R), enter the following after the SER Points Line 1 prompt:

1: **IN101,"Circuit BK1 SF6 Gas","Alarm","Normal","Y"**

The circuit breaker alarm condition is indicated by the set state, "Alarm" and the circuit breaker normal condition is indicated by the clear state "Normal." The HMI Alarm parameter is set to "Y" in order to enable alarm points screen display of this element.

While in the scrolling mode, the assertion of IN101 will cause the alarm points screen (as shown in *Figure 4.7*) to be automatically displayed. Upon the deassertion of IN101, the asterisk will disappear, as shown in *Figure 4.8*.

Example 4.1 Creating an Alarm Point (Continued)

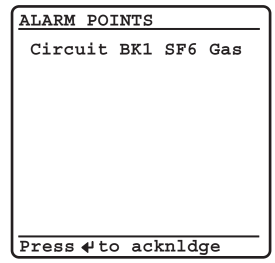

Figure 4.8 Deasserted Alarm Point

Pressing the ENT pushbutton will allow the user to acknowledge and clear deasserted alarms. Before clearing, you will be prompted to confirm that this is the intended action, as shown in *Figure* .

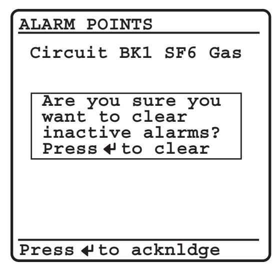

Figure 4.9 Clear Alarm Point Confirmation Screen

In the case that all alarms are deasserted, pressing the ENT pushbutton will allow the user to acknowledge and clear all alarms. After clearing, a screen showing the results of the action will be shown, as in *Figure 4.10*.

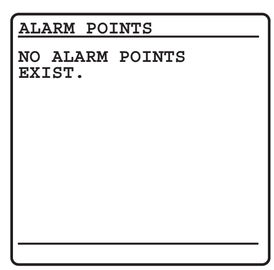

Figure 4.10 No Alarm Points Screen

Alarm points are not updated for a particular element if it has been deleted from the SER because of chatter criteria (see *Automatic Deletion and Reinsertion on page 9.31*). Upon reinsertion, the element state will be updated on the alarm point display. If the relay enters a period of SER data loss, the status of alarm points cannot be determined. The screen shown in *Figure 4.11* will appear until you exit the data loss condition, at which point the alarm point elements will be polled and displayed if asserted. Subsequent alarm point assertions will be displayed above the data loss message.

Example 4.1 Creating an Alarm Point (Continued)

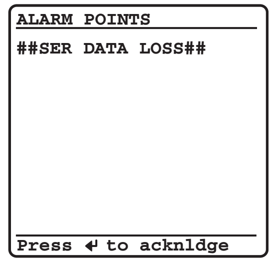

Figure 4.11 Alarm Points Data Loss Screen

Display Points

You can display messages on the relay front-panel LCD that indicate conditions in the power system. The relay uses display points to place these messages on the LCD.

Figure 4.12 shows a sample display points screen. Display points can show the status of Relay Word bits or display the value of analog quantities. The relay has 96 possible display points; *Table 4.3* and *Table 4.4* list the display points settings. The relay updates the display points data once per second if you are viewing the display points in manual-scrolling mode; in autoscrolling mode the relay updates the display points information each time the screen appears in the ROTATING DISPLAY sequence.

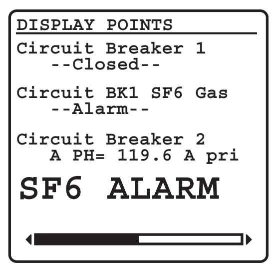

Figure 4.12 Sample Display Points Screen

To enable a display point, enter the display point settings listed in *Table 4.3* or *Table 4.4*. All display points occupy one, and only one, line on the display at all times. The height of the line is determined by the "Text Size" setting parameter. Display points of single-line height span one screen in total width. Display points of double-line height span two screens in total width. You can use multiple display points to simulate multiple lines.

Use the following syntax to display the given Relay Word bit exactly as seen in the navigational menu (name and value).

DPxx := **Name**

Use the following syntax to display the given Relay Word bit as seen in the navigational menu, replacing the name of the value with the given alias string. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Text Size"**

Use the following syntax to display the given Relay Word bit with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is deasserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then an empty line is displayed when the bit matches that state. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Set String", "Clear String", "Text Size"**

Use the following syntax to display the given analog quantity with the given text and formatting. Formatting must be in the form Width.Decimal,Scale with the value of Name, scaled by "Scale," formatted with total width "Width" and "Decimal" decimal places. The width value includes the decimal point and sign character, if applicable. The "scale" value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, "$" characters are displayed. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "(Text1 Width.Decimal,Scale) Text2", "Text Size"**

Table 4.3 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	See the relay-specific instruction manual for a list of Relay Word bits available in that relay.
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 4.4 Display Point Settings—Analog

Description	Range
Analog Quantity Name	See the relay-specific instruction manual for a list of available analog quantities
"User Text and Formatting"	ASCII string
Text Size	S, D

Table 4.5 Display Point Settings—Boolean and Analog Examples (Sheet 1 of 2)

Example Display Point Setting Value	Example Display
IN101	`IN101=1` `IN101=0`
MWHAIN,"{7.2}"	`1234.56`
50P1,Overcurrent,,	`Overcurrent=1` `Overcurrent=0`
PSV01,Control,On,Off	`Control=On` `Control=Off`
PSV02,Breaker,Tripped,	`Breaker=Tripped` *Empty Line*

Table 4.5 Display Point Settings—Boolean and Analog Examples (Sheet 2 of 2)

Example Display Point Setting Value	Example Display
50P1,,,Overcurrent	*Empty Line* `Overcurrent`
MWHAIN,“A Ph Import={7.2}”	`A Ph Import=1234.56`
MWHAIN,“A Ph Import={7.3}”	`A Ph Import=$$$.$$$`
MWHAIN,“A Ph Imp {4}MWh”	`A Ph Imp 1234MWh`
PAD,“{7.2}”	`1234.56`
PAD,“A Ph Dem Pwr={4.1}”	`A Ph Dem Pwr=1234.5`
ICD,“C Demand={5}”	`C Demand= 1230`
ICD,“C Demand={4.2,0.001} kA”	`C Demand=1.23 kA`
MWHAOUT,“A Phase Out={3, 1000}”	`A Phase Out=1234`
MWHAOUT,“A Phase Out={3, 1000} kWH”	`A Phase Out=$$$ kWh`
1,“Fixed Text”	`Fixed Text`
0,“Fixed Text”	`Fixed Text`
1,	*Empty Line*
0,	*Empty Line* *Display Point is hidden*

If you enter a Relay Word bit or Analog Quantity that does not match a valid relay element, the relay displays: `Invalid element`. If you enter a display point that exceeds the allowable length, the relay displays: `Too many characters`. If you enter an invalid scale factor, invalid width, too many parameters, or omit necessary quotation marks or brackets, the relay displays an error message. If a display point was used previously and you want to remove the display point, you can delete the display point. In the Front Panel settings (SET F), at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set the display points (see *Text-Edit Mode Line Editing on page 3.22*for information on text-edit mode line editing). To delete Display Point 1, type **DELETE <Enter>** at the Front Panel settings Line 1 prompt.

Example 4.2 Creating a Display Point

Display points screens can be used to provide operator feedback about the readiness of equipment connected to the relay. A display points screen contains 11 display points; this example demonstrates a method to set the display point messages that are shown in *Figure 4.12*. This example uses an SEL-451 with an additional I/O interface board.

This example is based on a three-pole circuit breaker. Relay Word bit 52AA1 will assert when Circuit Breaker 1 is in the closed position.

IN109 will assert when Circuit Breaker 1 is in an alarm condition. B2IAFIM is the filtered instantaneous magnitude for the A-Phase current through Circuit Breaker 2.

In the Front Panel settings (**SET F**), enter the following after the Display Points and Aliases Line 1 prompt:

1: **1,“Circuit Breaker 1”**

2: **52AA1,,“ --Closed--”,“ --Open--”**

Example 4.2 Creating a Display Point (Continued)

3: **0**

4: **0,"Circuit BK1 SF6 Gas"**

5: **IN109,," --Alarm--"," --Normal--"**

6: **1**

7: **1,"Circuit Breaker 2"**

8: **B2IAFIM," A PH=(6.1,1) A pri"**

9: **IN109,, "SF6 ALARM", D**

Fixed text is set by assigning an alias to a "1" or "0." Blank lines are set by assigning a blank alias to a "1" or "0." The circuit breaker closed condition is indicated by the set state, "--Closed--" where leading spaces are added to center the set state message. Add a clear state named "--Open--" to show that the circuit breaker is open. The circuit breaker alarm condition is indicated by the set state, "--Alarm--" where leading spaces are added to center the set state message. Add a clear state named "--Normal--" to show that the circuit breaker is not in alarm. User text "A PH=" and "A pri" allows for customized display of the Circuit Breaker 2 A-Phase current, which has been formatted to display numerically as XXXX.X. Double font display is used to give greater visibility to the SF6 Alarm. A horizontal scroll appears while in manual-scrolling mode regardless of whether or not the display point label width requires two full screens to display.

Example 4.3 Monitoring Test Modes With Display Points

This example uses the Relay Word bit TESTFM (Fast Meter test running) to activate a front-panel display point that alerts an onsite operator that the relay is in Fast Meter test mode.

In the Front Panel settings (**SET F**), enter the following after the Line 10 prompt:

10: **TESTFM,,"FAST METER TEST!!!!"**

The LCD displays the screen shown in *Figure 4.13* as a part of the ROTATING DISPLAY if the Fast Meter test is running. (Instruct the operator to view the relay front panel for messages or warnings as the last item on a "Leaving the Substation" checklist.)

Again, this display point application example does not require a clear state, so the clear state is blank. If the Fast Meter test is not running and no other display points are active, the relay shows a blank screen in the ROTATING DISPLAY.

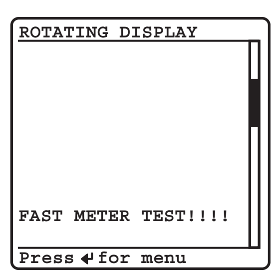

Figure 4.13 Fast Meter Display Points Sample Screen

Front-Panel Menus and Screens

Operate the relay front panel through a sequence of menus that you view on the front-panel display. The `MAIN MENU` is the introductory menu for other front-panel menus (see *Figure 4.5*). These additional menus allow you onsite access to metering, control, and settings for configuring the relay to your specific application needs. The following menus and screens are representative of what is typically found in SEL-400 series relays, but each relay has a slightly different list. See the relay-specific instruction manual to see what is available in that relay.

- Support Screens
  - `Contrast`
  - `Password`
- `MAIN MENU`
  - `METER`
  - `EVENTS`
  - `BREAKER MONITOR`
  - `RELAY ELEMENTS`
  - `LOCAL CONTROL`
  - `SET/SHOW`
  - `RELAY STATUS`
  - `VIEW CONFIGURATION`
  - `DISPLAY TEST`
  - `RESET ACCESS LEVEL`
  - `ONE LINE DIAGRAM`

Support Screens

The relay displays special screens over the top of the menu or screen that you are using to control the relay or view data. These screens are the `ADJUST CONTRAST` screen and the `PASSWORD REQUIRED` screen.

Contrast

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **ESC** pushbutton for one second. The relay displays a contrast adjustment box superimposed over the display.

Figure 4.14 shows the contrast adjustment box with the `MAIN MENU` screen in the background. Pressing the **Right Arrow** pushbutton increases the contrast. Pressing the **Left Arrow** pushbutton decreases the screen contrast. When finished adjusting the screen contrast, press the **ENT** pushbutton.

Figure 4.14 Contrast Adjustment

Password

⚠**WARNING**
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The relay uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Access Levels and Passwords on page 3.7* for more information on access levels and setting passwords. The relay front panel is at Access Level 1 upon initial power-up and after front-panel time out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 4.15*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

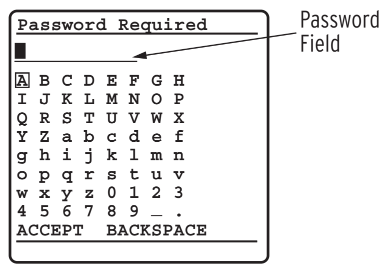

Figure 4.15 Enter Password Screen

Enter the password by pressing the navigation pushbuttons to move the highlight box through the alphanumeric field. When at the desired character, press **ENT**. The relay enters the selected character in the password field and moves the dark box cursor one space to the right. You can backspace at any time by highlighting the BACKSPACE character and then pressing **ENT**. When finished, enter the password by highlighting the ACCEPT option and then pressing **ENT**.

If you entered a valid password for an access level greater than or equal to the required access level, the relay authorizes front-panel access to the combination of access levels (new level and all lower levels) for which the password is valid. The relay replaces the password screen with the menu screen that was active before the password validation routine. When you enter Access Levels B, P, A, O, and 2, the Relay Word bit SALARM pulses for one second.

If you did not enter a valid password, the relay displays the error screen shown in *Figure 4.16*. Entering a valid password for an access level below the required access level also causes the relay to generate the error screen. In both password failure cases, the relay does not change the front-panel access level (it does not reset to Access Level 1 if at a higher access level). The relay displays the PASSWORD INVALID screen for five seconds. If you do not want to wait for the relay to remove the message, press any of the six navigational pushbuttons during the five-second error message to return to the previous screen in which you were working.

```
Password Invalid


The Password Entered
Is Not Sufficient for
The Required Access
Level.
```

Figure 4.16 Invalid Password Screen

Main Menu

The MAIN MENU is the starting point for all other front-panel menus. A representative relay MAIN MENU is shown in *Figure 4.17*. When the front-panel LCD is in the ROTATING DISPLAY, press the **ENT** pushbutton to show the MAIN MENU.

```
MAIN MENU
METER
EVENTS
BREAKER MONITOR
RELAY ELEMENTS
LOCAL CONTROL
SET/SHOW
RELAY STATUS
VIEW CONFIGURATION
DISPLAY TEST
RESET ACCESS LEVEL
```

Figure 4.17 MAIN MENU

Meter

The relay displays metering screens on the LCD. Highlight METER and press **ENT** on the MAIN MENU screen to select these screens. The metering screens available are relay specific and are described in each relay-specific instruction manuals.

Events

The relay front panel features summary event reporting, which simplifies post-fault analysis. These summary event reports include all trip events, event and data capture triggering (via the ER SELOGIC control equation), and manual triggers. The relay displays event reports based on the Relay Word bit elements in the ER (event report trigger) SELOGIC control equation. See *Event Report on page 9.14* for more information on event reports.

The front-panel event buffer size is 100 summaries. The relay numbers summary events in order from 10000 through 42767 and displays the most recent summaries on the LCD.

You can view summary event reports from the relay front-panel display by selecting EVENTS from the MAIN MENU. The relay presents the Events Menu as shown in *Figure 4.18*. Select Event Summary from the Events Menu to view event summary data. *Figure 4.19* shows sample Event Summary screens for a phase-to-phase-to-ground fault. Use the **Right Arrow** and **Left Arrow** pushbuttons to show each of the summary screens for the event. Event reports can also be viewed via a front-panel automatic message (see *Front-Panel Automatic Messages on page 4.31*) or programmable front-panel operator control pushbutton (see *Front-Panel Operator Control Pushbuttons on page 4.34*).

Figure 4.18 Events Menu Screen

The horizontal scroll bar indicates that you can view other event 10002 screens. Use the **Up Arrow** and **Down Arrow** pushbuttons to move among the events in the summary buffer. Press **ESC** to return to the `Events Menu` and **ESC** again to return to the `MAIN MENU`.

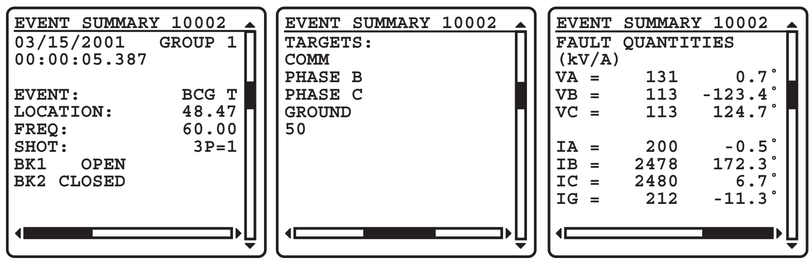

Figure 4.19 Example EVENT SUMMARY Screens

SER

The Sequential Events Recorder (SER) records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *Sequential Events Recorder (SER) on page 9.28* for more information on SER events. To view SER events from the front panel, select `EVENTS` from the `MAIN MENU` and `SER Events` from the `Events Menu` as shown in *Figure 4.18*. SER events are also viewable using programmable front-panel operator-control pushbuttons; see *Front-Panel Operator Control Pushbuttons on page 4.34*.

Figure 4.20 illustrates the SER Events display screen. Data reported in this screen for each event are the SER Point Alias Name, Asserted or Deasserted state, and the Date and Time of the event. When in the `SER Events` screen, three SER records are displayed on one screen. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The top event is the most recent event, and the bottom event is the oldest. The upper right of the screen displays the sequential indexes of the SER events currently being viewed. If a new event occurs while viewing the SER events, the display does not update with the new event automatically. To include the new SER event in the display, exit the SER screen by pressing **ESC** and re-enter the `SER Events` screen by pressing **ENT** with the `SER Events` selection highlighted. This rebuilds the `SER Events` display and contains the latest SER events triggered.

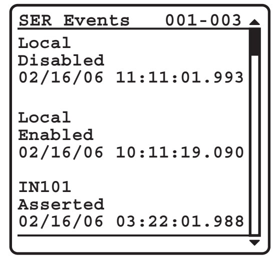

Figure 4.20 SER Events Screen

If no SER events are available, the message shown in *Figure 4.21* is displayed.

Figure 4.21 No SER Events Screen

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 4.6*.

Table 4.6 Front-Panel Pushbutton Functions While Viewing SER Events

Pushbutton	Description
Up Arrow, Down Arrow	Navigates one screen at a time up or down. Each screen contains three SER events. Accelerated scrolling is obtained when the pushbutton remains pressed (see accelerated scrolling behavior below).
Left Arrow, Right Arrow	Navigates between SER events to allow adjacent SER events to be displayed on one screen. For example, if events 1, 2, and 3 are displayed, press the Right Arrow once to display events 2, 3, and 4 in the same screen. No accelerated scrolling is provided with the Left Arrow and Right Arrow pushbuttons.
ESC	Returns to the Events Menu
ENT	Does nothing

Hold down either the Up Arrow or Down Arrow to achieve accelerated scrolling. Holding down the Up Arrow or Down Arrow navigates one screen at a time for the first five screens, and then increases to five screens at a time if the button remains pressed. Accelerated scrolling stops at the newest or oldest SER event record available, depending on the direction of the scrolling.

When the upper limit of the SER events is reached, press the Down Arrow one more time and the report will wrap around to display the screen containing the first SER event. Similarly, when the lower limit of the SER events is reached, press the Up Arrow one more time and the report will wrap around to display the screen containing the last SER event.

By default, three SER events are shown per screen. You can change this to five per screen by setting SER_PP to Y. This will cause the element name and state information to be shown on the same line, with the element name truncated to ten characters and the state truncated to eight characters.

Breaker Monitor

Some SEL-400 series relays feature an advanced circuit breaker monitor. Select BREAKER MONITOR from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display. See the relay-specific instruction manual for the supported options and example screens.

Relay Elements (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the relay. The relay has two unique manual-scrolling features for viewing these elements:

- ➤ Accelerated navigation
- ➤ Search

These Relay Word bit scrolling features make selecting elements from among the many relay targets easy and efficient. *Figure 4.22* shows an example of the RELAY ELEMENTS screen. If an alias exists for an element, the alias name is displayed instead of the element name. An asterisk character (*—shown in *Figure 4.22*) indicates that this Relay Word bit position is reserved for future use.

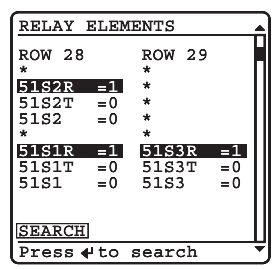

Figure 4.22 RELAY ELEMENTS Screen

When you move item by item through the Relay Word bit table, pressing the **Up Arrow** or **Down Arrow** pushbuttons shows each previous or next screen in turn.

Accelerated navigation occurs when you press and hold the **Up Arrow** or **Down Arrow** pushbuttons. Holding the **Up Arrow** or **Down Arrow** pushbuttons repeats the regular pushbutton action at two rows every second for the first ten rows. Continue pressing the **Up Arrow** or **Down Arrow** pushbutton to cause the relay screen scrolling to accelerate to 20 rows per second. When you are scrolling up in accelerated scrolling, scrolling will stop at the first relay elements screen. When you are scrolling down, scrolling will stop at the last screen.

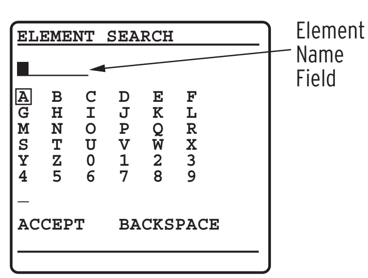

Figure 4.23 ELEMENT SEARCH Screen

Search mode allows you to find a specific relay target element quickly. *Figure 4.23* shows the menu screen that the relay displays when you select the SEARCH option of the RELAY ELEMENTS initial menu.

When you first enter this search menu, the block cursor is at the beginning of the element name field and the highlight box in the alphanumeric field is around the letter A. Use the navigation pushbuttons to move through the alphanumeric characters. If the highlight is on one of the characters, pressing **ENT** enters the character at the block cursor location in the element name field. Next, the block cursor moves automatically to the character placeholder to the right. If the block cursor was already at the first character position on the left, the block cursor remains at the end of the name field. To backspace the cursor in the element name field, move the highlight to BACKSPACE and press **ENT**. When you have finished entering an element name, move the highlight to ACCEPT and press **ENT**. At any time, pressing **ESC** returns the display to the RELAY ELEMENTS screen.

If the highlight is on ACCEPT, the relay finds the matching relay element when you press **ENT**. The relay first searches for alias names, seeking an exact match. If the relay does not find an exact alias name match, it searches for an exact primitive name match. If there is no exact primitive name match, the relay initiates a partial alias name string search, followed by a partial primitive name string search. If the relay finds no match, the screen displays an error message and stays in the ELEMENT SEARCH screen. If the relay finds a match, the screen displays the element row containing the matching element.

Local Control

The relay provides great flexibility in power system control through the LOCAL CONTROL menus. You can use the front-panel LOCAL CONTROL menus to perform these relay functions:

- Trip and close circuit breakers (password required)
- Assert, deassert, and pulse relay control outputs to command station control actions
- Test relay outputs (password required)

In the first LOCAL CONTROL submenu of *Figure 4.24*, you can choose BREAKER CONTROL, LOCAL BITS CONTROL, or OUTPUT TESTING. You must install the circuit breaker control enable jumper to enable circuit breaker control and output testing capability. The submenu will not display the --BREAKER CONTROL-- option and the --OUTPUT TESTING-- option if the breaker jumper is not installed. (The relay checks the status of the breaker jumper whenever you activate the front-panel settings and at power-up.) If the breaker jumper is not installed, and there are no local bits enabled, the relay displays an information message when you attempt to enter LOCAL CONTROL and the screen returns to the MAIN MENU after a short delay.

Local bit names that you have programmed (see *Example 4.4*) appear in the local control bit names field between --BREAKER CONTROL-- and --OUTPUT TESTING--, as shown in *Figure 4.24*. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the local control action you want to perform. Pressing **ENT** takes you to the specific LOCAL CONTROL screen.

```
LOCAL CONTROL
--BREAKER CONTROL--
Enable Bus Switching
North Bus MOD
South Bus MOD
Bus Tie Interlock
Alternate Settings 3
--OUTPUT TESTING--
```

Figure 4.24 LOCAL CONTROL Initial Menu

Breaker Control

The BREAKER CONTROL option presents a circuit breaker selection submenu if the relay is configured to control multiple breakers. Use the navigation pushbuttons and **ENT** to select the circuit breaker you want to control.

Figure 4.25 shows the BREAKER CONTROL submenu and sample circuit breaker control screens for BREAKER 1. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the TRIP BREAKER 1 or CLOSE BREAKER 1 control actions.

When you highlight the trip option and press **ENT**, the relay displays the confirmation message OPEN COMMAND ISSUED and trips Circuit Breaker 1 (Relay Word bit OC1 pulses). The BREAKER 1 STATUS changes to OPEN.

When you highlight the close option and press **ENT**, the relay displays the confirmation message CLOSE COMMAND ISSUED and closes Circuit Breaker 1 (Relay Word bit CC1 pulses). The BREAKER 1 STATUS changes to CLOSED. (Be aware that not all SEL-451 relays support breaker close operations.)

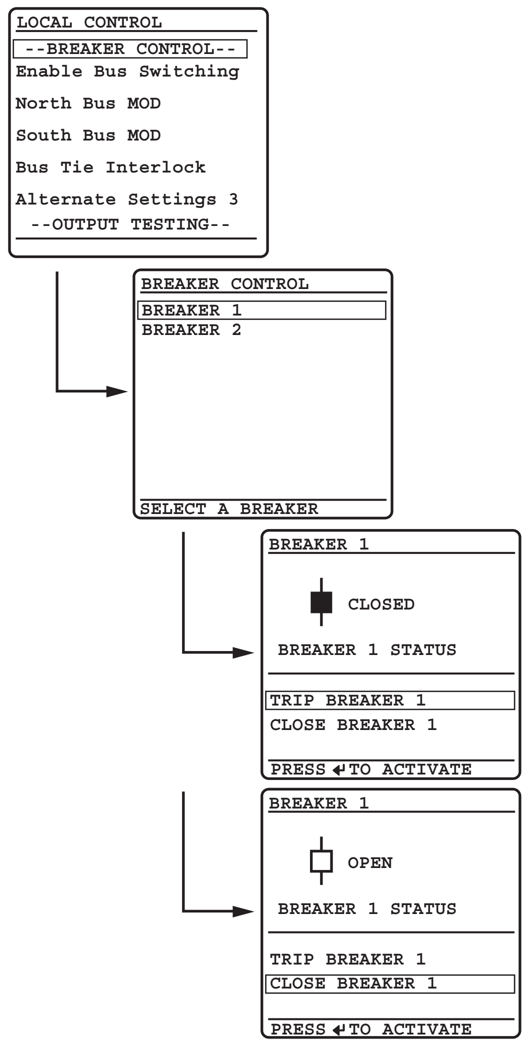

Figure 4.25 Example BREAKER CONTROL Screens

Local Control Bits

The relay provides 32 local control bits with SELOGIC control equation supervision. These local bits replace substation control handles to perform switching functions such as bus transfer switching. The relay saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power-up.

NOTE: The default settings for LB_SPnn are "1". The default settings satisfy the local bit supervision logic so that local bit operations can take place.

Local control bit supervision is available through a SELOGIC control equation provided in the Front Panel settings (LB_SP*nn*). For local bit operations to take place, the corresponding LB_SP*nn* must be asserted. *Table 4.8* defines the local bit SELOGIC settings available in the Front Panel settings class. *Figure 4.27* illustrates the logic that supervises all local bit operations (Set, Clear, Pulse).

NOTE: The default settings for LB_DP*nn* are LB*nn*. The default settings cause the local bit switch to move to the corresponding state of the local bit (asserted = 1, deasserted = 0).

The SELOGIC control equation local bit status (LB_DP*nn*) is provided to return the status of a device that is being controlled by the local bit. The LB_DP*nn* Relay Word bit drives the state of the graphical switch on the display (i.e., with LB_DP*nn* deasserted, the switch points to 0).

Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit state after you change the bit setting. Deleting a local bit sets that bit to the clear (logical 0) state.

In the top part of *Figure 4.26*, the following custom labeled functions are those controlled by local control bit operation.

- Enable Bus Switching
- North Bus MOD
- South bus MOD
- Bus Tie Interlock
- Alternate Settings 3

In addition, *Figure 4.26* gives an example of a custom-labeled function, Bus Tie Interlock. The LCD shows a graphic representation of a substation control handle. The LB_DP*nn* SELOGIC control equation determines the state of the switch position on the LCD. If the LB_DP*nn* Relay Word bit is deasserted, the graphic control handle points to 0; if the LB_DP*nn* Relay Word bit is asserted, the switch points to 1.

You can program names or aliases for the local bit clear and set states—these appear next to logical 0 and logical 1, respectively, in the lower portion of the sample Bus Tie Interlock screens of *Figure 4.26*. Use the **Up Arrow** and **Down Arrow** pushbuttons to highlight the set (1) or clear (0) control actions. Highlighting the set option (shown in *Figure 4.26* as `Closed (OK to TIE)`) and pressing **ENT** changes the local control bit and performs the required control action. If the LB_DP*nn* Relay Word bit asserts, the graphical switch moves to 1 to indicate the asserted local bit status.

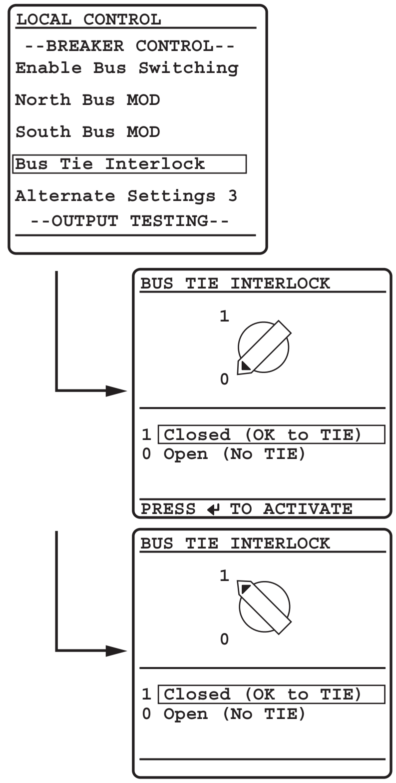

Figure 4.26 LOCAL CONTROL Example Menus

To enable a local bit, enter the local bit settings in *Table 4.7*. The format for entering the local bit data is the comma-delimited string:

> *local bit,control function name,alias for the set state,alias for the clear state,pulse enable*

Names or aliases can contain any printable ASCII character except double quotation marks. Use double quotation marks to enclose the name or alias. See *Example 4.4* for particular information on enabling a local control bit.

Table 4.7 Local Bit Control Settings[a]

Description	Range	Default
Local Bit *n*	1–32	1
Local Bit *n* Name	20-character maximum ASCII string	(blank)
Local Bit *n* Set Alias (1 state)	20-character maximum ASCII string	(blank)
Local Bit *n* Clear Alias (0 state)	20-character maximum ASCII string	(blank)
Pulse Local Bit *n*	Y, N	N

[a] *n* = 1–32.

The pulse state enable setting at the end of the setting string is optional. If your application requires a pulsed or momentary output, you can activate an output pulse by setting the option at the end of the local bit command string to Y (for Yes). The default for the pulse state is N (for No); if you do not specify Y, the local bit defaults at N and gives a continuous set or clear switch level.

If you enter an invalid setting, the relay displays an error message prompting you to correct your input. If you do not enter a valid local bit number, the relay displays A local bit element must be entered. If you enter a local bit number and that local bit is already in use, the relay displays The local bit element is already in use. Likewise, if you do not enter valid local bit name, set alias, and clear alias, the relay returns an error message. If an alias is too long, the relay displays the message `Too many characters`.

Table 4.8 Local Bit SELOGIC[a]

Description	Range	Default
Local Bit Supervision *n*	SELOGIC Equation, NA	1
Local Bit Status Display *n*	SELOGIC Equation, NA	LB*n*

[a] *n* = 1–32, and only available if the corresponding local bit is defined.

The Local Bit Supervision SELOGIC control equation provides supervision of Local Bit Set, Clear, and Pulse operations.

The Local Bit Status Display SELOGIC control equation returns the status of the local bit switch state.

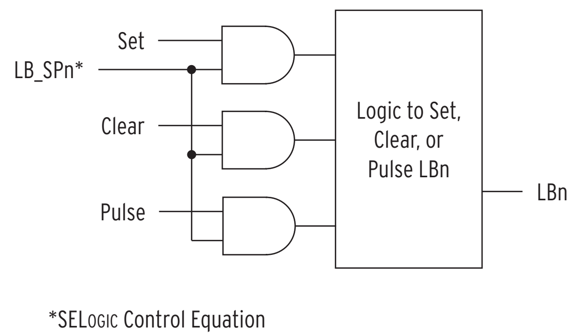

Figure 4.27 Local Bit Supervision Logic

Example 4.4 Enabling Local Bit Control

This application example demonstrates a method to create one of the control points in the `LOCAL CONTROL` screens of *Figure 4.26* to control the interlock on a power bus tie circuit breaker. Perform the following actions to create a local control bit:

- ➤ Eliminate previous usage of the local bit and condition the state of the local bit
- ➤ Set the local bit
- ➤ Assign the local bit to a relay output

If you are using a previously used local bit, delete all references to the local bit from the SELOGIC control equations already programmed in the relay. A good safety practice would be to disconnect any relay output that was programmed to that local bit.

Example 4.4 Enabling Local Bit Control (Continued)

To change the local bit state, select the bit and set it to the state you want. In addition, you can delete the local bit, which changes the state of this local bit to logical 0 when you save the settings. To delete, use the front-panel settings. When using a communications port and terminal, use the text-edit mode line setting editing commands at the Local Bits and Aliases prompt to go to the line that lists Local Bit 9. (See *Text-Edit Mode Line Editing on page 3.22* for information on text-edit mode line editing.) To delete Local Bit 9, type **DELETE <Enter>** after the line that displays Local Bit 9 information. For example, if a previously programmed Local Bit 9 appears in the **SET F** line numbered listings on Line 1, then typing **DELETE <Enter>** at Line 1 deletes Local Bit 9.

Next, set the local bit. In the Front Panel settings (SET F), enter the following:

1: **LB09,"Bus Tie Interlock","Closed (OK to TIE)","Open (No TIE)",N**

This sets Local Bit 9 to "Bus Tie Interlock" with the set state as "Closed (OK to TIE)" and the clear state as "Open (No TIE)."

Assign the local bit to a relay output. In the Output settings (**SET O**), set the SELOGIC control equation, OUT201, to respond to Local Bit 9.

OUT201 := **LB09**

Use the appropriate interface hardware to connect the circuit breaker interlock to OUT201.

Output Testing

NOTE: The circuit breaker control enable jumper BREAKER must be installed to perform output testing.

You can check for proper operation of the relay control outputs by using the `OUTPUT TESTING` submenu of the `LOCAL CONTROL` menu. A menu screen similar to *Figure 4.28* displays a list of the control outputs available in your relay configuration.

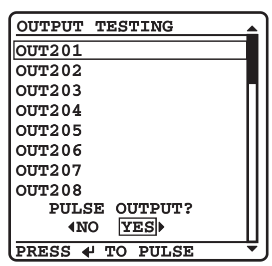

Figure 4.28 OUTPUT TESTING Screen

Set/Show

You can use the `SET/SHOW` menus to examine or modify relay port settings, Global settings, active group settings, and date/time. See *Table 4.9* for a list of settings classes and settings that you can change from the front panel.

Table 4.9 Settings Available From the Front Panel (Sheet 1 of 2)

Class/Setting	Description
PORT	Relay communications port settings
GLOBAL	Global relay settings
GROUP	Relay group settings

Table 4.9 Settings Available From the Front Panel (Sheet 2 of 2)

Class/Setting	Description
ACTIVE GROUP	Active settings group number 1–6
DATE/TIME	Date and time settings

Figure 4.29 shows an example of entering the SEL-451 setting CTRW (Terminal W CT ratio) from the front panel. At the MAIN MENU, select the SET/SHOW item and press **ENT**. The LCD screen displays the SET/SHOW screen as shown in *Figure 4.29*. You can use the navigation pushbuttons to select the relay settings class (PORT, GROUP, and GLOBAL) or to change the ACTIVE GROUP or the DATE/TIME. For this example, select the GROUP class.

Next, select the particular instance of the settings class. For the PORT settings class, the instances are PORT 1, PORT 2, PORT 3, PORT F, and PORT 5. For the GROUP class, the instances are the numbered groups from 1 through 6 and M, the breaker monitor (see the GROUP screen in *Figure 4.29*). The class GLOBAL, the setting ACTIVE GROUP = n (where *n* is a number from 1 to 6), and the settings for DATE/TIME have no settings instance screens. In the GROUP screen, move the highlight box to 3 and press **ENT**.

Proceed to selecting the settings category. The GROUP submenu in *Figure 4.29* is an example of settings Group 3 categories. Once you have highlighted the settings category, pressing **ENT** causes the relay to display the particular settings in that category. The LINE CONFIGURATION screen in *Figure 4.29* shows the settings that you can set in the line configuration settings category.

To edit or examine a setting, use the **Up Arrow** and **Down Arrow** pushbuttons to highlight that setting, then press **ENT**. The relay displays a settings entry screen with the existing setting value (see the SET CTRW screen in *Figure 4.29*). If the prompt for the selected setting does not fit on the line, the relay scrolls the setting prompt across the screen.

Enter the setting name using a method similar to the method described in *Relay Elements (Relay Word Bits) on page 4.19*. Place characters in the element name field (with the block cursor) using the navigation pushbuttons.

If the data you entered are valid (within settings range checks), the front-panel display returns to the settings category screen that shows each setting and corresponding present value (see the LINE CONFIGURATION screen of *Figure 4.29*). If the data you entered are invalid, the relay displays an error message screen, then returns to the particular settings entry screen so you can attempt a valid settings entry (see the CTRW screen of *Figure 4.29*).

When finished entering the new settings data, press **ESC**. The relay prompts you with a Save Settings screen. Using the navigation pushbuttons, answer YES to make the settings change(s), or NO to abort the settings change(s).

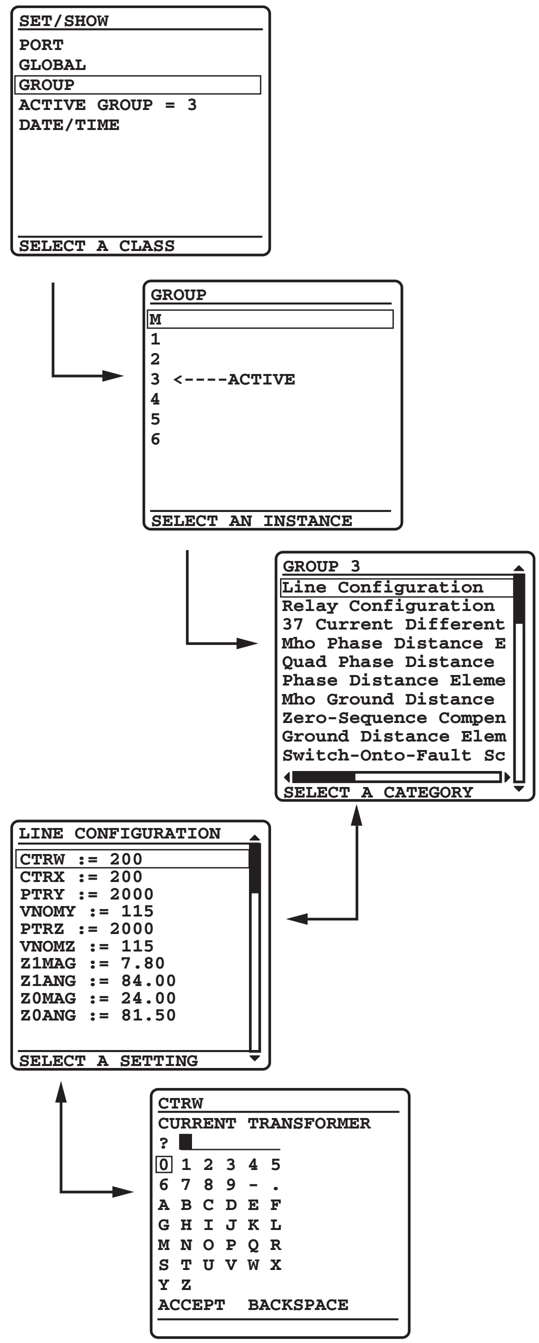

Figure 4.29 Example SET/SHOW Screens

The relay displays different settings entry screens depending on the settings type. For the CTRW setting in *Figure 4.29*, the relay requires basic alphanumeric input. Other settings can have other data input requirements. The front-panel settings input data types are the following:

- Basic alphanumeric
- Character or string or SELOGIC control equations
- Setting options

For alphanumeric settings, the relay presents the character or string input screen. Some settings have specific options; use the setting options screens to select these options. *Figure 4.30* shows examples of the settings input screens.

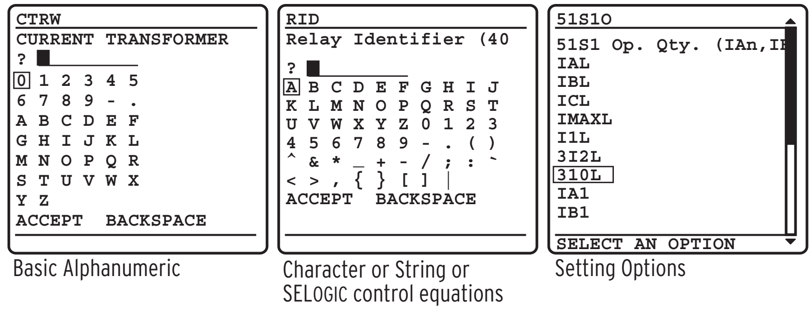

Figure 4.30 Sample Settings Input Screens

Active Group

Perform the following steps to change the active setting group:

Step 1. Select the `ACTIVE GROUP` option of the `SET/SHOW` submenu screen (shown in *Figure 4.29*) to change the settings group.

The relay performs a password validation test at this point to confirm that you have Breaker Access Level authorization or above.

Step 2. If access is allowed, and all the results of SELOGIC control equations SS1–SS6 are not logical 1 (asserted), then the relay displays the `EDIT ACTIVE GROUP` screen in *Figure 4.31*

The relay shows the active group and underlines the group number after `NEW GROUP =`.

Step 3. Use the **Up Arrow** and **Down Arrow** pushbuttons to increase or decrease the `NEW GROUP` number.

Step 4. Once you have selected the new active group, press **ENT** to change the relay settings to this new settings group.

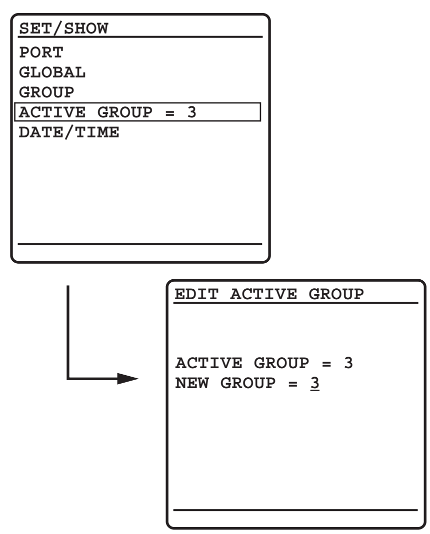

Figure 4.31 Changing the ACTIVE GROUP

Date/Time

Another submenu item of the `SET/SHOW` first screen (*Figure 4.29*) is the `DATE/TIME` screen shown in *Figure 4.32*. By default, the relay generates date and time information internally; you can also use external high-accuracy time modes with time sources such as a GPS receiver.

Figure 4.32 shows the relay date/time screen when a high-accuracy source is in use. Possible time sources, qqqqq, are listed in *Table 11.5 on page 11.8*. If you use a high-accuracy time source, edits are disabled, the DATE/TIME display does not show the highlight, and the screen does not show the help message on the bottom line.

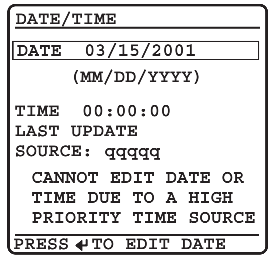

Figure 4.32 DATE/TIME Screen

When no external time source is connected, you can use the front-panel DATE and TIME entry screens to set the date and time.

Figure 4.33 shows an example of these edit screens. Use the **Left Arrow** and **Right Arrow** navigation pushbuttons to move the underscore cursor; use the **Up Arrow** and **Down Arrow** navigation pushbuttons to increment or decrement each date and time digit as appropriate to set the date and time. For a description of the LAST UPDATE SOURCE field, see *Configuring Timekeeping on page 3.75*.

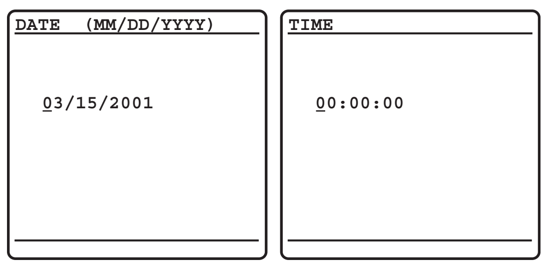

Figure 4.33 Edit DATE and Edit TIME Screens

To enable a high-accuracy external time source, connect an IRIG-B or PTP clock to the relay. For a discussion of the timing modes in the relay see *Section 11: Time and Date Management*.

Relay Status

The relay performs continuous hardware and software self-checking. If any vital system in the relay approaches a failure condition, the relay issues a status warning. If the relay detects a failure, the relay displays the status failure RELAY STATUS screen immediately on the LCD.

For both warning and failure conditions, the relay shows the error message for the system or function that caused the warning or failure condition. You can access the RELAY STATUS screen via the MAIN MENU. The RELAY STATUS screen shows the firmware identification number (FID), serial number, whether the relay is enabled, and any status warnings.

Figure 4.34 shows examples of a normal RELAY STATUS screen, a status warning RELAY STATUS screen, and a status failure RELAY STATUS screen. For more information on status warning and status failure messages, see *Relay Self-Tests on page 10.15*.

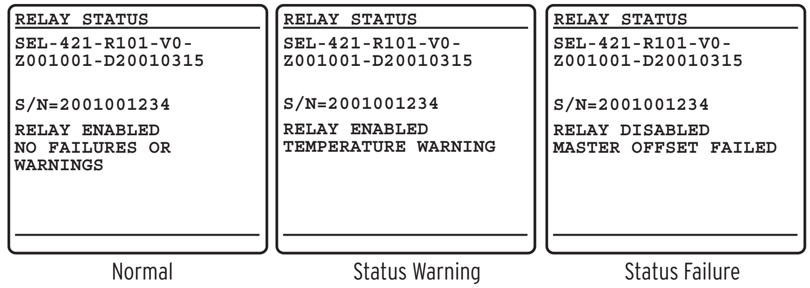

Figure 4.34 Relay STATUS Screens

View Configuration

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the relay. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. A series of screens will be presented describing the relay configuration. See the relay-specific instruction manual to see the specific information provided in that relay.

Display Test

You can use the DISPLAY TEST option of the MAIN MENU to confirm operation of all of the LCD pixels. The LCD screen alternates the on/off state of the display pixels once every time you press **ENT**. *Figure 4.35* shows the resulting two screens. The DISPLAY TEST option also illuminates all of the front-panel LEDs. To exit the test mode, press **ESC**.

NOTE: The LCD DISPLAY TEST does NOT reset the front-panel LED targets.

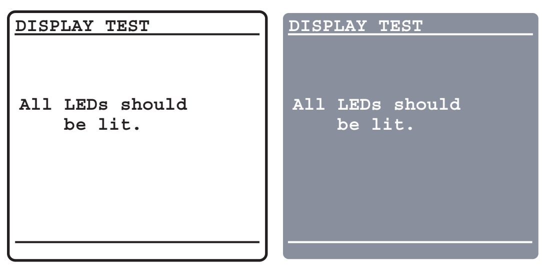

Figure 4.35 DISPLAY TEST Screens

Reset Access Level

The relay uses various passwords to control access to front-panel functions. As you progress through these menus, the relay detects the existing password level and prompts you for valid passwords before allowing you access to levels greater than Access Level 1 (see *Password on page 4.15*). When you want to return the front-panel to the lowest access level (Access Level 1), highlight RESET ACCESS LEVEL item on the MAIN MENU. Pressing **ENT** momentarily displays the screen of *Figure 4.36* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel time-out (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the time-out occurs.

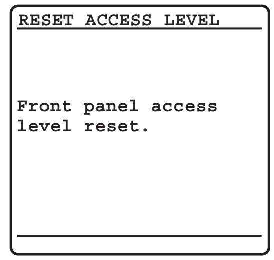

Figure 4.36 RESET ACCESS LEVEL Screen

One-Line Diagram

Most SEL-400 series relays support one-line diagrams on the front-panel LCD. The ONE-LINE DIAGRAM option from the front-panel MAIN MENU displays the one-line diagram that has been selected in the Bay settings class. From this screen, disconnect switch open and close operations, as well as breaker open and close operations can be performed. This screen also displays labels for the different apparatus in the bay configuration and Analog Quantity metering values. The one-line diagram, display labels, and Analog Quantities are settable in the Bay class settings. See *Figure 4.37* for an illustration of the one-line diagram.

For navigation and control operations in the one-line diagram screen, see *Bay Control Front-Panel Operations on page 5.12*.

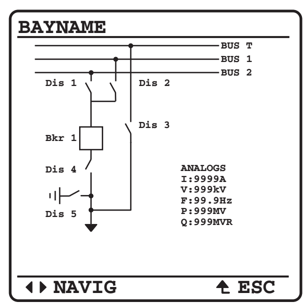

Figure 4.37 One-Line Diagram Screen

Front-Panel Automatic Messages

The relay automatically displays alert messages. Any message generated because of an alert condition takes precedence over the normal ROTATING DISPLAY and the MAIN MENU. Alert conditions include these significant events:

- Alarm Point asserts
- Event reports and trips (user-defined)
- Status warnings
- Status failures

To display event reports automatically from the ROTATING DISPLAY, you must set front-panel setting DISP_ER to Y. Front-panel setting TYPE_ER allows the user to define which types of event reports will be automatically displayed from the normal ROTATING DISPLAY; ALL will display all event types defined in the relay, and TRIP will display only the event types that include the assertion of the TRIP Relay Word bit.

For alarm point assertions, qualified event reports (including trip events) and status warnings, the relay displays the corresponding full-screen automatic message, only if the front-panel display is in the time-out or standby condition (the relay is scrolling through the default display points/enabled metering screens of the ROTATING DISPLAY or is displaying the MAIN MENU). When a status warning, alarm, or event is triggered, the relay full-screen presentation is similar to the screens of *Figure 4.38*.

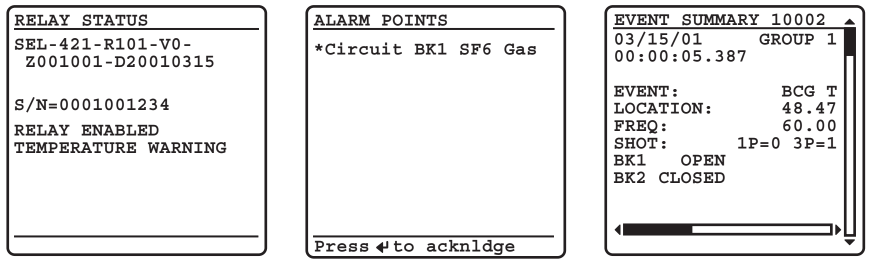

Figure 4.38 Sample Status Warning and Trip EVENT SUMMARY Screens

If you are on site using the relay front panel in menus and screens other than the MAIN MENU and a status warning occurs, an alarm point asserts, or an event report triggers, the relay shows automatic messages at the bottom of the active screen in the message area.

For example, the message area shows RELAY STATUS WARNING for a status warning. *Figure 4.39* is an example of a status warning notification that appears in the message area of a LOCAL CONTROL (local bit) screen. If an alarm point asserts while you are using a front-panel screen, the message area notification reads: ALARM EVENT. If a trip event occurs while you are using a front-panel screen, the message area notification reads RELAY EVENT. When you repeatedly press **ESC** (as if returning to the MAIN MENU) during this warning or trip alert situation, the relay displays the corresponding full-screen automatic message concerning the warning or trip in place of the MAIN MENU. If the front-panel display is at the MAIN MENU and a status warning occurs, the full-screen warning replaces the MAIN MENU. After you view the warning, alarm, or trip screen, pressing **ESC** returns the LCD to the MAIN MENU.

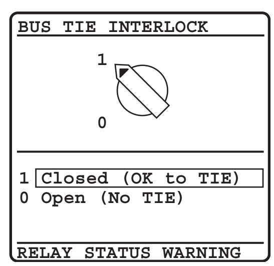

Figure 4.39 Sample Status Warning in the LCD Message Area

For a status failure, the relay immediately displays the full-screen status alert regardless of the present front-panel operating state. The relay displays no further LCD screens until the status failure clears. Should an unlikely status failure event occur, contact your local Technical Service Center or an SEL factory representative (see *Technical Support on page 10.31*).

Operation and Target LEDs

The relay gives you at-a-glance confirmation of relay conditions via operation and target LEDs. These LEDs are located in the middle of the relay front panel. SEL-400 series relays provide either 16 or 24 LEDs depending on ordering option.

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory-default programming described in this subsection. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED (*n* = 1–24). LED positions are described in parentheses next to each LED in *Figure 4.40*.

Set T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. The relay reports these targets in event reports; set the alias name listed in the report (as many as seven characters) by aliasing the T*n*_LED bits with the **SET T** command or with QuickSet. In 12-pushbutton models, the asserted and deasserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off. In some SEL-400 series relays, if T*n*LEDL = Y, the relay latches the target on the rising edge of the target bit. In these relays, to cause the bits to latch with trip, modify the equation to include AND R_TRIG TRIP. Refer to the *Target LEDs* subsection in the relay-specific *Front-Panel Operations* section to determine if the LED latches with the rising edge of TRIP or on the rising edge of T*n*_LED.

After setting the target LEDs, issue the **TAR R** command to reset the target LEDs. For a description of the default LED behavior for a specific relay, see the *Front Panel Operations* section in the relay-specific instruction manual.

Use the slide-in labels to mark the LEDs with custom names. Configurable label templates included on relay-specific Product Literature CDs allow you to customize the front-panel labels.

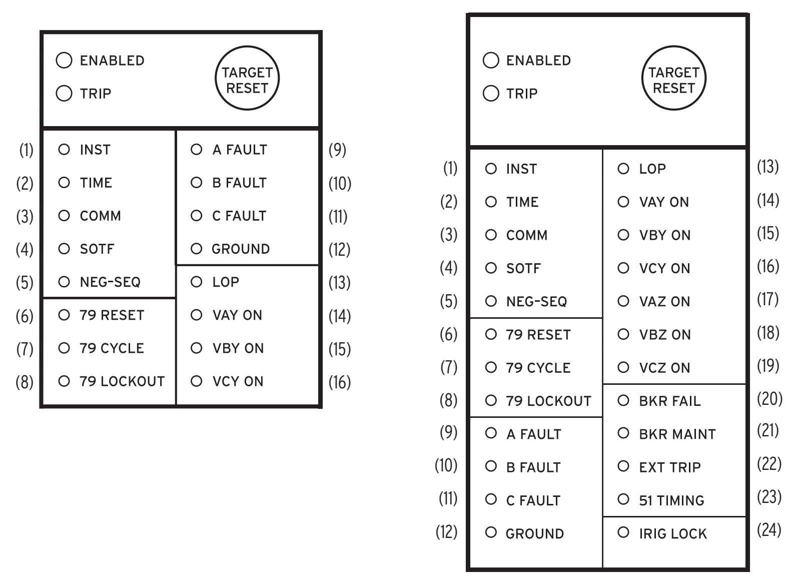

Figure 4.40 SEL-451 Factory-Default Front-Panel Target Areas (16 or 24 LEDs)

Operational

The ENABLED LED indicates that the relay is active. Trip events illuminate the TRIP LED. The prominent location of the TRIP LED in the top target area helps you recognize a trip event quickly. Program settings EN_LEDC and TR_LEDC to determine the color of the respective LED. Options include red or green.

TARGET RESET and Lamp Test

For a trip event, the relay latches the trip-involved target LEDs. Press the TARGET RESET pushbutton to reset the latched target LEDs. When a new trip event occurs and you have not reset the previously latched trip targets, the relay clears the latched targets and displays the new trip targets.

Pressing the TARGET RESET pushbutton illuminates all the LEDs. Upon releasing the TARGET RESET pushbutton, two possible trip situations can exist: the conditions that caused the relay to trip have cleared, or the trip conditions remain present at the relay inputs. If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The TARGET RESET pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Lamp Test Function With TARGET RESET

The TARGET RESET pushbutton also provides a front-panel lamp test. Pressing TARGET RESET illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as you press TARGET RESET. The target LEDs return to a normal operational state after you release the TARGET RESET pushbutton.

Other Target Reset Options

You can reset the target LEDs with the ASCII command **TAR R**; see *TARGET on page 14.53* for more information.

The **TAR R** command and the TARGET RESET pushbutton also control the TRGTR Relay Word bit, which can be used for other functions. TRGTR is the factory-default setting for the unlatch trip SELOGIC control equation, ULTR, in group settings.

You can reset the targets from the QuickSet **Control** branch of the HMI tree view. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method to reset the relay targets. Access RSTTRGT in the relay Global settings (**Data Reset Control**); to use RSTTRGT, you must enable data reset control with Global setting EDRSTC := Y.

Front-Panel Operator Control Pushbuttons

The relay front panel features large operator control pushbuttons coupled with amber annunciator LEDs for local control. *Figure 4.41* shows this region of the relay front panel with example factory-default configurable front-panel label text. SEL-400 series relays provide either 8 or 12 pushbuttons depending on the product and ordering option.

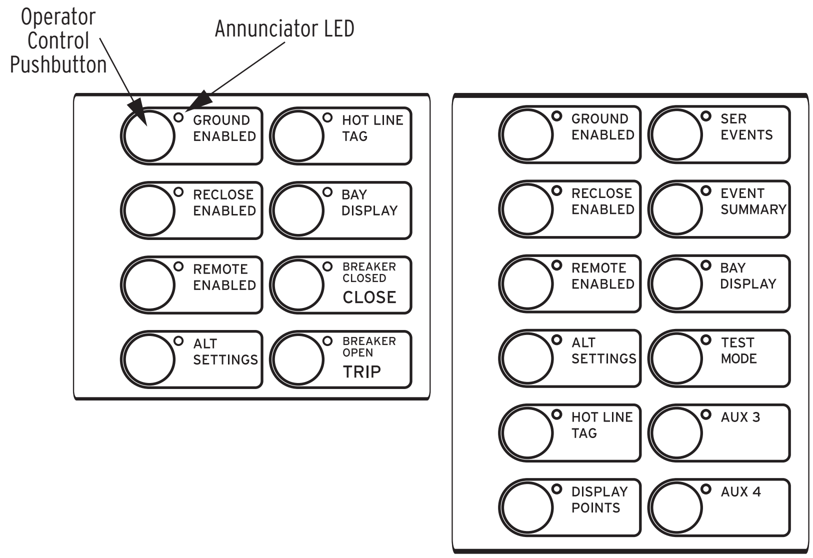

Figure 4.41 SEL-451 Default Operator Control Pushbuttons and LEDs (8 or 12 Pushbuttons)

See *Section 4: Front-Panel Operations* of the product-specific instruction manual for a description of the default configuration of operator control pushbuttons and LEDs.

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SECTION 5

Control

SEL-400 series relays provide many control features, including circuit breaker controls, disconnect controls, remote bit controls, and bay control. This section describes these control capabilities.

See the specific relay instruction manuals to see how many breakers, disconnects, and remote bits are available and to determine whether or not bay control is supported.

Circuit Breaker Status and Control

SEL-400 series relays include circuit breaker status logic for all supported circuit breakers. The circuit breaker status logic uses the 52A_*k* setting (SELOGIC equation) and open-phase detection logic to determine the state of Circuit Breaker *k*, and declare Circuit Breaker *k* alarm conditions. See *Section 5: Protection* of the product-specific instruction manual for a description of circuit breaker status logic Relay Word bits and circuit breaker status logic diagrams.

SEL-400 series relays support opening and closing breakers. These operations can be controlled via the terminal commands **OPEN** and **CLOSE**, the binary terminal Fast Operate messages, various supported communications protocols, the front-panel menus, and through the bay control one-line screens. These controls operate the open control (OC*k*) and close control (CC*k*) bits. These bits are used in the relay trip and close logic to integrate these external controls with the relay automatic trip and close behavior. See *Section 6: Protection Application Examples* in the product-specific instruction manual for more information on the trip and close logic.

Disconnect Logic

Disconnect Switch Close and Open Control Logic

Figure 5.1 and *Figure 5.2* shows the Disconnect Logic that generates open and close output signals necessary to perform the open and close disconnect operations. Use the seal-in timers (89CST*m* and 89OST*m*) to monitor and control disconnect operations. All disconnect control methods (HMI, ASCII, SELOGIC control equations, and Fast Operate) drive the Close and Open Control Logic in the relay.

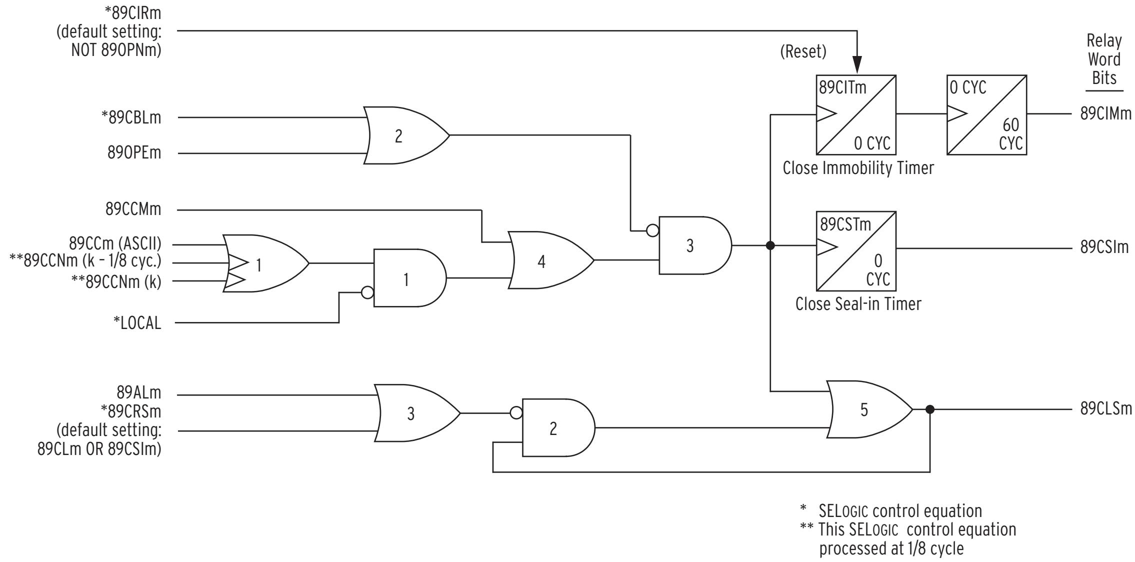


Figure 5.1 Disconnect Switch Close Logic

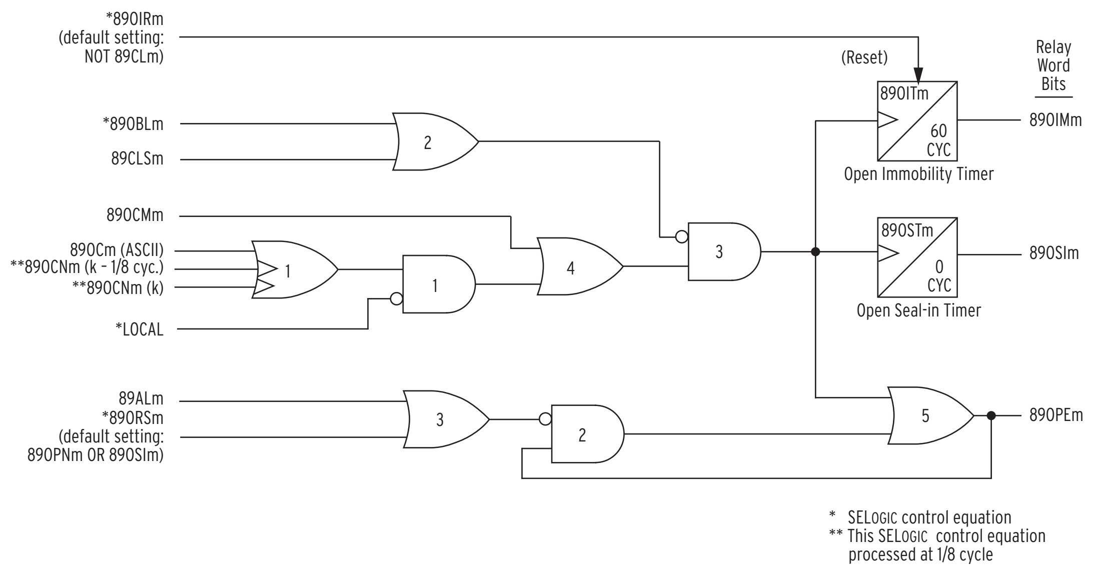


Figure 5.2 Disconnect Switch Open Logic

Disconnect Switch Close and Open Control Logic Status Inputs

89CLS*m*, 89OPE*m*

Disconnect Switch Close Logic (*Figure 5.1*) and Open Logic (*Figure 5.2*) generate Relay Word bits 89CLS*m* and 89OPE*m* which drive the open and close operations. To ensure that an open and close disconnect signal cannot occur at the same time, 89CLS*m* and 89OPE*m* also block operation of the opposing logic. Therefore, Relay Word bit 89CLS*m* is an input to the Disconnect Open Logic, and Relay Word bit 89OPE*m* is an input to the Disconnect Close Logic.

89CBL*m*, 89OBL*m*

The 89CBL*m* and 89OBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CRS*m*, 89ORS*m*

The 89CRS*m* and 89ORS*m* SELOGIC control equations provide the flexibility to select the signals that reset the close (89CLS*m*) or open (89OPE*m*) outputs. 89CRS*m* defaults to (89CL*m* OR 89CSI*m*), and 89ORS*m* defaults to (89OPN*m* OR 89OSI*m*).

89CSI*m*, 89OSI*m*

Set 89CST*m* and 89OST*m* to seal in the open and close signals for each individual installation. Relay Word bits 89CSI*m* and 89OSI*m* are the outputs of the close and open seal-in timers, and assert after the appropriate timers expire. By default, 89CSI*m* and 89OSI*m* are used in the 89CRS*m* and 89ORS*m* SELOGIC control equations to reset the close and open signals, 89CLS*m* and 89OPE*m*, that drive the disconnect switch motor.

89CL*m*, 89OPN*m*

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; if the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 5.3* for a description of these inputs. With the default settings, when Relay Word bit 89CL*m* asserts, the close seal-in circuit is blocked, causing 89CLS*m* to deassert. Likewise, with the default settings, when Relay Word bit 89OPN*m* asserts, the open seal-in circuit is blocked, causing 89OPE*m* to deassert.

89AL*m*

The disconnect switch status and alarm logic in *Figure 5.3* generates the 89ALm Relay Word bit. When Relay Word bit 89ALm asserts, it resets the seal-in circuits, deasserting the 89CLS*m*/89OPE*m* signals.

LOCAL

The LOCAL Relay Word bit asserts when LOCAL SELOGIC control equation asserts to a logical 1. When the LOCAL Relay Word bit asserts, only the HMI commands (89CCM*m* and 89OCM*m*), can initiate close and open operations. When the LOCAL Relay Word bit is deasserted, the 89CLOSE, 89OPEN, SELOGIC disconnect close/open, and Fast Operate disconnect close/open commands can perform disconnect close and open operations. The default value for this setting is NA.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCN*m*, 89OCN*m*

89CCN*m* and 89OCN*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the close or open SELOGIC equations to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CCM*m*, 89OCM*m*

89CCM*m* and 89OCM*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are initiated from the one-line diagram on the front-panel screen. If the LOCAL Relay Word bit is not asserted, then Relay Word bits 89CCM*m* or 89OCM*m* cannot assert.

89CC*m*, 89OC*m*

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Seal-In Timer Settings

89CST*m*, 89OST*m*

89CST*m* and 89OST*m* settings are for defining the time required for the disconnect switch to complete a close or open operation.

Disconnect Switch Close and Open Control Logic Output

89CLS*m*, 89OPE*m*

The 89CLS*m* and 89OPE*m* Relay Word bits are used in SELOGIC output equations to perform close and open disconnect switch operations.

Disconnect Switch Close and Open Control Logic Processing

Figure 5.1 shows the Disconnect Switch Close Logic and *Figure 5.2* shows the Disconnect Switch Open Logic.

Some motor-operated disconnect switches have their own seal-in circuits to seal the closing and opening signals in. Other motor-operated disconnect switches, however, require external sealed-in circuits to maintain the closing and opening signals for the duration of the disconnect operation.

⚠CAUTION
The outputs in the relay are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the relay opens. Failure to observe this safeguard could result in damage to the relay output contacts.

With SELOGIC equations 89CRS*m* and 89ORS*m* set to the default settings (include Relay Word bits 89CSI*m* and 89OSI*m*), the open and close signals remain asserted for the time settings of the Close and Open Seal-In Timers, 89CST*m* and 89OST*m*.

If the 89OBL*m* SELOGIC control equation and the 89OPE*m* and the LOCAL Relay Word bits are deasserted, then any of the relay close disconnect operate methods can assert Relay Word bit 89CLS*m*, and initiate the Close Seal-In Timer, 89CST*m*. Enter Relay Word bit 89CLS*m* into a SELOGIC output equation to drive the motor of the disconnect.

Set the Close Seal-In Timer, 89CST*m*, long enough to keep Relay Word bit 89CLS*m* asserted long enough to complete the disconnect operation.

To account for slow operate times because of cold weather or low battery voltage, set the 89CST*m* time 10 to 15 percent longer than the expected operate time. This guarantees that the disconnect switch has fully operated before the 89CLS*m* signal is removed. When the 89CST*m* seal-in timer expires, 89CSI*m* asserts, or the disconnect switch normally open contact closes (89CL*m* asserted), the 89CLS*m* output deasserts. This completes an open-to-close cycle of the Disconnect Close Logic; the Disconnect Open Logic in *Figure 5.2* behaves in the same manner.

Disconnect switch status and alarm logic in *Figure 5.3* generates Relay Word bit 89AL*m*. When Relay Word bit 89ALm asserts, a disconnect alarm condition exists. The 89AL*m* Relay Word bit ensures that the close or open signal does not remain asserted when a disconnect switch alarm condition exists. When Relay Word bit 89AL*m* asserts or the seal-in timer expires, the 89CLS*m* or 89OPE*m* signals deassert.

When a close operation is inadvertently initiated with the disconnect switch already closed, and the 89CRS*m* SELOGIC control equation is set as defaulted (89CL*m* OR 89CSI*m*), the asserted 89CL*m* Relay Word bit (close status) will block the seal-in circuit before the timer expires. This will deassert the 89CLS*m* Relay Word bit, which drives the disconnect switch motor. In this way, 89CLS*m* asserts for only one processing interval.

If an open command was sent within the 89CSI*m* time, an open and close signal could be sent to the disconnect switch at the same time. The 89CLS*m* Relay Word bit input to the Disconnect Switch Open Logic guarantees that open and close commands are not transmitted to the disconnect switch simultaneously. When the 89CLS*m* Relay Word bit deasserts, an open command can be performed. The 89OBL*m* SELOGIC control equation provides an additional customizable method for blocking the initiation of a close command. The Relay Word bit 89OPE*m*, and 89CBL*m* inputs to the Disconnect Switch Close Logic serves the same purpose.

Disconnect Switch Status and Alarm Logic

The disconnect switch auxiliary contacts are inputs to the Disconnect Switch Status and Alarm Logic as shown in *Figure 5.3*. SELOGIC control equation 89AM*m* is the input for the normally open an auxiliary contact, and SELOGIC control equation 89BM*m* is the input for the normally closed Form B auxiliary contact. For the Status and Alarm Logic to function correctly, wire the Form A and Form B contacts each to separate inputs on the relay. When ordering a relay, consider the number of inputs required for the disconnects being controlled. The number of auxiliary contacts for some systems may require that the relay be configured with additional I/O boards.

Disconnect operations are possible with only one auxiliary contact input, but with this implementation the Status and Alarm Logic will not provide accurate Alarm, Operation in Progress, or Bus-zone protection reporting. When only one auxiliary contact is available for input, set one SELOGIC control equation to the available auxiliary contact input and invert the other SELOGIC control equation:

89AM*m* := **IN102**

89BM*m* := **NOT IN102**

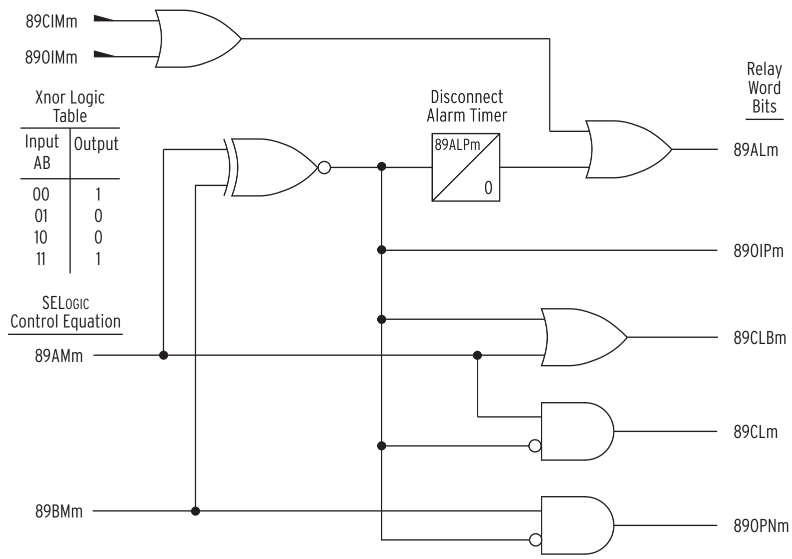


Figure 5.3 Disconnect Switch Status and Alarm Logic

Disconnect Switch Status and Alarm Logic Inputs

89AM*m*, 89BM*m*

The 89AM*m* and 89BM*m* SELOGIC control equations represent the normally open and normally closed disconnect switch auxiliary contacts. Typically, these are set to relay inputs that are wired to the auxiliary contacts.

89CIM*m*, 89OIM*m*

Input 89CIM*m* asserts for expiration of the close immobility timer, while input 89OIM*m* asserts for expiration of the open immobility timer. Timer expiration indicates one of two conditions. The first is that an open-to-close operation of the disconnect switch failed to move the switch enough to open the normally closed auxiliary contact 89BM*m*. The second is that a close-to-open operation of the disconnect switch failed to move the switch sufficiently to open the normally open auxiliary contact 89AM*m*.

Disconnect Switch Status and Alarm Logic Settings

89ALP*m*

This setting in the Bay settings class defines the disconnect switch alarm time.

Disconnect Switch Status and Alarm Logic Outputs

89AL*m*

If a disconnect switch operation initiated from the front panel does not complete, the 89ALP*m* timer expires and the 89AL*m* Relay Word bit asserts. Expiration of the 89ALP*m* timer indicates that an initiated disconnect operation failed to complete and the disconnect switch is in an undetermined state. In addition, the 89CST*m* or 89OST*m* timer also expires to deassert the output signal (89CLS*m* or 89OPE*m*), thus ensuring that there is not a constant signal applied to the disconnect.

89OIP*m*

When Relay Word bit 89OIP*m* asserts, a disconnect switch operation is in progress. Relay Word bit 89OIP asserts when the states of the 89BM*m* and 89AM*m* Relay Word bits are the same, i.e., both asserted or both deasserted.

89CLB*m*

This Relay Word bit is used for bus-zone protection and asserts when the disconnect is no longer open (89BM*m* deasserted).

89CL*m*

When Relay Word bit 89CL*m* asserts, the disconnect switch is closed.

89OPN*m*

When Relay Word bit 89OPN*m* asserts, the disconnect switch is open.

Disconnect Switch Status and Alarm Logic Processing

Figure 5.3 shows the Disconnect Switch Status and Alarm Logic. Inputs to this logic are the normally open (89AM*m*) and normally closed (89BM*m*) disconnect switch auxiliary contacts.

To understand the logic in *Figure 5.3*, consider an open-to-close operation. The first disconnect operation scenario looks at a successful open-to-close disconnect switch operation; a successful close-to-open operation is similar. In the open state, 89AM*m* is deasserted and 89BM*m* is asserted. Once a close command is initiated in the relay, the disconnect switch starts to move and 89BM*m* deasserts. When 89BM*m* deasserts, the 89ALP*m* pickup timer starts to time. With 89BM*m* deasserted, the state of the disconnect switch cannot be determined, because both disconnect switch auxiliary contacts are deasserted. Set the 89ALP*m* timer longer than the expected undetermined disconnect state time, but less than the 89CST*m* or 89OST*m* seal-in timers. If the 89ALP*m* timer expires, the 89AL*m* Relay Word bit asserts. Relay Word bit 89AL*m* asserts when the disconnect operation does not complete successfully. When the 89ALP*m* timer begins timing, the operation in progress, Relay Word bit 89OIP*m*, and Relay Word bit 89CLB*m* assert. The 89CLB*m* Relay Word bit is for bus-zone protection, this bit asserts when the 89BM*m* input deasserts.

During the disconnect switch operation-in-progress condition, Relay Word bits 89CL*m* and 89OPN*m* are both deasserted because the state of the disconnect switch is undetermined. Once the disconnect switch auxiliary contact Relay Word bit 89AM*m* asserts, the condition has been met to declare the disconnect switch closed. When 89AM*m* asserts, the 89CL*m* Relay Word bit asserts, 89ALP*m* stops timing, Relay Word bit 89OIP*m* deasserts, and Relay Word bit 89CLB*m* remains asserted. This sequence completes a successful open-to-close disconnect switch operation.

The second disconnect operation scenario is for an unsuccessful open-to-close operation, which, until 89ALP*m* starts timing, is identical to the successful operation in the previously discussed first scenario.

During operation of the 89ALP*m* timer, the disconnect switch begins moving. The close disconnect switch output signal 89CLS*m* clears upon expiration of the 89CST*m* seal-in timer. The logic then provides the disconnect switch additional time to complete the close operation, in case some inertia from the motor rotor keeps the disconnect motor in motion. By setting the 89ALP*m* timer longer than the 89CST*m* seal-in timer, you can ensure retention of the close signal until the disconnect switch closes completely. If there is no complete disconnect switch operation during the time 89ALP*m* defines, the relay asserts Relay Word bit 89AL*m* and reports that the disconnect switch is in an undetermined state.

The scenario in which both 89AM*m* and 89BM*m* are asserted simultaneously would occur on a rare disconnect switch failure or a short-circuited auxiliary contact wire connection. When this condition occurs for 89ALP*m* seconds, the 89AL*m* alarm status output will assert.

Disconnect Switch Close and Open Immobility Timer Logic

The Close and Open Immobility Timer Logic detects when a disconnect operation failed to initiate.

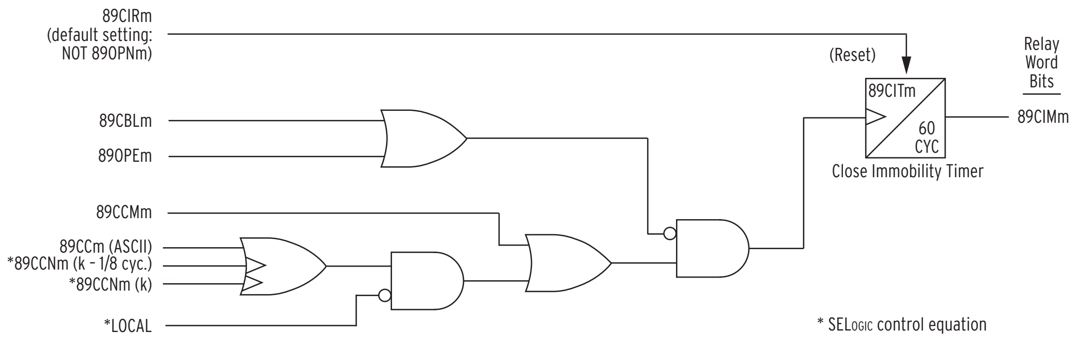


Figure 5.4 Close Immobility Timer Logic

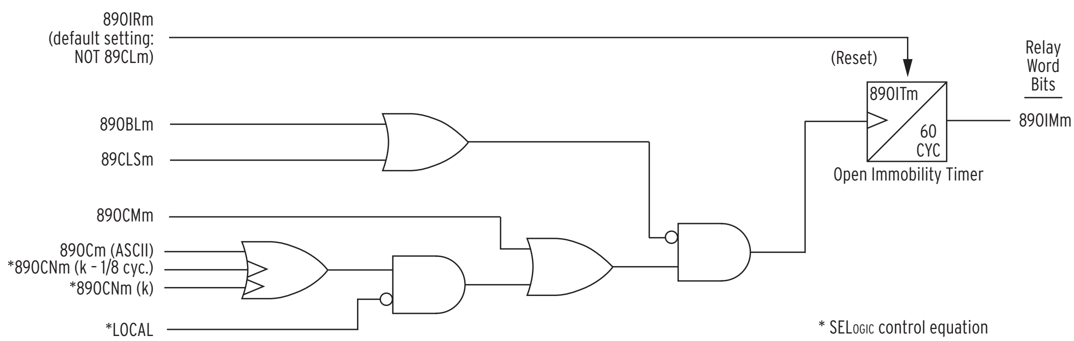


Figure 5.5 Open Immobility Timer Logic

Close and Open Immobility Timer Logic Inputs

LOCAL

The LOCAL Relay Word bit supervises local disconnect control and is based on the LOCAL SELOGIC control equation in the Bay settings class. Disconnect switch operations from the front panel are possible when the LOCAL Relay Word bit is asserted, in other words, the LOCAL Relay Word bit prevents control from the HMI without proper supervision.

89CBL*m*, 89OBL*m*

The 89CBL*m* and 89OBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CIR*m*, 89OIR*m*

The 89CIR*m* and 89OIR*m* SELOGIC control equations provide the flexibility to customize resetting the Close and Open Immobility Timers. By default, 89CIR*m* is set to NOT 89OPN*m*, and 89OIR*m* is set to NOT 89CL*m*.

89CL*m*, 89OPN*m*

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; if the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 5.3* for a description of these inputs.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCN*m*, 89OCN*m*

89CCN*m* and 89OCN*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the SELOGIC close or open to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CCM*m*, 89OCM*m*

89CCM*m* and 89OCM*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are executed from the one-line diagram on the front-panel screen. The LOCAL Relay Word bit must be asserted, for Relay Word bits 89CCM*m* or 89OCM*m* to assert.

89CC*m*, 89OC*m*

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Switch Close and Open Immobility Timer Logic Settings

89CIT*m*, 89OIT*m*

89CIT*m* and 89OIT*m* timer settings in the Bay settings class define the close and open immobility timers.

Disconnect Switch Close and Open Immobility Timer Logic Outputs

89CIM*m*, 89OIM*m*

When 89CIM*m* or 89OIM*m* asserts, the close or open immobility timer has expired.

Disconnect Switch Close and Open Immobility Timer Logic Processing

The Close and the Open Immobility Timer Logic detect when one of the close or open disconnect switch methods does not initiate successfully. In other words, it reports when the disconnect switch failed to start moving. The open and close immobility timer logic circuits are similar. When a close operation is initiated, the rising-edge-triggered Close Immobility Timer starts timing. Once the disconnect switch starts to move away from its open position, Relay Word bit 89OPN*m* deasserts (see *Figure 5.3*). If the 89OPN*m* Relay Word bit deasserts, the close immobility timer resets and 89CIM*m* remains deasserted. On the other hand, if the 89OPN*m* Relay Word bit stays asserted, the close immobility timer does not reset. After the close immobility timer expires, 89CIM*m* asserts for one second. When 89CIM*m* asserts, the close operation is considered to have failed to initiate. 89CIM*m* is an input to the disconnect switch status and alarm logic for alarm condition indications.

This logic also uses the LOCAL Relay Word bit to supervise front-panel operations. With the LOCAL Relay Word bit deasserted, no disconnect operations can be initiated from the one-line diagram. With the LOCAL Relay Word bit asserted, Relay Word bit 89CCM*m* asserts for one-quarter cycle when the **ENT** pushbutton is pressed and a disconnect switch is highlighted in the one-line diagram.

Close, Open, and Undetermined State Indications

This subsection discusses the way the close and open immobility timers work in conjunction with the disconnect alarm timer to provide disconnect control and alarm indications. When the disconnect switch main contact is stationary (closed or open) the state of the disconnect switch is easily determined.

If the disconnect switch main contact is open:

- normally closed Form B auxiliary contact (89BM*m* asserted) is closed
- normally open Form A auxiliary contact (89AM*m* deasserted) is open

If the disconnect switch main contact is closed:

- normally closed Form B auxiliary contact (89BM*m* deasserted) is open
- normally open Form A auxiliary contact (89AM*m* asserted) is closed

If an operation of the disconnect switch is in progress, the state of the disconnect switch main contact is undetermined:

- normally closed Form B auxiliary contact (89BM*m* deasserted) is open
- normally open Form A auxiliary contact (89AM*m* deasserted) is open

Any undetermined state of the disconnect switch main contact should be monitored. The relay can be configured to wait for the disconnect switch operation to complete, and issue an alarm if the disconnect switch remains in the undetermined state longer than the 89ALP*m* time. *Figure 5.6* illustrates how the state of the auxiliary contacts change for an open-to-close operation in progress and how the 89CST*m*, 89CIT*m*, and 89ALP*m* timers are configured to manage the undetermined time. The close-to-open scenario would be similar.

With the disconnect switch in the open state, the normally closed Form B auxiliary contact is closed (89BM*m* asserted) and the normally open Form A auxiliary contact is open (89AM*m* deasserted). The 89CST*m* seal-in timer starts timing when a disconnect switch close command is issued. The output of the 89CST*m* seal-in timer keeps the close signal asserted for the duration of the expected disconnect switch operate time. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time, to allow for slow disconnect operation times caused by cold temperatures or low battery voltages.

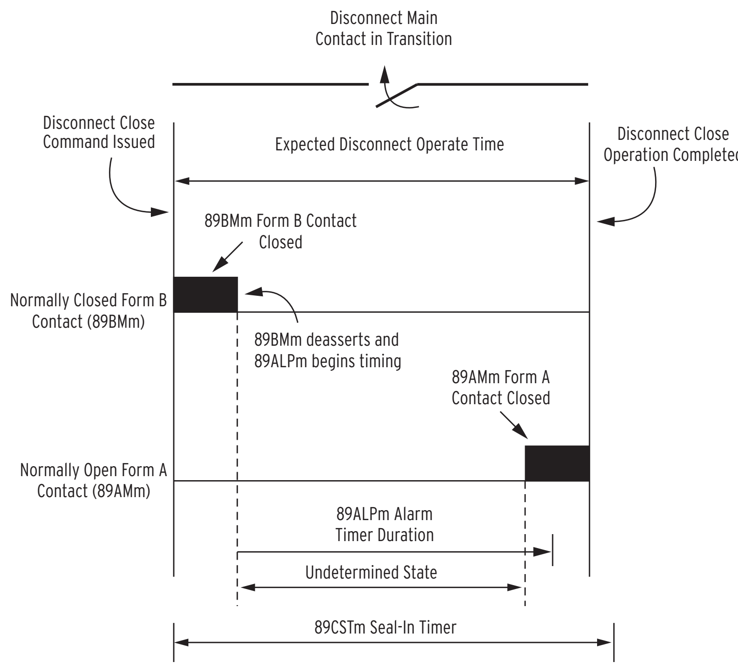


Figure 5.6 Disconnect in Transition

When the normally closed auxiliary contact (SELOGIC input 89BM*m*) deasserts, the disconnect switch is in an undetermined state. No proper position indication from either of the disconnect switch auxiliary contacts (89BM*m* or 89AM*m*) is available. Once the auxiliary normally closed contact (SELOGIC input 89BM*m*) deasserts, the 89ALP*m* timer starts timing. The 89ALP*m* timer monitors the undetermined state of the disconnect switch. For the 89ALP*m* timer to initialize, the disconnect switch has to move a minimum distance to open the normally closed auxiliary contact (open-to-close operation). Set the 89ALP*m* timer longer than the expected undetermined state time, but less than the 89CST*m* seal-in timer. If the normally open auxiliary contact fails to close within the undetermined state time, the 89ALP*m* timer expires and an alarm condition is declared.

The Close Immobility Logic starts the Close Immobility Timer for an operation where the disconnect switch does not move the minimum distance to open the normally closed auxiliary contact (open-to-close operation). When the close immobility timer expires, an alarm condition is declared and Relay Word bit 89AL*m* asserts. If the disconnect moves enough to open the normally closed auxiliary contact, the Close Immobility timer resets and no alarm condition is declared (see *Figure 5.4*).

Remote Bits

Remote bits provide a means for sending remote control commands to relay logic. As indicated in *CONTROL nn on page 14.16*, remote bits have three operating states: clear, set, and pulse. It is important to understand the differences between the use of pulsed remote bits in automation and protection SELOGIC control equations. Remote bits can be operated from multiple communications interfaces, including the **CON** command from a terminal (serial or Telnet), Fast Operate messages, and DNP3.

A pulsed remote bit will assert the respective remote bit Relay Word bit (RB*nn*, *nn* = 01–32) for one processing interval (1/8 of a power system cycle). When used in Protection SELOGIC, which also executes at one processing interval, pulsed remote bits provide a momentary means for operating a variety of logic functions, including Protection Latches, Boolean logic expressions, and Protection Logic Counters. Because the pulsed remote bit and Protection processing both operate within the same processing interval, the use of pulsed remote bits is reliable and deterministic.

To provide reliable detection of pulsed remote bits that assert for one protection logic processing interval within automation logic, conditioning is applied to the remote bit to extend the momentary assertion through the automation processing interval. This conditioning ensures the reliable detection of remote bit (RB01–RB32) assertion in automation logic. Remote bits that assert and deassert multiple times within the same automation logic processing interval will be processed as asserting continuously for the entire automation logic processing interval.

Bay Control Front-Panel Operations

Each relay has a default one-line diagram. Sometimes these diagrams fit on a single screen and sometimes they require more than one screen that you can pan across. For example, *Figure 5.7* shows the default one-line diagram for the SEL-487E. You can display either of two parts of the diagram by using the **Up Arrow** and **Down Arrow** pushbuttons to pan between an upper screen and a lower screen. The upper screen shows the HV equipment and transformer, while the lower screen shows the transformer and LV equipment. The relay displays the upper screen by default.

NOTE: Not all SEL-400 series relays support bay control operations.

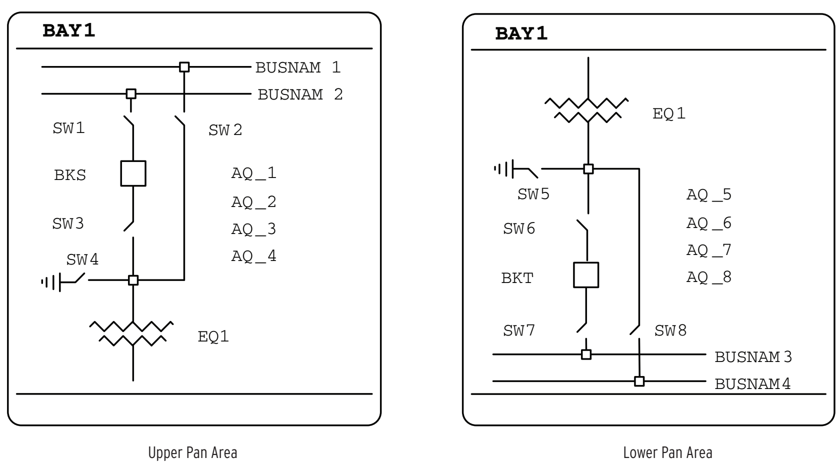


Figure 5.7 SEL-487E Default One-Line Diagram

One-Line Diagram and Labels

Figure 5.8 is an example of a default one-line diagram. The Bay settings class has settings for defining labels and analog quantities. One-line diagrams are comprised of the following:

- ➤ Bay Names and Bay Labels
- ➤ Busbars and Busbar Labels
- ➤ Breakers and Breaker Labels
- ➤ Disconnect Switches and Disconnect Switch Labels
- ➤ Equipment and Equipment Labels
- ➤ Analog Display Points

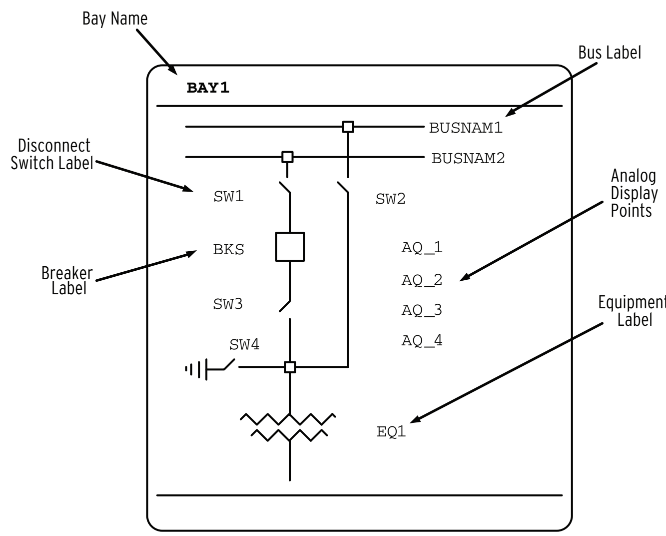


Figure 5.8 Bay Control One-Line Diagram

Front-Panel Pushbutton Navigation Operations in the One-Line Diagram

Navigation within the one-line diagram requires that the front-panel access level be at Breaker Access Level or higher and the Breaker Jumper be installed. If navigation is attempted when:

- ➤ The front panel is not at the Breaker Access Level or higher and passwords are enabled, the relay prompts you to enter the appropriate passwords.
- ➤ The Breaker Jumper is not installed, the `Breaker Control Disabled Please Install the Breaker Jumper` message briefly appears on the screen.

Use the arrow pushbuttons on the front panel to navigate within the one-line diagram. When you first select the one-line diagram, none of the apparatus on the one-line diagram are highlighted. Press the **Left Arrow** or **Right Arrow** pushbutton to enter the one-line diagram and highlight the apparatus. Once you enter the one-line diagram, navigation between the disconnect switch and circuit breaker symbols as follows:

- ➤ Pressing the **Right Arrow** pushbutton highlights the elements from left-to-right and top-to-bottom.
- ➤ When reaching the right-most bottom element, the following **Right Arrow** keystroke “rolls over” and again highlights the left-most top element.

- ➤ The **Left Arrow** pushbutton operates in reverse, i.e., from right-to-left, and bottom-to-top.
- ➤ Pressing the **ENT** pushbutton selects the highlighted symbol.
- ➤ Pressing the **ESC** pushbutton returns you to the previous screen.

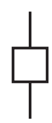
Additionally, if the one-line diagram spans multiple screens, you can pan between the portions of the diagram using the up and down arrows:

- ➤ Pressing the **Down Arrow** pushbutton while displaying the top bay control screen, displays the bottom bay control screen.
- ➤ Pressing the **Down Arrow** pushbutton while displaying the bottom bay control screen or the **Up Arrow** pushbutton while displaying the top bay control screen, does nothing.
- ➤ Pressing the **Up Arrow** pushbutton while displaying the bottom bay control screen displays the top bay control screen.

Circuit Breaker and Disconnect Definitions and State Representations

Table 5.1 shows the apparatus definitions and symbols displayed on the one-line diagram.

Table 5.1 Circuit Breaker and Disconnect Switch Definitions

Circuit Breaker Open	Circuit Breaker Closed	Disconnect Open	Disconnect Closed
			

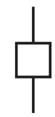
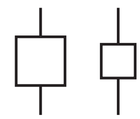
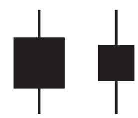
NOTE: The intermediate states only apply to disconnect switches because circuit breaker operations have a short duration.

Each apparatus (circuit breaker or disconnect switch) can be in one of the following six states:

- ➤ Open, not highlighted
- ➤ Open, highlighted
- ➤ Closed, not highlighted
- ➤ Closed, highlighted
- ➤ Intermediate, not highlighted (intermediate = transition between open and closed states)
- ➤ Intermediate, highlighted

Table 5.2 describes how the one-line diagram represents the different states of the breakers, and how highlighting the breaker affects the display of the symbol.

Table 5.2 Circuit Breaker State Representations

Apparatus Position	Symbol	Asserted Relay Word Bit
Circuit breaker open, not highlighted		NOT 52CLSM*m*
Circuit breaker open, highlighted[a]		NOT 52CLSM*m*
Circuit breaker closed, not highlighted		52CLSM*m*
Circuit breaker closed, highlighted		52CLSM*m*

[a] When the circuit breaker is highlighted, the two symbols shown alternate in the display.

Table 5.3 describes how the one-line diagram represents the different states of the disconnect switches, and how highlighting the disconnect switch affects the display of the symbol. Unlike the fast operation time of the circuit breaker, the disconnect switch operation-in-progress time is longer than the breaker operation time. *Table 5.3* describes how apparatus appear in the one-line diagram when a disconnect operation is in progress.

Table 5.3 Disconnect Switch State Representations (Sheet 1 of 2)

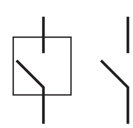
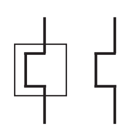
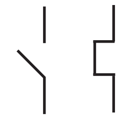
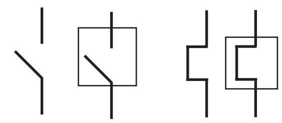
Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect open, not highlighted		89OPN*m*
Disconnect closed, not highlighted		89CL*m*
Disconnect open, highlighted[a]		89OPN*m*
Disconnect closed, highlighted[a]		89CL*m*

Table 5.3 Disconnect Switch State Representations (Sheet 2 of 2)

Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect Operation In Progress, not highlighted[b]		89OIP*m*
Disconnect Operation In Progress, highlighted[c]		89OIP*m*

[a] When the disconnect switch is highlighted and no operation is in progress, a square box alternately frames the switch symbol.

[b] For a disconnect switch operation in progress where the disconnect switch is not highlighted, the symbol displayed is the present state symbol and then the opposite state symbol. This sequence repeats until the disconnect switch operation completes.

[c] For a disconnect switch operation in progress where the disconnect is highlighted, the symbol displayed is the present state symbol, then the present state symbol highlighted, then the opposite state symbol, and finally the opposite state symbol highlighted. This sequence repeats until the disconnect switch operation completes.

The one-line diagram indicates highlighted text with a box around the current selection.

Circuit Breaker and Disconnect Switch Operations From the Front Panel

Circuit Breaker Open/Close

Figure 5.9 shows the Breaker Control Screens available after pressing the **ENT** pushbutton (`ONELINE` bay control screen), with the circuit breaker highlighted (Only highlighted breakers on the one-line diagram can initiate breaker open or close operations). Pressing the **ENT** pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted displays the Breaker Control Screen in *Figure 5.9(b)*. If the LOCAL Relay Word bit is not asserted when the **ENT** push-button is pressed, the relay displays the screen in *Figure 5.9(c)* for three seconds and then returns to the screen in *Figure 5.9(a)*.

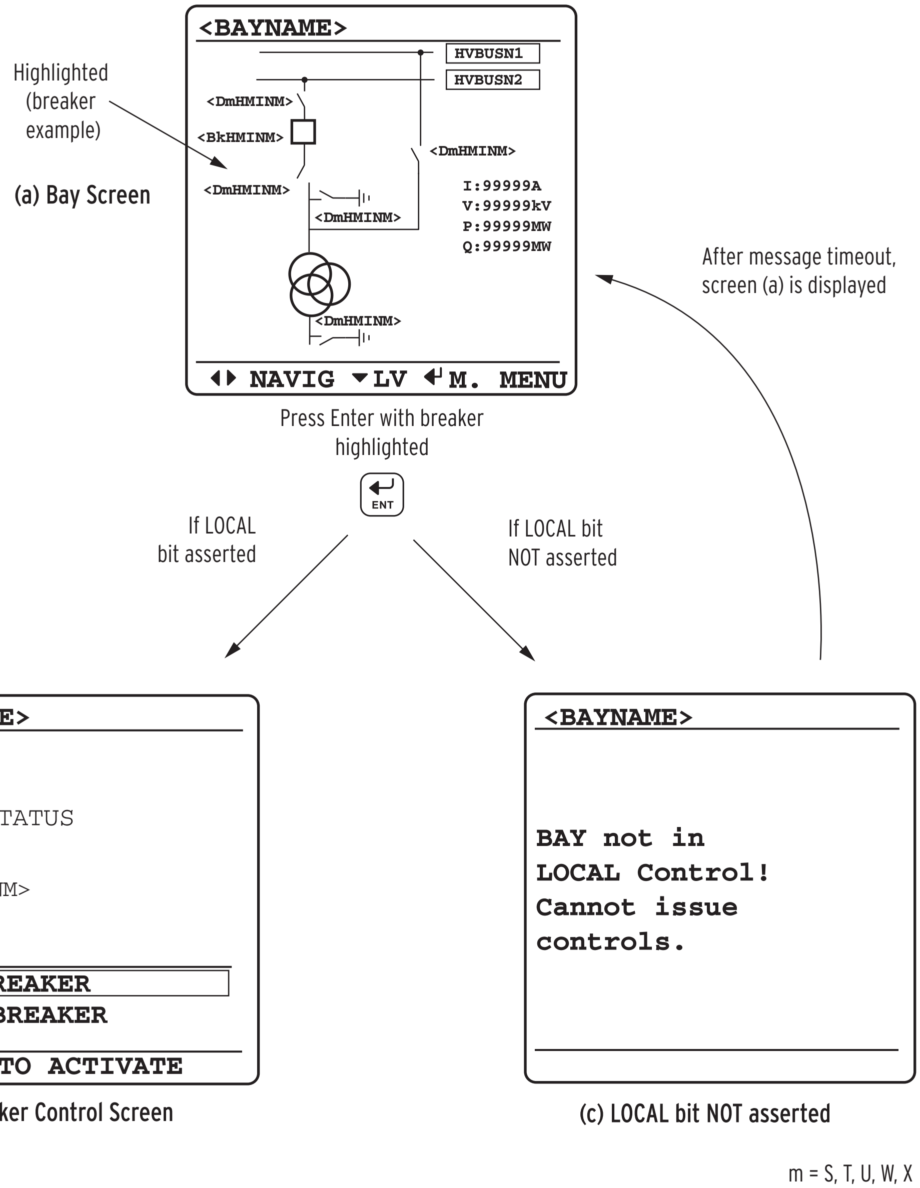


Figure 5.9 Screens for Circuit Breaker Selection

Single-Pole Tripping

With a single-pole breaker, the individual poles operate independently, and normal operation is for one pole to be open for a short period, while the other two poles are closed. However, it is possible that one (or more) poles may fail to complete a particular operation, resulting in a pole-discrepancy condition. For example, if the breaker is issued a **CLOSE** command, two poles may close but one pole may remain open. If this condition lasts for longer than 1.5 seconds, the HMI displays the pole discrepancy screen shown in *Figure 5.10(c)* so that the operator can immediately identify the offending pole. You can operate the breaker from the pole discrepancy screen after the discrepancy has been rectified. All other screens are the same as when you set the relay to three-pole operations.

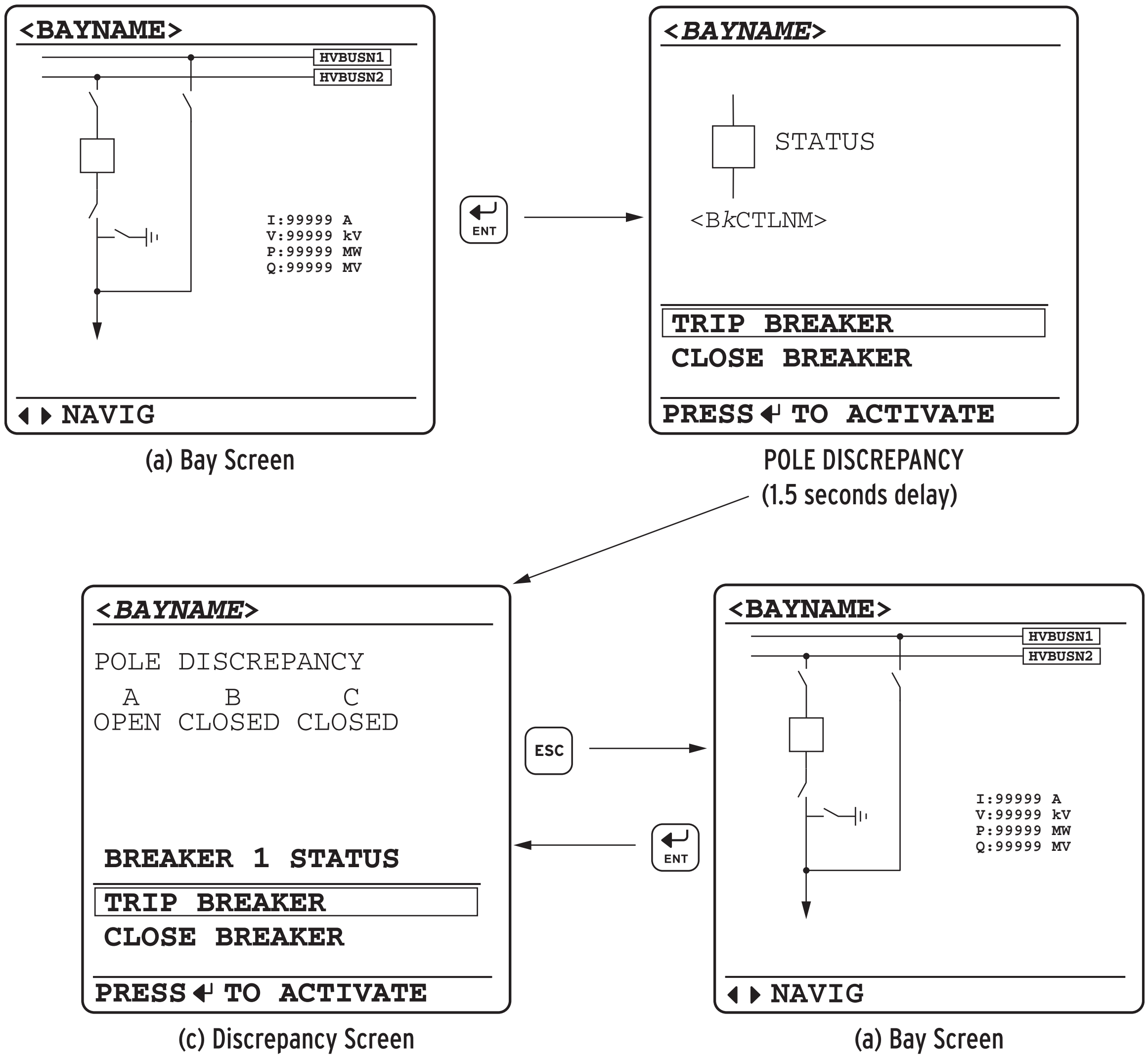


Figure 5.10 Screens During a Pole-Discrepancy Condition

Disconnect Switch Open/Close

Figure 5.11(a) shows the Disconnect Control Screens available when you press the ENT pushbutton, in ONELINE bay control screen, with the disconnect switch highlighted. If the LOCAL Relay Word bit is asserted and the disconnect switch is highlighted when you press the ENT pushbutton, the Disconnect Control Screen in *Figure 5.11*0*(b)* appears. Use the Up Arrow and Down Arrow pushbuttons to navigate between the disconnect control functions in *Figure 5.11(b)*. If the LOCAL Relay Word bit is not asserted when the ENT pushbutton is pressed, the relay displays screen in *Figure 5.11(c)* for three seconds and then returns to the screen in *Figure 5.11(a)*.

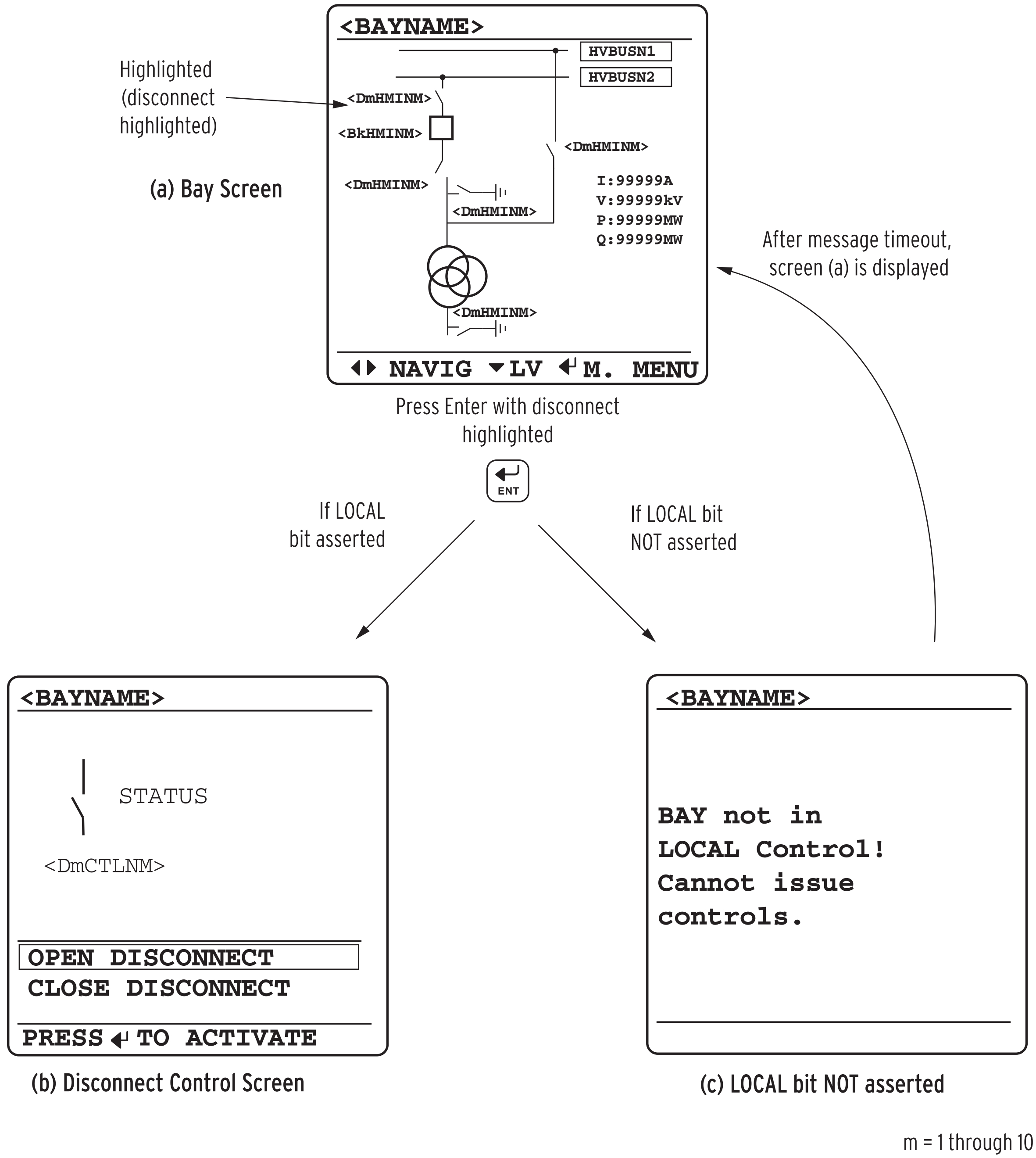


Figure 5.11 Screens for Disconnect Switch Selection

Figure 5.12, *Figure 5.13*, and *Figure 5.14* show all the possible screens during an open-to-close operation of Disconnect 1. Operation of the remaining disconnects is identical. Close-to-open operations are similar, the only difference being that the open Relay Word bits apply instead of the close Relay Word bits. The screen in *Figure 5.12(a)* is displayed after you press the **ENT** pushbutton with Disconnect 1 open and highlighted in the one-line diagram.

When you enter the disconnect screen in *Figure 5.12(a)*, the state that the disconnect switch is in is highlighted, in other words, if Relay Word bit 89OPN1 is asserted, the `OPEN DISCONNECT` text has a box drawn around it.

To close the disconnect switch, use the **Up Arrow** or **Down Arrow** pushbutton to highlight the `CLOSE DISCONNECT` text.

If Relay Word bit 89CCM1 asserts after you press the **ENT** key, the relay displays the screen with the caption CLOSE COMMAND ISSUED in *Figure 5.12(c)* for three seconds. While the disconnect operation is in progress, the relay displays the screen with the caption IN PROGRESS in *Figure 5.13(a)* and the disconnect symbol alternately displays the present state symbol and the opposite state symbol. If another disconnect operation attempt is made while a disconnect operation is in progress, the relay displays the screen with the caption *NOT ALLOWED* in *Figure 5.13(b)* for three seconds and then the relay returns to the screen in *Figure 5.13(a)*.

If Relay Word bit 89CCM1 does not assert, the relay displays the *NOT ALLOWED* error message shown in *Figure 5.12(d)* for three seconds and then displays again the screen in *Figure 5.12(b)*.

When Relay Word bit 89CCMD1 asserts, the Close Immobility Timer starts. If Relay Word bit 89CCMD1 asserts, two scenarios are possible: the disconnect fails to close, or the disconnect closes successfully. In the case of a successful close operation, the relay displays the screen in *Figure 5.14(b)*.

Failing to close also has two possible scenarios: the disconnect starts to move, but does not complete the operation, or the disconnect switch operation does not initiate.

When Relay Word bit 89OPN1 deasserts, the Close Immobility timer resets, indicating that the disconnect switch has started to move. If Relay Word bit 89CL1 fails to assert in the expected operation time, the disconnect switch has failed to complete the close operation in the expected time. Failure of the 89CL1 Relay Word bit to assert in the expected disconnect switch operation time causes the 89AL1 Relay Word bit to assert. When Relay Word bit 89AL1 asserts, the relay displays the screen *Figure 5.14(a)* (see *Disconnect Switch Status and Alarm Logic on page 5.5*).

If Relay Word bit 89OPN1 fails to deassert before the Close Immobility Timer expires, Relay Word bit 89ICM1 asserts and the relay displays the screen with the caption STATUS UNKNOWN in *Figure 5.14(a)*. See *Disconnect Switch Close and Open Immobility Timer Logic on page 5.8* for more information regarding the close and open immobility timer logic.

When the disconnect operation completes successfully, the relay displays the screen in *Figure 5.14(b)* until the front-panel timer times out or the **ESC** pushbutton is pressed.

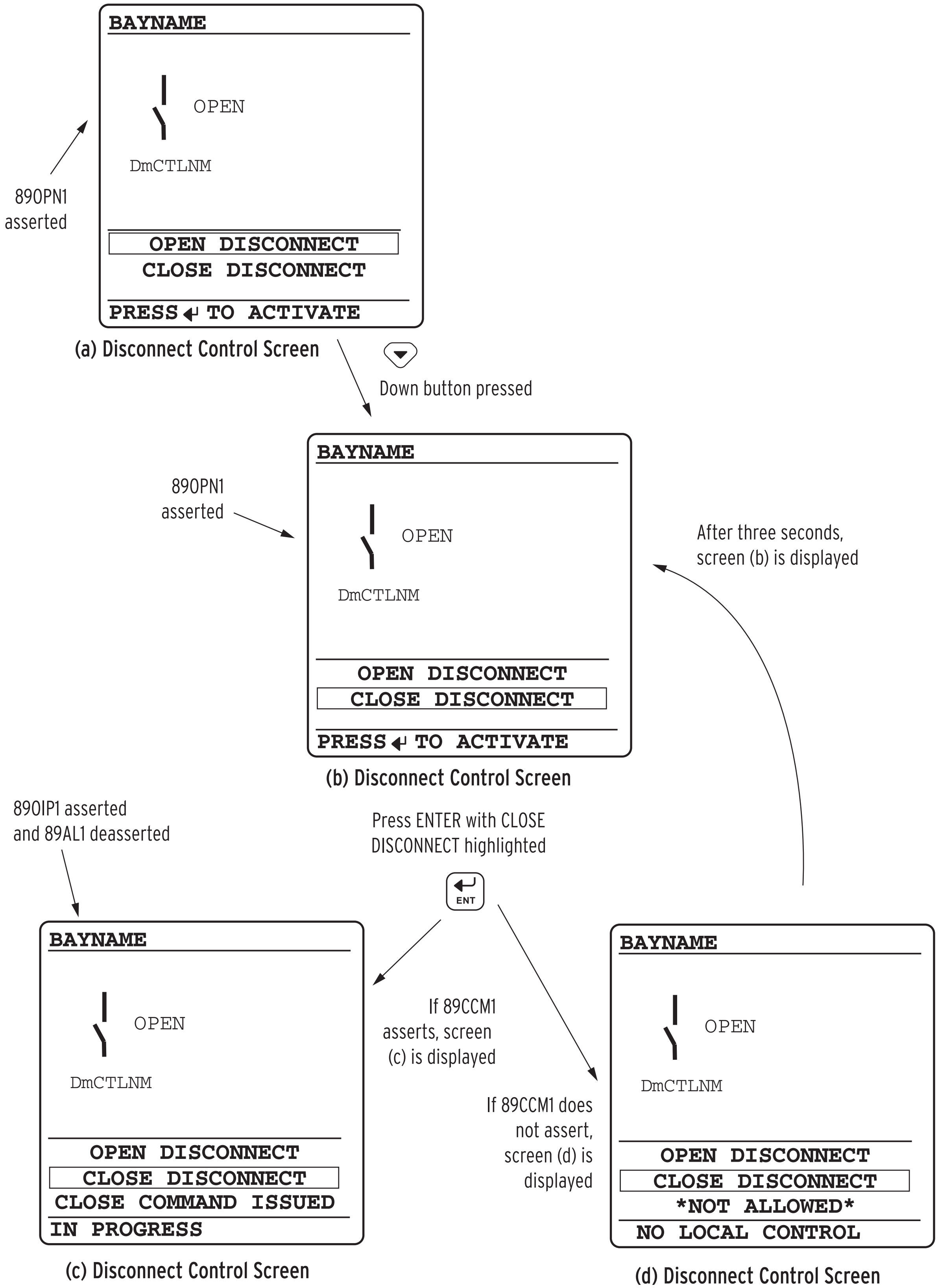


Figure 5.12 HMI Disconnect Operation Initiation

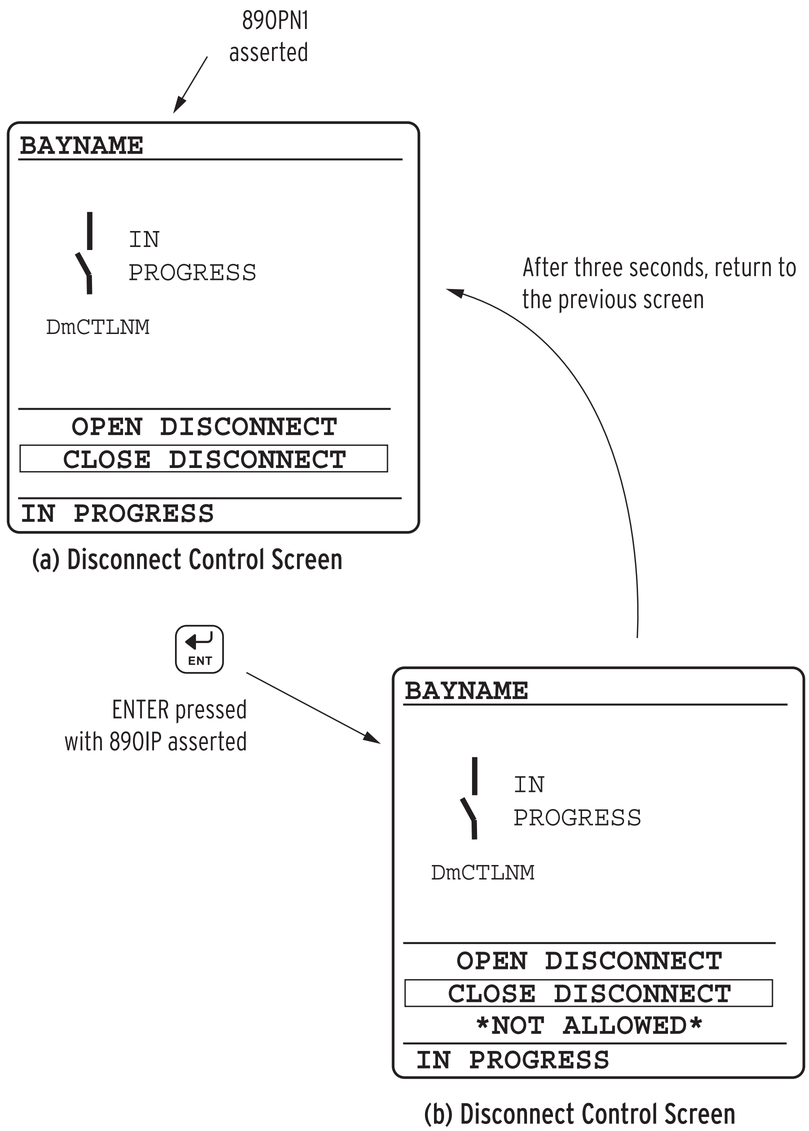


Figure 5.13 HMI Disconnect Operation in Progress

When you initially enter the Disconnect Control Screen, the disconnect switch is in one of four states: disconnect open (89OPN*m*), disconnect closed (89CL*m*), disconnect undetermined without alarm (89OIP*m*), or disconnect undetermined with alarm (89AL*m*). If Relay Word bit 89OIP*m* is asserted, the relay displays the screen in *Figure 5.13(a)*; if Relay Word bit 89AL*m* is asserted, the relay displays the screen in *Figure 5.14(a)*. If both Relay Word bits 89OIP*m* and 89AL*m* are asserted, Relay Word bit 89AL*m* takes priority. If Relay Word bit 89OPN*m* is asserted, the relay displays the screen in *Figure 5.12(a)*. This is the initial screen for an open-to-close operation. If Relay Word bit 89CL*m* is asserted, the relay displays the screen in *Figure 5.14(b)*. This is the initial screen for a close-to-open operation.

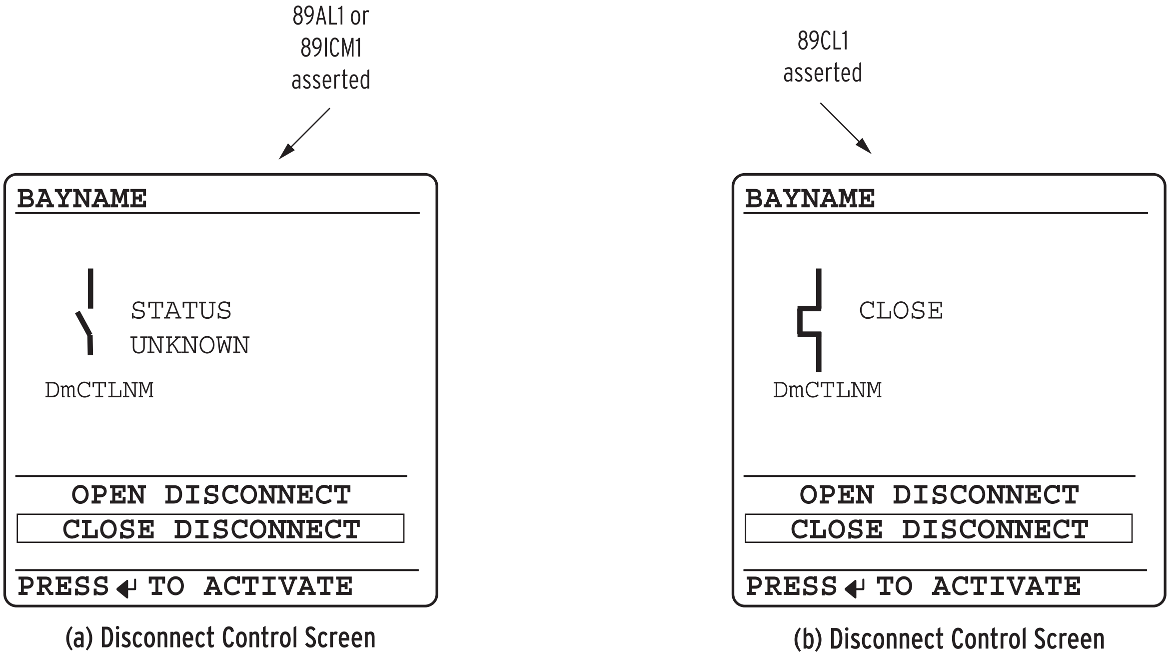


Figure 5.14 HMI Disconnect Operation Completed

Three-Position Disconnect State Representation and Operations From the Front Panel

A three-position disconnect switch consists of two standard disconnects that operate together to form a three-position disconnect. All logic diagrams of the standard disconnect apply to the three-position disconnect, including all settings and Relay Word bits associated with the two individual disconnects. The three-position disconnect has two labels, one for the in-line branch and one for the ground (perpendicular) branch. In the example shown in *Figure 5.15*, the three-position disconnect is made up of Disconnect SW3 and Disconnect SW4. As with the standard disconnect, be sure to correlate the disconnect wiring and settings with the disconnects assigned to the three-position disconnect image on the one-line diagram.

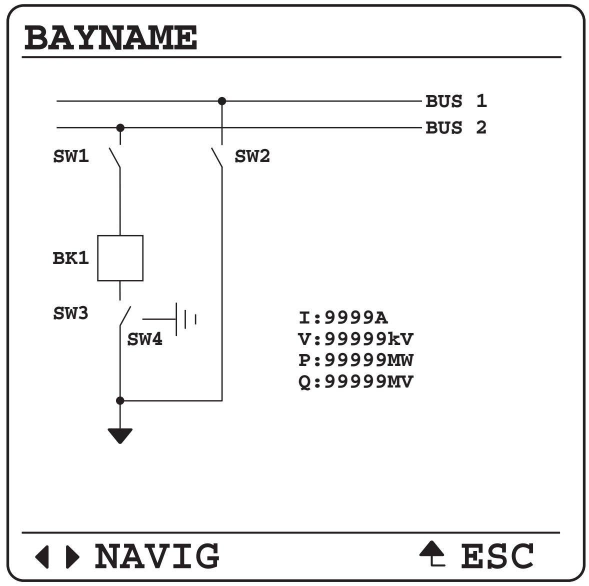
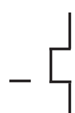
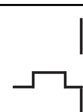
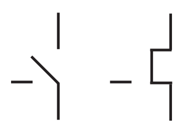
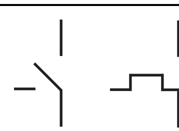
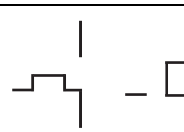


Figure 5.15 Bay Control One-Line Diagram With Three-Position Disconnect Open

Table 5.4 displays how the bay screen one-line diagram represents the different states of the three-position disconnect switch.

Table 5.4 Three-Position Disconnect Switch State Representations

Apparatus Position	Symbol	Asserted Relay Word Bits
Both disconnects open		89OPN3 and 89OPN4
Disconnect 3 (in-line) closed Disconnect 4 (ground) opened		89CL3 and 89OPN4
Disconnect 3 (in-line) opened Disconnect 4 (ground) closed		89OPN3 and 89CL4
Disconnect 3 (in-line) intermediate[a] Disconnect 4 (ground) opened	 [b]	(89OIP3 or 89AL3) and 89OPN4
Disconnect 3 (in-line) opened Disconnect 4 (ground) intermediate[a]	 [b]	89OPN3 and (89OIP4 or 89AL4)
All other status combinations Disconnect 3 closed, Disconnect 4 closed Disconnect 3 closed, Disconnect 4 intermediate[a] Disconnect 3 intermediate[a], Disconnect 4 closed Disconnect 3 intermediate[a], Disconnect 4 intermediate[a]	 [b]	 89CL3 and 89CL4 89CL3 and (89OIP4 or 89AL4) (89OIP3 or 89AL3) and 89CL4 (89OIP3 or 89AL3) and (89OIP4 or 89AL4)

[a] Intermediate = transition between open and closed states.
[b] The image alternates between the two symbols shown.

Similar to the standard disconnect, if a three-position disconnect is highlighted on the one-line diagram and the **ENT** pushbutton is pressed, a control screen is displayed. The control screen shows the present status of the disconnect based on the disconnect status bits (89CL*m*, 89OPN*m*, 89OIP*m*, and 89AL*m*) from both disconnects that make up the three-position disconnect. The status is shown via the disconnect symbol and the status labels as shown in *Figure 5.16(a)*.

Figure 5.16(a) shows the control screen of a three-position disconnect with both disconnects in the open state. *Figure 5.16(b)* shows the control screen of a three-position disconnect with the in-line disconnect closed and the ground disconnect open. Likewise, *Figure 5.16(c)* shows the control screen of a three-position disconnect with the in-line disconnect open and the ground disconnect closed.

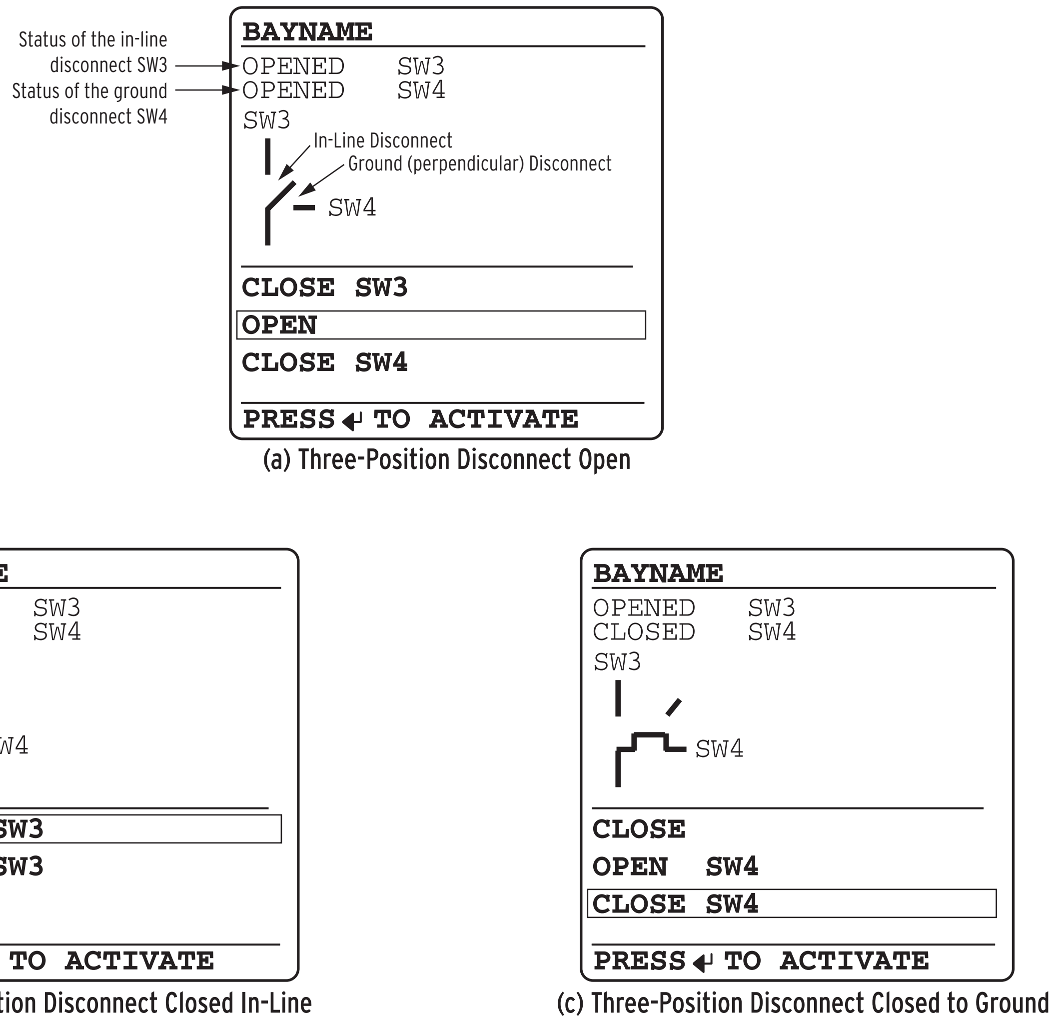


Figure 5.16 Three-Position Disconnect Control Screens

The three-position disconnect logic is identical to two standard disconnects, but control actions are limited as shown in *Table 5.5*. A control action is only available if the disconnect name is listed next to the action as indicated in the Control Options Displayed column. For example, in the second set of control actions, where Disconnect SW3 is closed and Disconnect SW4 is open, the only control actions available are to open or close Disconnect SW3. *Figure 5.16(b)* shows the control screen for this condition.

Table 5.5 Three-Position Disconnect Switch Control Screen Status and Control Options

State of Disconnects	Status Displayed	Control Options Displayed	Control Actions Available
Disconnect SW3: Open Disconnect SW4: Open	OPENED SW3 OPENED SW4	CLOSE SW3 OPEN[a] CLOSE SW4	CLOSE SW3 NO OPEN CONTROL CLOSE SW4
Disconnect SW3: Closed Disconnect SW4: Open	CLOSED SW3 OPENED SW4	CLOSE SW3[b] OPEN SW3 CLOSE	CLOSE SW3 OPEN SW3 NO CONTROL for SW4
Disconnect SW3: Open Disconnect SW4: Closed	OPENED SW3 CLOSED SW4	CLOSE OPEN SW4 CLOSE SW4[c]	NO CONTROL for SW3 OPEN SW4 CLOSE SW4
Disconnect SW3: Open Disconnect SW4: Alarm	OPENED SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Alarm Disconnect SW4: Open	UNKNOWN SW3 OPENED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Closed Disconnect SW4: Alarm	CLOSED SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Alarm Disconnect SW4: Closed	UNKNOWN SW3 CLOSED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Closed Disconnect SW4: Closed	CLOSED SW3 CLOSED SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect
Disconnect SW3: Alarm Disconnect SW4: Alarm	UNKNOWN SW3 UNKNOWN SW4	CLOSE OPEN CLOSE	NO CONTROL for either disconnect

[a] See *Figure 5.16(a)*.
[b] See *Figure 5.16(b)*.
[c] See *Figure 5.16(c)*.

The following example shows the process of changing a three-position disconnect from closed in-line to closed to ground. This process requires that you first open the in-line disconnect before you can close the ground disconnect.

Starting with the one-line diagram in *Figure 5.17*, highlight the three-position disconnect and press the **ENT** pushbutton. If the LOCAL Relay Word bit is asserted, the control screen shown in *Figure 5.16(b)* is displayed on the screen. Note that the only options at this point are to open or close Disconnect SW3. Therefore, use the **Up Arrow** or **Down Arrow** pushbutton to move the highlight box to the OPEN SW3 position. Then press the **ENT** pushbutton to open Disconnect SW3. If Disconnect SW3 successfully opens, the control screen will change as shown in *Figure 5.16(a)*. Note that the control actions changed so that Disconnect SW4 can now be closed. At this point, use the **Up Arrow** or **Down Arrow** pushbutton to move the highlight box to the `CLOSE SW4` position and press the **ENT** pushbutton to close Disconnect SW4. If Disconnect SW4 is successfully closed, the control screen will change as show in *Figure 5.16(c)*.

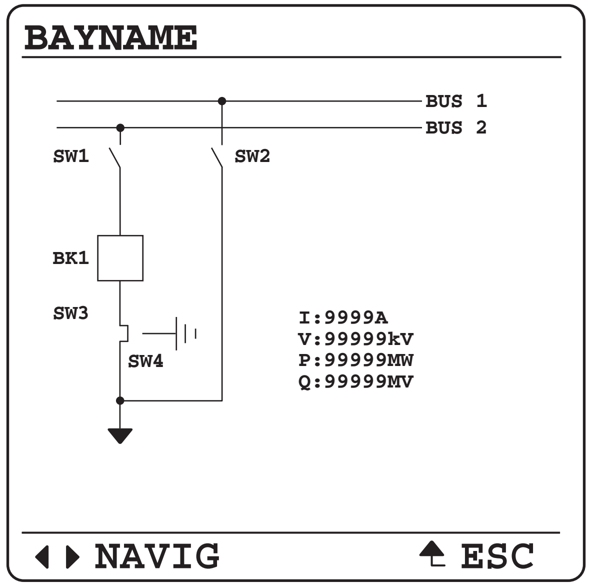


Figure 5.17 Bay Control One-Line Diagram With Three-Position Disconnect Closed In-Line

The relay does not include any default bay mimic screens with three-position disconnects. Should your application require different bay mimic screens with three-position disconnects, contact SEL.

QuickSet Bay Control Screens

QuickSet provides an easy and intuitive way to configure and set the bay control function.

Select the **Bay Control** button from the tree to see the first interactive bay forms in QuickSet, as shown in *Figure 5.18*.

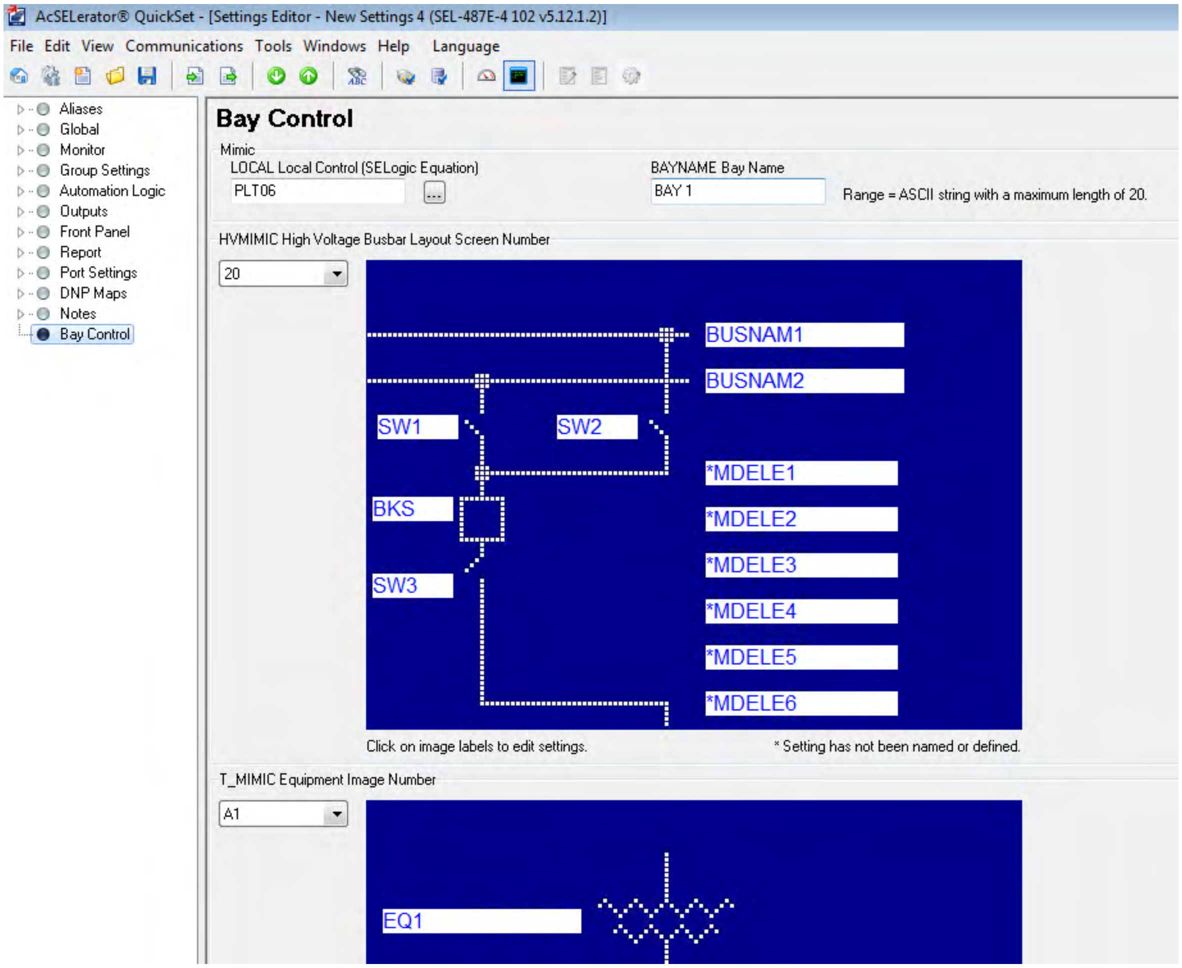


Figure 5.18 Interactive Bay Control Setting Form

MIMIC

In most SEL-400 series relays, a single one-line diagram needs to be selected. However, in some relays, such as the SEL-487E, multiple screens need to be selected to build up the total composite one-line diagram.

Bay Name

There are 20 characters available for the bay name. This name appears on all the bay control screens.

Local

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the input contact IN107 can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 5.19*. With the contact of the switch wired to the input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when IN107 is asserted.

LOCAL := **IN107**

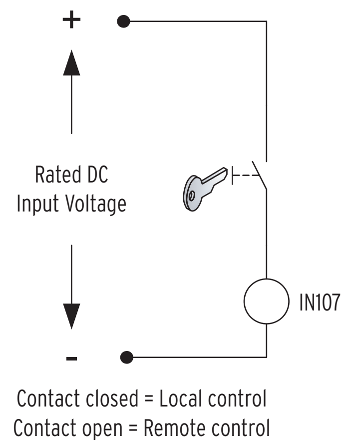


Figure 5.19 Local and Remote Control Logic With Key Control

Bus Names

Figure 5.20 shows the dialog box that appears when you click on the busbar name. Enter the name of the busbar (e.g., **132 Bus No 1**), and click **OK**.

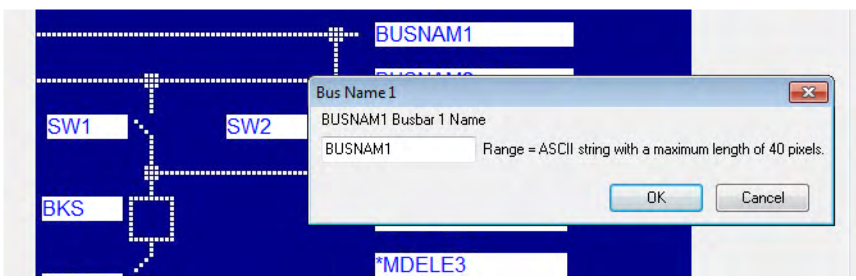


Figure 5.20 Setting Busbar Names in QuickSet

Disconnect Assignments

To configure disconnects, click the box next to the disconnect switch. A dialog box appears, as shown in *Figure 5.21*.

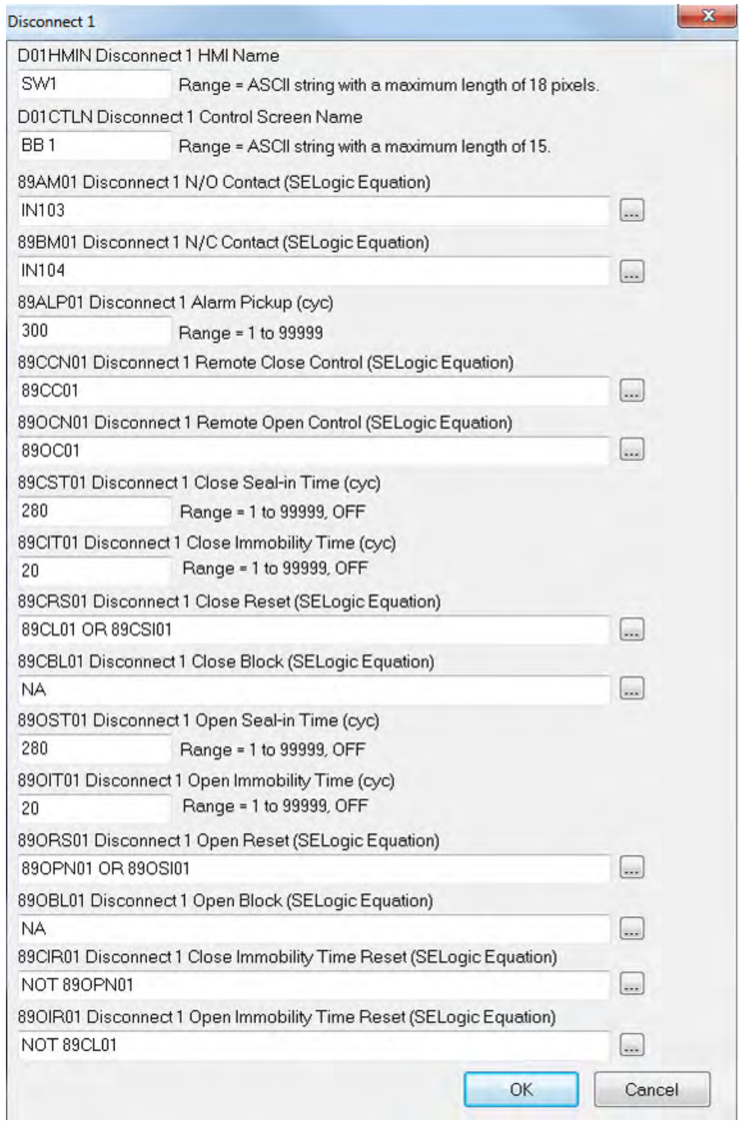


Figure 5.21 Disconnect Assignment Dialog Box, SW1

D01HMIN

Enter a Disconnect 1 label on the HMI (*Figure 5.21*). The number of characters is limited to a maximum string width of 18 pixels (approximately four characters).

D01CTLN

Enter a Disconnect 1 label on the control screen. Enter a descriptive name (there are 15 characters available) that clearly identifies the disconnect.

89AM01, 89BM01

These SELOGIC control equations report the state of Disconnect 1 auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89ALP01

This timer counts down when both 89AM01 and 89BM01 are in the same state (both asserted or both deasserted). When this disconnect alarm timer expires, an alarm condition exists and the 89AL01 Relay Word bit asserts.

Set the 89ALP01 timer longer than the expected operation (undetermined state) time, but less than the 89CST01 or 89OST01 seal-in timers.

89CCN01, 89OCN01

These SELOGIC control equations close or open Disconnect 1. Take care when programming these equations, because there is no breaker jumper supervision or access level safeguard in place for this disconnect operate method. These settings only work when the LOCAL Relay Word bit is deasserted.

89CST01, 89OST01

These seal-in timers are intended to keep the close or open signal asserted long enough to allow the Disconnect 1 operation to complete. Set the seal-in timers 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the seal-in timers.

89CIT01, 89OIT01

The close/open Disconnect 1 immobility timers are triggered at the same time as the seal-in timers. Expiration of these immobility timers indicates that the Disconnect 1 auxiliary contact status failed to change state within the expected time frame.

Set the immobility timers longer than the expected time for the disconnect to leave the initial state (as reported by the 89AM01 and 89BM01 Relay Word bits), but less than the seal-in timer.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the immobility timers.

89CRS01, 89ORS01

These settings reset the seal-in circuit when either the seal-in timer expires or the intended open/close status signal asserts. This is intended to stop driving the Disconnect 1 motor to close or open when the desired state has been reached.

89CBL01, 89OBL01

These SELOGIC control equations provide an optional custom method for blocking all means of close/open control for Disconnect 1.

89CIR01, 89OIR01

These SELOGIC control equations reset the Disconnect 1 close/open immobility timers.

Breaker Assignments

Configure the breaker by clicking the box next to the breakers. A dialog box appears, as shown in *Figure 5.22*.

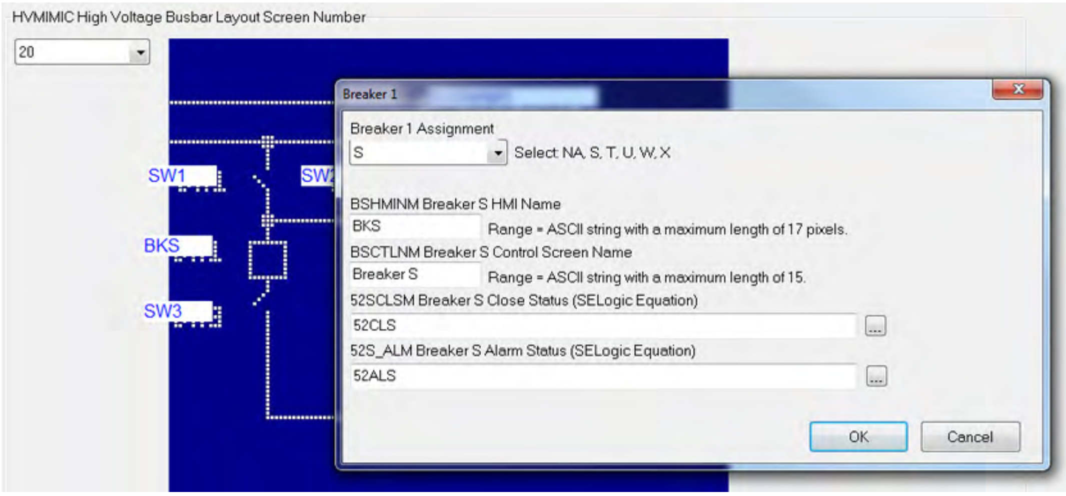


Figure 5.22 Breaker Settings, Breaker S

BK*q*

In some relays, each numbered breaker (*q* = 1, 2, 3, 4, or 5) can be assigned to NA or one of the terminals. No terminal can be assigned twice. Unused breaker numbers are forced to NA.

B*m*HMINM

Enter a Breaker *m* label on the HMI (one-line diagram). The number of characters is limited to a maximum string width of 17 pixels (approximately four characters).

B*m*CTLNM

Enter a Breaker *m* label on the control screen. Enter a descriptive breaker name (as many as 15 characters).

52*m*CLSM, 52*m*_ALM

These SELOGIC control equations report breaker close status and breaker alarm status. Any bit in the Relay Word, as well as logical operators, can be programmed into these SELOGIC control equations.

Analog Display

If analog display points are not required, leave the setting(s) blank, because the relay displays only the defined display points.

Click on analog display label MDELE1 in the interactive one-line diagram to display the form shown in *Figure 5.23*. Click on the Expression Builder button to display the form shown in *Figure 5.24*. The Expression Builder helps build the analog quantity setting string. Press the Expression Builder button on the form shown in *Figure 5.24* to find the Analog or Fixed Element to be displayed.

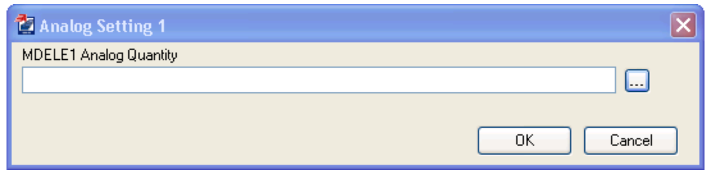


Figure 5.23 Analog Quantity Setting Form

To display fixed text instead of analog quantities, enter the number 1 in the Analog or Fixed Element field.

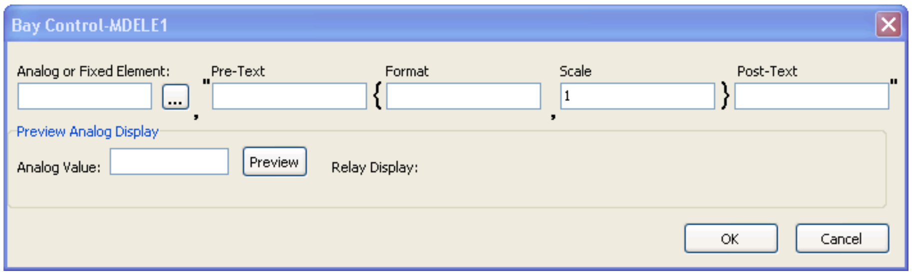


Figure 5.24 Analog Quantity Setting Form

Select the FREQ System Frequency (see *Figure 5.25*). Enter a Pre-Text, for example 'Frq=', as shown in *Figure 5.25*. Set the numerical display format to 5.2; this displays frequency up to two decimal places. You can scale the numerical value of FREQ to display a scaled value of the analog quantity. For example, a scaling value of 0.5 displays only half the value of FREQ, while a scaling value of 2 displays twice the value of FREQ. Enter text, such as the units of the analog quantity in the Post-Text field. Test the entries by typing a value of 60.51 in the preview analog display field. Click the **Preview** button, and verify that all entries are correct and will fit on the screen.

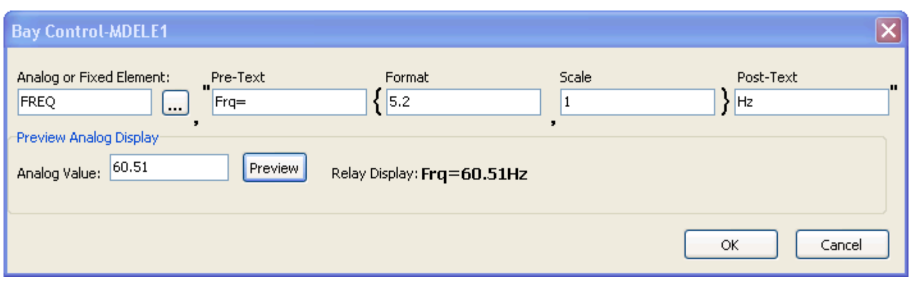


Figure 5.25 Example of an Analog Quantity Expression

Equipment Name

Edit the equipment name by clicking the text box next to the equipment. A dialog screen appears, as shown in *Figure 5.26*.

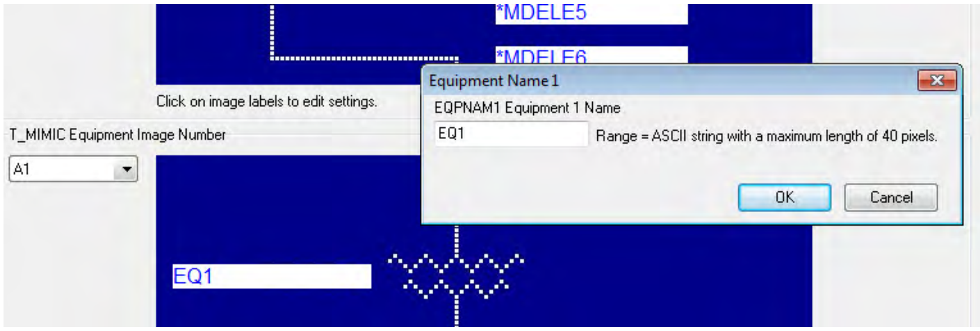


Figure 5.26 Interactive Transformer Image Number

Customizable Screens

SEL-400 series relays support custom mimic display screens. Custom mimic display screens are developed by the SEL factory using your requirements, and then added to the QuickSet relay driver. The images below show the breaker and power system variants supported in custom mimic display screens.

Available Circuit Breakers

Figure 5.27 shows the different types of circuit breakers and disconnects available.

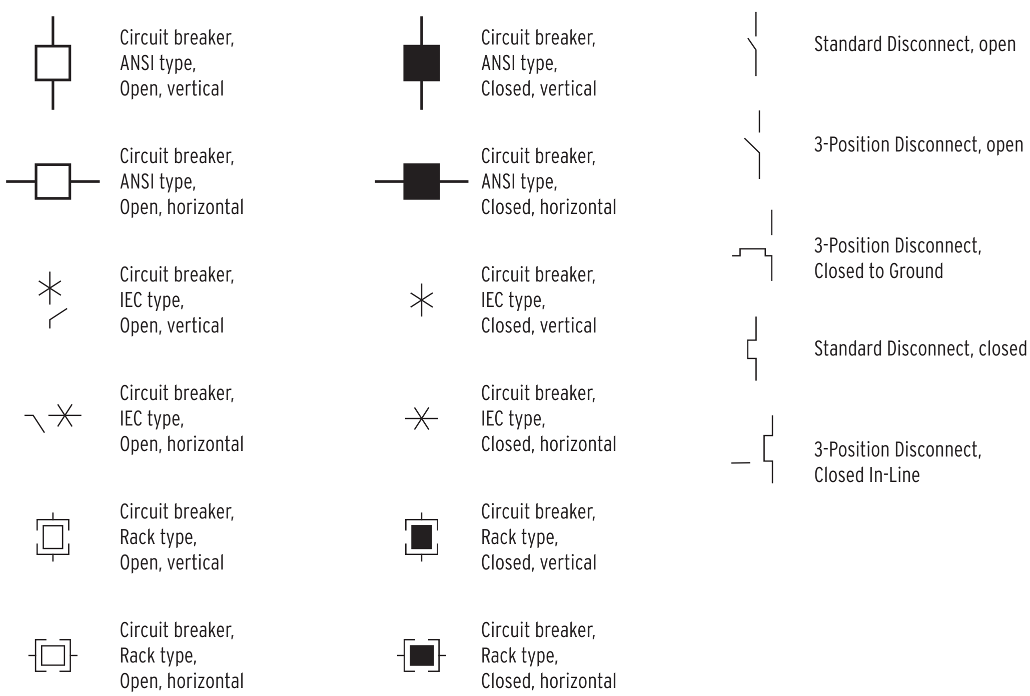


Figure 5.27 Different Types of Circuit Breakers and Disconnects

Available Power System Components

Figure 5.28 shows the different types of power system components available.

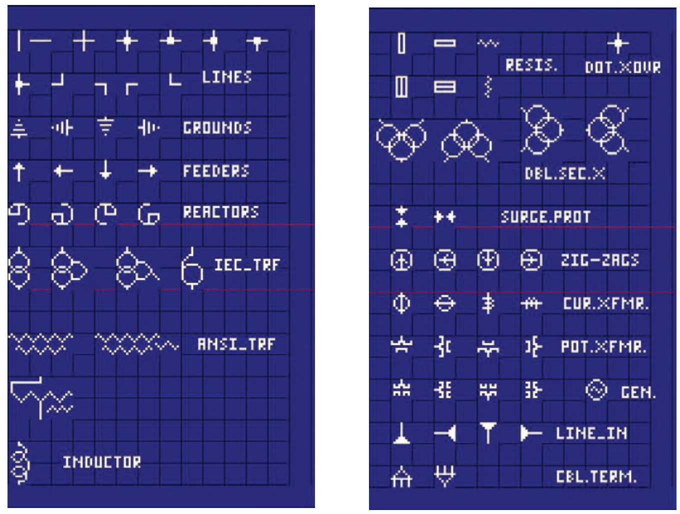


Figure 5.28 Power System Components

Bay Control Example Application

This example demonstrates configuring a bay control screen for an SEL-451. Similar configurations can be done with other SEL-400 series relays.

Bus 1, Bus 2, and Transfer BUS Bay With Ground Switch (MIMIC := 4)

Figure 5.29 illustrates the Bus 1, Bus 2, and Transfer Bus Bay with Ground Switch (MIMIC := 4). The Bay configuration used in this example provides five disconnect switches, one breaker, and the ability to display as many as six Analog Quantities. The labels and Analog Quantities shown in *Figure 5.29* are all a result of the settings entered in this example. See *Table 5.6* for a complete list of Bay settings for this application.

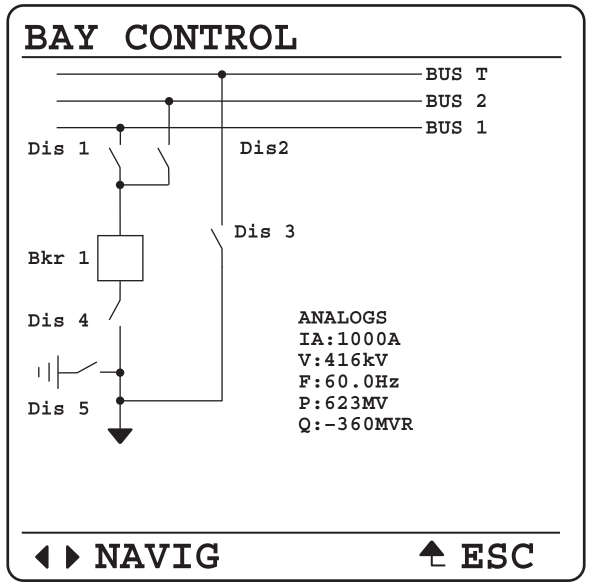


Figure 5.29 Illustration of One-Line Diagram After Entering Example Settings

Bay Control Settings

General One-Line Settings

One-Line Diagram

This setting selects the one-line diagram that defines the bay configuration, and it must exactly match the bay configuration being controlled. Failure to select the exact one-line diagram that describes the bay configuration being controlled could result in misapplications.

MIMIC := **4**

Bay Name

Enter a bay name (as many as 20 characters) that defines the bay being controlled.

BAYNAME := **BAY CONTROL**

Bay Label

As many as two bay labels are available in one-line diagrams 14, 17, 18, and 23. BAYLAB1 and BAYLAB2 settings can accept as many as eight characters, depending on the pixel width of the string.

BAYLAB1 or BAYLAB2 are not required because the MIMIC setting selected in this example does not include bay labels. If MIMIC 14, 17, 18, or 23 had been selected, the relay would have prompted for BAYLAB1 and BAYLAB2 settings.

Busbar Information

Bus-Name Labels

Based on the MIMIC setting, the relay provides as many as nine bus-name labels in the one-line diagram. With MIMIC set to 4, the relay requires three bus-name labels, one for the transfer bus, one for Bus 2, and one for Bus 1. The top-most bus in the one-line diagram is `BUSNAM1` and the bottom-most bus in the one-line diagram is the highest number bus available for the selected MIMIC setting, three in this case.

Enter bus-name labels (as many as ten characters) that describe each bus in the one-line diagram.

The actual number of characters accepted depends on the pixel width of the string.

BUSNAM1 := **Bus T**

BUSNAM2 := **Bus 2**

BUSNAM3 := **Bus 1**

Breaker Information

The relay displays breaker information for as many as three breakers. For the bay configuration in this example, the relay displays one. If more breakers were supported, based on the MIMIC setting selected, the settings associated with additional breakers would follow Breaker 1 settings.

Breaker Name Label

Enter a breaker name (as many as six characters) that describes each circuit breaker in the one-line diagram.

The actual number of characters accepted depends on pixel width of the string.

B1HMINM := **Bkr 1**

Breaker Status

This SELOGIC control equation reports breaker close status and breaker alarm status. Any bit in the Relay Word can be programmed into this SELOGIC control equation, as well as logical operators. The equations below return the state of the Bkr 1 status and any Bkr 1 alarm conditions.

521CLSM := **52ACL1**

521_ALM := **52AAL1**

Disconnect Information

The relay provides disconnect switch information for as many as ten disconnect switches. For the bay configuration selected in this example, the relay supports five disconnect switches.

Disconnect Name Label

Enter disconnect labels of as many as six characters in length that describe each disconnect switch in the one-line diagram. The actual number of characters accepted depends on pixel width of the string.

D01HMIN := **Dis 1**

Disconnect Status

Wire the normally open and normally closed auxiliary contacts from the disconnect switch to relay inputs, and program the relay inputs into 89AM01 and 89BM01 SELOGIC control equations. These equations report the state of the disconnect switch auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89AM01 := **IN103**

89BM01 := **IN104**

Disconnect Alarm Pickup Delay

This setting monitors disconnect open/close operations (the undetermined time) of the disconnect switch. When the disconnect alarm timer expires, an alarm condition exists and the 89AL1 Relay Word bit asserts. Set the 89ALP*m* timer longer than the expected operation (undetermined state) time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. The expected disconnect operation time in this example is 250 cycles. 89ALP*m* is entered in cycles and has a range of 1–99999.

89ALP01 := **260**

Disconnect Close/Open Control

Program SELOGIC control equations 89CCN*n* and 89OCN*n* to close or open disconnect switch *n*, respectively. Great care needs to be used when programming these equations because there are no breaker jumper supervision or access level safeguards in place for this disconnect operate method. The settings in this example close the disconnect switch when Remote Bit 1 is set and open the disconnect switch when Remote Bit 1 is cleared. The 89CCN01 SELOGIC example below also includes additional supervision logic where the close operation only operates if Breaker 1 is open (NOT 52CLS1) and the disconnect switch is in the opposite state (89OPN1). When these conditions are met, a close disconnect operation will initiate. Relay Word bit 89CLS1 is the output of the seal-in timer and asserts when Relay Word bit 89CCN01 asserts. Relay Word bit 89OPN1 deasserts as soon as the disconnect switch starts to move. The OR combination of Relay Word bit 89CLS1 and 89OPN1 keeps the close disconnect signal asserted until the disconnect operation has completed. The SELOGIC control equations below demonstrate disconnect lockout control in the relay. The 89OCN01 SELOGIC control equation illustrates the same type of supervision for the disconnect switch open logic.

89CCN01 := **RB01 AND (89OPN1 OR 89CLS1) AND NOT 52CLSM1**

89OCN01 := **NOT RB01 AND (89CL1 OR 89OPEN1) AND NOT 52CLSM1**

Disconnect Close/Open Seal-in Timers

The seal-in timers assert the close or open signal long enough to allow the disconnect operation to complete. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation. 89CST*m* and 89OST*m* are entered in cycles and have a range of 1–99999. The example shown anticipates a disconnect switch operate time of approximately 250 cycles.

Cold weather and low battery voltages can impact operation times. Be sure to consider these conditions when setting the seal-in timers.

The output contacts must not be used to break the motor coil current. An auxiliary contact with adequate current interrupting capacity must first interrupt current supply to the motor before the relay contact opens. Include the auxiliary contact clearing time when setting the disconnect seal-in timer.

89CST01 := **280**

89OST01 := **280**

Disconnect 2–5

Disconnect switch settings 2–5 are similar to the Disconnect Switch 1 examples above. See *Table 5.6* for a complete list of Bay Class settings for this application.

One-Line Analog Display

One-line diagrams in the relay can contain as many as six Analog Quantity display points. The MIMIC setting selected in this example displays six Analog Display points. See *Display Points on page 4.10* for Display Point programming. The settings below illustrate how to display text and Analog Quantities available in the mimic display. If analog display points are not required to appear in the one-line diagram, leave the setting(s) blank, and the relay will only display the defined display points.

1. 1, “Analogs”
2. IAWM, “IA:(4.0,1)A”
3. VABFM, “V:(3.0,1)kV”
4. FREQ, “F:(4.1,1)Hz”
5. 3P, “P:(3.0,1)MW”
6. 3Q_F, “Q:(3.0,1)MVR”

Control Selection

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the SEL-451 input contact IN107 can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 5.30*. With the contact of the switch wired to the SEL-451 input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when IN107 is asserted.

LOCAL := **IN107**

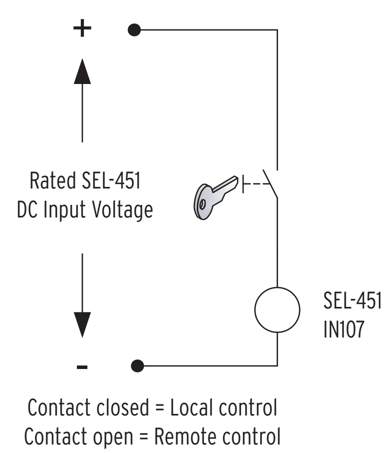


Figure 5.30 Local and Remote Control Logic With Key Control

Front-Panel Settings

The one-line diagram is one of the screens that are available for display in the rotating display. To display RMS_V, RMS_I, and ONELINE screens on the rotating display every five seconds, make the following Front-Panel settings.

SCROLD := **5**

RMS_V := **Y**

RMS_I := **Y**

RMS_VPP := **N**

RMS_W := **N**

FUNDVAR := **N**

RMS_VA := **N**

RMS_PF := **N**

RMS_BK1 := **N**

RMS_BK2 := **N**

STA_BAT := **N**

FUND_VI := **N**

FUNDSEQ := **N**

FUND_BK := **N**

ONELINE := **Y**

The following settings in the Front-Panel settings provide immediate display of the one-line diagram screen when Pushbutton 2 is pressed.

PB2_HMI := **BC**

Output Settings

Output Logic Settings

This illustrates the ability to program disconnect lockout protection for the selected one-line diagram. To eliminate the danger of closing or opening the ground switch on an energized line, the disconnect switch cannot operate unless Breaker 1 is open. When the Disconnect 1 close command is executed (89CLS1), OUT103 only asserts if the state of Breaker 1 is open (NOT 52CLS1). This illustrates disconnect switch lockout protection through SELOGIC control equations. The SELOGIC control equation for OUT104 below illustrates similar lockout protection for the disconnect switch open operation. Wire OUT103 to the disconnect switch closing circuit and OUT104 to the disconnect switch opening circuit.

OUT103 := **89CLS1 AND NOT 52CLSM1**

OUT104 := **89OPEN1 AND NOT 52CLSM1**

⚠CAUTION
The outputs in the relay are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current-interrupting capacity must clear the coil current in the disconnect motor before the output opens. Failure to observe this safeguard could result in damage to the output contacts.

Another example of disconnect lockout would be to ensure that Dis 3 never closes when the ground disconnect switch Dis 5 is closed. Enter the SELOGIC control equation below for Dis 3 switch lockout protection. 89CLS3 is the close disconnect switch Relay Word bit for Disconnect 3 and the 89OPN5 Relay Word bit is the status of Disconnect 5. The SELOGIC control equation below will not assert OUT201 unless both conditions are true.

OUT201 := **89CLS3 AND 89OPN5**

These are just a few examples of disconnect lockout control. Use Relay Word bits and SELOGIC programming to design lockout control scenarios required for the configuration being controlled.

The SELOGIC Output settings listed in *Table 5.6* are example close and open disconnect equations with disconnect lockout control for Switches 1–5.

Table 5.6 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 1 of 2)

Setting	Description	Entry
General One-Line Settings		
MIMIC	One-line Screen Number (1–999)	4
BAYNAME	Bay Name (20 characters)	BAY CONTROL
Busbar Information		
BUSNAM1	Busbar 1 Name (40 pixels, 6–10 characters)	Bus T
BUSNAM2	Busbar 2 Name (40 pixels, 6–10 characters)	Bus 2
BUSNAM3	Busbar 3 Name (40 pixels, 6–10 characters)	Bus 1
Breaker Information		
B1HMINM	Breaker 1 HMI Name (max 3–17 characters)	Bkr 1
B1CTLNM	Breaker 1 HMI Cntl Scr. Name (max. 15 characters)	Bkr 1
521CLSM	Breaker 1 Close Status (SELOGIC Equation)	52ACL1
521_ALM	Breaker 1 Alarm Status (SELOGIC Equation)	52AAL1
Disconnect Information		
D1HMIN	Disconnect 1 HMI Name (max 3–17 characters)	D1
D1CTLN	Disconnect 1 Name (25 pixels, max. 15 characters)	Dis 1
89AM1	Disconnect 1 N/O Contact (SELOGIC Equation)	IN103
89BM1	Disconnect 1 N/C Contact (SELOGIC Equation)	IN104
89ALP1	Disconnect 1 Alarm Pickup Delay (1–99999 cyc)	260
89CCN1	Disconnect 1 Close Control (SELOGIC Equation)	89CC01
89OCN1	Disconnect 1 Open Control (SELOGIC Equation)	89OC01
89CST1	Disconnect 1 Close Seal-in Time (1–99999 cyc)	280
89OST1	Disconnect 1 Open Seal-in Time (1–99999 cyc)	280
D2HMIN	Disconnect 2 HMI Name (max. 3–17 characters)	D2
D2CTLN	Disconnect 2 Name (25 pixels, 4–6 characters)	Dis 2
89AM2	Disconnect 2 N/O Contact (SELOGIC Equation)	1
89BM2	Disconnect 2 N/C Contact (SELOGIC Equation)	0
89ALP2	Disconnect 2 Alarm Pickup Delay (1–99999 cyc)	260
89CCN2	Disconnect 2 Close Control (SELOGIC Equation)	89CC02
89OCN2	Disconnect 2 Open Control (SELOGIC Equation)	89OC02
89CST2	Disconnect 2 Close Seal-in Time (1–99999 cyc)	280
89OST2	Disconnect 2 Open Seal-in Time (1–99999 cyc)	280
D3HMIN	Disconnect 3 HMI Name (max. 3–17 characters)	D3
D3CTLN	Disconnect 3 Name (25 pixels, 4–6 characters)	Dis 3
89AM3	Disconnect 3 N/O Contact (SELOGIC Equation)	1
89BM3	Disconnect 3 N/C Contact (SELOGIC Equation)	0
89ALP3	Disconnect 3 Alarm Pickup Delay (1–99999 cyc)	260
89CCN3	Disconnect 3 Close Control (SELOGIC Equation)	89CC03
89OCN3	Disconnect 3 Open Control (SELOGIC Equation)	89OC03
89CST3	Disconnect 3 Close Seal-in Time (1–99999 cyc)	280
89OST3	Disconnect 3 Open Seal-in Time (1–99999 cyc)	280

Table 5.6 Application Example Bay Control Settings for Bus 1, Bus 2, and Transfer Bus Bay With Ground Switch Application (Sheet 2 of 2)

Setting	Description	Entry
D4HMIN	Disconnect 4 HMI Name (1–99999 cyc)	D4
D4CTLN	Disconnect 4 Name (25 pixels, 4–6 characters)	Dis 4
89AM4	Disconnect 4 N/O Contact (SELOGIC Equation)	1
89BM4	Disconnect 4 N/C Contact (SELOGIC Equation)	0
89ALP4	Disconnect 4 Alarm Pickup Delay (1–99999 cyc)	260
89CCN4	Disconnect 4 Close Control (SELOGIC Equation)	89CC04
89OCN4	Disconnect 4 Open Control (SELOGIC Equation)	89OC04
89CST4	Disconnect 4 Close Seal-in Time (1–99999 cyc)	280
89OST4	Disconnect 4 Open Seal-in Time (1–99999 cyc)	280
D5HMIN	Disconnect 5 HMI Name (1–9999)	D5
89AM5	Disconnect 5 N/O Contact (SELOGIC Equation)	0
89BM5	Disconnect 5 N/C Contact (SELOGIC Equation)	0
89ALP5	Disconnect 5 Alarm Pickup Delay (1–99999 cyc)	260
89CCN5	Disconnect 5 Close Control (SELOGIC Equation)	89CC05
89OCN5	Disconnect 5 Open Control (SELOGIC Equation)	89OC05
89CST5	Disconnect 5 Close Seal-in Time (1–99999 cyc)	280
89OST5	Disconnect 5 Open Seal-in Time (1–99999 cyc)	280
One-Line Analog Display		
1		1, “Analogs”
2		IAWM, “IA:(4.0,1)A”
3		VABFM, “V:(3.0,1)kV”
4		FREQ, “F:(4.1,1)Hz”
5		3P, “P:(3.0,1)MW”
6		3Q_F, “Q:(3.0,1)MVR”
Control Selection		
LOCAL	Local Control (SELOGIC control equation)	IN107

Table 5.7 Application Example Front-Panel Settings (Sheet 1 of 2)

Setting	Description	Entry
Selectable Screens for the Front Panel		
SCROLD	Front Panel Display Update Rate (OFF, 1–15 secs)	5
RMS_V	RMS Line Voltage Screen (Y, N)	Y
RMS_I	RMS Line-Current Screen (Y, N)	Y
RMS_VPP	RMS Line Voltage Phase-to-Phase Screen	N
RMS_W	RMS Active Power Screen	N
FUNDVAR	Fundamental Reactive Power Screen	N
RMS_VA	RMS Apparent Power Screen	N
RMS_PF	RMS Power Factor Screen	N
RMS_BK1	RMS Breaker 1 Currents Screen	N
RMS_BK2	RMS Breaker 2 Currents Screen	N

Table 5.7 Application Example Front-Panel Settings (Sheet 2 of 2)

Setting	Description	Entry
STA_BAT	Station Battery Screen	N
FUND_VI	Fundamental Voltage and Current Screen	N
FUNDSEQ	Fundamental Sequence Quantities Screen	N
FUND_BK	Fundamental Breaker Currents Screen	N
ONELINE	One-Line Bay Control Diagram	Y
Selectable Operator Pushbuttons		
PB2_HMI	Pushbutton 2 HMI Screen	BC

Table 5.8 Application Example Output Settings, Output SELOGIC Control Equations

Setting	Description	Entry
OUT103	OUT103 SELOGIC control equation	89CLS1 AND NOT 52CLSM1
OUT104	OUT104 SELOGIC control equation	89OPEN1 AND NOT 52CLSM1
OUT105	OUT105 SELOGIC control equation	89CLS2 AND NOT 52CLSM1
OUT106	OUT106 SELOGIC control equation	89OPEN2 AND NOT 52CLSM1
OUT201	OUT201 SELOGIC control equation	89CLS3 AND 89OPN5
OUT202	OUT202 SELOGIC control equation	89OPEN3 AND 52CLSM1
OUT203	OUT203 SELOGIC control equation	89CLS4 AND NOT 52CLSM1
OUT204	OUT204 SELOGIC control equation	89OPEN4 AND NOT 52CLSM1
OUT205	OUT205 SELOGIC control equation	89CLS5 AND NOT 52CLSM1
OUT206	OUT206 SELOGIC control equation	89OPEN5 AND NOT 52CLSM1

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SECTION 6

Autoreclosing

This section describes the operation of autoreclose logic in SEL-4XX relays that include an autorecloser. This section covers the following topics:

The relay autoreclose function provides complete control for single circuit breaker and two circuit breaker reclosing schemes. The autoreclose function accommodates both single-pole and three-pole reclosing. Some SEL-400 series relays only support three-pole operations. See the *Features* subsection in *Section 1: Introduction and Specifications* in the product-specific instruction manual to determine the reclosing capability of each relay. Relays that support single-pole breaker operations can be set for a total of two single-pole reclose shots. Three-pole breaker operations can be set for as many as four three-pole reclose shots.

You can designate the leader and follower circuit breakers in a two-circuit breaker configuration. The relay recloser can dynamically change leader and follower designations based on settings and operating conditions.

You can program the autoreclose logic to perform one shot of high-speed three-pole reclose. This high-speed three-pole shot replaces one of the four delayed time three-pole shots. There is no difference between a shot of high-speed three-pole reclose and a shot of delayed three-pole autoreclose; simply select the open interval time accordingly.

NOTE: The relay voltage check elements (for bus and line voltages) may be used without the synchronism check feature, however, for certain voltage connections, some of the synchronism check settings need to be entered to ensure that the correct voltages are used.

Two autoreclose modes are available when using the relay to control two circuit breakers:

- Combined two-breaker mode (setting E79 := Y)—both circuit breakers must trip before any reclosing can occur.
- Independent two-breaker mode (setting E79 := Y1)—the follower circuit breaker can trip and reclose even when the lead breaker has not operated. This is useful on both ring bus and breaker-and-a-half schemes, where the follower breaker is a tie breaker that can be tripped by protection on either side.

For single circuit breaker applications, use setting E79 := Y.

Autoreclosing States

The autoreclose logic for either circuit breaker can be in one of the following five states (see *Figure 6.1*):

- Start (common to both circuit breakers) (79STRT)
- Reset per circuit breaker (BK1RS, BK2RS)
- Single-pole autoreclose cycle (common to both circuit breakers) (79CY1)
- Three-pole autoreclose cycle (common to both circuit breakers) (79CY3)
- Lockout, per circuit breaker (BK1LO, BK2LO)

Start (79STRT)

The autoreclose logic is in the Start state for both circuit breakers during the following conditions:

- Startup
- Restart
- Any relay settings change

The relay stores the previous reclosing state for Relay Word bits 79CY1, 79CY3, BK1LO, BK2LO, BK1RS, and BK2RS when a restart or any relay settings change occurs.

At startup, the recloser logic goes from the start state to the lockout state. For a restart or a settings change, the recloser logic enters the start state, then goes to lockout if the circuit breakers were open before the restart or settings change. If the circuit breakers were previously closed, then the recloser logic proceeds through the 3PMRCD (Manual Close Reclaim Time Delay) time and then goes to the ready state.

Reset (BK1RS, BK2RS)

The autoreclose logic is in the reset or ready state for either circuit breaker when the circuit breaker is ready to begin an autoreclose cycle. There are three reset state timers. After a successful reclose cycle, the relay goes to the reset state after reclaim times SPRCD (Single-Pole Reclaim Time Delay) for single-pole automatic and 3PRCD (Three-Pole Reclaim Time Delay) for three-pole automatic reclosing. If the recloser has been in a lockout condition, the Ready or Reset state cannot occur until the 3PMRCD (Manual Close Reclaim Time Delay) timer has expired. You can only block the reclaim time after a successful reclose cycle. Setting 79BRCT (Block Reclaim Timer) prevents timing of reclaim timers SPRCD, 3PRCD, and 3PMRCD.

Single-Pole Autoreclose (79CY1)

This state does not apply to relays that only support three-pole reclosing. The autoreclose logic is in a single-pole autoreclose cycle for either circuit breaker if all of the following conditions are satisfied:

- Single-pole trip occurs
- Condition(s) to initiate a single-pole autoreclose cycle are satisfied
- Circuit breaker(s) is in-service and ready to begin a single-pole autoreclose cycle (that is, reset)

Three-Pole Autoreclose (79CY3)

The autoreclose logic is in a three-pole autoreclose cycle for either circuit breaker if all of the following conditions are satisfied:

- Three-pole trip occurs
- Condition(s) to initiate a three-pole autoreclose cycle are satisfied
- Circuit breaker(s) is in-service and ready to begin a three-pole autoreclose cycle (that is, reset)

Lockout (BK1LO, BK2LO)

The lockout state is the default state of any circuit breaker after startup. Other conditions place the recloser in the LO state. The relay recloser has a drive-to-lockout function that you can program for any external or internal condition—use setting 79DTL. A circuit breaker can go to lockout by two methods. The circuit breaker enters the lockout state if either of the following occur:

- Supervisory Relay Word bits SP*n*CLS or 3P*n*CLS do not assert within the BK*n*CLSD time
- The circuit breaker does not close within the BKCFD time

The timer for both supervisory Relay Word bits SP*n*CLS and 3P*n*CLS is setting BK*n*CLSD. Setting BK*n*CLSD = OFF disables the BK*n*CLSD delay timer, requiring either SP*n*CLS or 3P*n*CLS to assert before transitioning to the next state.

In applications using two circuit breakers, you can designate one circuit breaker as the leader and the other circuit breaker as the follower. The relay freezes the leader/follower decision during an autoreclose cycle unless the autoreclose logic receives another initiation.

If the recloser receives another initiation, the logic reevaluates the leader and follower circuit breakers to determine the number of circuit breakers in a scheme (NBK*n*), the leader circuit breaker (LEADBK*n*), and the follower circuit breaker (FOLBK*n*). This determination is based on the service status of the circuit breakers. The logic considers a circuit breaker out of service if the circuit breaker goes to lockout. The logic considers a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

State Diagram

NOTE: The autoreclose function runs once per power-system cycle. To ensure that the logic detects transient element state changes that initiate closing, you should extend the assertion time of transient element states to 1 cycle.

Figure 6.1 illustrates how the autoreclose logic moves from one state to another with respect to Circuit Breaker 1. (This diagram is identical for Circuit Breaker 2; replace the 1 in the Relay Word bits with 2.) The Relay Word bits that correspond to each state are shown (see *Table 6.1*). A solid path between two states indicates that the logic can move in only one direction. Two broken paths between two states indicate the logic can move in either direction between the two states. The dashed vertical line that runs through the center of the figure indicates the states common to both circuit breakers.

Table 6.1 describes each of the five states with respect to Circuit Breaker 1, along with the corresponding Relay Word bits.

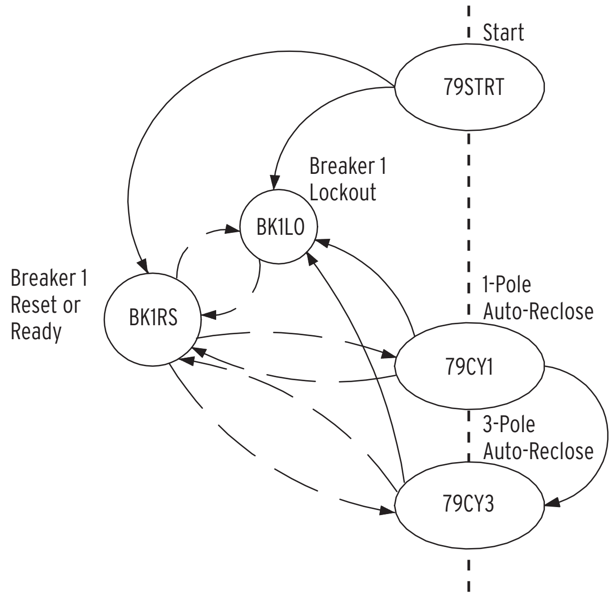

Figure 6.1 Autoreclose State Diagram for Circuit Breaker 1

Table 6.1 Autoreclose Logical States for Circuit Breaker 1

State	Description	Relay Word Bit
Start	Startup, or relay settings change	79STRT
Reset	Circuit Breaker 1 reset	BK1RS
Single-pole autoreclose cycle[a]	Single-pole autoreclose	79CY1
Three-pole autoreclose cycle	Three-pole autoreclose cycle	79CY3
Lockout	Lockout	BK1LO

[a] 79CY1 is only available in relays that support single-pole breaker operations.

One-Circuit-Breaker Autoreclosing

Modes

The autoreclose logic can operate in one of three modes, depending upon the relay autoreclose capabilities:

- ➤ Single-pole mode (SPAR)
- ➤ Three-pole mode (3PAR)
- ➤ Single- and three-pole mode (SPAR/3PAR)

Relay settings ESPR1 (Single-Pole Reclose Enable—BK1) and E3PR1 (Three-Pole Reclose Enable—BK1) determine the autoreclose mode (see *Recloser Mode Enables on page 6.8*). These settings are inputs to the recloser initiation Relay Word bits SPARC (Single-Pole Reclose Initiate Qualified) and 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 6.8* and *Figure 6.9*. SPARC asserts when all necessary conditions to begin a single-pole autoreclose cycle are satisfied (ESPR1, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 6.8*). Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole autoreclose cycle are satisfied (E3PR1, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 6.9*).

Other recloser settings include the initial recloser settings (see *Enable Autoreclose Logic for Two Circuit Breakers on page 6.22*) and the trip logic enable settings E3PT, E3PT1, and E3PT2. When SELOGIC control equations E3PT, E3PT1, and E3PT2 are deasserted, a single-pole reclose follows a single-pole trip; when these SELOGIC control equations are asserted, only three-pole tripping and reclosing result (see *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.9*).

Single-Pole Mode

NOTE: Single-pole mode is only supported in relays that provide single-pole breaker control.

Figure 6.11 shows the one circuit breaker single-pole autoreclose cycle 79CY1. The cycle starts when Relay Word bit SPARC asserts. The recloser waits as long as 10 cycles for the circuit breaker to open (indicated by Relay Word bit SPO) and then begins timing SPOID (Single-Pole Open Interval Delay) when the circuit breaker opens. After single-pole open interval time SPOID expires, the relay recloses the circuit breaker if supervisory condition SP1CLS (Single-Pole BK1 Reclose Supervision) is satisfied within the duration of timer BK1CLSD (BK1 Reclose Supervision Delay).

At the reclose command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the circuit breaker fails to close, the recloser goes to lockout (BK1LO) after timer BKCFD expires.

SPRCD Reclaim Timing

If the circuit breaker closes, the recloser starts timer SPRCD (Single-Pole Reclaim Time Delay). The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit SPLSHT (Single-Pole Reclose Last Shot). When SPLSHT is asserted, the recloser forces all subsequent relay trips to three-pole only mode.

SPLSHT Asserted (Last Shot)

The recloser exits the 79CY1 state via one of the following three methods while SPLSHT is asserted:

➤ If no further trip conditions occur, the recloser goes to the reset state BK1RS after reclaim timer SPRCD expires.

➤ If a fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied and proceeds to the autoreclose three-pole cycle state 79CY3.

➤ If a fault occurs during the SPRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example) the recloser exits the 79CY1 cycle state and goes to the lockout state BK1LO.

SPLSHT Deasserted (Single-Pole Shot Remains)

The recloser exhibits four possible state transitions when SPLSHT is not asserted:

➤ If no further trip conditions occur, the recloser goes to the reset state BK1RS after timer SPRCD expires.

➤ If a single-phase fault occurs while the SPRCD reclaim timer is timing, the recloser asserts SPARC for single-pole initiate conditions and returns to the beginning of the 79CY1 cycle state; the recloser increments the shot counter and begins the next open interval timer.

- If a multiphase fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR1 is logical 1, for example) and proceeds to the autoreclose three-pole cycle state 79CY3.
- If a multiphase fault occurs during the SPRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example), the recloser exits the 79CY1 cycle state and goes to the lockout state BK1LO.

Lockout State From 79CY1

The recloser goes to lockout (BK1LO) when any of the following occur:

- The number of trips exceeds the maximum number of shots (NSPSHOT).
- Supervision condition SP1CLS fails to assert in BK1CLSD time.
- Relay Word bit 3POLINE asserts (for a circuit breaker manual opening).
- The circuit breaker fails to close within BKCFD time.
- Any time Relay Word bit 79DTL asserts.

Three-Pole Mode

Figure 6.12 shows the one circuit breaker autoreclose cycle 79CY3. The cycle starts when Relay Word bit 3PARC asserts. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter. The recloser waits indefinitely for the circuit breaker to open, as indicated by Relay Word bit 3POLINE. The recloser begins timing 3POID1 (Three-Pole Open Interval 1 Delay) when the circuit breaker opens. After the open interval time 3POID1 expires, the relay asserts Relay Word bit BK1CL to reclose the circuit breaker if supervisory condition 3P1CLS (Three-Pole BK1 Reclose Supervision) is satisfied within the duration of timer BK1CLSD (BK1 Reclose Supervision Delay).

At the reclose command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the circuit breaker fails to close, the recloser goes to lockout (BK1LO) after timer BKCFD expires.

3PRCD Reclaim Timing

If the circuit breaker closes, the recloser starts timer 3PRCD (Three-Pole Reclaim Time Delay). The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Asserted (Last Shot)

The recloser exits the 79CY3 state via one of the following two methods while 3PLSHT is asserted:

- If no further trip conditions occur, the recloser goes to the reset state BK1RS after reclaim timer 3PRCD expires.
- If a fault occurs during the 3PRCD reclaim time, then the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

3PLSHT Deasserted (Three-Pole Shot Remains)

The recloser exhibits three possible state transitions when 3PLSHT is not asserted:

- ➤ If no further trip conditions occur, the recloser goes to the reset state BK1RS after timer 3PRCD expires.
- ➤ If a fault occurs during the 3PRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR1 is logical 1, for example) and returns to the beginning of the 79CY3 cycle state; the recloser increments the shot counter and begins the next open interval timer.
- ➤ If a fault occurs during the 3PRCD reclaim time, and the three-pole reclose conditions are not satisfied (E3PR1 is logical 0, for example), the recloser exits the 79CY3 cycle state and goes to the lockout state BK1LO.

Lockout State From 79CY3

The recloser goes to lockout (BK1LO) when any of the following occur:

- ➤ The number of trips exceeds the maximum number of shots (N3PSHOT)
- ➤ Supervision condition 3P1CLS fails to assert in BK1CLSD time
- ➤ Relay Word bit 3POLINE asserts (for a circuit breaker manual opening)
- ➤ The circuit breaker fails to close within BK1CFD time
- ➤ Relay Word bit 79DTL asserts

Single- and Three-Pole Mode

NOTE: Single- and three-pole mode is only supported in breakers that provide single-pole breaker control.

The single- and three-pole mode (SPAR/3PAR) uses elements of both the single-pole mode (SPAR) and the three-pole mode (3PAR). Reclosing begins after a single-pole trip in the single-pole cycle 79CY1 with a valid SPARC as described in *Single-Pole Mode on page 6.5*. The recloser closes the circuit breaker and proceeds to the reclaim timer SPRCD. If a fault occurs during the SPRCD reclaim time and SPLSHT is asserted, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied. Upon asserting 3PARC, the recloser exits the 79CY1 cycle state and goes to the beginning of the three-pole autoreclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page 6.6*.

Three-Pole Priority

If a single-pole autoreclose cycle 79CY1 is in progress and the relay receives an initiation for three-pole reclosing 3PRI, the recloser immediately starts a three-pole autoreclose cycle 79CY3.

Active Circuit Breakers

Two Relay Word bits describe when Circuit Breaker 1 is active for the autoreclose logic:

- ➤ NBK0, No Breaker Active in Reclose Scheme
- ➤ NBK1, One Breaker Active in Reclose Scheme

NBK1 equals logical 1 when Circuit Breaker 1 is closed and the autoreclose logic is reset, or if the autoreclose logic is in an autoreclose cycle (79CY1 or 79CY3). NBK0 equals logical 1 when Circuit Breaker 1 is open and not in an autoreclose cycle (79CY1 or 79CY3), or if the autoreclose logic is locked out (BK1LO).

Enable Autoreclose Logic for One Circuit Breaker

Three-Pole Trip Circuit Breaker

The initial settings necessary to enable autoreclose for a single three-pole trip circuit breaker are shown in *Table 6.2*.

Table 6.2 One-Circuit-Breaker Three-Pole Reclosing Initial Settings

Setting	Description	Entry
General Global Settings (Global)		
NUMBK	Number of Breakers in Scheme	1
Breaker Configuration (Breaker Monitor)		
BK1TYP[a]	Breaker 1 Trip Type	3
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC control equation)	IN101
Relay Configuration (Group)		
E79	Reclosing	Y

[a] Only applies to relays that support single-pole breaker operations.

Single-Pole Trip Circuit Breaker

The initial settings necessary to enable autoreclose for one single-pole trip circuit breaker are shown in *Table 6.3*.

Table 6.3 One-Circuit-Breaker Single-Pole Reclose Initial Settings

Setting	Description	Entry
General Global Settings (Global)		
NUMBK	Number of Breakers in Scheme	1
Breaker Configuration (Breaker Monitor)		
BK1TYP	Breaker 1 Trip Type	1
Breaker 1 Inputs (Breaker Monitor)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
52AB1	B-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN102
52AC1	C-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN103
Relay Configuration (Group)		
E79	Reclosing	Y

Recloser Mode Enables

The SELOGIC control equations E3PR1 and ESPR1 are used to set the relay autoreclose modes. *Table 6.4* illustrates how to enable the autoreclose modes for Circuit Breaker 1.

Table 6.4 One Circuit Breaker Modes of Operation

E3PR1	ESPR1[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] ESPR1 only applies to relays that support single-pole reclosing.

E3PR1 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker 1. You can assign this setting to a control input. When E3PR1 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker 1. If E3PR1 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker 1.

ESPR1 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker 1. You can assign this setting to a control input. When ESPR1 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker 1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle.

Set either or both E3PR1 and ESPR1 according to your reclosing requirements and relay reclosing capabilities. For single-pole reclosing, set ESPR1 to evaluate to logical 1 and set NSPSHOT to the desired number of single-pole reclose shots. For three-pole reclosing, set E3PR1 to evaluate to logical 1 and set N3PSHOT for the desired number of three-pole shots. For both single-pole and three-pole reclosing, set ESPR1 to evaluate to logical 1, set E3PR1 to evaluate to logical 1, and configure settings NSPSHOT and N3PSHOT for the desired number of reclose shots of each type (see *Recloser Mode Enables on page 6.8*).

Trip Logic and Reclose Sources for Single-Pole Breaker Applications

Internal Recloser

Program the recloser function to drive the trip logic with Relay Word bits R3PTE (recloser three-pole trip enable) and R3PTE1 (recloser three-pole trip enable Circuit Breaker 1) as follows:

E3PT := **R3PTE** Three-Pole Trip Enable (SELOGIC equation)

E3PT1 := **R3PTE1** Breaker 1 3PT (SELOGIC equation)

These settings connect the internal recloser for both three-pole reclosing and single-pole reclosing. Enter enable settings ESPR1 and E3PR1 as appropriate for your application.

Relay Word bits R3PTE and R3PTE1 are logical 1 for either of the following conditions when the setting NUMBK (number of breakers in scheme) is logical 1 and SPLSHT (single-pole last shot) is asserted (see *Figure 6.9*):

- BK1TYP := 3 (Breaker 1 Trip Type)
- NSPSHOT := N (Number of Single-Pole Reclosures)

External Recloser

If reclosing is performed by an external relay, assert SELOGIC control equations E3PT and E3PT1 via a control input (for example):

E3PT := **NOT IN104** Three-Pole Trip Enable (SELOGIC equation)

E3PT1 := **NOT IN104** Breaker 1 3PT (SELOGIC equation)

Connect the external recloser single-pole trip output signal to IN104. Other external recloser signals are required; consult the external recloser documentation for interconnection with the relay.

Two-Circuit-Breaker Autoreclosing

Modes

The autoreclose logic can operate in one of three modes, depending upon the relay reclose capabilities:

- Single-pole mode (SPAR)
- Three-pole mode (3PAR)
- Single- and three-pole mode (SPAR/3PAR)

NOTE: In the following discussion, *n* =1 or 2 for Circuit Breaker BK1 or BK2.

Relay settings ESPR*n* (Single-Pole Reclose Enable—BK*n*) and E3PR*n* (Three-Pole Reclose Enable—BK*n*) determine the autoreclose mode (see *Recloser Mode Enables on page 6.8*). These settings are inputs to the recloser initiation Relay Word bits SPARC (Single-Pole Reclose Initiate Qualified) and 3PARC (Three-Pole Reclose Initiate Qualified); see *Figure 6.9* and *Figure 6.10*. SPARC asserts when all necessary conditions to begin a single-pole autoreclose cycle are satisfied (ESPR*n*, for example) and the recloser receives a single-pole reclose initiation SPRI (see *Figure 6.9*). Relay Word bit 3PARC asserts when all necessary conditions to begin a three-pole autoreclose cycle are satisfied (E3PR*n*, for example) and the recloser receives a three-pole reclose initiation 3PRI (see *Figure 6.10*).

Single-pole recloser settings also include the initial recloser settings (see *Enable Autoreclose Logic for One Circuit Breaker on page 6.8*) and the trip logic enable settings E3PT, E3PT1, and E3PT2. When SELOGIC control equations E3PT, E3PT1, and E3PT2 are deasserted, a single-pole reclose follows a single-pole trip; when these SELOGIC control equations are asserted, only three-pole tripping and reclosing result (see *Trip Logic and Reclose Sources for Single-Pole Breaker Applications on page 6.25*).

Single-Pole Mode

Figure 6.13 and *Figure 6.14* show the two circuit breaker single-pole autoreclose cycle 79CY1 when E79 := Y and E79 := Y1, respectively. The cycle starts when Relay Word bit SPARC asserts. The recloser freezes calculation of the number of breakers, the leader circuit breaker, and the follower circuit breaker. Depending on the calculation, the recloser asserts the appropriate Relay Word bits NBK0, NBK1, NBK2, LEADBK0, LEADBK1, LEADBK2, FOLBK0, FOLBK1, and FOLBK2.

The recloser checks for an SPO (Single-Pole Open) condition for either the leader or follower, and waits as long as 10 cycles for the circuit breakers to open. If the leader or follower shows a single-pole open inside the 10-cycle window, the recloser proceeds to timing SPOID (Single-Pole Open Interval Delay). The recloser goes to lockout if the circuit breakers fail to open (no close attempts follow). If an evolving fault results in a three-pole trip condition that asserts 3PARC, then the recloser exits the 79CY1 cycle and goes to the three-pole cycle 79CY3. When E79 := Y1, a Single-Pole Open Interval Supervision Condition (SPOISC) must be satisfied before the recloser can proceed to timing SPOID. If the supervisory condition is not met within the duration of timer SPOISD (Single-Pole Open Interval Supervision Delay), the recloser goes to lockout.

After single-pole open interval time SPOID expires, the recloser closes the leader if the single-pole open condition is still in effect and supervisory condition SP*n*CLS (Single-Pole BK*n* Reclose Supervision) is satisfied within the duration of timer BK*n*CLSD (BK*n* Reclose Supervision Delay). If the leader circuit breaker has more than one pole open at the end of the SPOID time, the recloser sends the leader to lockout BK*n*LO.

At the leader close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the leader fails to close, the recloser sends the leader to lockout after timer BKCFD expires. If the leader closes within the BKCFD time, the recloser goes to SPRCD (Single-Pole Reclaim Time Delay) reclaim timing if NBK1 is asserted, or prepares to close the follower circuit breaker if NBK2 is asserted.

To close the follower circuit breaker, the recloser checks for two active circuit breakers in the scheme. If NBK2 is asserted, the recloser checks for a single-pole open on the follower and starts timer TBBKD (Time Between Breakers For ARC). If multiple poles of the follower circuit breaker are open, the recloser sends the follower to lockout BK*n*LO. When TBBKD expires, the recloser closes the follower breaker if FBKCEN (Follower Breaker Closing Enable) is asserted and supervisory condition SP*n*CLS is satisfied within the duration of timer BK*n*CLSD. At the follower close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the follower fails to close, the recloser sends the follower to lockout after timer BKCFD expires. If the leader circuit breaker is not in lockout, the recloser begins timing SPRCD reclaim time for the leader.

If the follower breaker closes successfully, the recloser starts the SPRCD (Single-Pole Reclaim Time Delay) timer if 79BRCT (Block Reclaim Timer) is not asserted.

SPRCD Reclaim Timing

The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit SPLSHT (Single-Pole Reclose Last Shot). When SPLSHT is asserted, the recloser forces all subsequent relay trips to three-pole only mode.

SPLSHT Deasserted (Single-Pole Shot Remains)

The recloser exhibits four possible state transitions when SPLSHT is not asserted:

- If no further trip conditions occur and timer SPRCD expires, the recloser returns to the reset states BK*n*RS.
- If a single-phase fault occurs while the SPRCD reclaim timer is timing, then the recloser asserts SPARC if all single-pole initiate conditions are satisfied and goes to the beginning of the 79CY1 cycle. The recloser then recalculates and freezes the calculation for the number of active circuit breakers, the leader, and the follower. The recloser then increments the shot counter and begins the next open interval timer.

- If a multiphase fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied (E3PR*n* is logical 1, for example) and recalculates the number of active circuit breakers, the leader, and the follower before proceeding to the autoreclose three-pole cycle state 79CY3.
- If a multiphase fault occurs during the SPRCD reclaim time, SPLSHT is not asserted, and the three-pole reclose conditions are not satisfied (E3PR*n* is logical 0, for example) and the recloser exits the 79CY1 cycle state and goes to the lockout state BK*n*LO.

SPLSHT Asserted (Last Shot)

The recloser exits the 79CY1 state via three methods while SPLSHT is asserted:

- If no further trip conditions occur and timer SPRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs during the SPRCD reclaim time, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied and proceeds to the autoreclose three-pole cycle state 79CY3.
- If a fault occurs during the SPRCD reclaim time and the three-pole reclose conditions are not satisfied (E3PR*n* is logical 0, for example), then the recloser exits the 79CY1 cycle state and goes to the lockout state Bk*n*LO.

Lockout State From 79CY1

The recloser goes to lockout (BK*n*LO) when the number of trips exceeds the maximum number of shots (NSPSHOT), supervision condition SP*n*CLS fails to assert in BK*n*CLSD time, Relay Word bit 3POLINE asserts (for a circuit breaker manual opening), the circuit breaker fails to close within BKCFD time, or any time Relay Word bit 79DTL asserts.

Three-Pole Mode

Figure 6.15 and *Figure 6.16* show the two circuit breaker three-pole autoreclose cycle 79CY3 when E79 := Y and E79 := Y1, respectively. The cycle starts when Relay Word bit 3PARC asserts. The recloser freezes calculation of the number of breakers, the leader circuit breaker, and the follower circuit breaker. Depending on the calculation, the recloser asserts the appropriate Relay Word bits NBK0, NBK1, NBK2, LEADBK0, LEADBK1, LEADBK2, FOLBK0, FOLBK1, and FOLBK2. The recloser checks SELOGIC control equation 79SKP at this point to determine whether to increment the shot counter.

The recloser waits for 3POLINE to assert:

- if E79 := Y, 3POLINE asserts when both breakers (leader and follower) open (see *Figure 6.15*)
- if E79 := Y1, 3POLINE asserts when at least one breaker (leader or follower) opens (see *Figure 6.16*)

If 3POLINE asserts within the 3PRIH time delay, the recloser proceeds to timing 3POID1 (Three-Pole Open Interval 1 Delay). If 3POLINE fails to assert within the 3PRIH time-delay setting, the recloser goes to lockout. If the 3PRIH setting = OFF, the recloser will wait indefinitely for 3POLINE to assert before proceeding to timing 3POID1. If SELOGIC control equation 3PFARC (Three-Pole Fast ARC Enable) is asserted, the recloser times the open interval time from setting 3PFOID (Three-Pole Fast Open Interval Delay). When E79 := Y1, a Three-Pole Open Interval Supervision Condition (3POISC) must be satisfied before the recloser can proceed to timing 3POID1. If the supervisory condition is not met within the duration of timer 3POISD (Three-Pole Open Interval Supervision Delay), the recloser goes to lockout.

After three-pole open interval time 3POID or 3PFOID expires.

- and E79 := Y, the recloser attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS).
- and E79 := Y1, the recloser checks if the leader breaker is open. If open, it attempts to close the leader breaker, as discussed below (first checking the supervisory condition 3P*n*CLS). If the leader breaker is closed (it never opened at the outset), the recloser skips the leader breaker close logic and attempts to close the follower breaker, as discussed further below (first checking for two active breakers and an open follower breaker, before starting timer TBBKD [Time Between Breakers for ARC]).

The recloser closes the leader if supervisory condition 3P*n*CLS (Three-Pole BK*n* Reclose Supervision) is satisfied within the duration of timer BK*n*CLSD (BK*n* Reclose Supervision Delay).

At the leader close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the leader fails to close, the recloser sends the leader to lockout BK*n*LO after timer BKCFD expires. If the leader closes within the BKCFD time, the recloser goes to 3PRCD (Three-Pole Reclaim Time Delay) reclaim timing if NBK1 is asserted, or prepares to close the follower circuit breaker if NBK2 is asserted.

To close the follower circuit breaker, the recloser checks for two active circuit breakers in the scheme. If NBK2 is asserted, the recloser checks for a three-pole open on the follower and starts timer TBBKD (Time Between Breakers For ARC). When TBBKD expires, the recloser closes the follower breaker if FBKCEN (Follower Breaker Closing Enable) is asserted and supervisory condition 3P*n*CLS is satisfied within the duration of timer BK*n*CLSD. At the follower close command, the recloser starts timer BKCFD (Breaker Close Failure Delay). If the follower fails to close, the recloser sends the follower to lockout after timer BKCFD expires. If the leader circuit breaker is not in lockout, the recloser begins timing 3PRCD reclaim time for the leader.

If the follower breaker closes successfully, the recloser starts the 3PRCD (Three-Pole Reclaim Time Delay) timer if 79BRCT (Block Reclaim Timer) is not asserted.

3PRCD Reclaim Timing

The recloser determines subsequent state transitions during reclaim timing according to the status of Relay Word bit 3PLSHT (Three-Pole Reclose Last Shot).

3PLSHT Deasserted (Three-Pole Shot Remains)

The recloser exhibits two possible state transitions when 3PLSHT is not asserted:

- If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs while the 3PRCD reclaim timer is timing, then the recloser asserts 3PARC if all three-pole initiate conditions are satisfied and goes to the beginning of the 79CY3 cycle. The recloser then recalculates and freezes the number of active circuit breakers, the leader, and the follower. The recloser then increments the shot counter and begins the next open interval timer.

3PLSHT Asserted (Last Shot)

The recloser exits the 79CY3 state via two methods while 3PLSHT is asserted:

- If no further trip conditions occur and timer 3PRCD expires, the recloser returns to the reset states BK*n*RS.
- If a fault occurs during the 3PRCD reclaim time and 3PLSHT is asserted, then the recloser goes to lockout BK*n*LO.

Lockout State From 79CY3

The recloser goes to lockout (BK*n*LO) when any of the following occur:

- The number of trips exceeds the maximum number of shots (N3PSHOT)
- Supervision condition 3P*n*CLS fails to assert in BK*n*CLSD time
- Relay Word bit 3POLINE asserts for a circuit breaker manual opening (no qualified autoreclose initiation 3PARC)
- The circuit breaker fails to close within BKCFD time
- SELOGIC equation 79DTL asserts

Single- and Three-Pole Mode

The single- and three-pole mode (SPAR/3PAR) uses elements of both the single-pole mode (SPAR) and the three-pole mode (3PAR). Reclosing begins after a single-pole trip in the single-pole cycle 79CY1 with a valid SPARC as described in *Single-Pole Mode on page 6.10*. The recloser closes the circuit breakers and proceeds to the reclaim timer SPRCD. If a fault occurs during the SPRCD reclaim time and SPLSHT is asserted, then the recloser asserts Relay Word bit 3PARC if all three-pole reclose conditions are satisfied. Upon asserting 3PARC, the recloser exits the 79CY1 cycle state and goes to the beginning of the three-pole autoreclose cycle state 79CY3. The recloser proceeds through the 79CY3 state and exits this state as described in *Three-Pole Mode on page 6.12*.

Three-Pole Priority

If a single-pole autoreclose cycle is in progress (79CY1) and the relay receives an initiation for three-pole reclosing (3PRI), the recloser immediately starts a three-pole autoreclose cycle (79CY3).

Active Circuit Breakers

The following three Relay Word bits describe when Circuit Breaker BK1 and Circuit Breaker BK2 are active for the autoreclose logic:

- NBK0, No Breaker Active in Reclose Scheme
- NBK1, One Breaker Active in Reclose Scheme
- NBK2, Two Breakers Active in Reclose Scheme

Leader and Follower Circuit Breakers

One circuit breaker is the leader and the other is the follower for circuit breaker-and-a-half and ring-bus arrangements. *Figure 6.2* illustrates a multiple circuit breaker arrangement. The leader recloses first. If the leader recloses successfully, the follower also typically recloses.

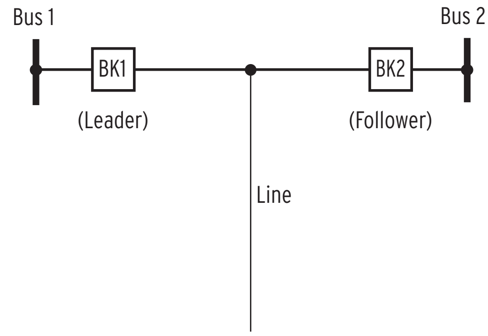

Figure 6.2 Multiple Circuit Breaker Arrangement

Choose Circuit Breaker BK1 as the leader and Circuit Breaker BK2 as the follower. If Circuit Breaker BK1 is out of service (for maintenance, for example), the relay can automatically make Circuit Breaker BK2 the leader.

The relay freezes the leader, follower, and number of active circuit breaker designations during an autoreclose cycle. If the logic receives another reclose initiation, the relay reevaluates the leader, follower, and number of active circuit breaker designations. The logic considers a circuit breaker out of service if the circuit breaker goes to lockout, and declares a circuit breaker to be in service as soon as the circuit breaker closes and is no longer in lockout.

Leader Logic

Relay settings SLBK1 (Leader Breaker = Breaker 1) and SLBK2 (Leader Breaker = Breaker 2) SELOGIC control equations determine the criteria for relay selection of the active leader. Set SLBK1 := 1 to select Circuit Breaker BK1 as the leader; set SLBK2 := 1 to select Circuit Breaker BK2 as the leader. SLBK1 has priority over SLBK2; if you set both settings to 1 or both to 0, Circuit Breaker BK1 is the leader.

Circuit Breaker BK1 is the leader for the following conditions:

- ➤ BK1 is the only circuit breaker in service
- ➤ BK1 and BK2 are in service and BK1 is selected as the leader (SLBK1 := 1)
- ➤ BK1 and BK2 are in service and the setting combination SLBK1 := 0 and SLBK2 := 1 is not in effect

Circuit Breaker BK2 is the leader for the following conditions:

- ➤ BK2 is the only circuit breaker in service
- ➤ BK1 and BK2 are in service and BK2 is selected as the leader (SLKBK1 := 0 and SLBK2 := 1)
- ➤ If neither circuit breaker is in service, there is no leader

The following three Relay Word bits describe which circuit breaker is the leader:

- ➤ LEADBK0, No Breaker In Service
- ➤ LEADBK1, Leader Breaker = Breaker 1
- ➤ LEADBK2, Leader Breaker = Breaker 2

The relay loads the corresponding circuit breaker settings into the leader Relay Word bits (LEADBK0, LEADBK1, and LEADBK2). If there is no leader (no circuit breaker is active), the relay loads a logical 0 into LEADBK1 and LEADBK2, and a logical 1 into LEADBK0.

Follower Logic

The FBKCEN SELOGIC control equation, Follower Breaker Closing Enable, defines the conditions necessary for the follower breaker to reclose.

The relay selects the follower as follows:

- ➤ If Circuit Breaker BK1 is the leader and Circuit Breaker BK2 is not locked out, then Circuit Breaker BK2 is the follower.
- ➤ If Circuit Breaker BK2 is the leader and Circuit Breaker BK1 is not locked out, then Circuit Breaker BK1 is the follower.
- ➤ If fewer than two circuit breakers are in service (NBK0 or NBK1 is asserted), then there is no follower.

The following three Relay Word bits describe which circuit breaker is the follower:

- ➤ FOLBK0, No Follower Breaker
- ➤ FOLBK1, Follower Breaker = Breaker 1
- ➤ FOLBK2, Follower Breaker = Breaker 2

If there is no follower (in the case of only one circuit breaker, for example), the relay loads a logical 0 into the follower SELOGIC control equation FBKCEN.

Dynamic Selection of Leader and Follower Circuit Breakers

The relay dynamically selects the leader and follower circuit breakers during the reclose cycle. The relay calculates the leader in the ready (reset) state. At the start of the reclose cycle, the relay freezes this calculation and sets circuit breaker designations. The leader/follower designation can dynamically change in the cycle if the leader circuit breaker goes to lockout and FBKCEN is asserted.

Set the initial leader/follower designation and follower close conditions with settings SLBK1 (Lead Breaker = Breaker 1), SLBK2 (Lead Breaker = Breaker 2), and FBKCEN (Follower Breaker Closing Enable). *Table 6.5* shows the permutations of these settings.

Table 6.5 Dynamic Leader/Follower Settings (Sheet 1 of 2)

SLBK1	SLBK2	FBKCEN	Comments
0	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.
0	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1→ LO after BKCFD. BK2 will close as the follower upon successful close of the leader BK1.
0	1	0	BK2 is the leader; BK1 is the leader only if BK2→ LO and BK1 is closed. BK1 will not close as the follower upon successful close of leader BK2.
0	1	1	BK2 is the leader; BK1 is the leader only if BK2→ LO. BK1 will close if BK2→ LO after BKCFD. BK1 will close as the follower after TBBKD upon successful close of the leader BK1.
1	0	0	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will not close as the follower upon successful close of leader BK1.

Table 6.5 Dynamic Leader/Follower Settings (Sheet 2 of 2)

SLBK1	SLBK2	FBKCEN	Comments
1	0	1	BK1 is the leader; BK2 is the leader only if BK1→ LO and BK2 is closed. BK2 will close as the follower if BK1→ LO after BKCFD. BK2 will close as the follower upon successful close of the leader BK1.
1	1	0	Same as 1/0/0.
1	1	1	Same as 1/0/1.
1	0	52AA1	BK1 is the leader; BK2 to LO is the leader if BK1→ LO. BK2 will close as the follower after TBBKD upon successful close of the leader BK1.

Circuit Breaker BK1 is always the leader if SLBK1 is asserted and BK1 is not locked out. Circuit Breaker BK2 is the leader if SLBK2 is asserted, BK2 is not locked out, and SLBK1 is not asserted. The second circuit breaker can become the leader when the leader is locked out.

Setting FBKCEN does not pick the follower, but decides when the second circuit breaker can reclose. If the leader goes to lockout, then the follower goes to lockout if FBKCEN := 0. If, however, the leader is manually opened, the follower breaker can become the leader (after being manually closed) and can close via a reclose cycle if FBKCEN := 1. If you want the follower breaker to close only for specific conditions, use the enable settings to force this close requirement. For example, Circuit Breaker BK2 can dynamically become the leader if BK1 is locked out and BK2 is closed. If you do not want BK2 to become the leader, set FBKCEN := 52AA1. Also see *Example One: No Follower on page 6.17* for another method to prevent BK2 from becoming the leader.

The following examples help illustrate how the relay autoreclose logic dynamically determines the leader and follower circuit breakers. These examples describe a two circuit breaker scheme (such as used in a circuit breaker-and-a-half arrangement) as shown in *Figure 6.3*.

Example One: No Follower

This example describes recloser states when Circuit Breaker BK1 fails to reclose following the first three-pole open interval delay. Set the FBKCEN SELOGIC control equation to prevent Circuit Breaker BK2 from closing as the follower. The leader and follower selection settings are shown in *Table 6.6*.

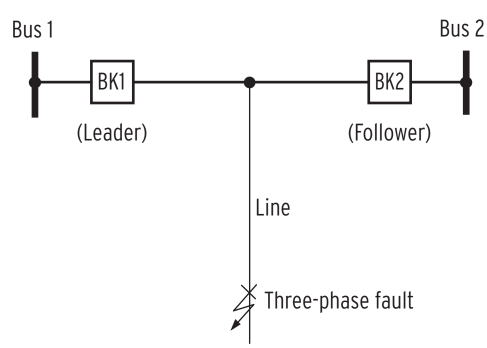

Figure 6.3 Multiple Circuit Breaker Arrangement

Table 6.6 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	0

Reset State and 79CY3 Cycle State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. *Table 6.7* defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle.

Table 6.7 Example One: Reset and 79CY3 States

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

Lockout State

Circuit Breaker BK1 fails to close when the first three-pole open interval expires and goes to lockout. Circuit Breaker BK2 goes to lockout. *Table 6.8* defines the logical state of the autoreclose logic at this point.

Table 6.8 Example One: Lockout State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Reset State After Reclaim Time

Circuit Breaker BK2 is manually closed and now becomes active as the leader after 3PMRCD (Manual Close Reclaim Time Delay). Subsequent reclosing occurs with BK2. *Table 6.9* defines the logical state of the autoreclose logic at this point.

Table 6.9 Example One: Reset State After Reclaim Time

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Block Reclosing With Enable Settings

To block BK2 as leader use the enable settings; set ESPR2 := NBK2 and E3PR2 := NBK2. With these enable settings BK2 never becomes the leader circuit breaker.

Example Two: BK2 as Successful Follower and Dynamic Leader

Another example is similar to the first with SLBK1/SLBK2/FBKCEN at 1/0/1 (see *Table 6.10*).

Table 6.10 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	1

Reset State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. At the start of the reclose cycle, Relay Word bits LEADBK1, FOLBK2, and NBK2 are asserted (see *Table 6.11*).

Table 6.11 Example Two: Initial Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

When BK1 successfully recloses, BK2 closes as the follower after timer TBBKD (Time Between Breakers for ARC).

If BK1 goes to lockout during a reclose cycle (after BKCFD time), then BK2 will close as the follower. After timer 3PRCD (Three-Pole Reclaim Time Delay) expires, the recloser enters the reset state for BK2 (BK2RS). The recloser dynamically recalculates the leader and follower circuit breakers. BK2 becomes the leader with Relay Word bits LEADBK2, FOLBK0, and NBK1 asserted (see *Table 6.12*). When BK2 becomes the leader, the recloser immediately issues the close command to BK2 and does not add any additional SPOID or 3POID interval time.

Table 6.12 Example Two: Final Reset State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Three: BK2 as Conditional Follower

One method to program BK2 for closing only after a successful BK1 close is to set SLBK1/SLBK2/FBKCEN as in *Table 6.13*.

Table 6.13 Leader/Follower Selection

Setting Label	Value
SLBK1	1
SLBK2	0
FBKCEN	52AA1

Reset State

Prior to receiving initiation for a three-phase fault, the autoreclose logic resets for both circuit breakers. *Table 6.14* defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle.

Table 6.14 Example Three: Reset State (Sheet 1 of 2)

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0

Table 6.14 Example Three: Reset State (Sheet 2 of 2)

Relay Word Bit	Description	Logical State
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

79CY3 Cycle State

The autoreclose logic receives a three-pole initiation. *Table 6.15* defines the logical state of the autoreclose logic for this example during the three-pole autoreclose cycle.

Table 6.15 Example Three: Three-Pole Cycle State

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	1
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	1
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	0
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	1

BK2 closes as the follower when BK1 successfully closes (after timer TBBKD).

Lockout State

Circuit Breaker BK1 must close before Circuit Breaker BK2. If Circuit Breaker BK1 fails to close and goes to lockout, then Circuit Breaker BK2 goes to lockout as well because BK2 cannot close as the follower and cannot dynamically become the leader. *Table 6.16* defines the logical state of the autoreclose logic for this example following the unsuccessful reclose attempt.

Table 6.16 Example Three: Lockout State, BK

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	1
NBK1	One Breaker Active in Reclose Scheme	0
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	1
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	0
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Example Four: Input Selection of Leader

Figure 6.4 illustrates a circuit breaker-and-a half configuration for this particular example. The leader and follower selection settings are shown in *Table 6.17*. Circuit Breaker BK1 is out of service for maintenance and Disconnect Switch 1 is open.

Table 6.17 Leader/Follower Selection

Setting Label	Setting
SLBK1	IN106 (Disconnect 1 a contacts)
SLBK2	IN107 (Disconnect 2 a contacts)
FBKCEN	0

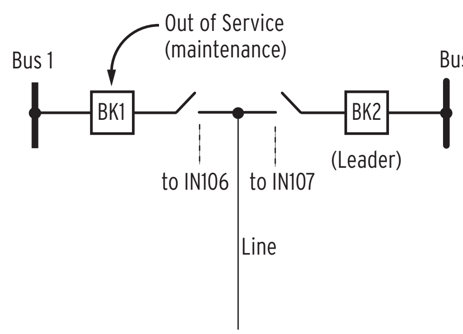

Figure 6.4 Leader/Follower Selection by Relay Input

Table 6.18 defines the logical state of the autoreclose logic for this example prior to the initiation of an autoreclose cycle. These conditions are frozen during an autoreclose cycle. The relay autoreclose logic can unfreeze these conditions if the relay receives another initiation.

Table 6.18 Two Circuit Breakers: Circuit Breaker BK1 Out of Service

Relay Word Bit	Description	Logical State
NBK0	No Active Breakers in Reclose Scheme	0
NBK1	One Breaker Active in Reclose Scheme	1
NBK2	Two Active Breakers in Reclose Scheme	0
LEADBK0	No Leader Breaker	0
LEADBK1	Leader Breaker = Breaker 1	0
LEADBK2	Leader Breaker = Breaker 2	1
FOLBK0	No Follower Breaker	1
FOLBK1	Follower Breaker = Breaker 1	0
FOLBK2	Follower Breaker = Breaker 2	0

Enable Autoreclose Logic for Two Circuit Breakers

Three-Pole Trip Circuit Breakers

The initial settings necessary to enable autoreclose for two three-pole trip circuit breakers are shown in *Table 6.19*.

Table 6.19 Two-Circuit-Breaker Three-Pole Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker Configuration (Breaker Monitor)		
BK1TYP[a]	Breaker 1 Trip Type	3
BK2TYP[a]	Breaker 2 Trip Type	3
Breaker 1 Inputs (Breaker Monitor)		
52AA1	N/O Contact Input—BK1 (SELOGIC Equation)	IN101
Breaker 2 Inputs (Breaker Monitor)		
52AA2	N/O Contact Input—BK2 (SELOGIC Equation)	IN102
Relay Configuration (Group)		
E79	Reclosing	Y or Y1

[a] Only applicable to products that support single-pole tripping and reclosing.

Single-Pole Trip Circuit Breakers

The initial settings necessary to enable autoreclose for two single-pole trip circuit breakers are shown in *Table 6.20*.

Table 6.20 Two-Circuit-Breaker Single-Pole Reclose Initial Settings

Setting	Description	Entry
NUMBK	Number of Breakers in Scheme	2
Breaker Configuration (Breaker Monitor)		
BK1TYP	Breaker 1 Trip Type	1
BK2TYP	Breaker 2 Trip Type	1
Breaker 1 Inputs (Breaker Monitor)		
52AA1	A-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN101
52AB1	B-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN102
52AC1	C-Phase N/O Contact Input—BK1 (SELOGIC Equation)	IN103
Breaker 2 Inputs (Breaker Monitor)		
52AA2	A-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN104
52AB2	B-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN105
52AC2	C-Phase N/O Contact Input—BK2 (SELOGIC Equation)	IN106
Relay Configuration (Group)		
E79	Reclosing	Y or Y1

Recloser Mode Enables

The SELOGIC control equations E3PR*n* and ESPR*n* set the relay for the three autoreclose modes. *Table 6.21* and *Table 6.22* illustrate how to enable the autoreclose modes per circuit breaker.

Table 6.21 Circuit Breaker BK1 Modes of Operation (Sheet 1 of 2)

E3PR1	ESPR1[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled

Table 6.21 Circuit Breaker BK1 Modes of Operation (Sheet 2 of 2)

E3PR1	ESPR1[a]	Result
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] Only applicable to relays that support single-pole reclosing.

E3PR1 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker BK1. You can assign this setting to a control input. ESPR1 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker BK1. You can assign this setting to a control input.

When ESPR1 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker BK1. If ESPR1 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle for Circuit Breaker BK1.

When E3PR1 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker BK1. If E3PR1 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker BK1 and the corresponding leader logic transfers automatically to Circuit Breaker BK2.

Table 6.22 Circuit Breaker BK2 Modes of Operation

E3PR2	ESPR2[a]	Result
0	0	Autoreclose disabled
0	1	Single-pole autoreclose only enabled
1	0	Three-pole autoreclose only enabled
1	1	Single- and three-pole autoreclose enabled

[a] Only applicable to relays that support single-pole reclosing.

E3PR2 is the SELOGIC control equation that enables three-pole autoreclose for Circuit Breaker BK2. You can assign this setting to a control input. ESPR2 is the SELOGIC control equation that enables single-pole autoreclose for Circuit Breaker BK2. You can assign this setting to a control input.

When ESPR2 equals logical 1, the relay can attempt a single-pole autoreclose cycle for Circuit Breaker BK2. If ESPR2 equals logical 0, the relay cannot initiate a single-pole autoreclose cycle for Circuit Breaker BK2.

When E3PR2 equals logical 1, the relay can attempt a three-pole autoreclose cycle for Circuit Breaker BK2. If E3PR2 equals logical 0, the relay goes to lockout following a three-pole trip for Circuit Breaker BK2.

Assert one or all SELOGIC control equations E3PR1, E3PR2, ESPR1, and ESPR2 according to your reclosing requirements.

For single-pole reclosing, set ESPR1 := 1 and set NSPSHOT to the desired number of single-pole reclose shots. For three-pole reclosing, set E3PR1 := 1 and set N3PSHOT for the desired number of three-pole shots. For both single-pole and three-pole reclosing, set ESPR1 := 1, E3PR1 := 1, and configure settings NSPSHOT and N3PSHOT for the desired number of reclose shots of each type (see *Recloser Mode Enables on page 6.8*).

Example 6.1 Conditional Three-Pole Tripping for Circuit Breaker BK2

Your system reclosing requirement is that Circuit Breaker BK2 always three-pole trips, unless Circuit Breaker BK2 is the leader. (This occurs when Circuit Breaker BK1 is out of service.) Program SELOGIC control equation ESPR2 as follows:

ESPR2 := **LEADBK2 AND BK1LO** Single-Pole Reclose Enable—BK2 (SELOGIC Equation)

Trip Logic and Reclose Sources for Single-Pole Breaker Applications

Internal Recloser

Program the recloser function to drive the trip logic with Relay Word bits R3PTE (Recloser Three-Pole Trip Enable), R3PTE1 (Circuit Breaker BK1 Recloser Three-Pole Trip Enable) and R3PTE2 (Circuit Breaker BK2 Recloser Three-Pole Trip Enable) as follows:

E3PT := **R3PTE** Three-Pole Trip Enable (SELOGIC Equation)

E3PT1 := **R3PTE1** Breaker 1 Three-Pole Trip (SELOGIC Equation)

E3PT2 := **R3PTE2** Breaker 2 Three-Pole Trip (SELOGIC Equation)

These settings connect the internal recloser for both three-pole reclosing and single-pole reclosing.

Enter enable settings ESPR1 and E3PR1 as appropriate for your application. By default, the relay is a single-pole tripping relay; that is, if E3PT is logical 0 and E3PT1 equals logical 0, the relay can single-pole trip Circuit Breaker BK1. If E3PT1 equals logical 1, the relay can only three-pole trip Circuit Breaker BK1. The same conditions apply to setting E3PT2 and Circuit Breaker BK2.

Table 6.23 summarizes the relay trip logic enable options.

Table 6.23 Trip Logic Enable Options

Enable Condition			Circuit Breaker BK1		Circuit Breaker BK2	
E3PT	E3PT1	E3PT2	Single-Pole Trip	Three-Pole Trip	Single-Pole Trip	Three-Pole Trip
0	0	0	x		x	
0	0	1	x			x
0	1	0		x	x	
0	1	1		x		x
1	0	0		x		x
1	0	1		x		x
1	1	0		x		x
1	1	1		x		x

Relay Word bits R3PTE1 and R3PTE2 both equal logical 1 for any of the following conditions when Global setting NUMBK (Number of Breakers in Scheme) is 2 and SPLSHT (Single-Pole Last Shot) is asserted (see *Figure 6.9*):

- BK1TYP and BK2TYP equal 3 (Circuit Breaker 1 and Circuit Breaker 2 Trip Type)
- NSPSHOT := N (Number of Single-Pole Reclosures)

External Recloser

If reclosing is performed by an external relay, assert SELOGIC control equations E3PT, E3PT1, and E3PT2 via control inputs (for example):

E3PT := **IN104** Three-Pole Trip Enable (SELOGIC Equation)

E3PT1 := **IN105** Breaker 1 Three-Pole Trip (SELOGIC Equation)

E3PT2 := **IN106** Breaker 2 Three-Pole Trip (SELOGIC Equation)

Connect the external recloser single-pole trip output signal to IN104, the Circuit Breaker BK1 trip type signal to IN105, and the Circuit Breaker BK2 trip type signal to IN106. Other external recloser signals are required; consult the external recloser documentation for interconnection with the relay.

In installations where the external reclosing relay does not provide three-phase trip control signals, the TOP (Trip during Open-Pole) Relay Word bit can be used in the E3PT setting. This Relay Word bit will assert just after a single- or two-pole trip, and remain asserted until the TOPD timer expires. If a new trip occurs during this time, the E3PT := TOP setting would then cause a three-pole trip.

Autoreclose Logic Diagrams

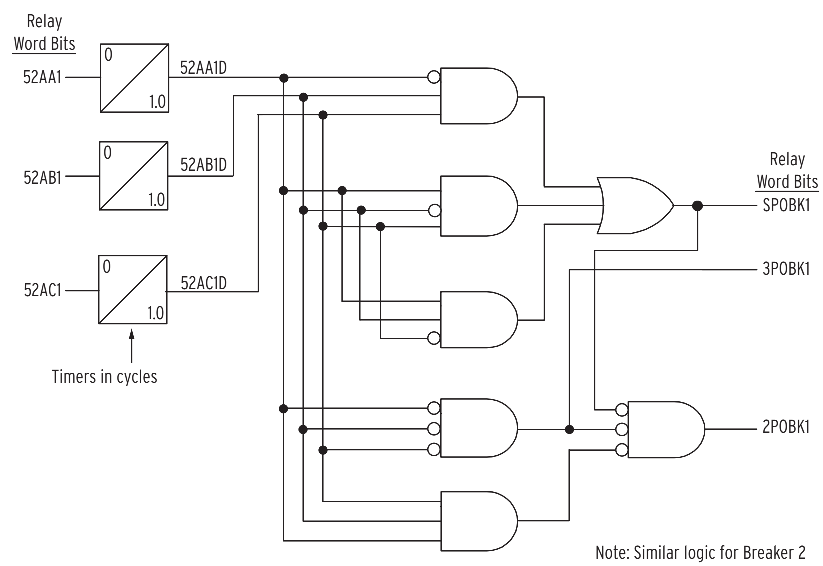

Figure 6.5 Circuit Breaker Pole-Open Logic Diagram—Single-Pole Relays

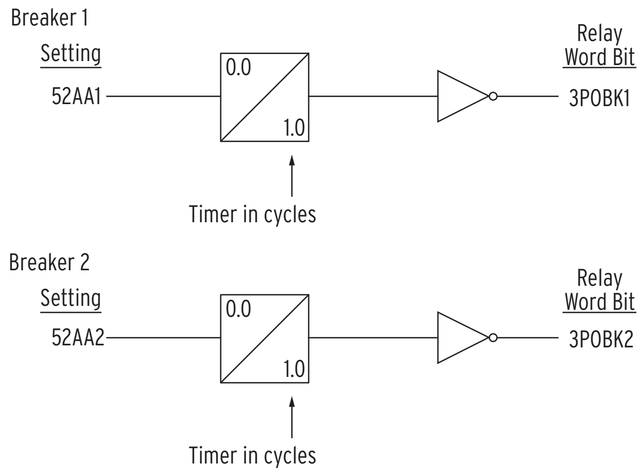

Figure 6.6 Circuit Breaker Pole-Open Logic Diagrams—Three-Pole Relays

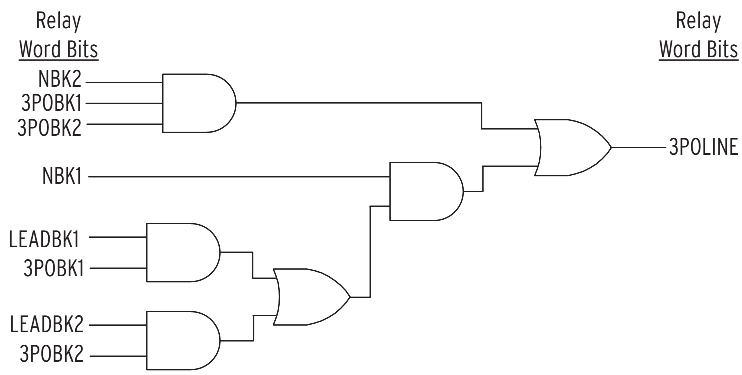

Figure 6.7 Line-Open Logic Diagram When E79 := Y

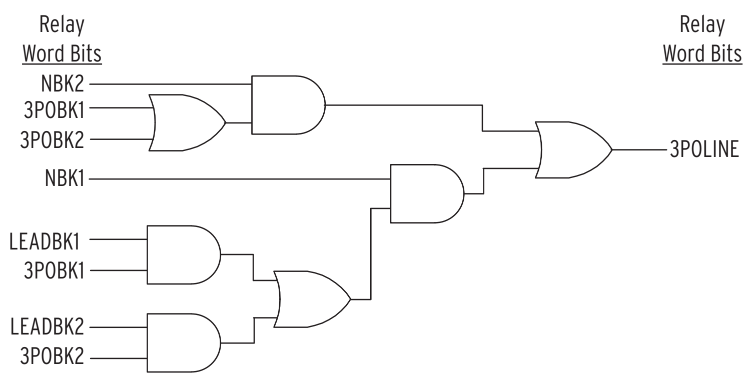

Figure 6.8 Line-Open Logic Diagram When E79 := Y1

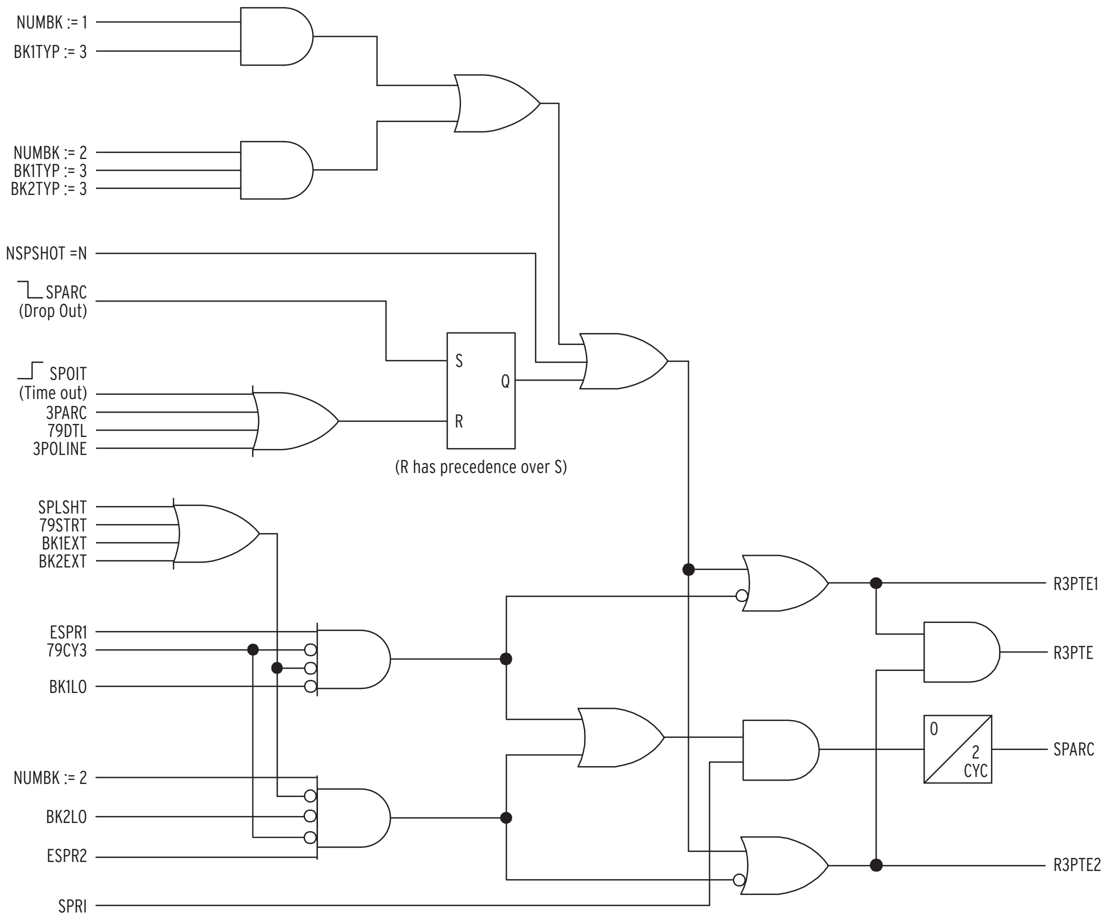

Figure 6.9 Single-Pole Reclose Enable

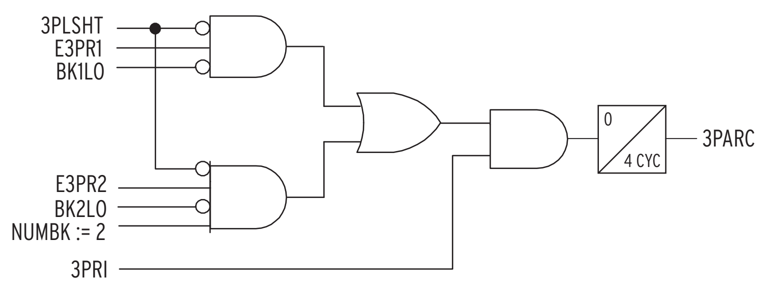

Figure 6.10 Three-Pole Reclose Enable

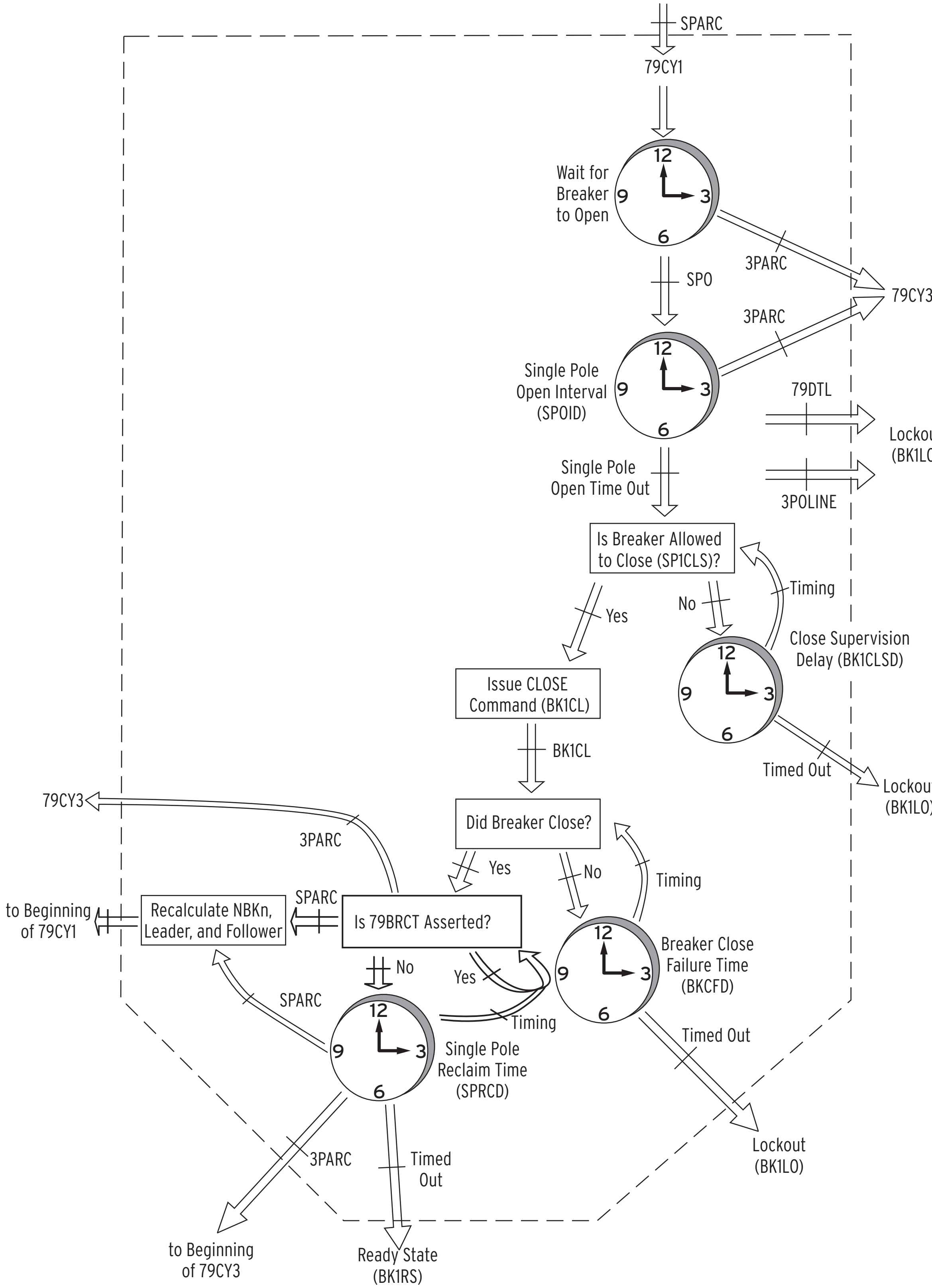

Figure 6.11 One Circuit Breaker Single-Pole Cycle State (79CY1)

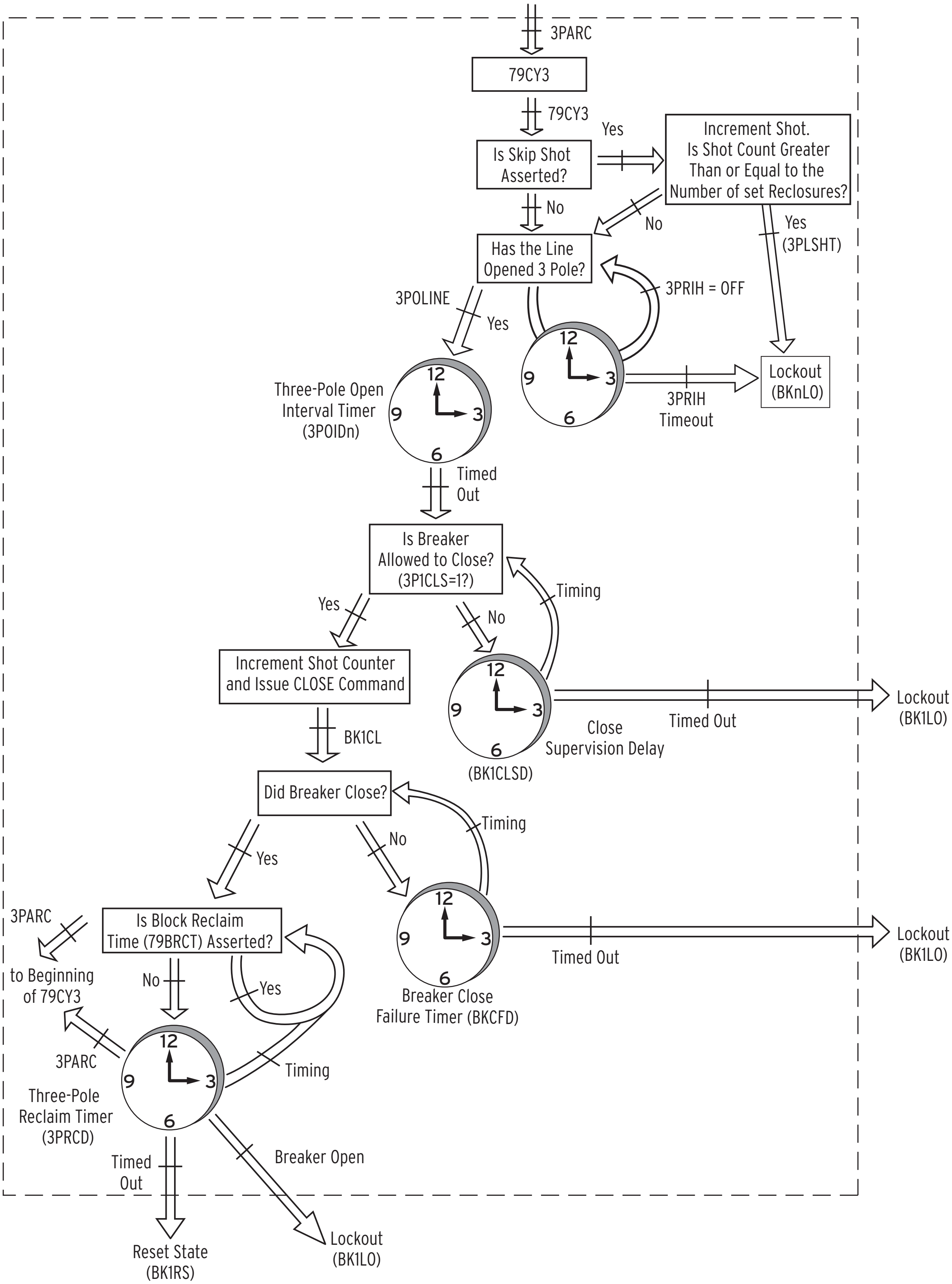

Figure 6.12 One Circuit Breaker Three-Pole Cycle State (79CY3)

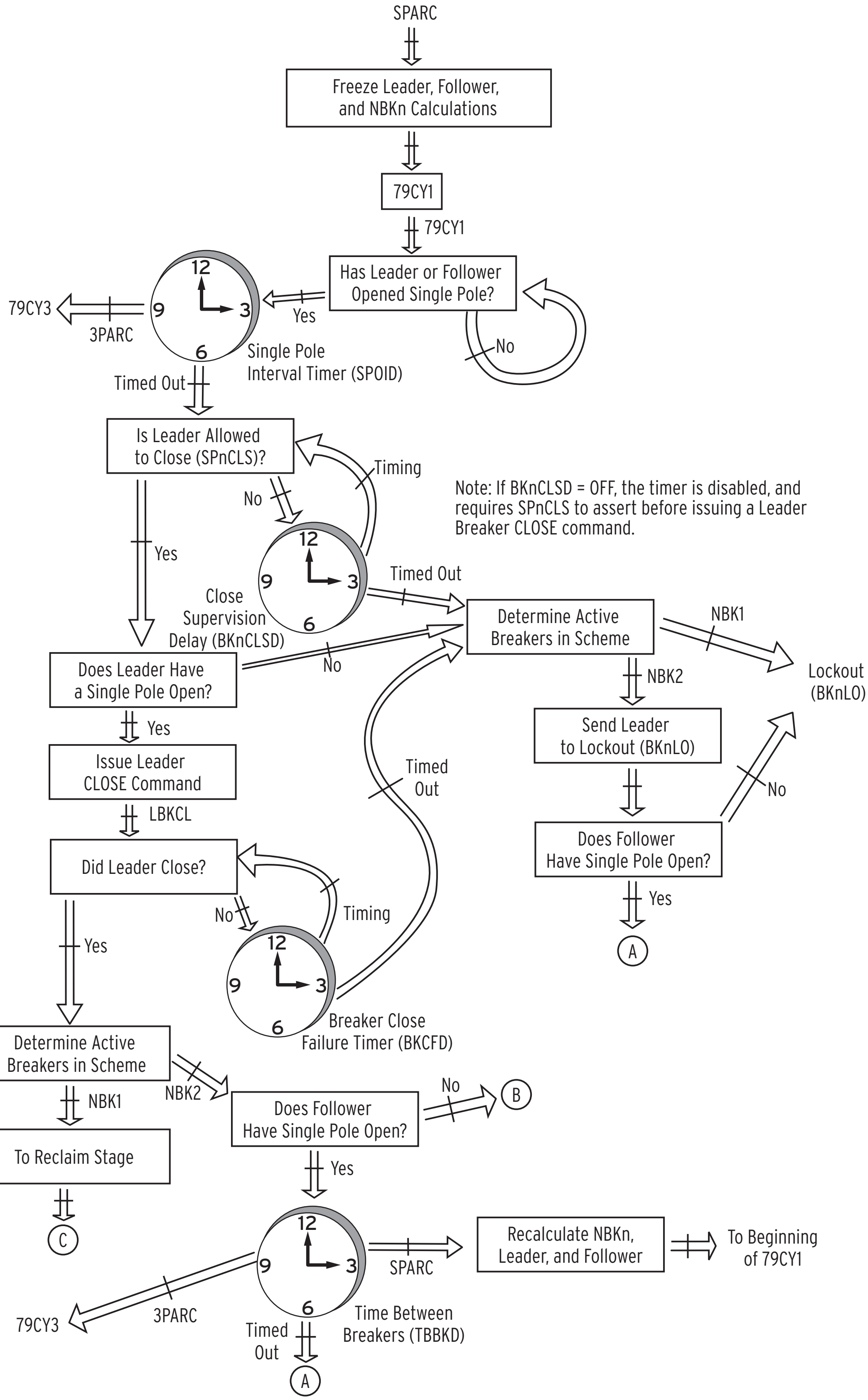

Figure 6.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y

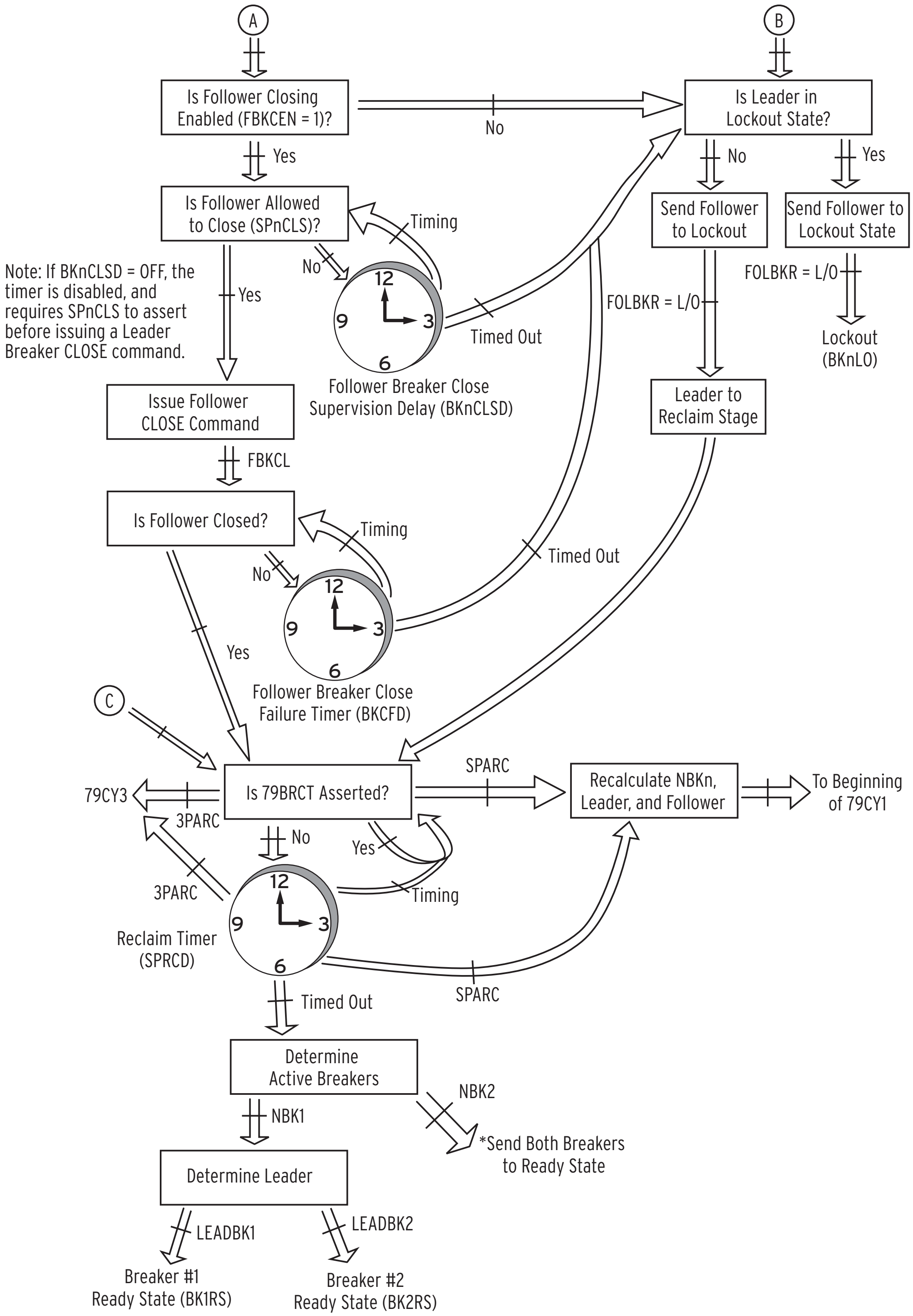

Figure 6.13 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y (Continued)

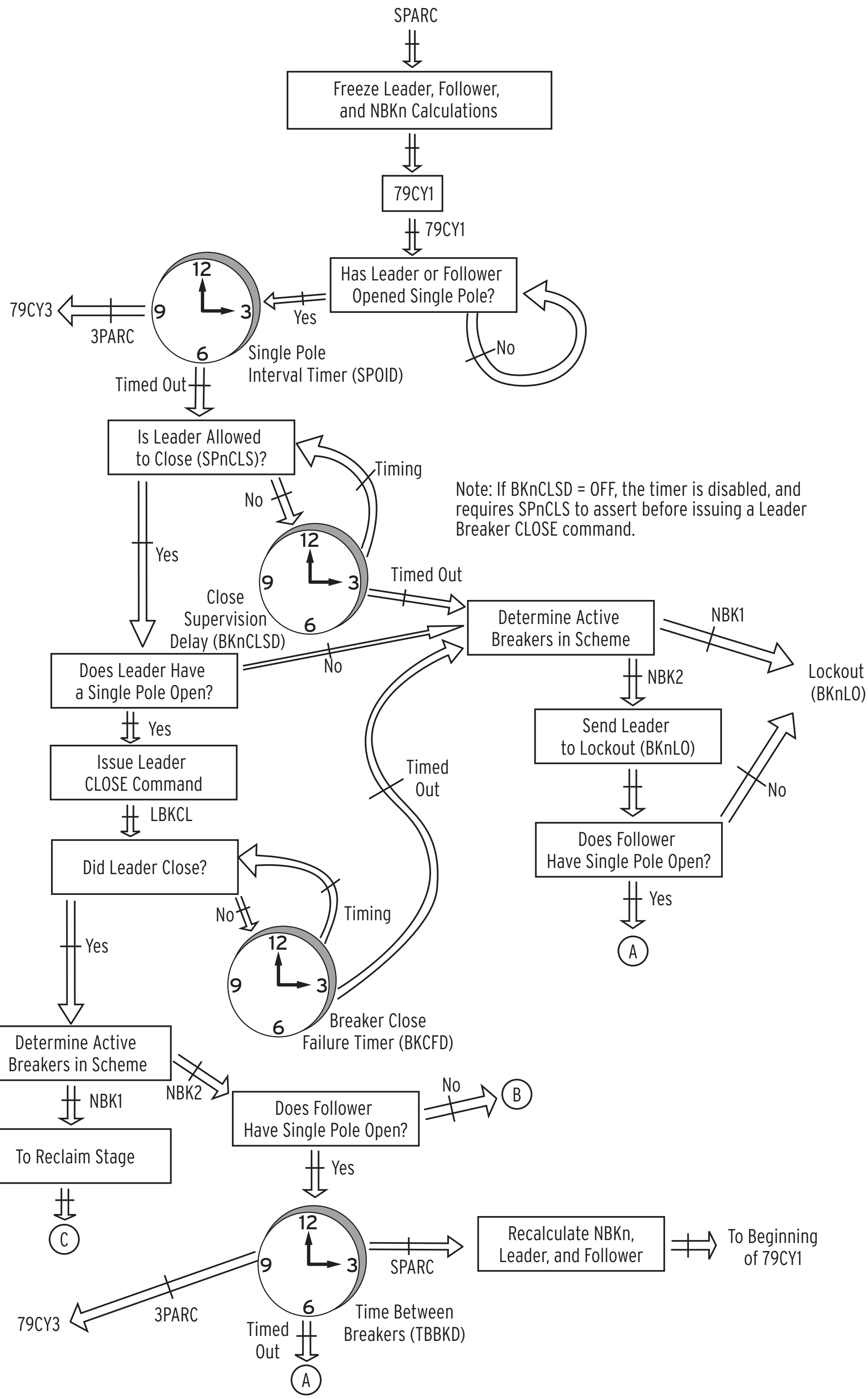

Figure 6.14 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1

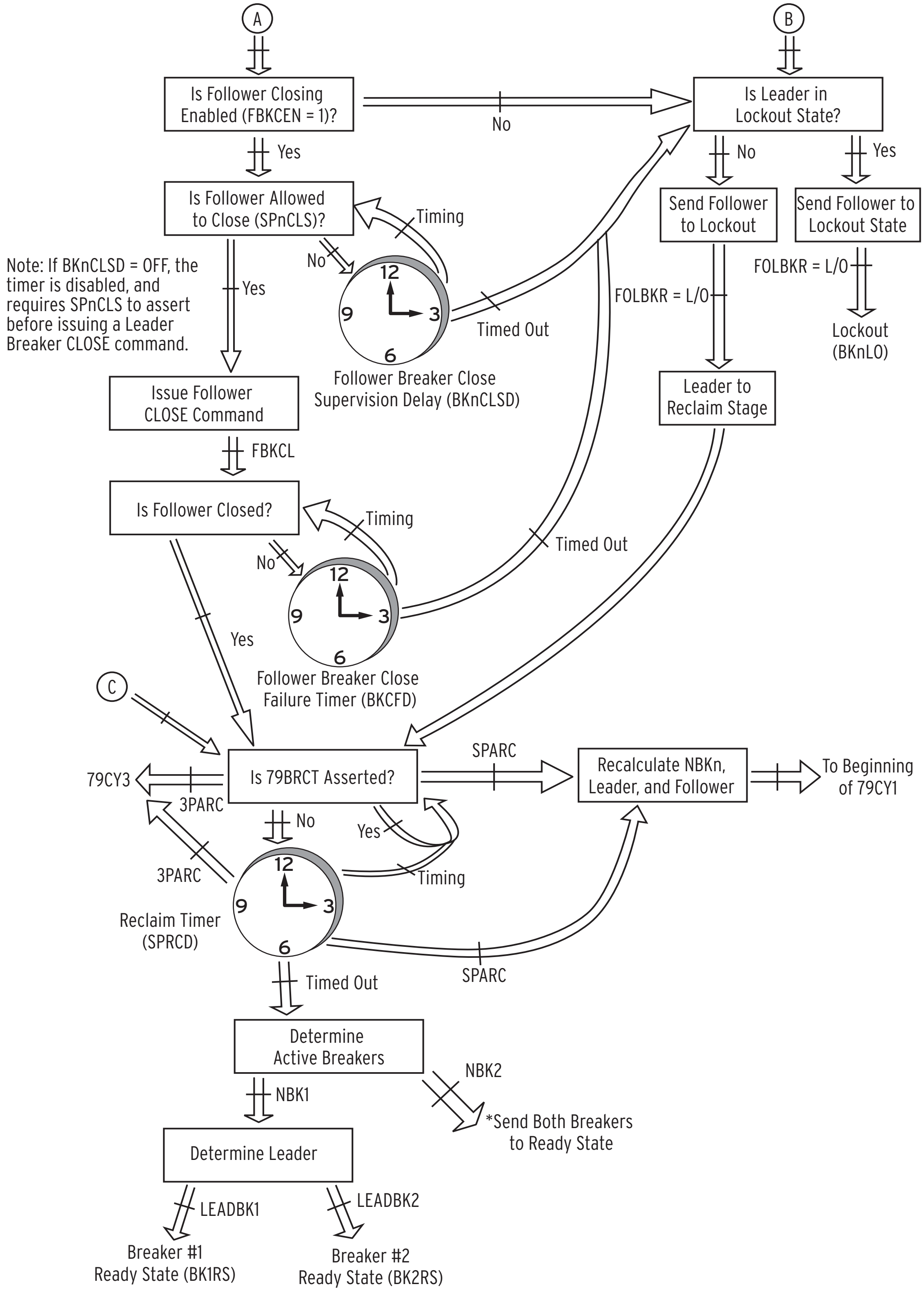

Figure 6.14 Two Circuit Breakers Single-Pole Cycle State (79CY1) When E79 := Y1 (Continued)

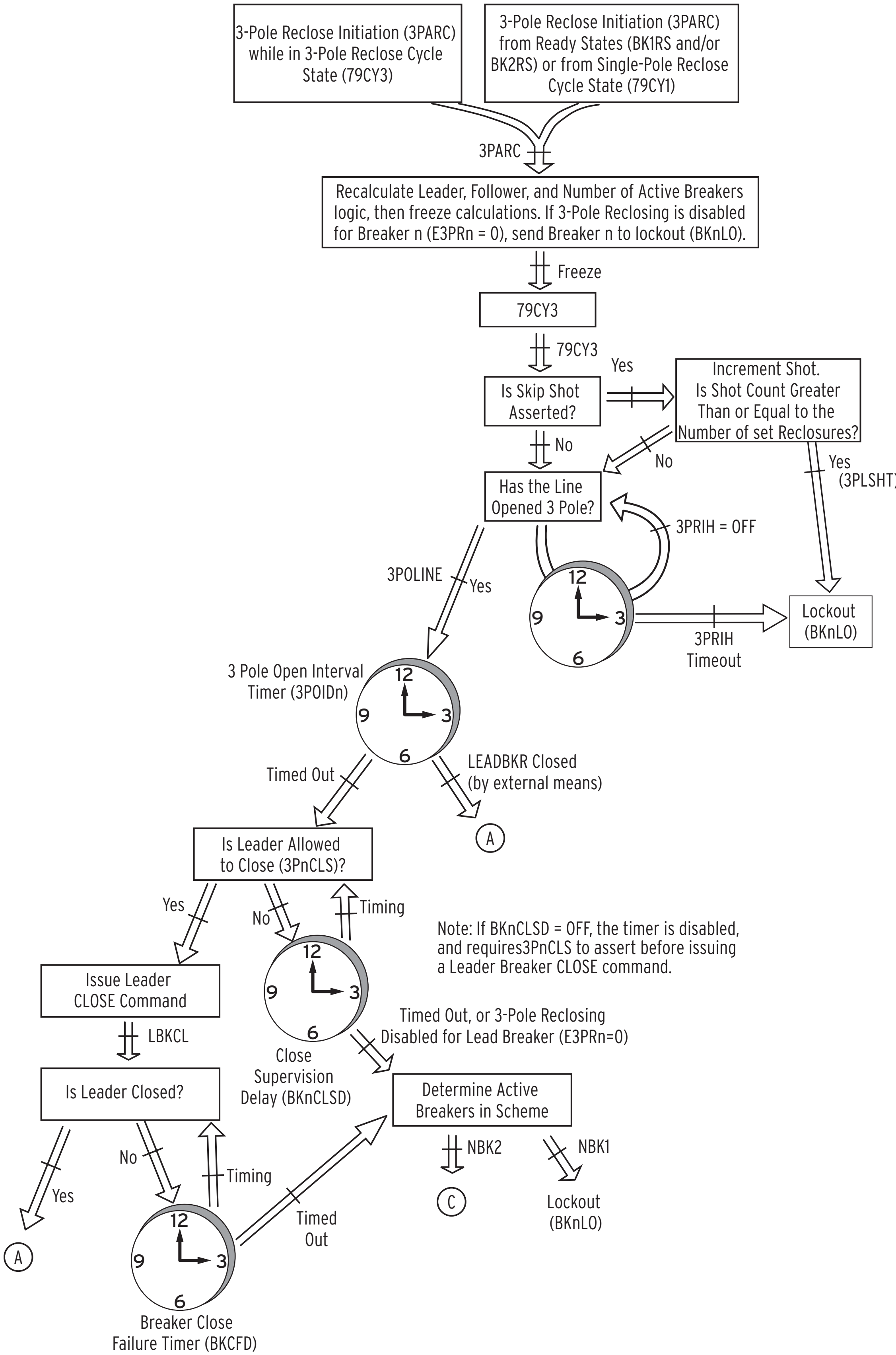

Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y

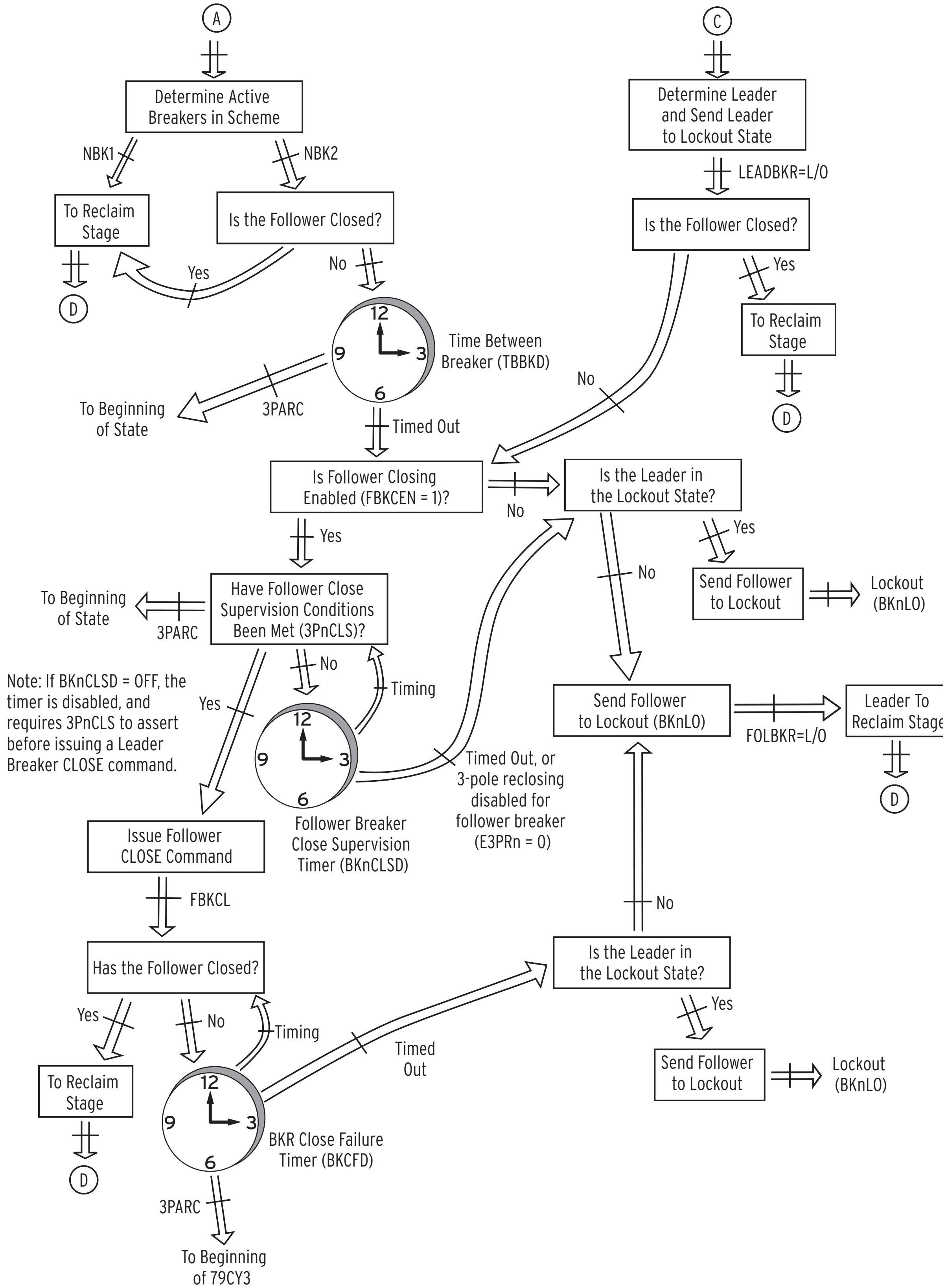

Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (Continued)

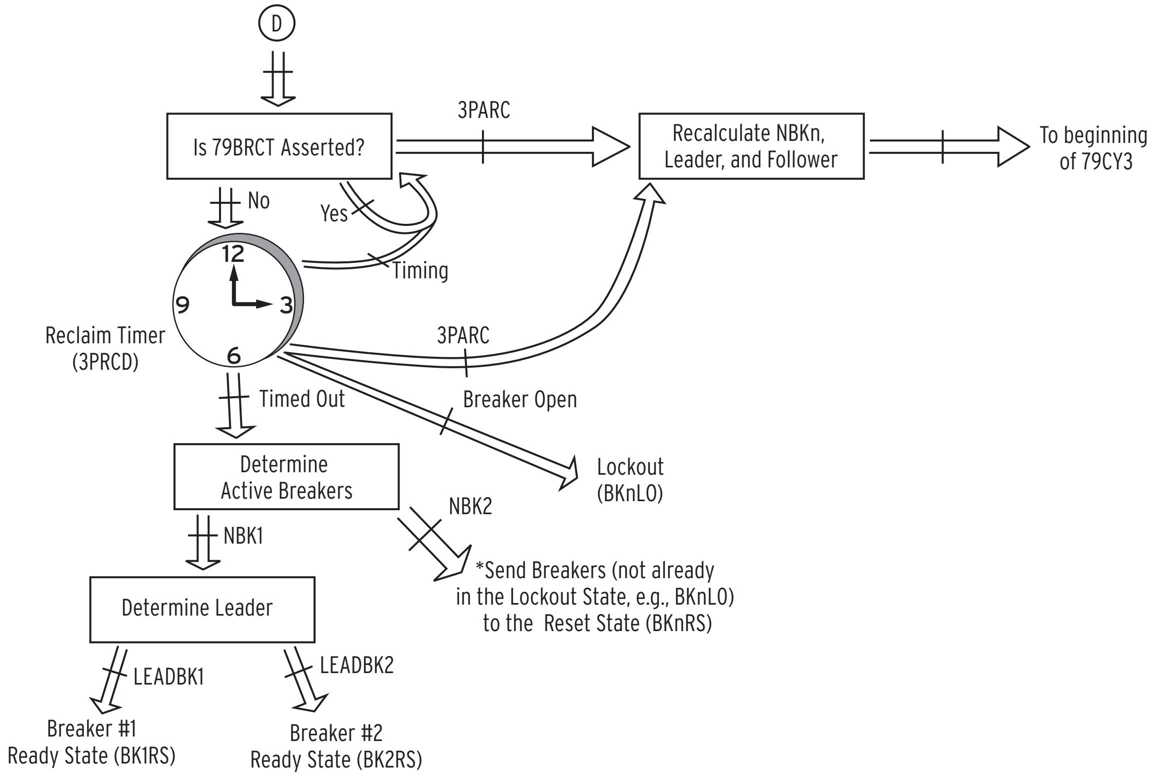

Figure 6.15 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y (Continued)

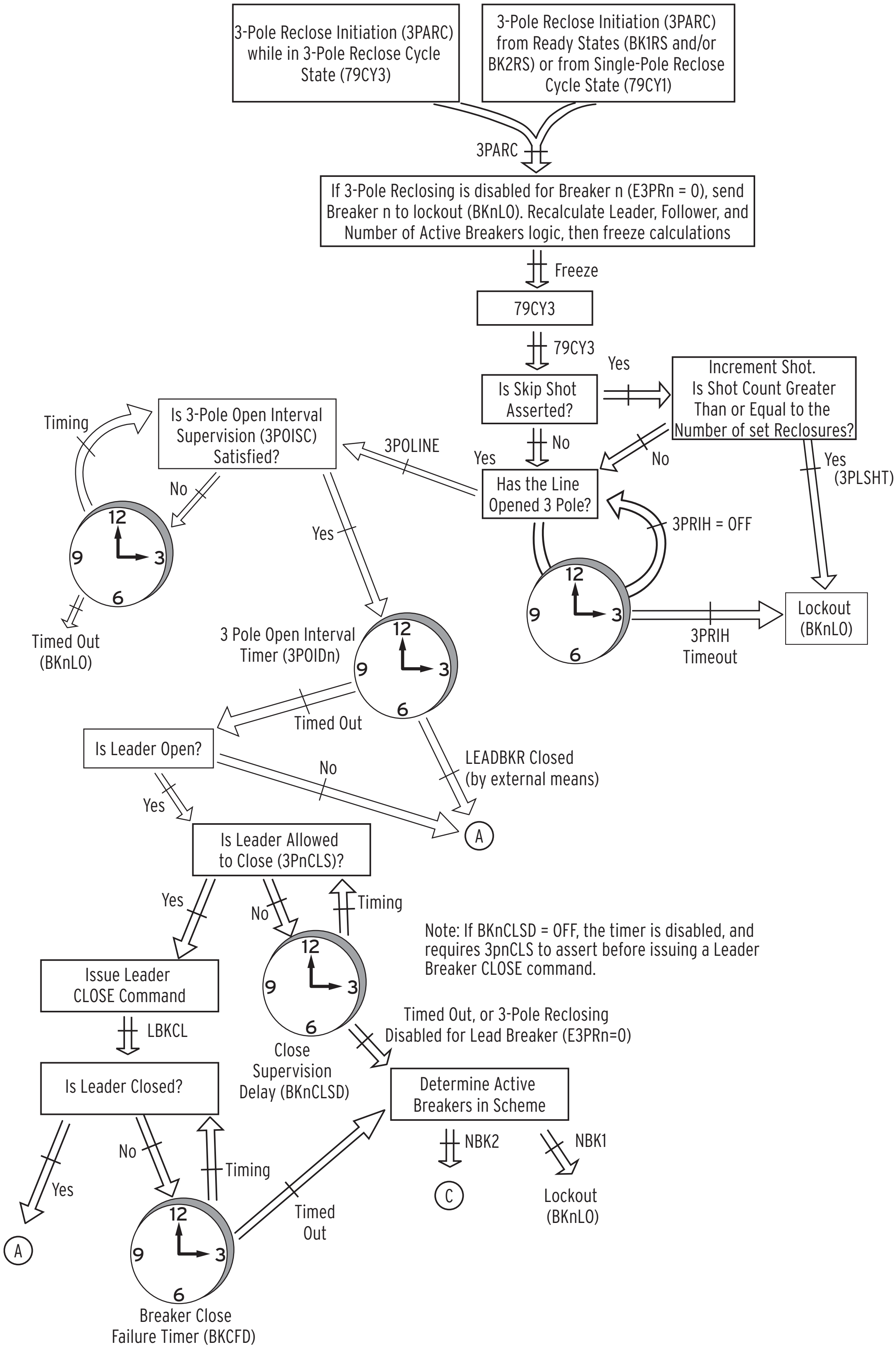

Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1

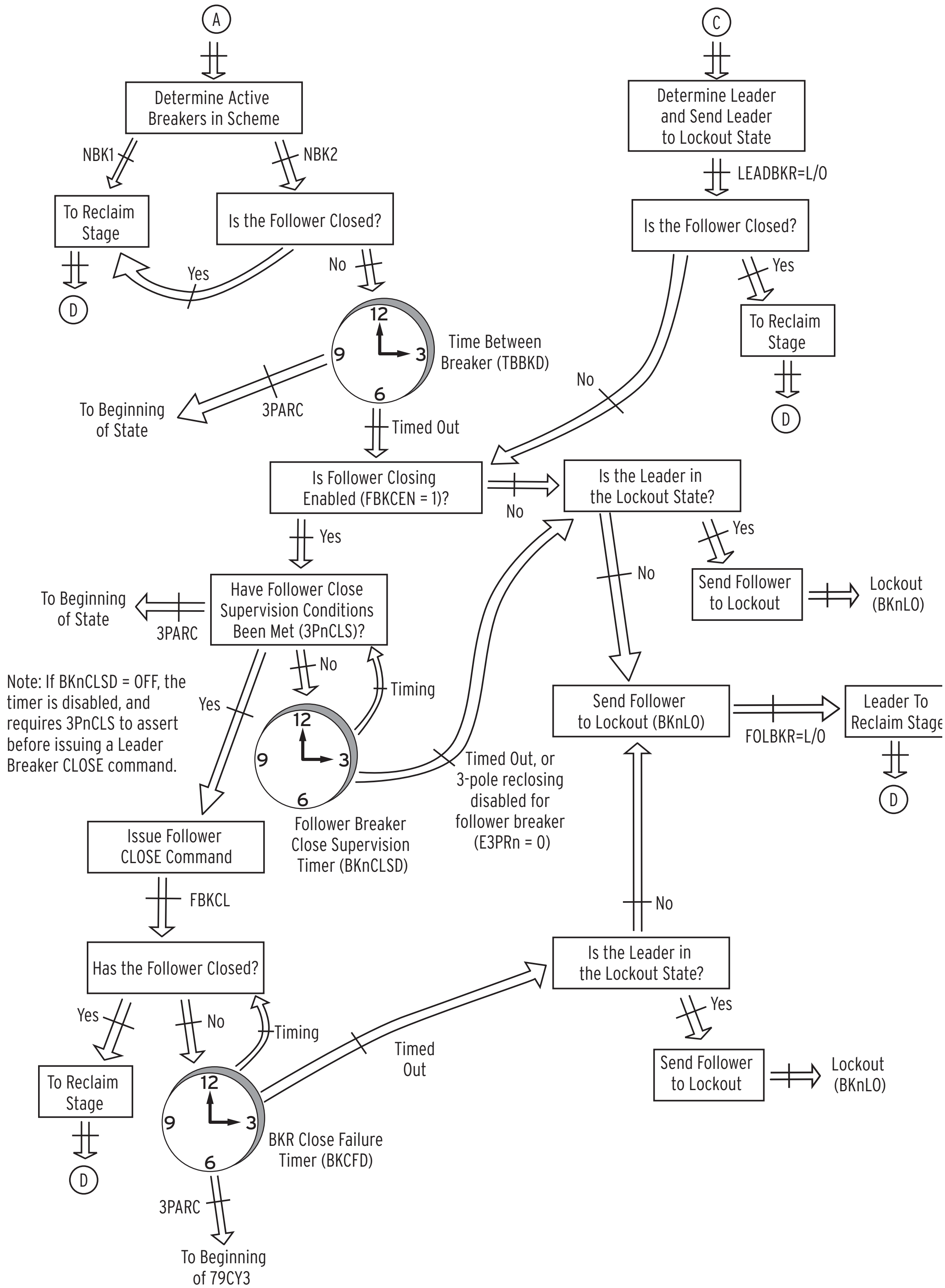

Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (Continued)

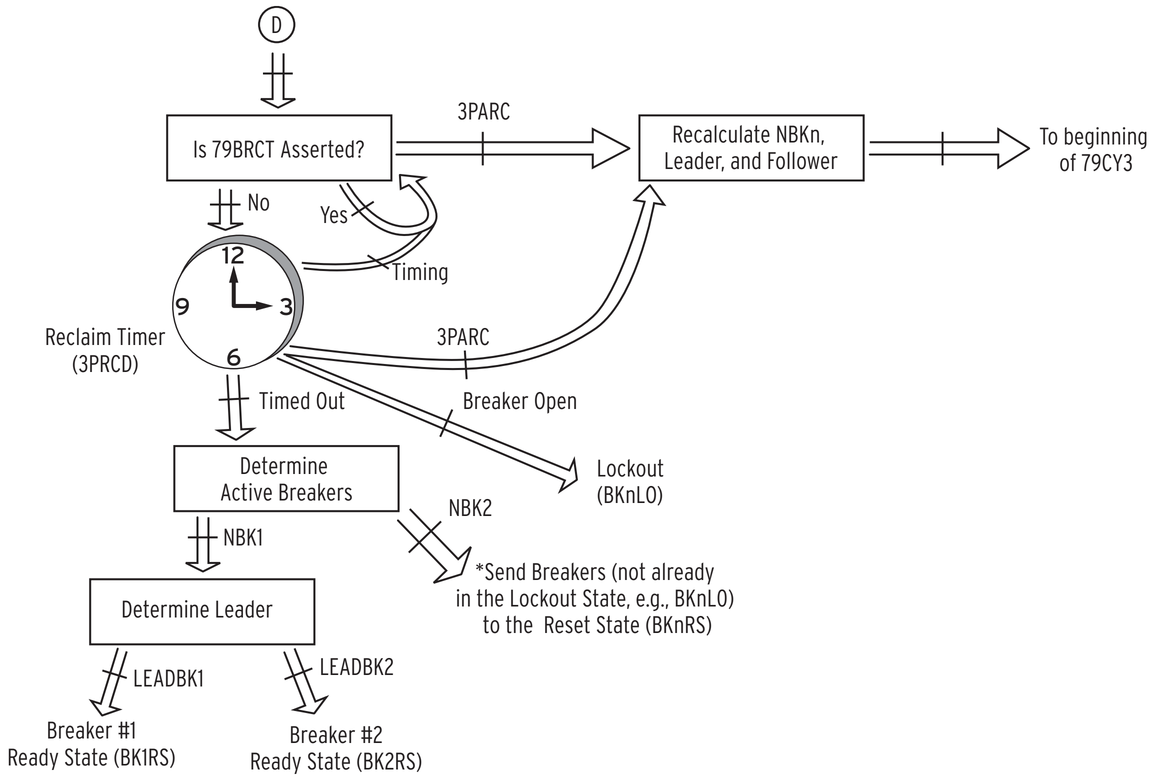

Figure 6.16 Two Circuit Breakers Three-Pole Cycle State (79CY3) When E79 := Y1 (Continued)

Manual Closing

Manual closing is available via the relay to issue a close to the circuit breaker(s) via the same close logic outputs used in autoreclosing (Relay Word bits BK1CL and BK2CL for as many as two circuit breakers). The manual close logic can be user-configured in most any manner with SELOGIC settings BK1MCL and BK2MCL. *Figure 6.17* is a flowchart of the manual close logic. This logic is enabled with Manual Closing enable setting EMANCL := Y.

Figure 6.17 only details the manual close logic for one circuit breaker (breaker BK1). The manual close logic for a second circuit breaker (breaker BK2), if enabled (Global setting NUMBK := 2), is similar. The only difference between the breaker BK1 and breaker BK2 manual close logic in *Figure 6.17* is the substitution of settings and logic outputs (BK2MCL for BK1MCL, ULCL2 for ULCL1, etc.). A manual close is issued for breaker BK1 if all of the following are true:

- A new manual close signal for breaker BK1 is detected (rising edge assertion of SELOGIC setting BK1MCL)
- No unlatch close conditions are present (SELOGIC setting ULCL1 deasserted)
- No close is presently in progress for breaker BK1 (Relay Word bit output BK1CL is deasserted)

If a manual close is successfully issued for breaker BK1, then:

- Close logic output BK1CL asserts
- The close failure timer starts timing

If breaker BK1 closes successfully, then:

- ➤ The unlatch close condition asserts (indicating breaker closure)
- ➤ Close logic output BK1CL deasserts

If breaker BK1 does not close successfully, then:

- ➤ The close failure timer times out (Relay Word bit BK1CFT asserts momentarily)
- ➤ Close logic output BK1CL deasserts

Note in *Figure 6.17* that if breaker BK1 manual close logic is actively operating (as described in the preceding steps), then breaker BK2 manual close logic cannot be actively operating. Breaker BK2 manual close logic only has a chance to operate if breaker BK1 manual close logic is not actively operating and two breakers are enabled for the scheme (Global setting NUMBK := 2). Thus, manual closing can only be attempted for one breaker at a time.

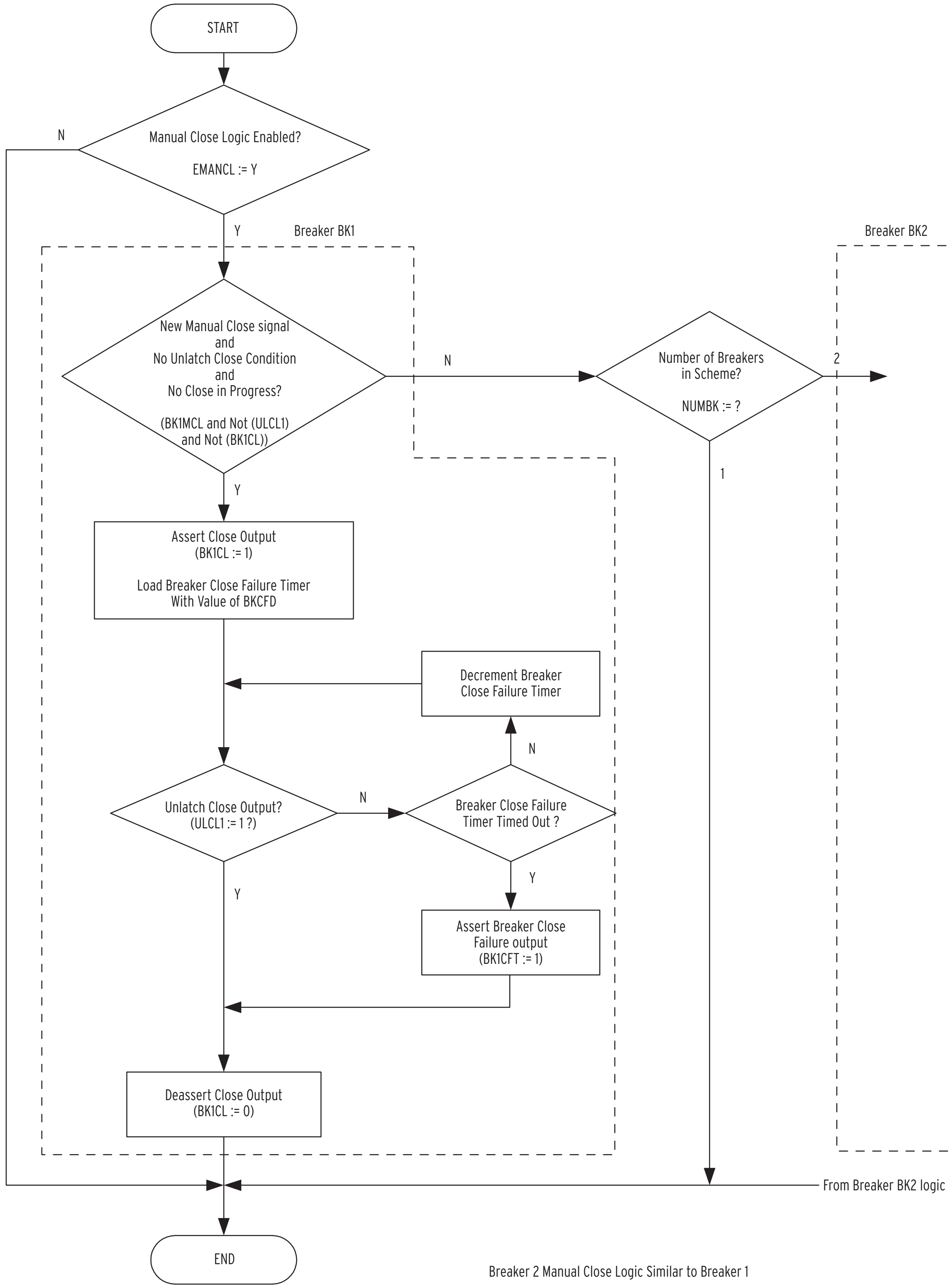

Figure 6.17 Manual Close Logic

Voltage Checks for Autoreclosing and Manual Closing

Voltage elements are available for a final check of line and bus voltages before an autoreclose or manual close is issued. These voltage elements and corresponding pickup settings are enabled with Reclosing Voltage Check enable setting EVCK := Y. *Figure 6.18* shows the application of these voltage elements and *Figure 6.19* shows their implementation. Check voltages for arrangements of as many as two circuit breakers (Global setting NUMBK := 2), as shown in *Figure 6.18*. If the relay is only connected to a single breaker (Global setting NUMBK := 1), then settings 27BK2P and 59BK2P and their associated elements (LLDB2, DLDB2, and DLLB2) are not available.

Voltages VP, VS1, and VS2 in *Figure 6.18* and *Figure 6.19* come from corresponding voltage source selection settings SYNCP, SYNCS1, and SYNCS2. Review details of synchronism checking in the Protection section of the desired product-specific Instruction Manual.

The pickup settings in *Figure 6.19* are made on the VP voltage base. VP is the voltage reference for voltage angle and magnitude. Only voltage magnitude is of concern for the settings in *Figure 6.19*, not voltage angle.

Figure 6.18 implies that three-phase voltage is available from the line PTs. But, resultant voltage VP corresponds to only one phase of this three-phase voltage (e.g., setting SYNCP = VAY; VP is the normalized voltage from voltage input VAY). All the voltage elements in *Figure 6.19* are single-phase voltage elements, detecting live or dead voltage on the bus side with a single-phase voltage element, and likewise on the line side.

Whether or not synchronism-check logic is used, it still has to be enabled for the respective breaker (E25BK1 := Y, Y1, or Y2 and E25BK2 := Y, Y1, or Y2) to allow the corresponding voltage source selection settings (SYNCP, SYNCS1, and SYNCS2) to be made.

Live Line/Live Bus

Note in *Figure 6.18* that live line/live bus is not available for either circuit breaker. Voltage elements 59VP, 59VS1, and 59VS2, described in the *Section 5: Protection Functions* of the desired product-specific instruction manual, are available for such a function (e.g., 59VP AND 59VS1 for live line/live bus 1).

Supervising Circuit Breaker Closing with Voltage Checks

Supervising Autoreclosing

For a fault on the line in *Figure 6.18*, both breakers trip open and the lead breaker recloses first. For example, presume the lead breaker closes only if its respective bus is live and the line is dead (dead line/live bus; see *Figure 6.18*). Then, after successful reclose of the lead breaker, the follower breaker closes on synchronism check. Such reclose supervision logic is realized as follows for respective breakers BK1 and BK2:

3P1CLS := **LEADBK1 AND DLLB1 OR FOLBK1 AND 25A1BK1 OR …**

3P2CLS := **LEADBK2 AND DLLB2 OR FOLBK2 AND 25A1BK2 OR …**

Note that the lead breaker and follower breaker supervision (Relay Word bits LEADBK*n* and FOLBK*n*, respectively) provides dynamic control for reclose supervision. One, but not both, of the breakers can reclose for a dead line/live bus condition (lead breaker), while the other then closes for a synchronism-check condition (follower breaker).

Supervising Manual Closing

Voltage checks can also be used to supervise manual closing. For example, presume that manual closing of breaker BK1 (*Figure 6.18*) should not be allowed if the respective bus is dead (dead line/dead bus or live line/dead bus condition):

BK1MCL := **NOT(DLDB1 OR AND LLDB1) AND (…)**

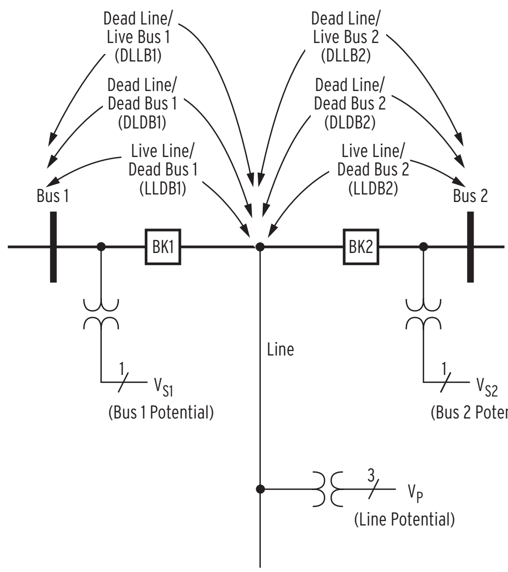

Figure 6.18 Voltage Check Element Applications

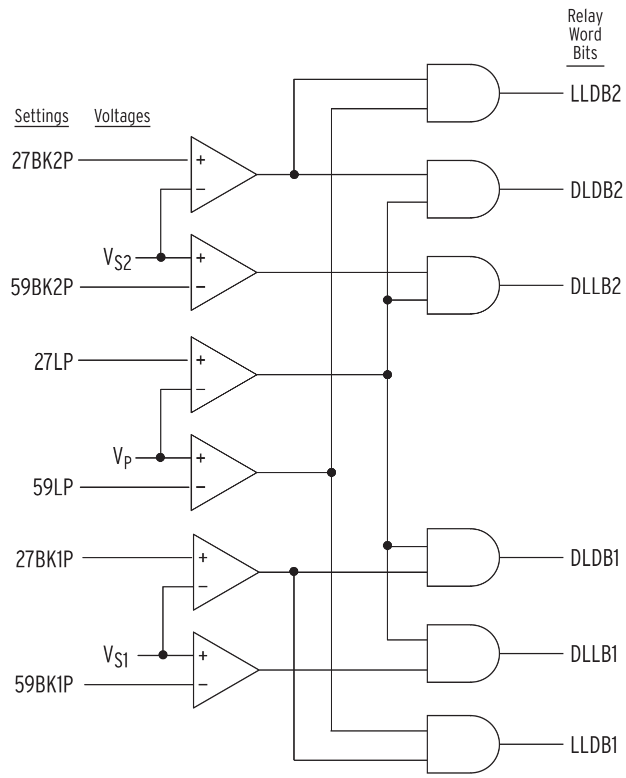

Figure 6.19 Voltage Check Element Logic

Settings and Relay Word Bits for Autoreclosing and Manual Closing

See the product-specific instruction manual Group Settings tables related to Reclose under the Settings section for a complete list of all autoreclose related settings. *Table 6.24* provides all of the Relay Word bits for autoreclosing.

Table 6.24 Autoreclose Logic Relay Word Bits (Sheet 1 of 3)

Name	Description
BK1RS	Breaker 1 in Reset State
BK2RS	Breaker 2 in Reset State
79CY1[a]	Relay in Single-Pole Reclose Cycle State
79CY3	Relay in Three-Pole Reclose Cycle State
BK1LO	Breaker 1 in Lockout State
BK2LO	Breaker 2 in Lockout State
SPARC[a]	Single-Pole Reclose Initiate Qualified
SPOISC[a]	Single-Pole Open Interval Supervision Condition
SPOI[a]	Single-Pole Open Interval Timing
SPSHOT0[a]	Single-Pole Shot Counter = 0
SPSHOT1[a]	Single-Pole Shot Counter = 1
SPSHOT2[a]	Single-Pole Shot Counter = 2

Table 6.24 Autoreclose Logic Relay Word Bits (Sheet 2 of 3)

Name	Description
SPLSHT[a]	Single-Pole Reclose Last Shot
SPRCIP[a]	Single-Pole Reclaim In-Progress
3PARC	Three-Pole Reclose Initiate Qualified
3POISC	Three-Pole Open Interval Supervision Condition
3POI	Three-Pole Open Interval Timing
3PSHOT0	Three-Pole Shot Counter = 0
3PSHOT1	Three-Pole Shot Counter = 1
3PSHOT2	Three-Pole Shot Counter = 2
3PSHOT3	Three-Pole Shot Counter = 3
3PSHOT4	Three-Pole Shot Counter = 4
3PLSHT	Three-Pole Reclose Last Shot
3PRCIP	Three-Pole Reclaim In-Progress
SPOBK1[a]	Single-Pole Open Breaker 1
2POBK1[a]	Two Poles Open Breaker 1
3POBK1	Three-Pole Open Breaker 1
SPOBK2[a]	Single-Pole Open Breaker 2
2POBK2[a]	Two Poles Open Breaker 2
3POBK2	Three-Pole Open Breaker 2
3POBK1	Three-Pole Open Breaker 1
3POLINE	Three-Pole Open Line
R3PTE	Three-Pole Tripping and Reclosing Only
R3PTE1	Recloser Three-Pole Trip Enable -BK1
R3PTE2	Recloser Three-Pole Trip Enable -BK2
BK1CL	Breaker 1 Close Command
BK2CL	Breaker 2 Close Command
BK1CLST	Breaker 1 Close Supervision Delay Timed Out
BK2CLST	Breaker 2 Close Supervision Delay Timed Out
BK1CFT	Breaker 1 Close Failure Delay Timed Out
BK2CFT	Breaker 2 Close Failure Delay Timed Out
BK1CLSS	Breaker 1 in Close Supervision State
BK2CLSS	Breaker 2 in Close Supervision State
BK1EXT	Breaker 1 Closed Externally
BK2EXT	Breaker 2 Closed Externally
BK1RCIP	BK1 Reclaim in Progress
BK2RCIP	BK2 Reclaim in Progress
79STRT	Relay in Start State
TBBK	Time Between Breakers Timing
LEADBK0	No Leader Breaker
LEADBK1	Leader Breaker = Breaker 1
LEADBK2	Leader Breaker = Breaker 2
FOLBK0	No Follower Breaker

Table 6.24 Autoreclose Logic Relay Word Bits (Sheet 3 of 3)

Name	Description
FOLBK1	Follower Breaker = Breaker 1
FOLBK2	Follower Breaker = Breaker 2
NBK0	No Breaker Active in Reclose Scheme
NBK1	One Breaker Active in Reclose Scheme
NBK2	Two Breakers Active in Reclose Scheme
LLDB1	Live Line—Dead Bus 1 (59L AND 27BK1)
DLLB1	Dead Line—Live Bus 1 (27L AND 59BK1)
DLDB1	Dead Line—Dead Bus 1 (27L AND 27BK1)
LLDB2	Live Line—Dead Bus 2 (59L AND 27BK2)
DLLB2	Dead Line—Live Bus 2 (27L AND 59BK2)
DLDB2	Dead Line—Dead Bus 2 (27L AND 27BK2)

[a] Only applicable to products that support single-pole reclosing.

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SECTION 7

Metering

The relay provides extensive capabilities for metering important power system parameters.

This section provides basic information about metering capabilities in typical SEL-400 series relays. Not all SEL-400 series relays support every metering feature described in this section. See *Section 7: Metering, Monitoring, and Reports* of the product-specific instruction manual for information on the specific metering capabilities of a specific relay.

SEL-400 series relays typically provide the following metering modes for measuring power system operations:

Monitor present power system operating conditions with instantaneous metering. Maximum/Minimum metering displays the largest and smallest system deviations since the last reset. Demand metering includes either thermal or rolling analyzes of the power system and peak demand metering. Energy metering displays the megawatt-hours imported, megawatt-hours exported, and total megawatt-hours. Time-synchronized metering displays the line voltage and current synchrophasors.

The relay processes various sets of currents and voltages, depending on the specific relay.

Use the **MET** command to access the metering functions. Issuing the **MET** command with no options returns fundamental measurement quantities. The **MET** command followed by a number, **MET *k***, specifies the number of times the command will repeat (*k* can range from 1–32767). This is useful for troubleshooting or investigating uncharacteristic power system conditions.

Table 7.1 lists some common **MET** command variants.

Table 7.1 MET Command (Sheet 1 of 2)

Name	Description
MET	Display fundamental line metering information
MET RMS	Display rms line metering information

Table 7.1 MET Command (Sheet 2 of 2)

Name	Description
MET M	Display line maximum/minimum metering information
MET RM	Reset line maximum/minimum metering information
MET D	Display demand line metering information
MET RD	Reset demand line metering information
MET RP	Reset peak demand line metering information
MET E	Display energy line metering information
MET RE	Reset energy line metering information
MET BAT	Display dc battery monitor information
MET RBM	Reset battery monitor min/max measurements
MET PM	Display phasor measurement (synchrophasor) metering information
MET RTD	Display SEL-2600 temperature quantities
MET PMV	Display protection math variable values
MET AMV	Display automation math variable values
MET ANA	Display remote analogs received from MIRRORED BITS

Instantaneous Metering

Use instantaneous metering to monitor power system parameters in real time. The relay typically provides these fundamental frequency readings:

- Fundamental frequency phase voltages and currents
- Phase-to-phase voltages
- Sequence voltages and currents
- Fundamental real, reactive, and apparent power
- Displacement power factor

NOTE: After startup, automatic restart, or a warm start, including settings change and group switch, in the beginning period of 20 cycles, the 10-cycle average values are initialized with the latest calculated 1-cycle average values.

You can also typically monitor these real-time rms quantities (with harmonics included):

- RMS phase voltages and currents
- Real and apparent rms power
- True power factor

Power

The instantaneous power measurements are derived from 10-cycle averages that the relay reports by using the generator condition of the positive power flow convention; for example, real and reactive power flowing out (export) is positive, and real and reactive power flowing in (import) is negative (see *Figure 7.1*).

NOTE: The SEL-487B does not include power and power factor in its metering reports.

For power factor, LAG and LEAD refer to whether the current lags or leads the applied voltage. The reactive power Q is positive when the voltage angle is greater than the current angle ($\theta V > \theta I$), which is the case for inductive loads where the current lags the applied voltage. Conversely, Q is negative when the voltage angle is less than the current angle ($\theta V < \theta I$); this is when the current *leads* the voltage, as in the case of capacitive loads.

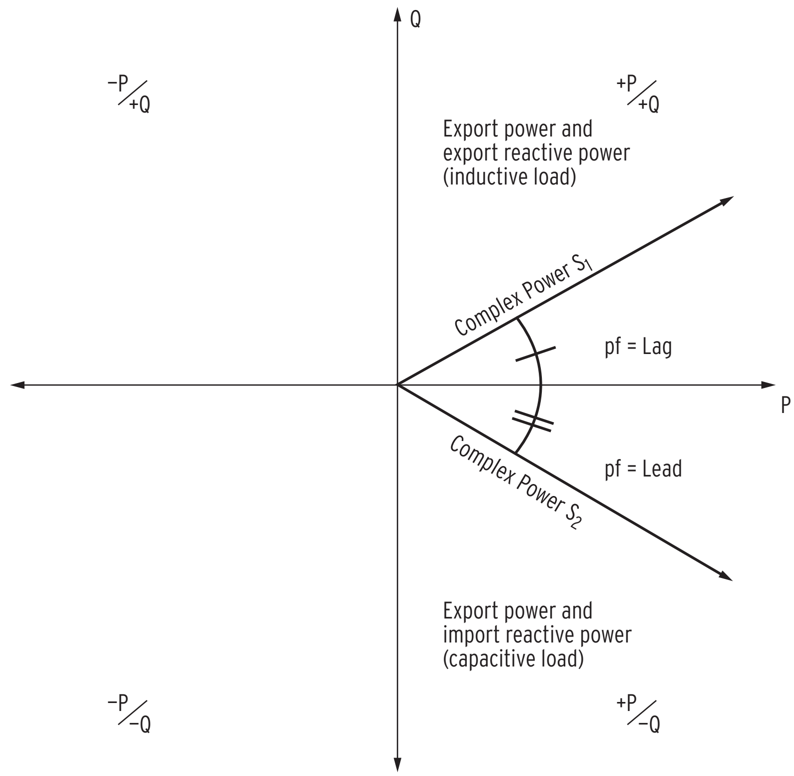

Figure 7.1 Complex Power (P/Q) Plane

Some products include Relay Word bits to indicate the leading or lagging power factor (see *Section 11: Relay Word Bits* in the product-specific instruction manual). In the case of a unity power factor or loss of phase or potential condition, the resulting power factor angle would be on this axis of the complex power (P/Q) plane shown in *Figure 7.1*. This would cause the power factor Relay Word bits to rapidly change state (chatter). Be aware of expected system conditions when monitoring the power factor Relay Word bits. It is not recommended to use chattering Relay Word bits in the SER or anything that will trigger an event.

High-Accuracy Instantaneous Metering

The relay is a high-accuracy metering instrument. *Table 7.2* and *Table 7.3* show the metering accuracy for the relay instantaneous metering quantities at nominal power system frequency and at 20°C. Use a method similar to that in *Example 7.1* to compute exact error coefficients.

Table 7.2 Instantaneous Metering Accuracy—Voltages, Currents, and Frequency

Quantity	Magnitude Accuracy		Phase Accuracy
	Range	Specification	
Vϕ, Vϕϕ	33.5 – 200 $V_{L–N}$	± 0.1%	+0.05°
3V0, V1, 3V2	33.5 – 200 $V_{L–N}$	± 0.15%	+0.10°
Iϕ	(0.5 – 3)• I_{NOM}	±0.2% ± (0.8 mA) • I_{NOM}	+0.20°
3I0, I1, 3I2	(0.5 – 3)• I_{NOM}	± 0.3% ± (1.0 mA) • I_{NOM}	+0.30°
ϕ	40–65 Hz	±0.01 Hz	

Table 7.3 Instantaneous Metering Accuracy—Power

Quantity	Description	Power Factor	Accuracy (%)[a]
At 0.1 • I_{NOM}			
3P	Three-phase rms real power	Unity	±0.40
		–0.5 or +0.5	±0.70
$3Q_1$	Reactive power	–0.5 or +0.5	±0.50
At 1.0 • I_{NOM}			
3P	Three-phase fundamental real power	Unity	±0.40
		–0.5 or +0.5	±0.40
$3Q_1$	Reactive power	–0.5 or +0.5	±0.40

[a] Power accuracy is valid for applied currents in the range (0.1–1.2) • I_{NOM}, and applied voltages from 33.5–75 V.

Example 7.1 Calculating Exact Error Coefficients

Consider the case of a 5 A relay during normal operating conditions. The secondary current in the CT is 1.0 A for nominal system operation. Noting that this current is greater than 10 percent of I_{NOM} (1 A > 0.5 A), calculate the error coefficient:

$$\begin{aligned} \text{error} &= \pm(0.2\% \bullet 1.0\text{ A}) \pm (0.8\text{ mA} \bullet I_{NOM}) \\ &= \pm(0.002 \bullet 1.0\text{ A}) \pm (0.0008\text{ A} \bullet 5) \\ &= \pm(0.002\text{A} \pm 0.004\text{A}) \\ &= +0.002\text{ A to } +0.006\text{ A} \\ &\quad \text{and} \\ &= -0.006\text{ A to } -0.002\text{ A} \end{aligned}$$

Equation 7.1

Figure 7.2 represents the calculated accuracy range. The error is very small, indicating that the relay measures normal operating currents accurately.

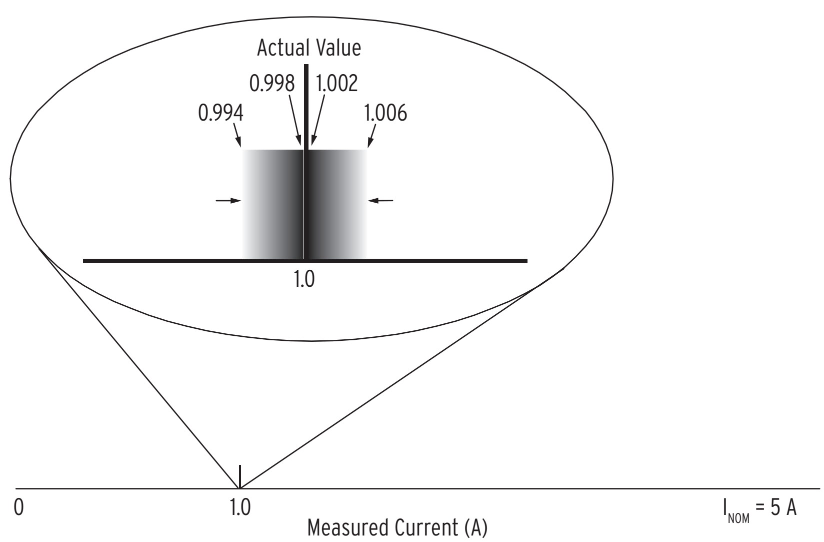

Figure 7.2 Typical Current Measuring Accuracy

Example 7.1 Calculating Exact Error Coefficients (Continued)

When you use *Equation 7.1*, you add an error amount related to the nominal current rating of the relay, I_{NOM}. Use just the numeric portion of I_{NOM}, either “5” for a 5 A relay or “1” for a 1 A relay; do not use the unit (A). The errors in *Equation 7.1* are very small and qualify the relay as a high-accuracy meter.

Maximum/Minimum Metering

The relay measures and retains the deviations of the power system since the last maximum/minimum reset. Knowing these maximum and minimum quantities can help you operate your power system more effectively in a variety of ways. For example, you can benefit from maximum/minimum metering information by using it to track power flow for troubleshooting, planning future expansion, and scheduling maintenance.

NOTE: Not all SEL-400 series relays support maximum/minimum metering.

The relay provides maximum/minimum metering for a variety of line and breaker quantities, as well as for dc battery voltage. The relay also records the maximum values of the sequence voltages and sequence currents.

View or Reset Maximum/Minimum Metering Information

The relay shows time stamped maximum/minimum quantities when you use a communications port or ACSELERATOR QuickSet SEL-5030 Software to view these quantities. In addition, you can read the maximum/minimum quantities on the relay front-panel LCD screen.

To reset the maximum/minimum values, use the **MET RM** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Maximum/Minimum** window, or answer Y and press ENT at the Maximum/Minimum submenu reset prompt on the front-panel LCD screen. You can also reset maximum/minimum metering with Global settings (typically RSTMML, RSTMMB1, and RSTMMB2).

Maximum/Minimum Metering Updating and Storage

The relay updates maximum/minimum values once per power system cycle. The relay stores maximum/minimum values and the corresponding dates and times to nonvolatile storage once per day. If greater than a previously stored maximum or less than a previously stored minimum, the new value overwrites the previous value. Should the relay lose control power, it will restore the maximum/minimum information saved at 23:50 hours on the previous day.

The relay updates maximum/minimum values under the following conditions:

- DFAULT is deasserted (equals logical 0)
- The metering value is greater than the previous maximum, or less than the previous minimum, for 2 cycles
- Voltage input is greater than 13 V secondary
- Current input is greater than $0.05 \cdot I_{NOM}$ (in secondary amperes)

Megawatt and megavar maximum/minimum values are subject to the above voltage thresholds, current thresholds, and conditions.

FAULT SELOGIC Control Equation

The relay suspends updating maximum/minimum metering when SELOGIC control equation FAULT asserts to logical 1. If there is a fault, the elements programmed in FAULT pick up and assert Relay Word bit DFAULT (Delayed FAULT Suspend). This Relay Word bit remains asserted for one minute after SELOGIC control equation FAULT deasserts. While DFAULT is asserted, the relay does not record maximum/minimum data.

In addition, the relay also suspends demand metering during the time that Relay Word bit DFAULT is asserted.

Demand Metering

Economic operation of the power system involves the proper allocation of the load demand among the available generating units. By knowing the demand requirements at different points in the system and at different times of the day you can optimize your system generation resources or your consumption of electric power. The relay provides you this demand information and enables you to operate your power system with an effective economic strategy.

NOTE: Not all SEL-400 series relays support demand metering.

The relay uses longer-term accumulations of the metering quantities for reliable demand data.

Thermal Demand and Rolling Demand

Two methods exist for measuring power system current and power demand. These methods are thermal demand metering and rolling demand metering. *Figure 7.3* and *Figure 7.4* illustrate the step input response of the two demand measuring methods with setting DMTC (demand meter time constant) at 15 minutes.

Thermal Demand

Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities. Thermal demand measurement is similar to parallel RC network integration. Thermal demand metering response is at 90 percent (0.9 per unit) of the full applied value after a period equal to the DMTC setting (15 minutes in *Figure 7.3*).

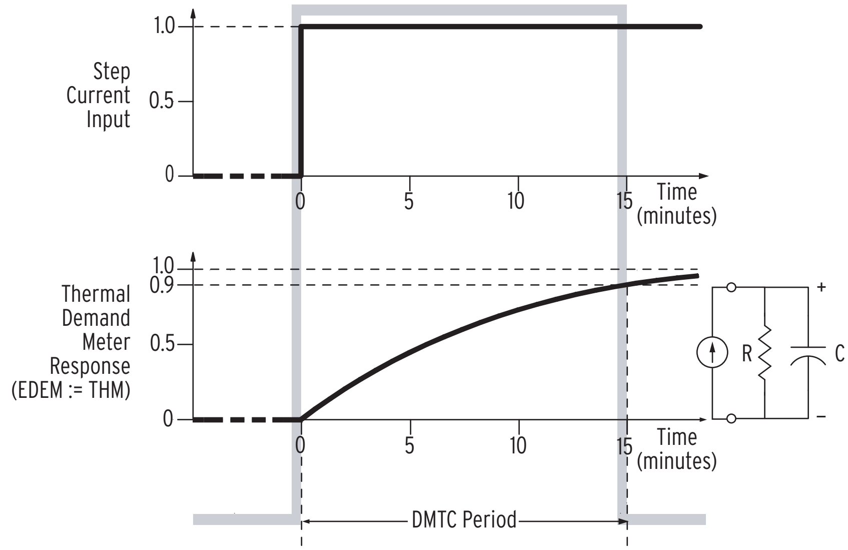

Figure 7.3 Thermal Demand Metering

Rolling Demand

Rolling demand is a sliding time-window arithmetic average. Rolling demand measurement is similar to a step-sampled A/D conversion system. *Figure 7.4* shows the rolling demand response for a step input for a demand meter time constant of 15 minutes (DMTC := 15). The relay divides the DMTC period into three 5-minute intervals and averages the three DMTC subinterval samples every DMTC period. *Table 7.4* lists the rolling demand response for four DMTC periods shown in *Figure 7.4*. Rolling demand metering response is at 100 percent (1.0 per unit) of the full applied value after a time equal to the fourth DMTC period (see (d) in *Figure 7.4*).

Table 7.4 Rolling Demand Calculations

DMTC Period (see Figure 9.18)	1/3 DMTC Interval (minutes)	Interval Sample (per unit)	Rolling Demand Total	Rolling Demand Calculation	Rolling Demand Response (per unit)
(a)	–5 to 0	0	0	0 / 3	0
(b)	0 to 5	1	1	1 / 3	0.33
(c)	5 to 10	1	2	2 / 3	0.67
(d)	10 to 15	1	3	3 / 3	1.00

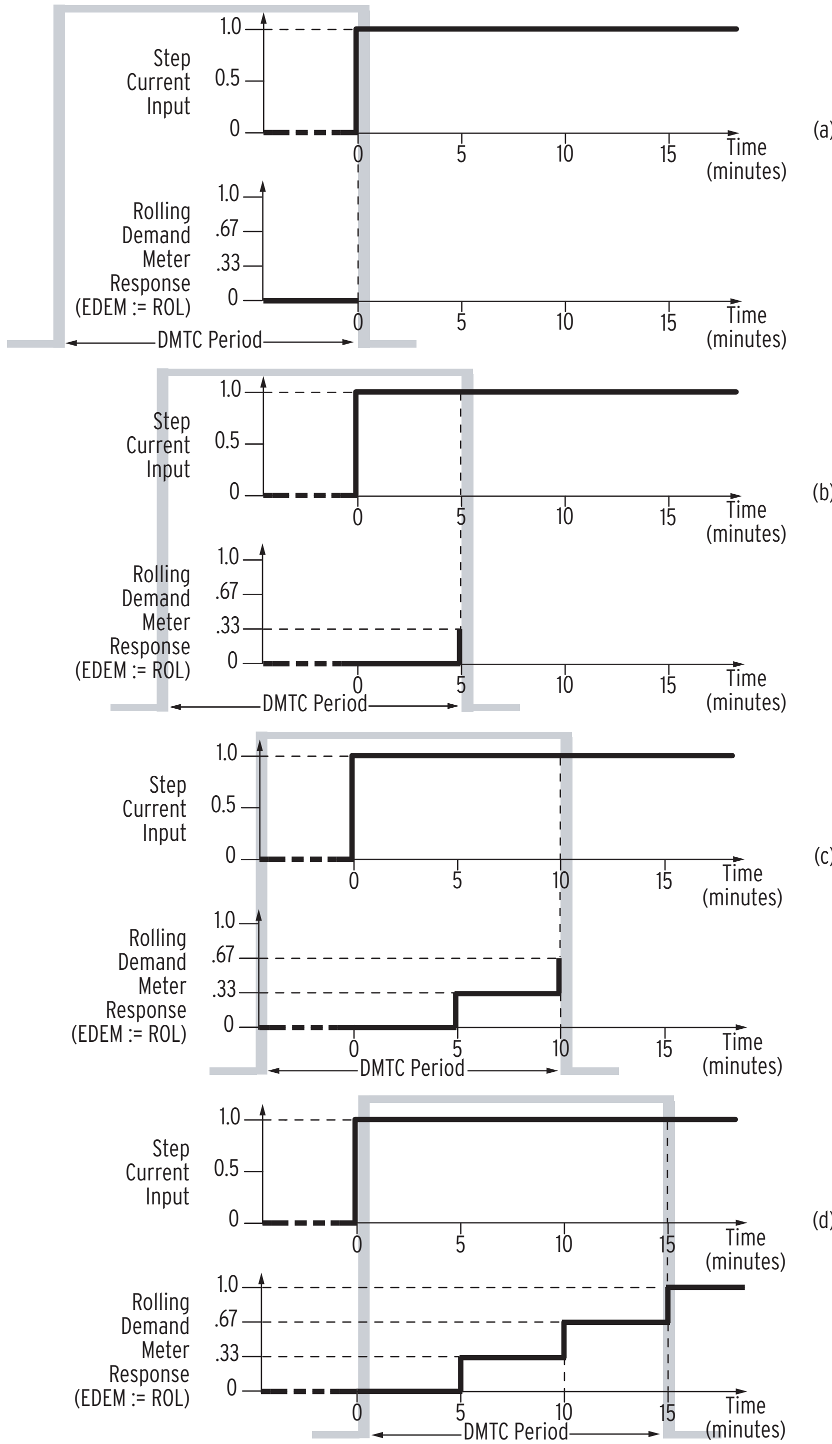

Figure 7.4 Rolling Demand Metering

Demand Metering Settings

Use the demand metering enable setting EDEM to select the demand metering type (thermal or rolling) appropriate to your needs. Use demand pickup settings (typically PDEMP, QDEMP, and GDEMP) to set alarm thresholds to notify you when demand currents exceed preset operational points.

NOTE: Changing EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active settings group where either setting EDEM or DMTC is different in the new active settings group. (Changing demand current pickup settings PDEMP, GDEMP, and QDEMP will not affect the demand meters.)

Figure 7.5 shows how the relay applies the demand current pickup settings over time. When residual ground demand current IG(DEM) exceeds the corresponding demand pickup setting GDEMP, Relay Word bit GDEM asserts to logical 1. Use these demand current logic outputs (PDEM, GDEM, and QDEM) for control or alarm for high loading or unbalance conditions.

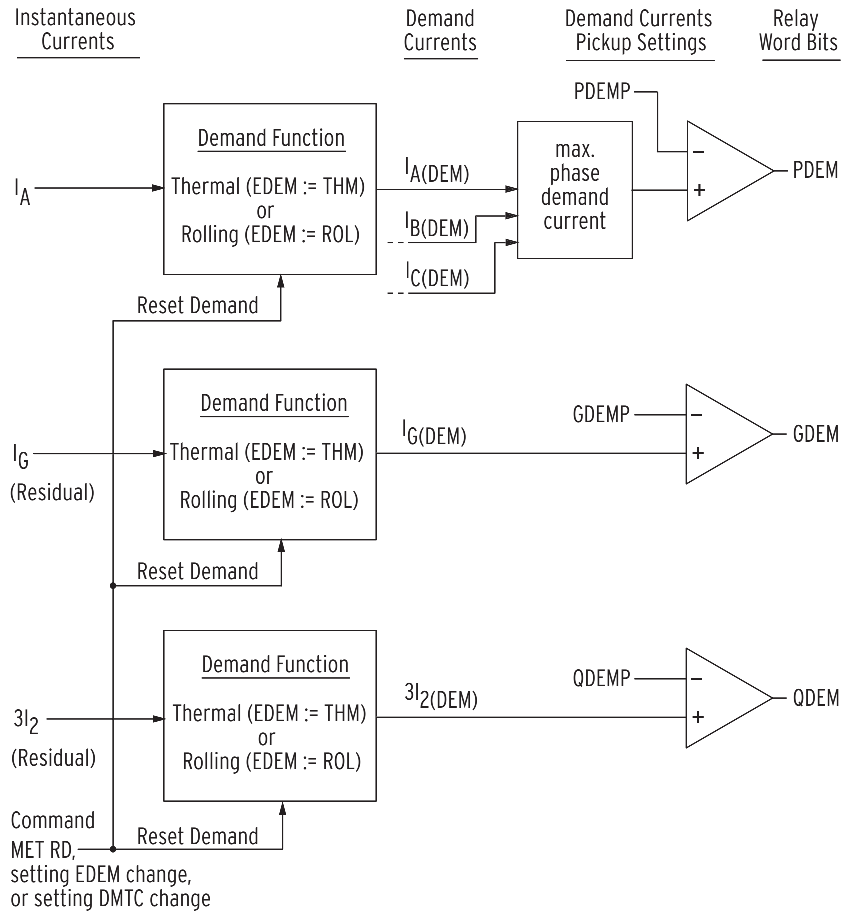

Figure 7.5 Demand Current Logic Outputs

View or Reset Demand Metering Information

The relay shows demand metering quantities and time-stamped peak demand quantities when you use a communications port or QuickSet to view these quantities. In addition, you can read the demand and peak demand quantities on the relay front-panel LCD screen.

To reset the demand metering values use the **MET RD** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer Y and press ENT at the Demand Submenu reset demand prompt on the front-panel LCD screen. The relay begins the demand meter sampling period from the time of the demand meter reset.

To reset the peak demand metering values, enter the **MET RP** command from a communications terminal, or use the RESET button in the QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer Y and press ENT at the Demand Submenu reset peak demand prompt on the front-panel LCD screen. You can also reset demand metering with Global settings RST_DEM and RST_PDM (for demand and peak demand) when EDRSTC (Data Reset Control) is Y.

Demand Metering Updating and Storage

The relay updates demand and peak demand values once per second. The relay also stores peak demand values and the date and time these occurred to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand information saved at 23:50 hours on the previous day.

Demand metering updating and peak recording is suspended during the time that SELOGIC control equation FAULT asserts Relay Word bit DFAULT (Delayed FAULT Suspend).

Energy Metering

Energy is the power consumed or developed in the electric power system measured over time. You can use accurate accounting of power system energy flow to manage billing revenues, whether your system is a net energy producer or consumer. Time-synchronized demand and energy measurements make demand and energy metering information even more useful for power system status applications.

NOTE: Not all SEL-400 series relays support energy metering.

The relay integrates energy imported and exported on a per-phase basis every second. As in demand metering, the relay uses the longer-term accumulations of rms or true real power for reliable energy data.

View or Reset Energy Metering Information

You can read the energy metering quantities by using a communications port, QuickSet, or the relay front-panel LCD screen.

To reset the energy values, use the **MET RE** command from a communications terminal, or use the **RESET** button in the QuickSet **HMI > Meter and Control > Energy** window, or answer `Y` and press **ENT** at the `Energy Meter` submenu reset prompt on the front-panel LCD screen. You can also reset energy metering with Global setting RST_ENE when EDRSTC (Data Reset Control) is Y.

Energy Metering Updating and Storage

The relay updates energy values once per second. The relay also stores energy values to nonvolatile storage once every four hours, referenced from 23:50 hours (it overwrites the previously stored value if it is exceeded). Should the relay lose control power, it restores the energy values saved at the end of the last four-hour period.

Synchrophasor Metering

The relay provides synchrophasor measurement with an angle reference according to IEEE C37.118. The relay calculates the phasor measurement quantities 50 or 60 times per second, depending on the nominal system frequency contained in Global setting NFREQ.

NOTE: Not all SEL-400 series relays support synchrophasor measurements.

When you issue the **MET PM** ***time*** command, the relay captures the time-synchronized data for the given trigger time (specify ***time*** in 24-hour format). The relay displays the synchrophasor data immediately after the time trigger.

The synchrophasor measurements are only valid when a suitable high-accuracy IRIG-B or PTP time source is connected to the relay, as indicated by Relay Word bit TSOK = logical 1.

The **MET PM** command is only available when the relay is configured for phasor measurement functions (Global settings) and the relay is in high-accuracy timekeeping mode.

Battery Metering

The relay monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 7.6* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report.

```
=>>MET BAT <Enter>

Relay 1                                     Date: 06/07/2008  Time: 22:51:47.067
Station A                                   Serial Number: 2008030645

Station Battery        VDC      VDCPO     VDCNE      VAC
   VDC1 (V)            115.86    57.32    -58.54     0.01

             VDC1(V)    Date       Time
Minimum       105.86 04/07/2008  22:43:04.022
Enter L-Zone         04/07/2008  22:40:14.162
Exit L-Zone          04/07/2008  22:44:09.223


Maximum       125.86 04/09/2008  12:34:14.321
Enter H-Zone         04/09/2008  12:31:32.543
Exit H-Zone          04/09/2008  12:35:12.657

LAST DC RESET:  01/15/2008  20:10:31.427

=>>
```

Figure 7.6 Battery Metering: Terminal

Any battery voltage between setting DCLWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Battery voltages in the H-Zone are voltages higher than the DCHWP setting.

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. You can program a SELOGIC control equation RST_BAT (in Monitor settings) to control dc battery monitor reset.

RTD Metering

Use the **MET RTD** command to display the RTD values, as shown in *Figure 7.7*.

```
=>>MET RTD <Enter>

Relay 1                                    Date: 04/12/2008  Time: 06:06:31.366
Station A                                  Serial Number: 2008030645


RTD Input Temperature Data (deg. C)
RTD  1 = -50
RTD  2 = 250
RTD  3 = 0
RTD  4 = 45
RTD  5 = 34
RTD  6 = 65
RTD  7 = -23
RTD  8 = 39
RTD  9 = 23
RTD 10 = 11
RTD 11 = 54
RTD 12 = 78

=>>
```

Figure 7.7 RTD Report

Protection Math Variable Metering

Use the **MET PMV** command to display all 64 PMV values, as shown in *Figure 7.8*.

```
=>>MET PMV <Enter>

Relay 1                                    Date: 04/07/2008  Time: 21:03:40.451
Station A                                  Serial Number: 2008030645

Protection Analog Quantities
  PMV01 =      0.000       PMV02 =      0.000       PMV03 =      0.000
  PMV04 =      0.000       PMV05 =      0.000       PMV06 =      0.000
  PMV07 =      0.000       PMV08 =      0.000       PMV09 =      0.000
  PMV10 =      0.000       PMV11 =      0.000       PMV12 =      0.000
  PMV13 =      0.000       PMV14 =      0.000       PMV15 =      0.000
  PMV16 =      0.000       PMV17 =      0.000       PMV18 =      0.000
  PMV19 =      0.000       PMV20 =      0.000       PMV21 =      0.000
  PMV22 =      0.000       PMV23 =      0.000       PMV24 =      0.000
  PMV25 =      0.000       PMV26 =      0.000       PMV27 =      0.000
  PMV28 =      0.000       PMV29 =      0.000       PMV30 =      0.000
  PMV31 =      0.000       PMV32 =      0.000       PMV33 =      0.000
  PMV34 =      0.000       PMV35 =      0.000       PMV36 =      0.000
  PMV37 =      0.000       PMV38 =      0.000       PMV39 =      0.000
  PMV40 =      0.000       PMV41 =      0.000       PMV42 =      0.000
  PMV43 =      0.000       PMV44 =      0.000       PMV45 =      0.000
  PMV46 =      0.000       PMV47 =      0.000       PMV48 =      0.000
  PMV49 =      0.000       PMV50 =      0.000       PMV51 =      0.000
  PMV52 =      0.000       PMV53 =      0.000       PMV54 =      0.000
  PMV55 =      0.000       PMV56 =      0.000       PMV57 =      0.000
  PMV58 =      0.000       PMV59 =      0.000       PMV60 =      0.000
  PMV61 =      0.000       PMV62 =      0.000       PMV63 =      0.000
  PMV64 =      0.000
=>>
```

Figure 7.8 PMV Report

Automation Math Variable Metering

Use the **MET AMV** command to display all 256 AMV values, as shown in *Figure 7.9*.

```
=>>MET AMV <Enter>

Relay 1                                     Date: 04/07/2008  Time: 21:04:33.579
Station A                                   Serial Number: 2008030645

Automation Analog Quantities
 AMV001 =      0.000       AMV002 =      0.000       AMV003 =      0.000
 AMV004 =      0.000       AMV005 =      0.000       AMV006 =      0.000
 AMV007 =      0.000       AMV008 =      0.000       AMV009 =      0.000
 AMV010 =      0.000       AMV011 =      0.000       AMV012 =      0.000

 AMV013 =      0.000       AMV014 =      0.000       AMV015 =      0.000
 .
 .
 .

 AMV238 =      0.000       AMV239 =      0.000       AMV240 =      0.000
 AMV241 =      0.000       AMV242 =      0.000       AMV243 =      0.000
 AMV244 =      0.000       AMV245 =      0.000       AMV246 =      0.000
 AMV247 =      0.000       AMV248 =      0.000       AMV249 =      0.000

 AMV250 =      0.000       AMV251 =      0.000       AMV252 =      0.000
 AMV253 =      0.000       AMV254 =      0.000       AMV255 =      0.000
 AMV256 =      0.000
=>>
```

Figure 7.9 AMV Report

MIRRORED BITS Remote Analog Metering

Use the **MET ANA** command to display the analog values used with MIRRORED BITS communications, as shown in *Table 7.5*.

Table 7.5 Information Available With the MET ANA Command

Command	Information
MET ANA	Analog value in channel A Analog value in channel B

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SECTION 8

Monitoring

The relay provides extensive capabilities for monitoring substation components. Most SEL-400 series relays provide the following useful features:

- ➤ *Circuit Breaker Monitor on page 8.1*
- ➤ *Station DC Battery System Monitor on page 8.21*

This section describes monitoring capabilities that are common to many SEL-400 series relays. Some relays include additional monitoring capabilities that are not common to other SEL-4 series relays. See the relay specific instruction manuals to determine the specific monitoring features available in each relay.

Circuit Breaker Monitor

The relay features advanced circuit breaker monitoring. *Figure 8.1* shows that the relay processes phase currents, circuit breaker auxiliary contacts, and the substation dc battery voltages to detect out-of-tolerance and maximum life circuit breaker parameters. These parameters include current interrupted, operating times, and contact wear. By using relay monitoring, maintenance personnel can determine the extent of a developing circuit breaker problem and select an appropriate response to correct the problem. These monitoring features are available online in real-time; you can detect impending problems immediately. The result is better power system reliability and improved circuit breaker life expectancy.

NOTE: This section lists settings for Circuit Breaker 1. The number of circuit breakers and the circuit breaker references vary between relays. See the product-specific instruction manual for the specific breakers available for circuit breaker monitoring.

One of the many circuit breaker monitor features is the circuit breaker contact wear monitor. The relay tracks the number of circuit breaker close-open operations and respective fault interrupting levels for each of two circuit breakers. The relay uses data from the circuit breaker manufacturer to compare the recorded operational data with the manufacturer's recommended maintenance requirements. The relay notifies you when each set of circuit breaker pole contacts exceeds preset wear thresholds. Using this information, you can operate your substation more economically by accurately scheduling circuit breaker maintenance.

You can also collect the following data on these circuit breaker parameters:

- ➤ Circuit breaker wear
- ➤ Electrical operating time
- ➤ Mechanical operating time
- ➤ Circuit breaker inactivity time
- ➤ Interrupted current
- ➤ Pole scatter (for single-pole breakers only)
- ➤ Pole discrepancy (for single-pole breakers only)
- ➤ Motor run time

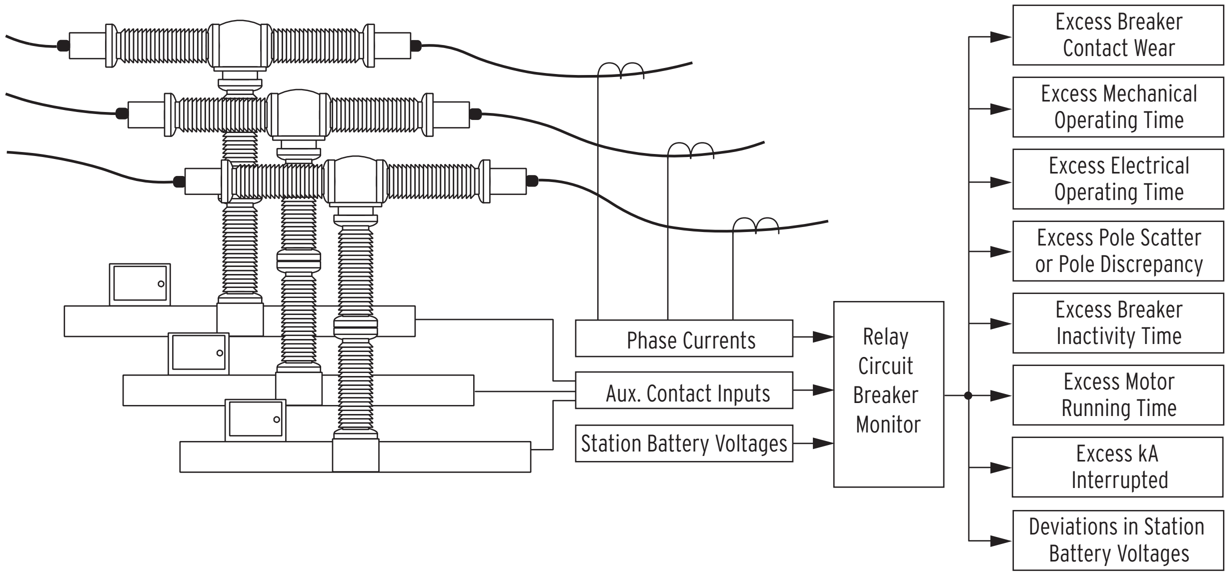

Figure 8.1 Intelligent Circuit Breaker Monitor

You can program the relay to alarm when any of the above quantities exceed a preset threshold. In addition, the relay stores a 128-event circuit breaker history in nonvolatile memory. The circuit breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and other important parameters. The alarm and reporting features help you operate your substation safely and reliably.

Enabling the Circuit Breaker Monitor

NOTE: Some SEL-400 series relays do not support single-pole tripping breakers. In these cases, the corresponding BK*n*TYP setting is not available and only information related to three-pole breakers will be available.

NOTE: Some SEL-400 series relays use a BK_SEL setting to list enabled breakers, rather than the EB*n*MON settings shown here.

Enable and configure the relay circuit breaker monitor by using the settings listed in *Table 8.1* for each of two possible circuit breakers. Power system circuit breakers are either single-pole tripping or three-pole tripping circuit breakers; set the relay for the circuit breaker type that the relay controls. For a single-pole tripping circuit breaker, set BK1TYP := 1, and for a three-pole tripping circuit breaker, set BK1TYP := 3. The factory default setting is BK1TYP := 1. Be sure to configure the relay with the settings that match your circuit breakers.

Table 8.1 Circuit Breaker Monitor Configuration

Name	Description	Range
EB1MON	Enable Circuit Breaker 1 monitoring	Y, N
BK1TYP	Circuit Breaker 1 type	1, 3
EB2MON	Enable Circuit Breaker 2 monitoring	Y, N
BK2TYP	Circuit Breaker 2 type	1, 3

Circuit Breaker Contact Wear Monitor

The circuit breaker contact wear monitor in the relay provides information that helps you schedule circuit breaker maintenance. This monitoring function accumulates the number of close-open operations and integrates the per-phase current during each opening operation. The relay compares this information to a predefined circuit breaker maintenance curve to calculate the percent contact wear on a per-pole basis.

The circuit breaker maintenance curve also incorporates the accumulated fault current arcing time ($\Sigma I^2 t$), assuming an identical arcing time for each trip. You can obtain the one-cycle arcing time from circuit breaker manufacturer data.

The relay updates and stores the contact wear information and the number of trip operations in nonvolatile memory. You can view this information through any communications port.

Any phase wear percentage that exceeds the threshold setting B1BCWAT asserts the alarm Relay Word bit, B1BCWAL, for Circuit Breaker 1. You can use this Relay Word bit in a SELOGIC control equation to alert operations personnel, or you can control other functions such as blocking reclosing. The relay limits the maximum reported circuit breaker wear percentage to 150 percent.

NOTE: In the following discussion, three elements are specified, one for each phase: ϕ = A, B, and C.

The relay integrates currents and increments the trip counters for the contact wear monitor each time the SELOGIC control equation BM1TRPϕ asserts. Set the logic for this function from a communications port with the **SET M** ASCII command, with the ACSELERATOR QuickSet SEL-5030 software program **Breaker Monitor Settings** tree view, or by using the front-panel SET/SHOW menu. (See *Making Simple Settings Changes on page 3.15* for information on setting the relay using these methods.) The default settings cause the contact wear monitor to integrate and increment each time the relay trip logic asserts.

Perform the following specific steps to use the circuit breaker contact wear monitor:

Step 1. Enable the circuit breaker monitor.

Step 2. Load the manufacturer's circuit breaker maintenance data.

Step 3. Preload any existing circuit breaker wear (if setting up the contact wear monitor on a circuit breaker with preexisting service time).

Step 4. Program the SELOGIC control equations for trip and close conditions.

Enable the Circuit Breaker Monitor

You must enable the circuit breaker monitor before you load the manufacturer's data, preload any existing circuit breaker wear, and set the trip initiate and close initiate SELOGIC control equations. Set the circuit breaker monitor enable setting EB*x*MON to Y (for Yes) for Breaker *x*.

Load Manufacturer Circuit Breaker Maintenance Data

Load the maintenance data supplied by the circuit breaker manufacturer. Circuit breaker maintenance information lists the number of permissible operating cycles (close/open operations) for a given current interruption level. *Table 8.2* shows typical circuit breaker maintenance information from an actual SF6 circuit breaker. The *Figure 8.2* log/log plot is the circuit breaker maintenance curve, produced from the *Table 8.2* data.

Table 8.2 Circuit Breaker Maintenance Information—Example (Sheet 1 of 2)

Current Interruption Level (kA)	Permissible Close/Open Operations
0.00–1.2	10000
2.00	3700
3.00	1500
5.00	400
8.00	150

Table 8.2 Circuit Breaker Maintenance Information—Example (Sheet 2 of 2)

Current Interruption Level (kA)	Permissible Close/Open Operations
10.00	85
20.00	12

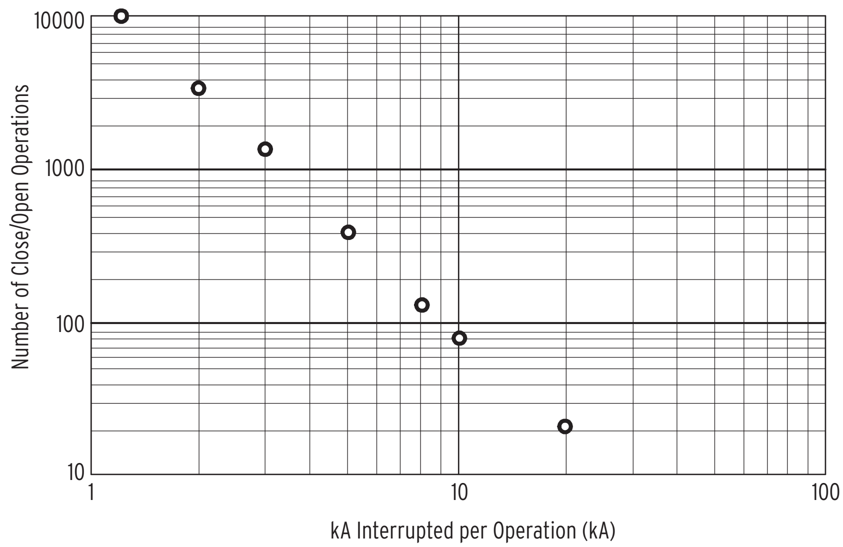

Figure 8.2 Circuit Breaker Maintenance Curve (Manufacturer's Data)

The three set points necessary to reproduce this circuit breaker maintenance curve in the relay are listed in *Table 8.3* for Circuit Breaker 1. *Figure 8.3* shows how to determine these three set points from the maintenance curve shown in *Figure 8.2*.

Table 8.3 Contact Wear Monitor Settings—Circuit Breaker 1

Setting	Definition	Range
B1COSP1	Close/open set point 1—max	0–65000 close/open operations
B1COSP2	Close/open set point 2—mid	0–65000 close/open operations
B1COSP3	Close/open set point 3—min	0–65000 close/open operations
B1KASP1[a]	kA interrupted set point 1—min	1.0–999 kA in 0.1-kA steps
B1KASP2	kA interrupted set point 2—mid	1.0–999 kA in 0.1-kA steps
B1KASP3[a]	kA interrupted set point 3—max	1.0–999 kA in 0.1-kA steps

[a] The ratio of settings B1KASP3/B1KASP1 must be in the range: 5 ≤ B1KASP3/B1KASP1 ≤ 100.

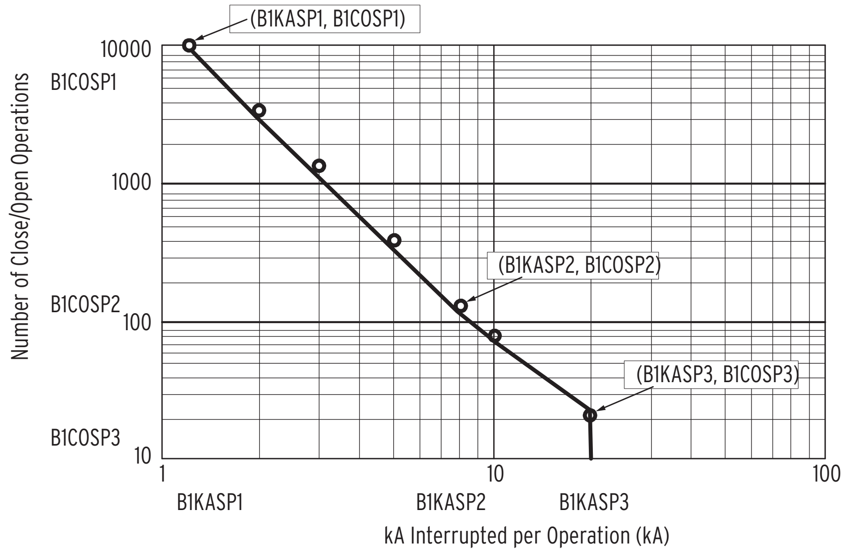

Figure 8.3 Circuit Breaker Contact Wear Curve With Relay Settings

Circuit Breaker Contact Wear Curve Details

Circuit breaker maintenance information from the two end values of *Table 8.2* or *Figure 8.2* determine set point (B1KASP1, B1COSP1) and set point (B1KASP3, B1COSP3) for the contact wear curve of *Figure 8.3*. Set point (B1KASP2, B1COSP2) is the middle maintenance point in these data. There are two philosophies for selecting the middle set point. One method places the middle set point to provide the best "curve-fit" for your plot of the manufacturer's circuit breaker maintenance data (shown in *Figure 8.2*). Another philosophy is to set the middle point based on actual experience or fault studies of the typical system faults.

Example 8.1 Creating the Circuit Breaker Contact Wear Curve

Acquire the manufacturer's maintenance information (this example uses the data of *Table 8.2* for Circuit Breaker 1). If you receive the data in tabular form, plot the manufacturer's maintenance information on log/log paper in a manner similar to *Figure 8.2*.

Choose the left and right set points from the extremes of the curve you just plotted. Select the left set point on the contact wear curve corresponding to (B1KASP1, B1COSP1) by setting B1KASP1 := 1.2 and B1COSP1 := 10000. Plot the right set point (B1KASP3, B1COSP3) by setting B1KASP3 := 20.0 and B1COSP3 := 12.

Choose the midpoint of the contact wear curve based on your experience and system fault studies. The majority of operations for a typical circuit breaker are to interrupt single-line-to-ground faults. Therefore, plot the midpoint (B1KASP2, B1COSP2) by setting B1KASP2 at or slightly greater than the expected single-line-to-ground fault current: B1KASP2 := 8.0 and B1COSP2 := 150.

There are two other notable portions of the circuit breaker contact wear curve in *Figure 8.3*. The curve is horizontal below the left set point (B1KASP1, B1COSP1). This is the close/open operation limit regardless of interrupted current value (for the *Example 8.1* circuit breaker, this is at B1COSP1 := 10000). Some manufacturers call this point the mechanical circuit breaker service life.

Another part of the circuit breaker maintenance curve falls vertically at the right set point (B1KASP3, B1COSP3). This is the maximum interrupted current limit (for the *Example 8.1* circuit breaker, this is at B1KASP3 := 20.0). If the interrupted current exceeds setting B1KASP3, the relay sets contact wear at 105 percent.

Example 8.2 I^2t Criteria Application

Some circuit breaker manufacturers do not provide a circuit breaker maintenance curve, but specify the accumulated fault current arcing time (ΣI^2t) for circuit breaker maintenance. For example, manufacturer's data specify ΣI^2t per phase at 750 kA^2 seconds for a particular circuit breaker, at a rated arcing duration for each trip of 1 cycle. The circuit breaker maximum interrupting current rating is 40 kA, and the continuous load current rating is 2 kA.

You can construct the contact wear curve for this circuit breaker from the specified ΣI^2t. Choose B1KASP1 := 2.0 (the continuous current rating) and B1KASP3 := 40.0 (the maximum interrupting current rating). Choose the middle of the contact wear curve based on experience and system fault studies. The majority of faults a typical circuit breaker interrupts are single-line-to-ground faults. Therefore, set B*n*KASP2 at or slightly greater than the expected single-line-to-ground fault current (B1KASP2 := 10.0 kA in this example). Using the following equations, calculate these settings points to obtain the number of close/open operations:

$$\text{B1COSP1} = \frac{\sum I^2 t}{(\text{B1KASP1})^2 \bullet t_{arc}} = \frac{750}{2^2 \bullet (0.01667 \bullet 1)} := 11250$$

Equation 8.1

$$\text{B1COSP2} = \frac{\sum I^2 t}{(\text{B1KASP2})^2 \bullet t_{arc}} = \frac{750}{10^2 \bullet (0.01667 \bullet 1)} := 450$$

Equation 8.2

$$\text{B1COSP3} = \frac{\sum I^2 t}{(\text{B1KASP3})^2 \bullet t_{arc}} = \frac{750}{40^2 \bullet (0.01667 \bullet 1)} := 28$$

Equation 8.3

In these equations, t_{arc} is the arcing time in seconds; $t_{arc} = (1/f_{NOM}) \bullet$ (arc duration in cycles); f_{NOM} is the nominal power system frequency (50 Hz or 60 Hz). These calculations show the number of close/open operations rounded to the nearest unit.

Preloading Contact Wear Data

Upon the first commissioning of the relay, the associated circuit breakers can already have some wear. You can preload a separate amount of wear for each pole of each circuit to preload existing contact wear data. The relay accepts integer values of percentage wear as great as 100 percent. The relay adds the incremental contact wear at the next circuit breaker monitor initiation (and at all subsequent initiations) to the preloaded value to obtain a total wear value. The limit for reporting circuit breaker contact wear is 150 percent for each pole.

Program the SELOGIC Control Equations for Trip and Close Conditions

Circuit Breaker Monitor Trip Initiation Settings: BM1TRPϕ

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C. With three-pole breakers, only phase A is used to represent the entire breaker. Some three-pole relays include A in the names and others disregard it.

The relay employs SELOGIC control equations to initiate the circuit breaker monitor. For Circuit Breaker 1, this setting is BM1TRPϕ. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor accumulates circuit breaker operating parameters from phases A, B, and C. When detecting a rising edge (a transition from logical 0 to logical 1) of the initiation settings, the relay accumulates the interrupted rms currents and advances the trip counter by one count. There are separate current accumulators and trip counters for each circuit breaker pole. *Table 8.4* shows the factory-default settings for circuit breaker monitor initiation.

NOTE: Factory defaults differ for single-pole tripping and three-pole tripping. Three-pole tripping uses the single setting BM1TRPA for all three poles.

Table 8.4 Circuit Breaker Monitor Initiate SELOGIC Control Equations

Name	Description	Comment[a]
BM1TRPA	BK1 monitor initiate equation	If BK1TYP := 3
BM1TRPA	A-Phase BK1 monitor initiate equation	If BK1TYP := 1
BM1TRPB	B-Phase BK1 monitor initiate equation	If BK1TYP := 1
BM1TRPC	C-Phase BK1 monitor initiate equation	If BK1TYP := 1

[a] See *Table 8.1*.

Initiation settings can include both internal and external tripping conditions. To capture trip information initiated by devices other than the relay, you must program the SELOGIC control equation BM1TRPϕ to sense these trips.

Example 8.3 Circuit Breaker Monitor External Trip Initiation

Connect external trip signals to the relay control inputs. This example uses input IN201; you can use any control inputs that are appropriate for your installation. Control Input IN201, an optoisolated input, is located on the relay I/O Interface Board #1.

If you want Circuit Breaker Monitor 1 to initiate for the trip elements TPA1, TPB1, and TPC1, or for external trips, set these SELOGIC control equations from the **SET M** ASCII command or the QuickSet **Breaker Monitor Settings** tree view:

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip Initiate—BK1

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip Initiate—BK1

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip Initiate—BK1

Example 8.4 Using a Control Input to Capture External and Internal Trip Commands

You can also capture all trip information for circuit breaker trips by using a relay control input to monitor the trip bus for the given circuit breaker. *Figure 8.4* shows an illustration of this method in which IN206 connects to the Circuit Breaker 1 A-Phase trip bus (via a parallel connection across the trip bus), and asserts for any trip from any source. This example uses inputs IN206; you can use any control inputs that are appropriate for your installation. Vdc for this example is 125 Vdc.

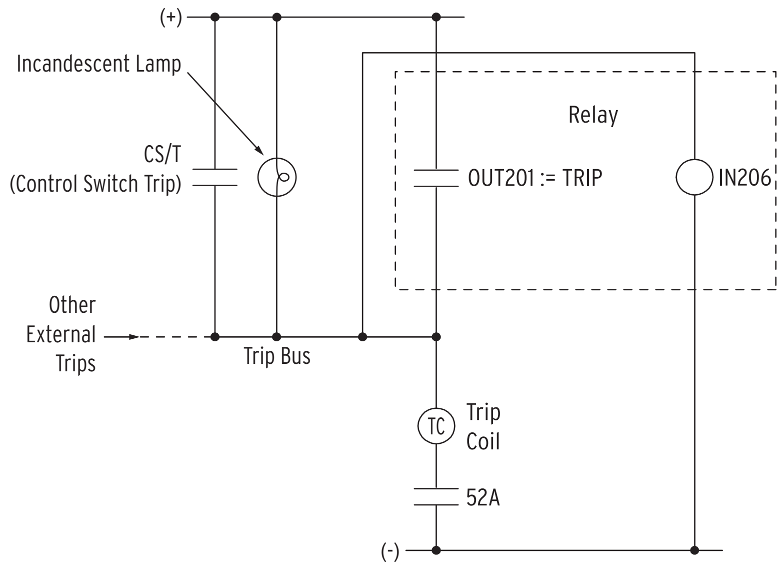

Figure 8.4 Trip Bus Sensing With Relay Input IN206

Many U.S. substation trip bus configurations have an incandescent trip indicator lamp from the battery + terminal to the trip bus. This lamp presents an impedance that can provide sufficient "pull-up" on the trip bus to falsely assert the control input. The worst case for this condition occurs when the circuit breaker is open (auxiliary circuit breaker (52A) contact in *Figure 8.4* is open). You can change the input debounce time IN206PU for slow or noisy mechanical switches; the default debounce time of 1/8 cycle should be sufficient for most trip bus arrangements.

Use the **SET G** (GLOBAL) command or the QuickSet **Global > Control Inputs Settings** tree view to confirm that the debounce time (settings IN206PU and IN206DO) are correct for your trip bus control voltage. You must enable independent control input conditioning by using Global setting EICIS. Enter these settings:

EICIS := **Y** Independent Control Input Settings (Y, N)

IN206PU := **0.1250** Input IN206 Pickup Delay (0.0000–5 cyc)

IN206DO := **0.1250** Input IN206 Dropout Delay (0.0000–5 cyc)

BM1TRPA := **IN206** Breaker Monitor Trip—BK1 (SELOGIC Equation)

Use this procedure to cause the circuit breaker monitor to initiate for either external or internal Circuit Breaker 1 A-Phase trips.

Circuit Breaker Monitor Close Initiation Settings: BM1CLSϕ

NOTE: In the following discussion, three elements are specified. There is one element for each phase: ϕ = A, B, and C. With three-pole breakers, only phase A is used to represent the entire breaker. Some three-pole relays include A in the names and others drop it.

The relay employs SELOGIC control equations to initiate the circuit breaker monitor duration timers for close functions. For Circuit Breaker 1, this setting is BM1CLSϕ. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor times mechanical closing, electrical closing, and pole scatter. *Table 8.5* shows the factory-default settings for circuit breaker monitor close initiation.

Table 8.5 Circuit Breaker Monitor Close SELOGIC Control Equations

Name	Description	Comment[a]
BM1CLSA	Breaker Monitor 1 close equation	If BK1TYP := 3
BM1CLSA	Breaker Monitor 1 A-Phase close equation	If BK1TYP := 1
BM1CLSB	Breaker Monitor 1 B-Phase close equation	If BK1TYP := 1
BM1CLSC	Breaker Monitor 1 C-Phase close equation	If BK1TYP := 1

[a] See *Table 8.1*.

As in *Example 8.4* (connection of the trip bus to a control input), you can also capture the circuit breaker close information by using a relay input to monitor the close bus for the given circuit breaker.

Other Circuit Breaker Monitor Functions

kA Interrupt Monitoring

The relay monitors the amount of phase current that each pole of the circuit breaker interrupts at each trip operation. The relay records the interrupted current as a percentage of the circuit breaker maximum interrupting rating specified by the manufacturer. Set the maximum interruption current with setting B1MKAI (Maximum kA Interrupt Rating—BK1). If the percent of current interrupt that the relay records exceeds threshold setting B1KAIAT (kA Interrupt Capacity Alarm Threshold—BK1), the relay asserts breaker monitor alarm Relay Word bit B1KAIAL.

Mechanical Operating Time

The mechanical operating time is the time between trip initiation or close initiation and the associated phase circuit breaker 52A normally open contact status change. (Assertion of 52Aϕ1 indicates that a particular circuit breaker phase has closed). The relay measures the tripping times for each phase from the assertion of the respective BM1TRPϕ Relay Word bit to the dropout of the respective 52Aϕ1 Relay Word bit. Similarly, for mechanical closing time, the relay measures the closing times for each phase from the assertion of the BM1CLSϕ Relay Word bit to the pickup of the 52Aϕ1 Relay Word bit. The relay compares these tripping or closing times to the mechanical slow operation time thresholds for tripping and closing, B1MSTRT and B1MSCLT, respectively. The relay issues a mechanical slow operation alarm, B1MSOAL, for 5 seconds when trip or close times exceed these thresholds. See *Figure 8.5* for a Circuit Breaker 1 A-Phase timing diagram.

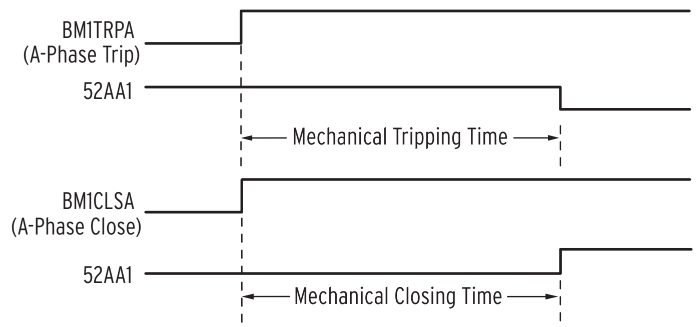

Figure 8.5 Mechanical Operating Time for Circuit Breaker 1 A-Phase

Example 8.5 Mechanical Operating Time Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. Connect the circuit breaker normally open 52A contacts through station battery power to IN201, IN202, and IN203. This example uses inputs IN201, IN202, and IN203 for A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN201–IN203 are direct-coupled inputs.

Set the Relay Word bits to respond to these inputs.

52AA1 := **IN201** A-Phase N/O Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN202** B-Phase N/O Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN203** A-Phase N/O Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN301, IN302, and IN303, and external close signals to IN304, IN305, and IN306 for the A-, B-, and C-Phases, respectively. Use the default settings for input conditioning (debounce time and assertion level), as with inputs IN201 to IN203 above.

Set the mechanical operating time threshold for the slow trip alarm (B1MSTRT) to 30 ms, and the slow close alarm threshold (B1MSCLT) to 70 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings:

B1MSTRT := **30** Mechanical Slow Trip Alarm Threshold—BK1 (1–999 ms)

B1MSCLT := **70** Mechanical Slow Close Alarm Threshold—BK1 (1–999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN301** Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPB := **TPB1 OR IN302** Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPC := **TPC1 OR IN303** Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)

Example 8.5 Mechanical Operating Time Settings (Continued)

BM1CLSA := **BK1CL OR IN304** Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)

BM1CLSB := **BK1CL OR IN305** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC **:= BK1CL OR IN306** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Assertion of the Relay Word bit B1MSOAL indicates any one of the following four conditions:

- The mechanical operating time for a trip operation exceeds 30 ms (the slow trip alarm setting)
- The mechanical operating time for a close operation exceeds 70 ms (the slow close setting)
- No 52Aϕ1 status change occurred during the time B1MSTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No 52Aϕ1 status change occurred during the time B1MSCLT plus approximately 100 ms after close initiation (a close time-out condition)

The relay makes a further check on the auxiliary circuit breaker (52A) contacts by testing whether these circuit breaker contacts have changed state within approximately 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This check verifies that the circuit breaker actually closed or opened, and it alerts you if maintenance is required on the circuit breaker mechanical linkages or auxiliary (52) contacts.

Electrical Operating Time

The electrical operating time is the time between trip or close initiation and an open-phase status change. For both circuit breakers, the relay measures the tripping time for each phase from the assertion of the BM1TRPϕ Relay Word bit to the time the relay detects an open-phase condition. Similarly, the relay measures electrical operating time for closing each phase from the assertion of BM1CLSϕ to the restoration of phase quantities. The relay compares these tripping or closing times to the electrical slow operation time thresholds for tripping and closing, B1ESTRT and B1ESCLT, respectively. The relay issues an electrical slow operation alarm, B1ESOAL, for 5 seconds when trip or close times exceed these thresholds. *Figure 8.6* shows the timing diagram for the A-Phase pole of Circuit Breaker 1.

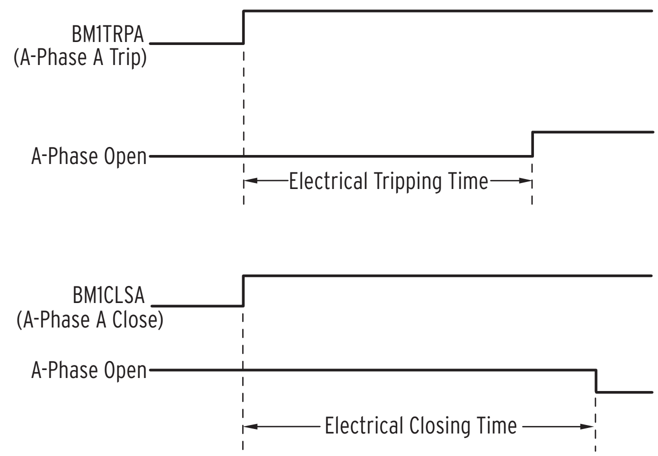

Figure 8.6 Electrical Operating Time for Circuit Breaker 1 A-Phase

Primary load/fault current can indicate contact closing, contact opening, and arc extinction, depending upon the actual circuit breaker monitor setup. You can detect problems within the circuit breaker arcing chamber by timing the interval from trip/close initiation to electric arc extinction.

Example 8.6 Electrical Operating Time Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. Connect external trip signals to IN201, IN202, and IN203, and external close signals to IN204, IN205, and IN206 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN201–IN206; you can use any control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

Control Inputs IN201–IN206 are located on the relay I/O Interface board #1.

Set the electrical operating time threshold for the slow trip alarm (B1ESTRT) at 25 ms, and the slow close alarm threshold (B1ESCLT) at 65 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings.

B1ESTRT := **25** Electrical Slow Trip Alarm Threshold—BK1 (1–999 ms)

B1ESCLT := **65** Electrical Slow Close Alarm Threshold—BK1 (1–999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)

Example 8.6 Electrical Operating Time Settings (Continued)

BM1CLSB := **BK1CL OR IN205** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC := **BK1CL OR IN206** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Assertion of the Relay Word bit B1ESOAL indicates any one of the following four conditions:

- The electrical operating time for a trip operation exceeds 25 ms (the slow trip alarm setting)
- The electrical operating time for a close operation exceeds 65 ms (the slow close setting)
- No pole-open logic status change occurred during the time B1ESTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No pole-open logic status change occurred during the time B1ESCLT plus approximately 100 ms after close initiation (a close time-out condition)

The relay further checks the circuit breaker by testing whether the circuit breaker has interrupted or restored current within 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This verifies that the circuit breaker actually closed or opened, and alerts you if maintenance is required on circuit breaker mechanical linkages.

Pole Scatter

The relay records and compares the operation time of each circuit breaker pole to detect time deviations between pairs of circuit breaker poles when tripping and closing all three poles simultaneously on single-pole-capable circuit breakers. The relay measures the differences in operating times resulting from auxiliary circuit breaker (52A) contact status changes. The logic compares the operation time of each individual circuit breaker pole against the time for each of the other poles. The relay triggers an alarm, B1PSAL, for any time deviation greater than the preset time threshold settings B1PSTRT and B1PSCLT for Circuit Breaker 1.

NOTE: Pole scatter applies only to single-pole mechanism circuit breakers (BK1TYP := 1). These circuit breakers have an auxiliary circuit breaker (52A) contact for each phase.

Figure 8.7 shows the operating time for each pole (A, B, and C) of Circuit Breaker 1. TAB represents the operating time deviation between poles A and B. TBC is the time between B and C, and TCA is the time between C and A. Once activated, the pole scatter alarm remains asserted for five seconds.

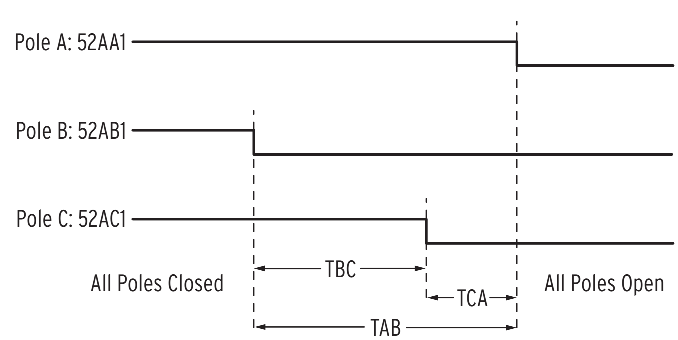

Figure 8.7 Timing Illustration for Pole Scatter at Trip

Example 8.7 Pole Scatter Settings

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. This example uses control inputs IN301, IN302, and IN303 for the A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation.

The control voltage for this example is 125 Vdc. Control Inputs IN301–IN303 are located on I/O Board #3. Connect the circuit breaker normally open auxiliary circuit breaker (52A) contacts through station battery power to IN301, IN302, and IN303.

Set the relay to respond to these inputs by using the QuickSet **Breaker Monitor (SET M)** settings:

52AA1 := **IN301** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN302** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN303** C-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN201, IN202, and IN203, and external close signals to IN204, IN205, and IN206 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN201–IN206; you can use any control inputs that are appropriate for your installation.

Set the pole scatter trip alarm time threshold (B1PSTRT) at 4 ms, the pole scatter close alarm time threshold (B1PSCLT) at 6 ms, and the pole discrepancy time delay (B1PDD) at 1400 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings:

B1PSTRT := **4** Pole Scatter Trip Alarm Threshold—BK1 (1–999 ms)

B1PSCLT := **6** Pole Scatter Close Alarm Threshold—BK1 (1–999 ms)

B1PDD := **1400** Pole Discrepancy Time Delay—BK1 (1–9999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

BM1TRPA := **TPA1 OR IN201** Breaker Monitor A-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPB := **TPB1 OR IN202** Breaker Monitor B-Phase Trip—BK1 (SELOGIC Equation)

BM1TRPC := **TPC1 OR IN203** Breaker Monitor C-Phase Trip—BK1 (SELOGIC Equation)

BM1CLSA := **BK1CL OR IN204** Breaker Monitor A-Phase Close—BK1 (SELOGIC Equation)

BM1CLSB := **BK1CL OR IN205** Breaker Monitor B-Phase Close—BK1 (SELOGIC Equation)

BM1CLSC := **BK1CL OR IN206** Breaker Monitor C-Phase Close—BK1 (SELOGIC Equation)

Example 8.7 Pole Scatter Settings (Continued)

If any of the pole-open times (TAB, TBC, and TCA in *Figure 8.7*) exceed 4 ms, or if any of the pole close times exceed 6 ms, the relay asserts the Relay Word bit B1PSAL. Assertion of B1PSAL indicates any one of the following four conditions:

- The pole scatter time for trip operation exceeds the alarm setting time (4 ms)
- The pole scatter time for close operation exceeds the alarm setting time (6 ms)
- One phase auxiliary circuit breaker (52A) contact status change exceeds B1PSTRT plus approximately 5 ms after the trip initiation
- One phase auxiliary circuit breaker (52A) contact status change exceeds B1PSCLT plus approximately 5 ms after the close initiation

Note that the relay provides a time out of approximately 200 ms after the trip or 300 ms after the close threshold to end detection of pole scatter alarms.

Pole Discrepancy

The relay continuously monitors the status of each circuit breaker pole to detect open or close deviations among the three poles. In addition, at tripping and closing, the relay measures the differences in operating times during the auxiliary circuit breaker (52A) contact status changes or open-phase logic operation. The relay triggers an alarm Relay Word bit, B1PDAL, if the status of any pole compared to another pole exceeds the time window setting B1PDD for the circuit breaker.

NOTE: Pole discrepancy applies only to single-pole mechanism circuit breakers (BK1TYP := 1). These circuit breakers have an auxiliary circuit breaker (52A) contact output for each phase.

You can set the relay to use the current flowing through the circuit breaker to supervise pole discrepancy timing of the auxiliary circuit breaker (52A) contacts. Enable this supervision by setting E1PDCS to Y for Circuit Breaker 1.

Pole discrepancy setting B1PDD should be longer than the single-pole reclosing dead time.

$$B1PDD := (SPOID + \text{circuit breaker pole operating time} + \text{contact latency}) \bullet 1.2$$

Equation 8.4

where:

SPOID is the single-pole open interval time and the factor 1.2 is a safety factor.

Round this time to the next higher hundreds of milliseconds value to give the pole discrepancy setting.

Figure 8.8 shows a Circuit Breaker 1 operation where Pole B closes first, followed by Pole C; Pole A closes slowly. If the time from a change in 52AB1 to the change in 52AA1 exceeds the pole discrepancy time threshold setting B1PDD, then the relay asserts the B1PDAL alarm. Once activated, the relay asserts the pole discrepancy alarm for five seconds.

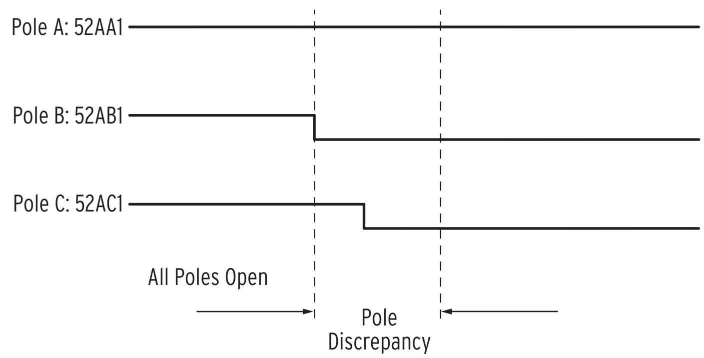

Figure 8.8 Pole Discrepancy Measurement

Example 8.8 Pole Discrepancy Alarm for Circuit Breaker 1—No Other Circuit Breaker Monitor Functions

Use Circuit Breaker 1, a single-pole tripping circuit breaker, for this example. This example uses control inputs IN301, IN302, and IN303 for the A-, B-, and C-Phases, respectively; you can use any control inputs that are appropriate for your installation.

The control voltage for this example is 125 Vdc. Control Inputs IN301–IN303 are located on I/O Board #2. Connect the circuit breaker normally open auxiliary circuit breaker (52A) contacts through station battery power to IN301, IN302, and IN303.

Set the relay internal Relay Word bits to respond to these inputs by using the QuickSet **Breaker Monitor (SET M)** settings:

52AA1 := **IN301** A-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AB1 := **IN302** B-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

52AC1 := **IN303** C-Phase Normally Open Control Input—BK1 (SELOGIC Equation)

Connect external trip signals to IN301, IN302, and IN303, and external close signals to IN304, IN305, and IN306 for the A-, B-, and C-Phases, respectively. This example uses control inputs IN301–IN306; you can use any control inputs that are appropriate for your installation.

Set the pole discrepancy time delay (B1PDD) at 1400 ms. This time delay assumes a dead time of 1000 ms plus a pole closing time of 100 ms (including contact latency), plus 20 percent (for security), rounded to the next higher hundreds of milliseconds value. This pole discrepancy time is longer than the single-pole open interval time default of 900 ms; confirm that this is the case for your application settings.

Enter the following settings:

B1PDD := **1400** Pole Discrepancy Time Delay—BK1 (1–9999 ms)

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

BK1TYP := **1** Breaker 1 Trip Type (Single Pole = 1, Three Pole = 3)

The pole discrepancy timing window is B1PDD := 1400 (ms). Assertion of the Relay Word bit B1PDAL indicates that the status of the three Circuit Breaker 1 poles disagrees for 1400 ms or longer.

Circuit Breaker Inactivity Time Elapsed

The relay circuit breaker inactivity time monitor detects the elapsed time (measured in days) since the last trip or close operation of a circuit breaker. Use setting B1ITAT to set the circuit breaker inactivity time. An alarm Relay Word bit, B1BITAL, asserts if the elapsed time exceeds a predefined setting. This alarm is useful to detect circuit breakers that are not operated on a regular basis. These circuit breakers can fail to operate when needed to perform a protection trip.

Example 8.9 Inactivity Time Settings

Use Circuit Breaker 1 for this example. To assert an alarm if Circuit Breaker 1 has not operated within the last 365 days, enter the following settings:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

B1ITAT := **365** Inactivity Time Alarm Threshold—BK1 (N, 1–9999 days)

Assertion of the Relay Word bit B1BITAL indicates that it has been more than 365 days since the last Circuit Breaker 1 operation.

When testing the inactivity timer, you must measure actual relay clock transitions across time 00:00:00.000 (to increment the day counter). If you set the relay to a specific date, enable the circuit breaker monitor (EB1MON := Y), then advance the date setting to a new date, the inactivity timer shows only one day of elapsed time.

Motor Running Time

The relay circuit breaker monitor measures circuit breaker motor running time. Depending on your circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressed air motor. An alarm asserts if the elapsed motor running time exceeds the predefined threshold setting B1MRTAT.

Setting B1MRTIN is a SELOGIC control equation to activate the motor-running timer. The rising edge of B1MRTIN indicates the motor starting time; a falling edge indicates the motor stop time. The motor running time logic asserts the alarm Relay Word bit, B1MRTAL, for 5 seconds when the motor running time exceeds the predefined threshold. Setting B1MRTIN to logical 0 disables the motor running time feature of the circuit breaker monitor.

Example 8.10 Motor Running Time Settings

Use Circuit Breaker 1 for this example.

Connect the motor control contact to IN207. This example uses control input IN207; you can use any control inputs that are appropriate for your installation.

To determine the motor run time value, take the circuit breaker out of service using your company standard circuit breaker maintenance policy. Issue a trip and close command while you measure the time that the circuit breaker motor requires for recharging the spring or reestablishing the return air pressure to normal. Add 20 percent to this time measurement to avoid false alarms. Use the resulting time value for the motor running time alarm setting B1MRTAL.

Example 8.10 Motor Running Time Settings (Continued)

The control voltage for this example is 125 Vdc. Control Input IN207 is located on the relay I/O Interface board #1.

The recharge time measurement for this circuit breaker was 20 seconds; add 20 percent (4 seconds) to give an alarm time of 24 seconds. To set the motor running time alarm threshold at 24 seconds, enter the following settings:

EB1MON := **Y** Breaker 1 Monitoring (Y, N)

B1MRTIN := **IN207** Motor Run Time Control Input—BK1 (SELOGIC Equation)

B1MRTAT := **24** Motor Run Time Alarm Threshold—BK1 (1–9999 seconds)

Assertion of the Relay Word bit B1MRTAL indicates the following condition: motor running time exceeds 24 seconds because IN207 was asserted for more than 24 seconds.

BREAKER Command

Use the **BRE** command to access vital information about the condition of substation circuit breakers and preset or reset circuit breaker monitor data. The relay monitors two separate circuit breakers; you must specify Circuit Breaker 1 and Circuit Breaker 2 for most **BRE** commands. *Table 8.6* shows the **BRE** commands. For more information on the **BRE** command, see *BREAKER on page 14.4*.

Table 8.6 BRE Command

Command	Description	Access Level
BRE C A	Clear all circuit breaker monitor data to zero.	B, P, A, O, 2
BRE *n* C[a]	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n*[a]	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2
BRE *n* H[a]	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2
BRE *n* P[a]	Preload previously accumulated Circuit Breaker *n* data.	B, P, A, O, 2

[a] *n* is the breaker reference.

The **BRE *n* C** command resets the accumulated circuit breaker monitor data for Circuit Breaker *n*. The clear command **BRE C A** clears all data for both circuit breakers.

The **BRE *n*** command displays the circuit breaker report for the most recent Circuit Breaker *n* operation.

You can also reset the circuit breaker report with Global SELOGIC setting RST_BK*n* for the Circuit Breaker *n* report. You must first set EDRSTC (Data Reset Control) to Y to access these Global settings.

The relay also displays the operation summary and the circuit breaker alarms. When the circuit breaker maintenance curve reaches 150 percent for a particular pole, the percentage wear for this pole remains at 150 percent (even if additional current is interrupted) until reset. However, the relay continues to advance the operation counter to as many as 9999999 operations per pole until reset. Accumulated circuit breaker wear/operations data are retained if the relay loses power or if the circuit breaker monitor is disabled (EB*n*MON := N).

Circuit Breaker Report

Figure 8.9 shows a sample breaker report (with typical data). The relay reports dc battery monitor voltages for the minimum dc voltage during a 20-cycle period at circuit breaker monitor trip initiation (BM1TRPϕ) and for a 30-cycle window at circuit breaker monitor close initiation (BM1CLSϕ). The circuit breaker report contains data only for options that you have enabled.

```
=>BRE 1 <Enter>

Relay 1                                    Date: 03/20/2001  Time: 17:21:42.577
Station A                                  Serial Number: 2001001234
Breaker 1
Breaker 1 Report
                                Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg Elect Op Time (ms)                                    5.8     7.5     8.4
Last Elect Op Time (ms)         18.2    20.0    17.9      8.4    10.4     8.4
Avg Mech Op Time (ms)
Last Mech Op Time (ms)          25.8    24.4    26.5     30.1    26.3    34.2
Inactivity Time (days)             1       1       1        1       1       1

                                     3 Pole Trip            3 Pole Close
                                  AB      BC      CA       AB      BC      CA
Max Pole Scatter (ms)            5.1     3.1     5.0      6.3     4.1     2.1
Last Pole Scatter (ms)           2.1     1.0     3.1      4.1     2.1     2.1

                              Pole A  Pole B  Pole C
Accum Pri Current (kA)       3.13657 0.43533 0.41785
Accum Contact Wear (%)           0.5     0.5     0.5
Max Interrupted Current (%)      1.6     0.2     0.2
Last Interrupted Current(%)      1.6     0.2     0.2
Number of Operations               5       5       5

                              Alarm   Total Count
Mechanical Operating Time     MSOAL       4
Electrical Operating Time     ESOAL       3
Breaker Inactivity Time       BITAL       0
Pole Scatter                   PSAL       2
Pole Discrepancy               PDAL       1
Current (kA) Interrupted      KAIAL       0
LAST BREAKER MONITOR RESET   03/15/2001   07:21:31.067

=>
```

Figure 8.9 SEL-411L Breaker Report (for the Most Recent Operation)

Breaker History

The relay displays the circuit breaker history report when you issue the **BRE *n* H** command. The report consists of as many as 128 circuit breaker monitor events stored in nonvolatile memory. These events are determined by settings BM*n*TRPϕ and BM*n*CLSϕ. The breaker history report is similar to that shown in *Figure 8.10* (shown with typical data).

```
=>BRE 1 H <Enter>
Breaker 1 History Report
Relay 1                                    Date: 03/15/2001  Time: 07:19:27.156
Station A                                  Serial Number: 01001234

No.     Date         Time        Bkr.Op Op Time(ms)   Pri I   VDC1   VDC2
                                        Elect Mech     (A)    (V)    (V)
1    06/01/2000  12:24:36.216    Trp A   26  28       5460   119    118
2    06/01/2000  12:24:36.216    Trp B   26  28       5260   119    118
3    06/01/2000  12:24:36.216    Trp C   26  28       5160   119    119
4    09/26/1999  16:24:36.214    Cls A   39  35       1020   118    118
5    09/26/1999  16:24:36.214    Cls B   39  35       990    118    118
6    09/26/1999  16:24:36.214    Cls C   39  35       1010   118    118
7    03/26/1999  11:24:36.218    Cls C   39  35       1100   117    115
8    03/26/1999  11:24:31.218    Trp C   26  28       3460   116    112
128
=>
```

Figure 8.10 Breaker History Report

Preload Breaker Wear

You can preload a separate contact wear value for each pole of each circuit breaker by using the command **BRE *n* P** for Circuit Breaker *n*. The relay adds the incremental contact wear at all subsequent circuit breaker monitor initiations to your preloaded value to obtain a total wear value. You can enter integer values of percentage wear from 1 to 100 percent. In addition to preloading contact wear data, you can enter values for previous operations and accumulated currents. The maximum number of operations or accumulated primary current (in kA) you can enter is 9999999. The circuit breaker preload terminal screen is similar to *Figure 8.11* for both the terminal and QuickSet.

```
=>BRE 1 P <Enter>
Accum Contact Wear (%)            A-phase % :=  5 ? 12 <Enter>
                                  B-phase % := 10 ? 15 <Enter>
                                  C-phase % :=  7 ? 10 <Enter>
Accum Num of Operations:          A-phase := 25 ? 11 <Enter>
                                  B-phase := 25 ? 11 <Enter>
                                  C-phase := 25 ? 11 <Enter>

Accum Pri Current (kA)            Trip A := 99.0 ? 299 <Enter>
                                  Trip B := 98.0 ? 254 <Enter>
                                  Trip C := 98.0 ? 257 <Enter>
                                    Pole A      Pole B      Pole C
Accum Contact Wear (%)                12          15          10
Accum Num of Operations               11          11          11
Accum Pri Current (kA)               299         254         257
```

Figure 8.11 Circuit Breaker Preload Data

When performing circuit breaker testing, capture the **BRE *n* P** information (write the date or use a terminal screen capture) before testing. Test the circuit breaker, then enter the previously recorded preload data with the **BRE *n* P** command. Using this method, you can eliminate testing operations from actual usage data in the circuit breaker monitor.

SEL Compressed ASCII Circuit Breaker Report

You can retrieve a Compressed ASCII circuit breaker report by using the **CBR** command from any communications port.

The relay arranges items in the Compressed ASCII circuit breaker report in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

The information presented below explains the message and serves as a guide to the items in a Compressed ASCII configuration circuit breaker report.

The format of the Compressed ASCII **CBR** message is the following.

```
“RID”,“SID”,“FID”,“yyyy”
relayid,station,fidstring,"yyyy"
"BID","yyyy"
breakerid,"yyyy"
"AVG_TR_ELE","LST_TR_ELE","AVG_TR_MEC","LST_TR_MEC","LST_TRmDC1",
   "LST_TRmDC2","TR_INAC(d)","MAX_TR_SCA","LST_TR_SCA", "AVG_CL_ELE",
   "LST_CL_ELE","AVG_CL_MEC","LST_CL_MEC","LST_CLmDC1",
   "LST_CLmDC2","CL_INAC(d)","MAX_CL_SCA","LST_CL_SCA", "ACC_I(kA)",
   "ACC_WEAR(%)","MAX_INT_I(%)","LAST_INT_I(%)","NUM_OPS","yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
fff,fff,fff,fff,fff,fff,iii,fff,fff,fff,fff,fff,fff,fff,fff,iii,fff,fff,
   fff,fff,fff,fff,iii,"yyyy"
"AVG_MOT_RT","LST_MOT_RT","RST_MONTH","RST_DAY","RST_YEAR","RST_HOUR","RST_MIN",
  "RST_SEC","yyyy"
iii,iii,iii,iii,iii,iii,iii,iii,"yyyy"
```

Definitions for the items and fields in the Compressed ASCII configuration are the following:

- yyyy is the checksum
- iii is an integer value
- fff is a floating-point value

The relay reports the data as A-Phase in the first line, B-Phase in the second line, and C-Phase in the third line. Pole scatter data are slightly different: TAB is in the first line, TBC is in the second line, and TCA is in the third line.

Station DC Battery System Monitor

NOTE: This section lists settings for Station DC Battery Monitor 1; settings for Station DC Battery Monitor 2 are similar; replace 1 in the setting with 2.

The relay automatically monitors station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. SEL-400 series relays provide either one or two dc monitor channels. See the product-specific instruction manual to see how many breaker monitor channels the relay supports. Four voltage thresholds give you the ability to create five sensing zones (low failure, low warning, normal, high warning, and high failure) for the dc voltage.

The ac ripple quantity indicates battery charger health. When configuring the ac ripple setting DC1RP, we can define the ripple content of a dc supply as the peak-to-peak ac component of the output supply waveform.

The relay also makes measurements between the battery terminal voltages and station ground to detect positive and negative dc ground faults. *Figure 8.12* shows a typical dual-battery dc system.

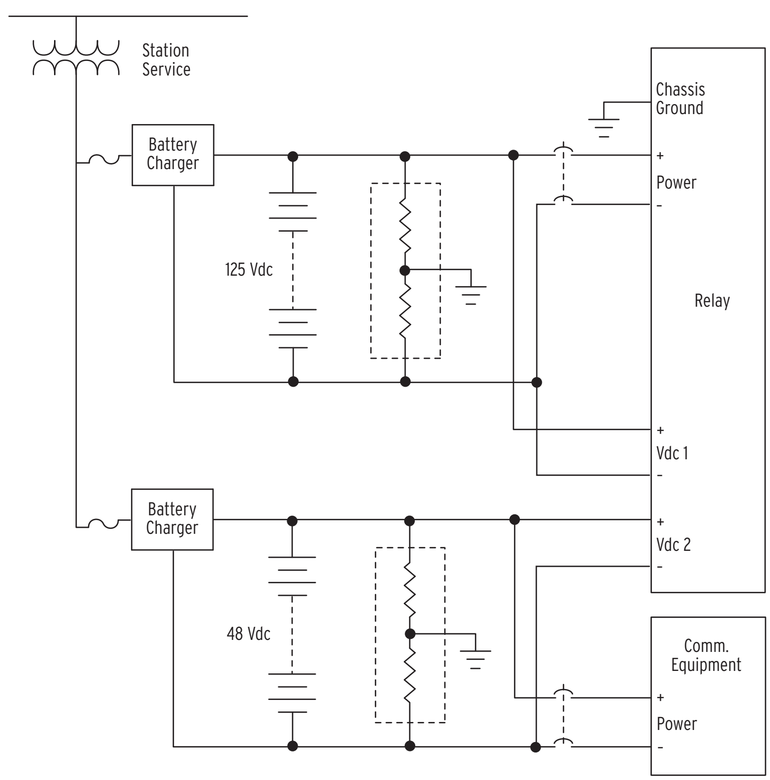

Figure 8.12 Typical Station DC Battery System

The dc battery monitor measures the station battery voltage applied at the rear-panel terminals labeled Vdc1 (+ and –) and Vdc2 (+ and –). Monitoring dc voltage during circuit breaker operation gives a quick test of the battery system, which includes wiring and junctions from the batteries to the circuit breaker. In the breaker report and in the breaker history report, the relay displays the minimum value of station battery voltage during circuit breaker operation on a per-pole basis.

NOTE: First enable Station DC Monitoring (with the Global setting EDCMON) to access station dc battery monitor settings.

Table 8.7 lists the station dc battery monitor settings and the corresponding Relay Word bits that assert when battery quantities exceed these settings thresholds. Use the **SET G** ASCII command from a terminal or use the QuickSet **Global > Station DC Monitoring** branch of the Settings tree view to access the DC Monitor settings.

Table 8.7 DC Monitor Settings and Relay Word Bit Alarms

Setting[a]	Definition	Relay Word Bit[a]
DC1LFP	Low Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1LWP	Low Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HWP	High Level Warn Pickup (OFF, 15–300 Vdc)	DC1W
DC1HFP	High Level Fail Pickup (OFF, 15–300 Vdc)	DC1F
DC1RP	Peak to Peak AC Ripple Pickup (1–300 Vac)	DC1R
DC1GF	Ground Detection Factor (1.00–2.00) (advanced setting)	DC1G

[a] For DC2 Monitor Settings and Relay Word bit Alarms, substitute 2 for 1 in the setting names and Relay Word bit names.

Station DC Battery System Monitor Application

In addition to providing a view of how much the station dc battery voltage dips when tripping, closing, and when other dc control functions occur, the dc monitor also alarms for under- or overvoltage dc battery conditions in five sensing regions. The following describes how to apply the dc battery monitor to a typical 125 Vdc protection battery system with a 48 Vdc communications equipment battery system. Adjust the values used here to meet the specifications of your company.

Battery Voltage

When setting the station dc battery monitor, you must determine the minimum and maximum dc levels in the battery system. In addition, you must also establish the threshold levels for different battery system states or conditions. The following voltage levels describe these battery system conditions:

- Trip/Close—the lowest dc voltage point at which circuit breaker trip and close operations occur
- Open-circuit—the dc battery voltage when all cells are fully charged and not connected to the battery charger
- Float low—the lowest charging voltage supplied by the battery charger
- Float high—the highest charging voltage supplied by the battery charger
- Equalize mode—a procedure during which the batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output

Set the low end of the allowable dc battery system voltage according to the recommendations of C37.90–1989 (R1994) IEEE Standard for Relays and Relay Systems Associated with Electric Power. Section 6.4 in this standard is titled Allowable Variation from Rated Voltage for Voltage Operated Auxiliary Relays. This section calls for an 80 percent low-end voltage and 28, 56, 140, or 280 Vdc high-end voltages for the popular nominal station battery voltages. *Table 8.8* lists expected battery voltages under various conditions using commonly accepted per-cell voltages.

Table 8.8 Example DC Battery Voltage Conditions

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 125 Vdc	100.0
Open-Circuit	60 (cells) • 2.06 (volts/cell)	123.6
Float Low	60 (cells) • 2.15 (volts/cell)	129.0
Float High	60 (cells) • 2.23 (volts/cell)	133.8
Equalize Mode	60 (cells) • 2.33 (volts/cell)	139.8
Trip/Close	80% • 48 Vdc	38.4
Open-Circuit	24 (cells) • 2.06 (volts/cell)	49.4
Float Low	24 (cells) • 2.15 (volts/cell)	51.6
Float High	24 (cells) • 2.23 (volts/cell)	53.5
Equalize Mode	24 (cells) • 2.33 (volts/cell)	55.9
Trip/Close	80% • 24 Vdc	19.2
Open-Circuit	12 (cells) • 2.06 (volts/cell)	24.7
Float Low	12 (cells) • 2.15 (volts/cell)	25.8
Float High	12 (cells) • 2.23 (volts/cell)	26.8
Equalize Mode	12 (cells) • 2.33 (volts/cell)	28.0

Use the expected battery voltages of *Table 8.9* to determine the relay station dc battery monitor threshold settings. *Table 8.9* shows these threshold settings for a nominal 125-Vdc battery system (the Vdc1 input) and a nominal 48-Vdc battery system (the Vdc2 input).

Table 8.9 Example DC Battery Monitor Settings—125 Vdc for Vdc1 and 48 Vdc for Vdc2

Setting	Description	Indication	Value (Vdc)
DC1LFP	Low-fail threshold, Mon. 1	Poor battery performance	100
DC1LWP	Low-warning threshold, Mon. 1	Charger malfunction	127
DC1HWP	High-warning threshold, Mon. 1	Equalization	137
DC1HFP	High-fail threshold, Mon. 1	Charger malfunction	142
DC2LFP	Low-fail threshold, Mon. 2	Poor battery performance	38
DC2LWP	Low-warning threshold, Mon. 2	Charger malfunction	50
DC2HWP	High-warning threshold, Mon. 2	Equalization	55
DC2HFP	High-fail threshold, Mon. 2	Charger malfunction	57

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The IEEE C37.90-1989 standard also identifies an “Allowable AC Component in DC Control Voltage Supply" (Section 6.5) as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous voltage is not less than 80 percent of the rated voltage.) The relay measures ac ripple as a peak-to-peak waveform, consequently, DC1RP and DC2RP should be set at or greater than 10 percent (2 • 5% peak) of the equalizing voltage. *Table 8.10* shows the ac ripple threshold settings for this example.

Table 8.10 Example DC Battery Monitor Settings—AC Ripple Voltages

Setting	Description	Indication	Value (Vac)
DC1RP	AC ripple threshold, Mon. 1	Charger malfunction	14
DC2RP	AC ripple threshold, Mon. 2	Charger malfunction	6

DC Ground

If a battery system is centered around chassis ground, then the magnitude of the voltage measured from the positive terminal to ground and from the negative terminal of the battery to ground should be approximately one-half of the nominal battery system voltage. The ratio of the positive-to-ground battery voltage to the negative-to-ground battery voltage is 1 to 1, or 1.00. *Equation 8.5* is the balanced (no grounding) ratio for a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{62.50\ V} = 1.00$$

Equation 8.5

If either terminal is partially or completely shorted to chassis ground, then the terminal voltage will be less than the nominal terminal-to-ground voltage. This causes the ratio of positive voltage to negative voltage to differ from 1.00. *Equation 8.6* is an example of the unbalanced (grounding) ratio for a partial short circuit to ground on the negative side of a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{59.10\ V} = 1.06$$

Equation 8.6

The relay uses this voltage ratio to calculate a ground detection factor. *Figure 8.13* shows a graphical representation of the ground detection factor setting and battery system performance.

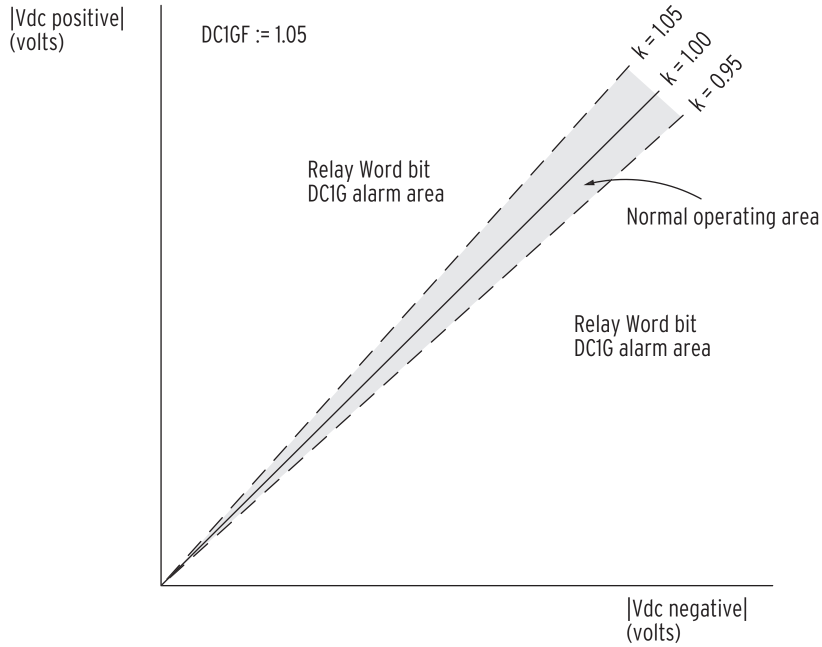

Figure 8.13 Ground Detection Factor Areas

NOTE: Only the upper ground detection factor in *Figure 8.12* is entered as a setting. The relay calculates the lower factor by taking the reciprocal of the upper factor: 1/1.05 = 0.952 in this case.

If the ground detection factor ratio exceeds a setting threshold, the relay asserts the DCIG Relay Word bit. To set the ground detection factor threshold, enable the advanced Global settings (set EGADVS := Y), and set the DC1GF and the DC2GF thresholds at a value close to 1.05 (the factory-default setting) to allow for some slight battery system unbalance of around 5 percent. *Table 8.11* lists the ground detection factor threshold settings for this example.

Table 8.11 Example DC Battery Monitor Settings—Ground Detection Factor (EGADVS := Y)

Setting	Description	Indication	Value
DC1GF	Ground detection factor, Mon. 1	Battery wiring ground(s)	1.05
DC2GF	Ground detection factor, Mon. 2	Battery wiring ground(s)	1.05

DC Battery Monitor Alarm

You can use the battery monitor Relay Word bits to alert operators for out-of-tolerance conditions in the battery systems. Add the appropriate Relay Word bit to the SELOGIC control equation that drives the relay control output you have selected for alarms. For example, use the Form B contact of control output OUT214. Set the SELOGIC control equation to include the battery monitor thresholds.

OUT214 := **NOT (HALARM OR SALARM OR DC1F OR DC1W OR DC1R OR DC1G)** (Output SELOGIC Equation)

This is one method; you can implement many other methods as well.

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SECTION 9

Reporting

The relay features comprehensive power system data analysis capabilities. The relay provides these useful analysis tools:

- *Data Processing on page 9.1*
- *Triggering Data Captures and Event Reports on page 9.6*
- *Duration of Data Captures and Event Reports on page 9.7*
- *Oscillography on page 9.9*
- *Event Reports, Event Summaries, and Event Histories on page 9.13*
- *Sequential Events Recorder (SER) on page 9.28*
- *Signal Profiling on page 9.31*

An event is a representation of the operating conditions of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from oscillograms, relay event reports, SER, and signal profiling data are very valuable if you are responsible for outage analysis, outage management, or relay settings coordination.

The relay accepts high-accuracy timing, such as IRIG-B. When a suitable external clock is used (such as the SEL-2407), the relay synchronizes the data acquisition system to the received signal. Knowledge of the precise time of sampling allows comparisons of data across the power system. Use a coordinated network of time-synchronized relays to create moment-in-time “snapshots” of the power system. These data are useful for determining power system dynamic voltage and current phasors, impedances, load flow, and system states.

Data Processing

SEL-400 series relays are numeric, or microprocessor-based, relays that sample power system conditions. The relay converts analog inputs received via CT and PT inputs or remote data acquisition to digital information for processing to determine relaying quantities for protection and automation. *Figure 9.1* shows a general overview of the input processing diagram for the relay. *Figure 9.2* shows a general overview of the input processing for a relay with Sampled Values (SV) remote data acquisition.

The relay outputs two types of analytical data: high-resolution raw data and filtered data. *Figure 9.1* shows the path a power system VT and CT signals take through relay input processing. A CT or PT analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection and automation processing. The initial hardware low-pass filter half-power or –3 dB point is 3.0 kHz. Next, the relay samples the power system voltage or current with an 8000 samples/second A/D (analog to digital) converter. This is the tap point for high-resolution raw data captures. You can select 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates for presentation and storage of the high-resolution raw data COMTRADE format (see *Oscillography on page 9.9*).

Figure 9.2 shows the path a power system signal received via SV remote data acquisition takes through relay processing. The received SV messages are first filtered, decoded, scaled, and resampled. The resampled data then continues through software filtering and progresses to protection and automation processing. The relay resamples the 4.8 kHz/4 kHz SV messages to 8 kHz analog samples. This is the tap point for high-resolution raw data captures.

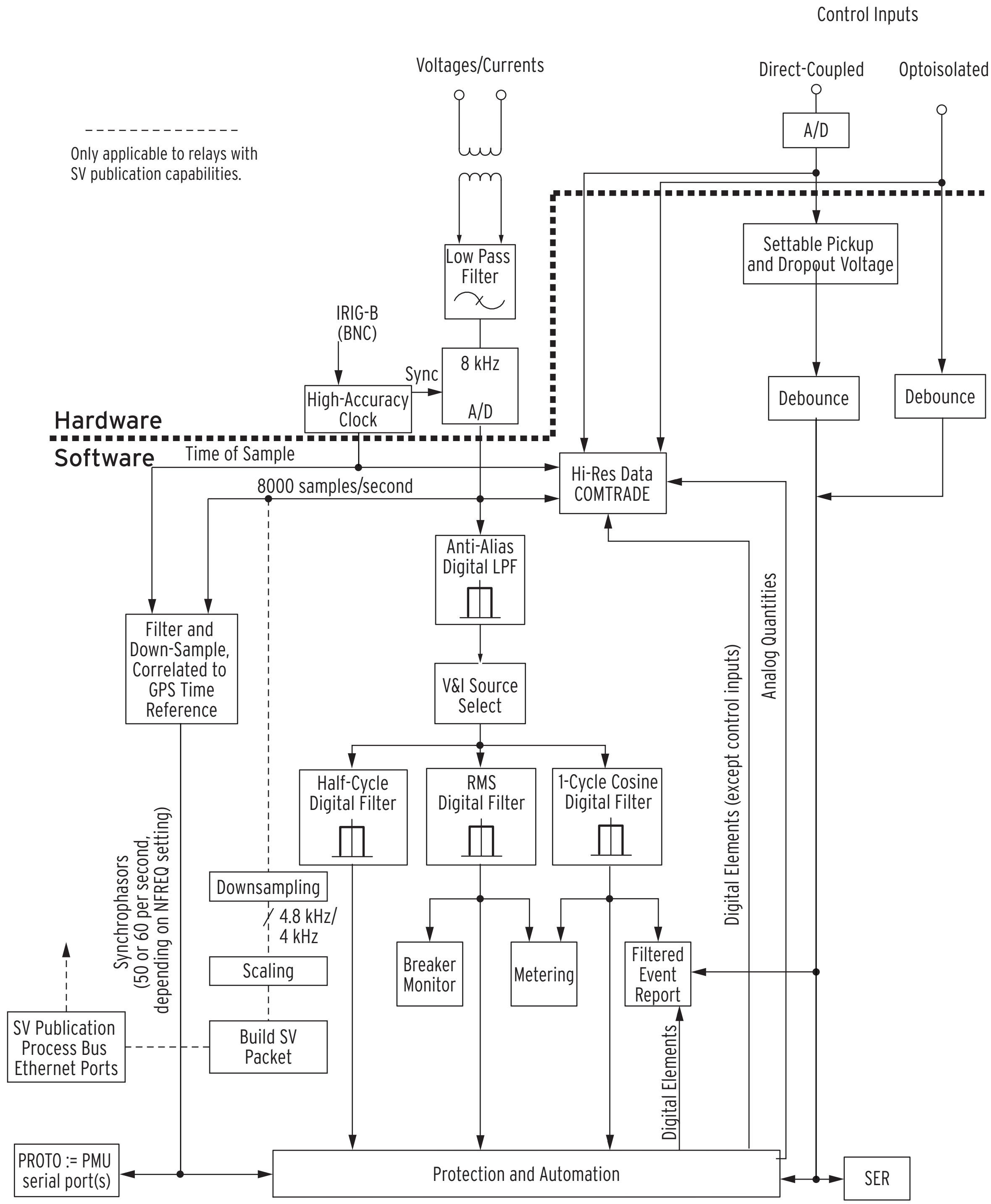

Figure 9.1 Input Processing

The software portion of input signal processing receives the high-resolution raw data sampled quantities and passes these to the Anti-Aliasing Digital Filter. The half-power or –3 dB point of the anti-aliasing filter is 640 Hz. Subsequent processing decimates the sampled data to the processing interval using additional digital filtering. This information is the filtered data for event reports and other relay functions. The relay downsamples the filtered data to present 4-samples/cycle event reports.

The relay samples the control inputs at a rate of 2 kHz. The raw input digital status is available in high-resolution (COMTRADE) data files. Contact bounce may be visible when the raw data are viewed.

The relay filters both types of control inputs with settable debounce timers, and updates the resulting Relay Word bits every processing interval. Event reports can include the filtered control input Relay Word bits.

Control input state changes will appear to occur faster in COMTRADE oscillography files than in event reports (**EVE** command) or Sequential Events Recorder reports (**SER** command) because of the control input debounce time delays.

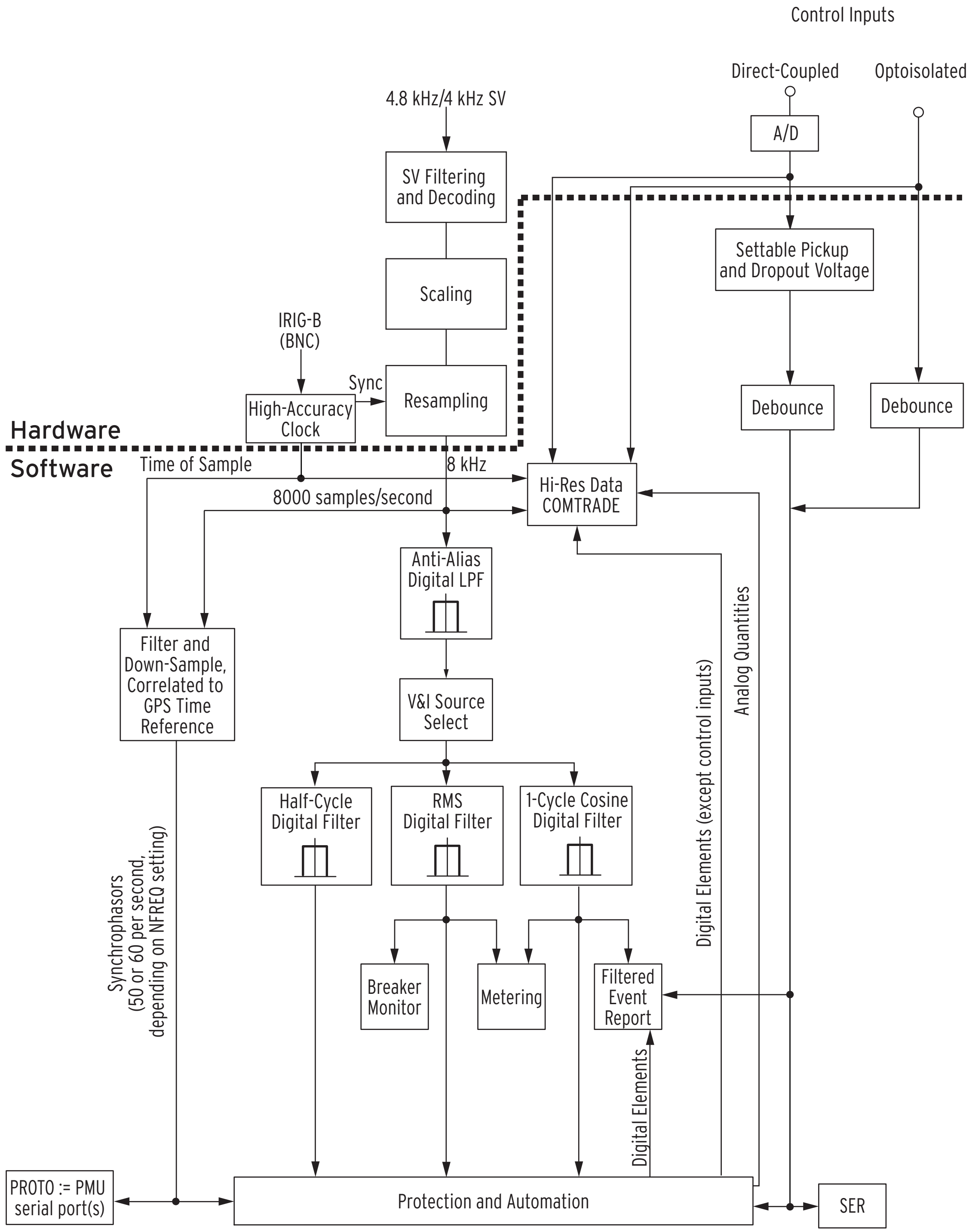

Figure 9.2 Input Processing of SEL-400 Series Relays With SV Remote Data Acquisition

Triggering Data Captures and Event Reports

Oscillograms and event reports are triggered both internally and externally depending on the event trigger that you program in the relay.

Use an event trigger to initiate capturing power system data. High-resolution raw data oscillography and event reports use the same triggering methods. The trigger for data captures comes from three possible sources:

- Relay Word bit TRIP assertions
- SELOGIC control equation ER (Event Report Trigger)
- **TRI** command

In some SEL relays, the **PUL** command initiated event recording. If you want the **PUL** command to initiate data capture, add the Relay Word bit TESTPUL to the SELOGIC control equation ER.

Relay Word Bit TRIP

If Relay Word bit TRIP asserts, the relay automatically generates a data capture event trigger on the rising edge of the TRIP Relay Word bit state change. In every instance, TRIP causes the relay to begin recording data. You therefore do not have to enter any condition that causes a trip in the ER SELOGIC control equation.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger high-resolution raw data oscillography, traveling wave data oscillography, and standard event reports for conditions other than TRIP conditions. When ER asserts, the relay begins recording data if the relay is not already capturing data initiated by another trigger.

Example 9.1 Triggering Event Report/Data Capture Using the ER SELOGIC Control Equation

This example shows how the elements in the ER SELOGIC control equation initiate relay data capture.

An example of a factory default setting for Group setting SELOGIC control equation ER in the SEL-411L is

ER := **R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S01 OR R_TRIG Z3P OR R_TRIG Z3G** Event Report Trigger Equation (SELOGIC Equation)

The element transitions in this setting are from the following Relay Word bits:

- Z2P, Z3P: Zone 2 phase-distance element, Zone 3 phase-distance element
- Z2G, Z3G: Zone 2 ground-distance element, Zone 3 ground-distance element
- 51S01: Instantaneous output of Inverse-Time Overcurrent Element 1

Example 9.1 Triggering Event Report/Data Capture Using the ER SELOGIC Control Equation (Continued)

The rising-edge operator, R_TRIG, occurs in front of each of the elements in the factory default ER equation. Rising-edge operators are especially useful for generating an event report at fault inception. The triggering element causes ER to assert, then clears the way for other elements to assert ER because the relay uses only the beginning of a long element assertion. The starting element in a continuously occurring fault does not mask other possible element triggers. This allows another rising-edge sensitive element to generate another event report later in that same continuously occurring fault (such as an overcurrent situation with the R_TRIG 51S01 element).

In the example factory default ER SELOGIC control equation, if the Z3G element remains asserted for the duration of the ground fault, the rising-edge operator, R_TRIG, in front of Z3G causes ER to assert for only one processing interval (a 1/8-cycle pulse). Other elements in the ER SELOGIC control equation can trigger event reports while the Z3G element remains asserted throughout the fault duration.

You can also use the falling-edge operator, F_TRIG, to initiate data captures.

Example 9.2 Including PUL Command Triggering in the ER SELOGIC Control Equation

This example shows you how to add the effect of the PUL command to emulate previous SEL relays. The relay asserts Relay Word bit, TESTPUL, when any output is pulsed via the PUL command.

Program the Group settings SELOGIC control equation ER as follows:

ER := **R_TRIG Z2P OR R_TRIG Z2G OR R_TRIG 51S01 OR R_TRIG Z3P OR R_TRIG Z3G OR TESTPUL** Event Report Trigger Equation (SELOGIC Equation)

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger the relay to begin recording high-resolution raw data, traveling wave data, and event report data. When testing with the **TRI** command, you can gain information on power system operating conditions that occur immediately after you issue the **TRI** command.

Duration of Data Captures and Event Reports

The relay stores unfiltered, high-resolution raw data (sampled at either 8 kHz, 4 kHz, 2 kHz, or 1 kHz), filtered event reports (available at both 4 samples/power system cycle and at the relay processing interval, typically 8 samples/cycle), and traveling wave data (1.5625 MHz). The number of stored high-resolution raw data captures and event reports is a function of the amount of data contained in each capture. You can configure the relay to record long data captures at high sampling rates, although this reduces the total number of stored events you can retrieve from the relay.

To use the data capture functions, select the effective sampling rate and data capture times. Relay setting SRATE, listed in *Table 9.1*, determines the number of data points the relay records per second. You can set SRATE to 8 kHz, 4 kHz, 2 kHz, and 1 kHz. The effective sampling rate (SRATE) and the event report length (LER) are related as follows:

- ➤ 8 kHz sampling—3.00 seconds total event report
- ➤ 4 kHz sampling—6.00 seconds total event report
- ➤ 2 kHz sampling—9.00 seconds total event report
- ➤ 1 kHz sampling—12.00 seconds total event report

The length of the data capture/event report (setting LER) and the pretrigger or prefault time (setting PRE) are related, as shown in *Figure 9.3*. The LER setting is the overall length of the event report data capture; the PRE setting determines the time reserved in the LER period when the relay records pretrigger (prefault) data. Typically, you set the PRE time to 20 percent of the total LER period. *Table 9.1* shows the relay settings for the data capture recording times at each effective sampling rate. Traveling wave records have a fixed sampling rate of 1.5625 MHz and a fixed event length of 7.5 ms.

NOTE: PRE has a dynamic range based on the current value of LER. The upper range of PRE = LER – 0.05.

Table 9.1 Report Settings

Label	Description	Range	Default
SRATE	Effective sample rate of event report	1, 2, 4, 8 kHz	2 kHz
SRATE = 8 kHz			
LER	Length of event report	0.25–3.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–2.95 seconds	0.1 seconds
SRATE = 4 kHz			
LER	Length of event report	0.25–6.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–5.95 seconds	0.1 seconds
SRATE = 2 kHz			
LER	Length of event report	0.25–9.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–8.95 seconds	0.1 seconds
SRATE = 1 kHz			
LER	Length of event report	0.25–12.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–11.95 seconds	0.1 seconds

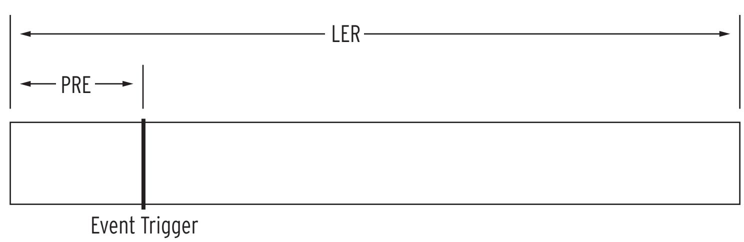

Figure 9.3 Data Capture/Event Report Times

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store one maximum length capture (maximum LER time) for a given SRATE. No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to nonvolatile storage to reenable data capture triggering. Thus, to record sequential events, you must set LER to half or less of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller.

See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual, to determine the event storage capacity for any specific relay. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

Oscillography

The relay features the following types of oscillography:

- ➤ Raw data oscillography—effective sampling rate as fast as 8000 samples/second
- ➤ Event report oscillography from filtered data—either a processing interval or 4 samples/cycle—including 20 settable analog quantities

Use high-resolution raw data oscillography to view transient conditions in the power system. You can set the relay to report these high-resolution oscillograms at 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates. The high-resolution raw data and traveling wave data oscillograms are available as files through the use of Ymodem file transfer and File Transfer Protocol (FTP) in the binary COMTRADE file format output (IEEE Std C37.111-1999, Common Format for Transient Data Exchange (COMTRADE) for Power Systems).

The filtered data oscillograms give you accurate information on the relay protection and automation processing quantities. The relay outputs filtered event reports through a terminal or as files in ASCII format and Compressed ASCII format, through FTP and Ymodem file transfers. *Figure 9.4* shows a sample filtered-data oscillogram.

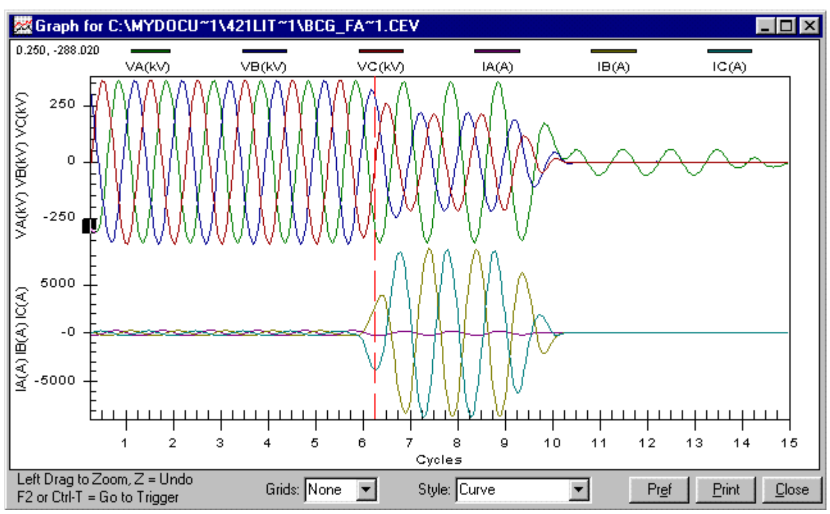

Figure 9.4 Sample Oscillogram

Raw Data Oscillography

Raw data oscillography produces oscillograms that track power system anomalies that occur outside relay digital filtering. If the relay receives signals via CT and PT, raw data oscillography captures data with content ranging from dc to greater than 3.0 kHz; the –3 dB point of the low-pass analog input filter is 3.0 kHz (with response rolling off at –20 dB per decade). The frequency of raw data oscillography of the SEL-400 series relays with SV remote data acquisition depends on the remote data acquisition unit. Furthermore, the received 4.8 kHz/4.0 kHz data are resampled to 8 kHz for raw data oscillography recording.

COMTRADE files always include all eight Relay Word bits from each row of the Relay Word used as the base set for the relay (see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for a list of these bits). Additionally, it includes the rows containing those Relay Word bits configured for inclusion by the ERDG setting.

The relay stores high-resolution raw data oscillography in binary format and uses COMTRADE file types to output these data:

- .HDR—header file
- .CFG—configuration file
- .DAT—high-resolution raw data file

The .HDR file contains summary information about the event in ASCII format. The .CFG file is an ASCII configuration file that describes the layout of the .DAT file. The .DAT file is in binary format and contains the values for each input channel for each sample in the record. These data conform to the IEEE C37.111-1999 COMTRADE standard.

.HDR File

The .HDR file contains the summary and relay settings information that appears in the event report for the data capture (see *Event Summary Section of the Event Report on page 9.23* and *Settings Section of the Event Report on page 9.24*). The settings portion is as illustrated in *Figure 9.5*.

<pre>Relay 1   Date: 02/02/2011 Time: 14:11:21.000
Station A   Serial Number: 2010265004
 	
Event: ABG T   Location: 59.61 (mi)   From: LOCAL   FLM: TW   Time Source: HIRIG
Event Number: 10121   Shot 1P: 0   Shot 3P: 0   Freq: 59.99   Group: 1
Targets:
Breaker 1: CLOSED
Breaker 2: OPEN
PreFault: IA   IB   IC   IG   3I2   VA   VB   VC   V1mem
MAG(A/kV)   200   200   200   1   1 133.946 133.938 133.941 133.935
ANG(DEG)   -0.7 -120.5 119.4 -51.7 -88.7   0.0   -119.9   120.2   0.1
 	
Fault:
MAG(A/kV)   2200   2200   2200   7   376 133.937 133.926 133.957 133.933
ANG(DEG)   -0.7 -120.6 119.5 -102.0 -83.5   0.0   -119.9   120.2   0.1
 	
                 87 Differential Currents
PreFault: IA   IB   IC   IQ   IG
MAG(pu)   0.00   0.00   0.00   0.00   0.00
ANG(DEG)   0.0   0.0   0.0   0.0   0.0
 	
Fault:
MAG(pu)   0.00   0.00   0.00   0.00   0.00
ANG(DEG)   0.0   0.0   0.0   0.0   0.0</pre>
	Summary Event Information

<pre>SET_G1.TXT
[INFO]
RELAYTYPE=SEL-411L
FID=SEL-411L-X136-V0-Z001001-D20110114
BFID=SLBT-4XX-R205-V0-Z001002-D20100128
PARTNO=0411L0X6X1B6BCXH5C4E4XX
[IOBOARDS]
INT4_E, , , 24, 8, 0, 0, 1
CFSINT8, , , 8, 8, 0, 0, 2
[G1]
"SID","Station A"
"RID","Relay 1"
"NUMBK",2
"BID1","Breaker 1"
"BID2","Breaker 2"
"NFREQ",60
.
.
.
"AR197",
"AR198",
"AR199",
"AR200",</pre>
	Relay Settings

Figure 9.5 Sample COMTRADE .HDR Header File

.CFG File

The .CFG file contains data such as sample rates, number of channels, line frequency, channel information, and transformer ratios (see *Figure*). A <CR><LF> follows each line. If control inputs or control outputs are not available because of board loading and configuration, the relay does not report these inputs and outputs in the analog and digital sections of the .CFG file.

Station A,FID=SEL-411L-1-R100-V0-Z001001-D20110311,1999	Relay Information (1999 = COMTRADE Standard)
398,14A,384D	398 = sum of analogs and digitals 14A = total number of analog channels 384D = total number of digital points[a]
1,IAW,A,,A,0.324059,0,0,-32767,32767,200.0,1,P 2,IBW,B,,A,0.324059,0,0,-32767,32767,200.0,1,P 3,ICW,C,,A,0.324059,0,0,-32767,32767,200.0,1,P 4,IAX,A,,A,0.324059,0,0,-32767,32767,200.0,1,P 5,IBX,B,,A,0.324059,0,0,-32767,32767,200.0,1,P 6,ICX,C,,A,0.324059,0,0,-32767,32767,200.0,1,P 7,VAY,A,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 8,VBY,B,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 9,VCY,C,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 10,VAZ,A,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 11,VBZ,B,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 12,VCZ,C,,kV,0.032406,0,0,-32767,32767,2000.0,1,P 13,VDC1,,,V,0.011178,-0.000000,0,-32767,32767,1,1,P 14,VDC2,,,V,0.011178,-0.000000,0,-32767,32767,1,1,P	14 Analog Channels

COMTRADE .CFG Configuration File Data

1,87USAFE,,,0 2,UNUSED2,,,0 3,UNUSED3,,,0 4,UNUSED4,,,0 5,OC1,,,0 6,CC1,,,0 7,OC2,,,0 8,CC2,,,0 9,87LA,,,0 10,87LB,,,0 11,87LC,,,0 12,87LQ,,,0 13,87LG,,,0 14,87FLSOK,,,0 15,87DTTRX,,,0 . . . 382,PCT06Q,,,0 383,PCT07Q,,,0 384,PCT08Q,,,0	384 Digital Points
60	Nominal System Frequency (INFREQ Setting)
1	
2000,1000	2000 = Sample Rate (SRATE setting) 1000 = Length of the Report x Sample Rate (LER x SRATE)
17/03/2011,08:36:38.697687	Time Stamp of the First Data Point
17/03/2011,08:36:38.799850	Time Stamp of the Trigger Point
BINARY	
1	

COMTRADE .CFG Configuration File Data (Continued)

[a] If ERDIG is set to S, the digital points are all the Relay Word bits set in ERDG as well as the Relay Word bits that are always included in the event report. If ERDIG is set to A, the digital points are all the Relay Word bits in the device.

The configuration file has the following format:

- Station name, device identification, COMTRADE standard year
- Number and type of channels
- Channel name units and conversion factors
- Line frequency
- Sample rate and number of samples
- Date and time of first data point
- Date and time of trigger point
- Data file type
- Time stamp multiplication factor

.DAT File

NOTE: The analog data are time-aligned to when the data changed on the input terminals. Similarly, the contact inputs are time-aligned to when the data changed on the input terminals. All other digital data are time-aligned to when the value changed in the relay.

The .DAT file follows the COMTRADE binary standard. The format of the binary data files is sample number, time stamp, data value for each analog channel, and grouped status channel data for each sample in the file. There are no data separators in the binary file, and the file contains no carriage return/line feed characters. The sequential position of the data in the binary file determines the data translation. Refer to the IEEE Std C37.111-1999, Common Format for Transient Data Exchange (COMTRADE) for Power Systems for more information. Programs that read the binary COMTRADE files include ACSELERATOR Analytic Assistant SEL-5601 Software and ACSELERATOR QuickSet SEL-5030 Software.

Generating Raw Data Oscillograms

To use high-resolution raw data oscillography, select the type of triggering event and use a trigger event method described in *Triggering Data Captures and Event Reports on page 9.6*. Use the settings SRATE, LER, and PRE to set the relay for the appropriate data sampling rate and data capture time (see *Duration of Data Captures and Event Reports on page 9.7*).

Retrieving Raw Data Oscillograms

Use a computer terminal emulation program and the **FILE** commands at any communications port to retrieve the stored high-resolution raw data capture from the relay file structure. If the relay has an Ethernet port, you can also use FTP to retrieve these files. You can also use QuickSet.

Event Report Oscillography

NOTE: In an SV subscriber relay, the event report analog channels are delayed by the CH_DLY setting relative to the raw oscillography.

Use a terminal or SEL-supplied PC software to retrieve filtered event report files stored in the relay and transfer these files to your computer. SEL-5601 SYNCHROWAVE Event or the ACSELERATOR Analytic Assistant SEL-5601 Software can be used to read the compressed event files that the relay generates for an event.

Event Reports, Event Summaries, and Event Histories

Event reports simplify post-fault analysis and help you improve your understanding of protection scheme operations. Event reports also aid in testing and troubleshooting relay settings and protection schemes because these reports contain detailed data on voltage, current, and relay element status. For further analysis assistance, the relay appends the active relay settings to each event report. The relay stores event reports in nonvolatile memory, and you can clear the event report memory on a port-by-port basis.

You decide the amount of information and length in an event report (see *Duration of Data Captures and Event Reports on page 9.7*).

The relay records the filtered power system data that the relay uses in protection and automation processing. You can view filtered information about an event in one or more of the following forms.

- Event report
- Event summary
- Event history

Alias Names

NOTE: If Alias names were changed after an event was recorded, the relay uses the present alias names in subsequent event reports.

To customize your event report, rename any Relay Word bit or analog quantity with more meaningful names to improve the readability of fault analysis and customized programming. After renaming the primitive quantities, the alias names rather than the primitive names appear in the event reports for the user-selectable analog and digital channels. The primitive names of the analog channels still appear in the event reports.

Event Report

The relay generates event reports to display analog data, digital data (control inputs, control outputs, and the state of Relay Word bits), and relay settings. The event report is a complete description of the data that the relay recorded in response to an event trigger. Each event report includes these components:

- Report header and analog section—Currents and voltages, sometimes including calculated quantities such as differential currents
- Digital section—Relay Word bit elements, control outputs, control inputs
- Event summary
- Settings
  - Group settings
  - Global settings
  - Output settings
  - SELOGIC control equations protection logic

Viewing the Event Report

Access event reports from the communications ports and communications cards at Access Level 1 and higher. (You cannot view event reports at the front panel, although you can view event summary information at the front-panel display.) You can independently acknowledge the oldest event report at each communications port (**EVE ACK** command) so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete sets of event reports. To acknowledge the oldest event report, you must first view that event report at a particular port by using the **EVE N(EXT)** command.

You can use the **EVE** command and a terminal to retrieve event reports by event order or by event serial number. (The relay labels each new event with a unique serial number as reported in the **HIS** command history report [see *Event History on page 9.27*].)

Events are referenced two ways: by relative reference or by event serial number. Relative references are in the range 1–9999, where 1 refers to the most recent event, 2 to the next most recent, and so on. Event serial numbers are in the range 10000–42767. You can find the event serial number in the event history report. With the **EVE** and **CEV** commands, you can retrieve events using either type of reference. Event files are names based on the event serial number.

By applying modifiers to the **EVE** command, you can retrieve only analog or digital information, and you can exclude the summary or settings portions of the report. The default **EVE** command event report data resolution is 4 samples/cycle and the default report length is 0.5 seconds (30 cycles at 60 Hz or 25 cycles at 50 Hz) with the factory default setting for LER.

See the **EVE** command description in *Section 9: ASCII Command Reference* in the product-specific instruction manual for a complete list of options.

You can retrieve event reports with the QuickSet **Tools > Events > View Event Files** menu. The **Analysis > View Event Files** menu gives you oscillogram/element displays, phasor displays, harmonic analysis, and an event summary for each event you select in the **Event History** dialog box.

You can also download event report files from the relay using a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher, type **FILE READ EVENTS E8_*nnnnn*.TXT <Enter>** for the 8-samples/cycle event report and type **FILE READ EVENTS E4_*nnnnn*.TXT <Enter>** for the 4-samples/cycle event report (*nnnnn* is the event serial number). Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, use the C8_*nnnnn*.TXT and C4_*nnnnn*.TXT file names for the 8-samples/cycle and 4-samples/cycle Compressed ASCII event reports, respectively.

The following discussion shows sample portions of an event report that you download from the relay using a terminal and the **EVE** command. An event report contains analog, digital, summary, and settings sections without breaks.

Report Header and Analog Section of the Event Report

The first portion of an event report is the report header and the analog section. Some relays have more than one analog section. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual for details on what the event reports look like in each relay. See *Figure 9.6* for an example of a SEL-421 event report.

The report header is the standard relay header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event. The report lists the RID setting (Relay ID) and the SID setting (Station ID). The FID string identifies the relay model, flash firmware version, and the date code of the firmware. The relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event. The relay reports the firmware checksum as CID.

The event report column labels follow the header. The data underneath the analog column labels contain samples of power system voltages and currents.

```
Relay 1                                          Date: 03/15/2001  Time: 23:30:49.026
Station A                                        Serial Number: 2001001234
FID=SEL-421-R101-V0-Z001001-D20010315            Event Number = 10007       CID=0x3425
```

Header
Firmware ID in bold

```
Currents (Amps Pri)                 Voltages (kV Pri)
    IA     IB     IC     IG     VA     VB     VC    VS1     VS2  V1mem

[1]
  -267    167     44    -56 -288.0  337.7  -47.8  215.3  144.9 -287.9
   -76   -203    241    -37 -223.7 -138.4  361.3 -290.5  331.3 -223.7
   266   -166    -45     55  288.2 -337.5   47.5 -215.2 -145.0  288.1
    76    202   -242     36  223.4  138.7 -361.4  290.5 -331.2  223.5
```

1 Cycle of Data
See *Figure 9.7* and *Figure 9.8* to calculate phasors for the data in bold.

•
•
•

```
[6]
  -269    167     46    -56 -289.3  336.9  -45.8  215.5  144.7 -289.4
   -74   -202    240    -35 -222.2 -140.2  361.5 -290.2  331.4 -221.8
   268   -165    -45     57  289.4 -336.7   45.6 -215.4 -144.6  289.5
    93    151   -888   -643  221.1  133.5 -335.0  290.2 -331.4  220.8
[7]
  -208   2701  -3760  -1267 -288.7  293.7  -24.1  215.5  144.5 -286.3
  -146   2941    173   2968 -219.6  -87.6  261.6 -290.1  331.4 -214.0>
   134  -5748   8310   2696  286.9 -232.4    3.5 -215.6 -144.4  273.3
   179  -6677   1811  -4688  219.8   47.4 -214.2  290.0 -331.5  202.8
```

Trigger

```
[8]
  -125   5661  -8506  -2971 -286.1  213.6   -3.8  215.8  144.2 -256.5
  -177   6857  -1950   4730 -220.8  -46.9  214.2 -289.9  331.6 -193.2*
   129  -5508   8382   3003  286.9 -213.8    3.6 -216.0 -144.0  243.9
   174  -6726   1839  -4712  220.4   47.2 -214.2  289.8 -331.6  185.9
```

Largest Current (to Event Summary)

Figure 9.6 Fixed Analog Section of an Example SEL-421 Event Report

```
[9]
  -128   5623  -8479  -2984 -287.1  213.9   -3.5  216.1  143.8 -234.5
  -173   6821  -1924   4724 -219.8  -47.3  214.0 -289.7  331.7 -180.4
   126  -5540   8404   2990  286.6 -213.7    3.5 -216.3 -143.7  227.3
   177  -6749   1860  -4713  220.0   47.4 -212.9  289.6 -331.8  176.2

[10]
  -126   4616  -6204  -1714 -282.9  178.6   41.9  216.4  143.5 -222.1
  -106   4288  -1047   3135 -231.6  -64.5   95.3 -289.4  331.9 -162.6      Circuit Breaker Open
    65  -1722   1878    221  140.2  -72.1  -43.6 -216.6 -143.3  194.6
    16   -807      4   -786  105.1   41.3   10.5  289.2 -332.0  130.7

[11]
    -1     -1     -2     -5   13.8    1.1    0.3  216.8  143.1 -147.1
     2      3      4      9   54.8   -0.7   -0.3 -289.1  332.1  -93.5
     1      1      2      5   -8.1   -1.6   -1.1 -217.0 -142.8  109.8
    -2     -2     -3     -8  -58.2    0.2    0.2  289.0 -332.2   65.3
```

Figure 9.6 Fixed Analog Section of an Example SEL-421 Event Report (Continued)

Within an event report, there are bracketed numbers at the left of the report (for example, [11]) that indicate the cycle number.

The trigger row is indicated by a > character following immediately after the last analog data column. This is the dividing point between the prefault or PRE time and the fault or remainder of the data capture.

The relay indicates which row has the largest current magnitudes, which are reported in the event summary, with an asterisk (*) character immediately after the last analog data column. The (*) takes precedence over the > if both occur on the same row in the analog section of the event report.

ERAQc (Analog Quantities)

To supplement the fixed analog quantities in the event report, select as many as 20 additional analog quantities in the event report. For example, say you programmed a function in the relay using Protection Math Variables PMV01–PMV06, and you want to include these six PMVs in the event report. Enter the six PMVs in the Event Reporting Analog Quantities as shown below.

```
Event Reporting Analog Quantities
(Maximum 20 Analog Quantities)
1: PMV01
2: PMV02
3: PMV03
4: PMV04
5: PMV05
6: PMV06
```

The relay correlates the freeform line number chronologically with the ERAQ*c* quantities. In this example, ERAQ01 = PMV01, ERAQ02 = PMV02, etc.

In the event report, the ERAQ quantities follow the fixed analog quantities.

```
PMV01      PMV02      PMV03      PMV04      PMV05      PMV06
[1]
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
[2]
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
    20.000     25.000    102.000     34.000     67.000     54.000
```

Obtaining RMS Phasors From 4-Samples/Cycle Event Reports

Use the column data in an event report to calculate rms values. You can use a calculator to convert rectangular data to phasor data, or use hand-calculations to separately determine the magnitude and angle of the rms phasor.

Hand Calculation Method

The procedure in the following steps explains a method for obtaining a current phasor from the IA channel data in the event report of *Figure 9.6*. You can process voltage data columns similarly. The drawings in *Figure 9.7* and *Figure 9.8* show 1 cycle of A-Phase current in detail. *Figure 9.7* shows how to relate the event report ac current column data to the sampled waveform and rms values. *Figure 9.8* shows how to find the phasor angle. If you use the larger 8-samples/cycle event report, take every other sample and apply those values in this procedure.

This examples assumes you have captured an event report and are prepared to calculate phasors from it.

Step 1. Calculate the phasor magnitude:

a. Select a cycle of data from the IA column of the event report.

Figure 9.6 Cycle [1] data for this example are shown in *Figure 9.7*.

There are three pairs of scaled instantaneous current samples from Cycle [1].

Compute phasor magnitude using the following expression:

$$\sqrt{X^2 + Y^2} = |\text{Phasor}|$$

Equation 9.1

b. In *Equation 9.1*, Y is the first row of IA column current of a data pair, and the next row is X, the present value of the pair.

For this example, the computation shown in *Figure 9.7* yields 277.0 A.

c. Compute phasor magnitudes from the remaining data pairs for Cycle [1].

d. Confirm that all values are similar.

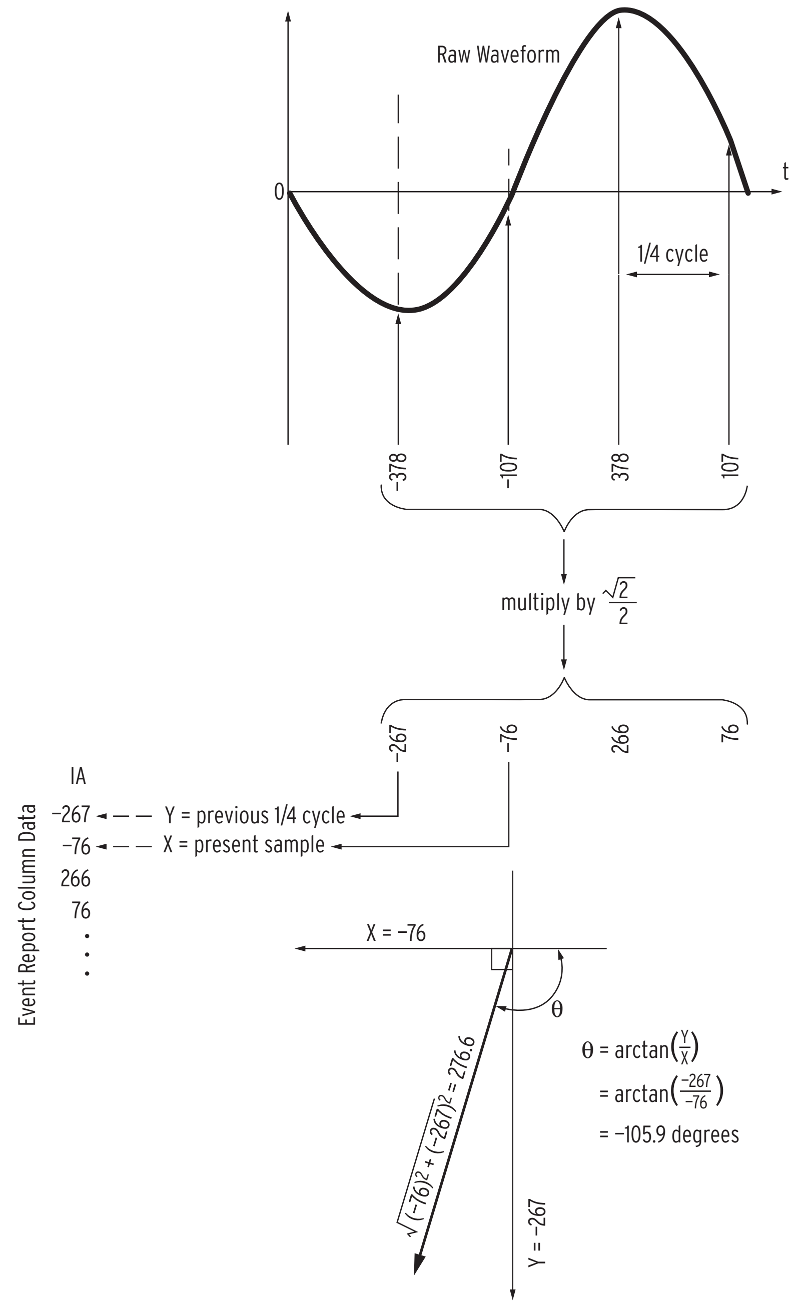

Figure 9.7 Event Report Current Column Data and RMS Current Magnitude

Step 2. Calculate the immediate phase angle.

a. Select the same cycle of data from the IA column of the event report as you did when finding the magnitude (Cycle [1] data for this example).

b. Compute phasor angle using the following expression:

$$\theta = \arctan\left(\frac{Y}{X}\right) = \angle \text{Phasor}$$

Equation 9.2

In *Equation 9.2*, Y is the first (or previous value) IA column current of a data pair, and X is the present value of the pair.

For this example, the computation shown in *Figure 9.8* yields –105.9 degrees.

c. Compute phasor angles from the remaining data pairs for Cycle [1].

NOTE: The arctan function of many calculators and computing programs does not return the correct angle for the second and third quadrants (when X is negative). When in doubt, graph the X and Y quantities to confirm that the angle that your calculator reports is correct.

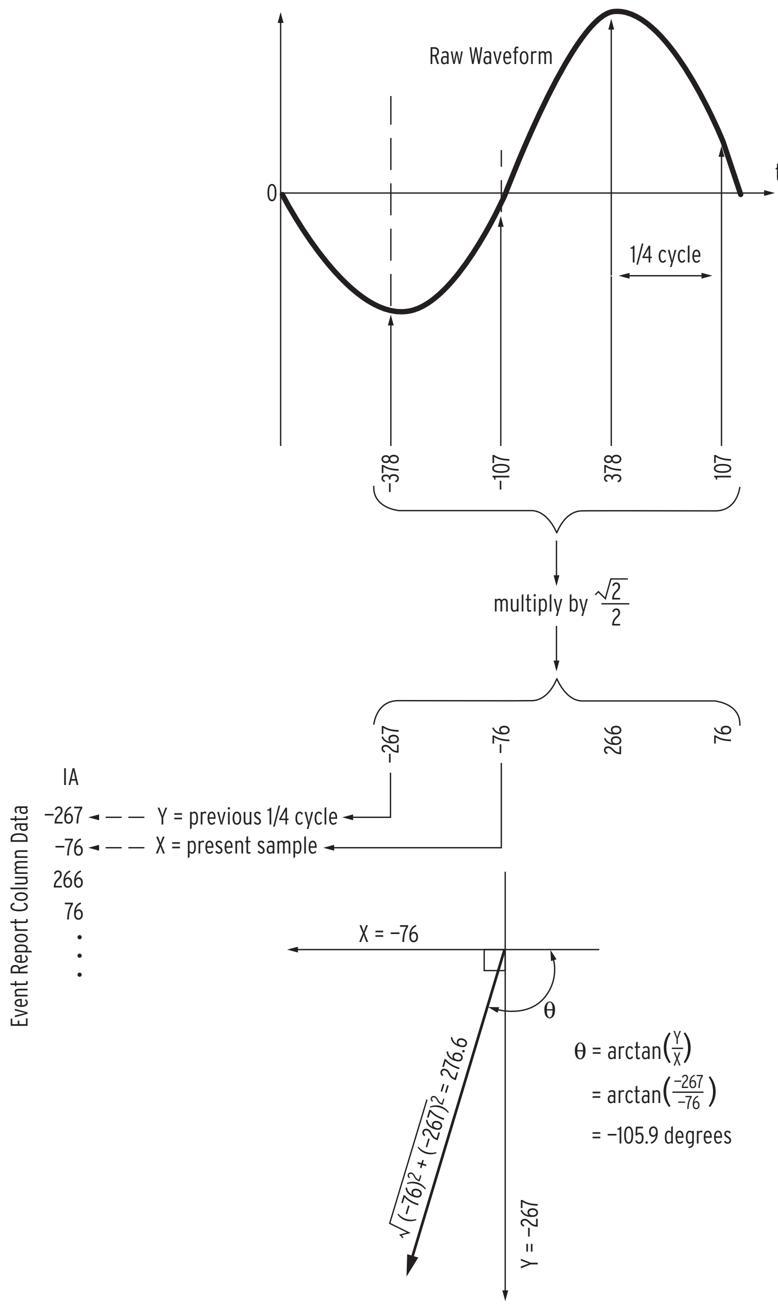

Figure 9.8 Event Report Current Column Data and RMS Current Angle

Step 3. Calculate the reference phase angle. Usually, you compare power system angles to a reference phasor (positive-sequence A-Phase voltage, for example):

Repeat *Step 2* for the row data in the VA column that correspond to the IA column data values you used in *Step 2*.

The angle calculation for the VA data is the following:

$$\begin{aligned}\theta &= \angle VA \\ &= \arctan\left(\frac{Y}{X}\right) \\ &= \arctan\left(\frac{-288.0}{-223.7}\right) \\ &= -127.8°\end{aligned}$$

Equation 9.3

(This is an example of an arctan calculation that yields the incorrect answer from some calculators and math programs.)

Step 4. Calculate the absolute phase angle:

Subtract the IA angle from the VA angle to obtain the A-Phase-referenced phasor angle for IA.

$$\angle VA - \angle IA = -127.8° - (-105.9°) = -21.9°$$

Equation 9.4

IA leads VA; thus, the rms phasor for current IA at the present sample is 277.0 A $\angle 21.9°$, referenced to VA.

In the procedure above, you use two rows of current data from the event report to calculate an rms phasor current. At the first sample pair of Cycle [1], the rms phasor is I_A = 277.0 A $\angle -105.9°$.

The present sample of the sample pair (X = –76) is a scaled instantaneous current value (not an rms quantity) that relates to the rms phasor current value by the expression.

$$X = -76 = 277.0 \bullet \cos(-105.9°)$$

Equation 9.5

Polar Calculator Method

A method for finding the phasor magnitude and angle from event report quarter-cycle data pairs is to use a polar-capable calculator or computer program. Many calculators and computer programs convert Cartesian (X and Y) coordinate data to polar data. Key or enter the X value (present value or lower value of a column pair) and the Y value (later value or upper value in a column pair) as Cartesian (rectangular) coordinates. Perform the keystrokes necessary for your calculator or computing program to convert to polar coordinates. This is the phasor value for the data pair.

Digital Section of the Event Report

The second portion of an event report is the digital section. Inspect the digital data to evaluate relay element response during an event. See *Figure 9.9* for an example from the SEL-411L. If you want to view only the digital portion of an event report, use the **EVE D** command. In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk (*) character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the two 8-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report.

The report displays the digital label header for each column in a vertical fashion, aligned on the last character. For example, if the first digital section elements are IN201, #, RMBA5, Z2P, LBOKA, #, OUT203, OUT204, and HALARM, the header appears as in *Figure 9.10*. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report.

```
                                                                      22 B B
                                                             C        55 F F
                      VZ             S      66     66  55    O BBBBBB AA T T
         MMM      ZZZ PL        3333 O5 666 77 666 77 511  Z M KKKKKK 11 RFRF     Digital Column Labels
TTT MMMM 234 ZZZZ 234 OOL OO 3S 2222 T0 777 GG 777 QQ 1SS  3KP 121212 BB IBIB
PPP 1234 PPP 1234 GGG LAO SS PP QQGG FP GGG 23 QQQ 23 S11 PRER RRLLCC KK PFPF
ABC PPPP TTT GGGG TTT VDP BT OO FRFR T1 123 TT 123 TT 1TR TBYM SSOOLL 12 1122

[1]

... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....   1 Cycle of Data
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

                                   •
                                   •
                                   •

[6]
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
... .... ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....
[7]
*** **.. ... .... ... *.. .. .. .... .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....>   Trigger

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[8]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....*   Values used in the Event Summary

*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[9]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
[10]
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** **.. ... .... ... *.. .. .. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. .* .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....

[11]                                                                              Circuit Breaker Open

*** .... ... .... ... *.. .. *. *.*. .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
*** .... ... .... ... *.. .. *. .... .. ... .. ... .. ... .... ...... .. ....
```

Figure 9.9 Digital Section of the SEL-411L Event Report

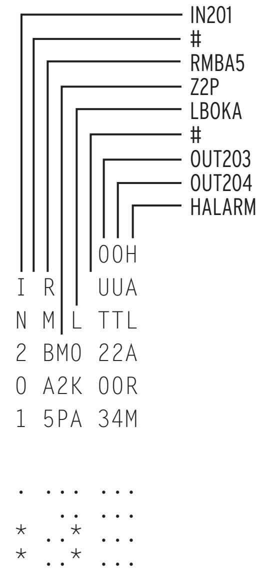

Figure 9.10 Sample Digital Portion of the Event Report

Selecting Event Digital Elements

NOTE: The compressed event reports and COMTRADE files from the relay may contain additional digital elements as compared to standard (ASCII) event reports (see *CEVENT on page 9.25*).

Specify the digital elements in the digital section of the event report by using the Event Reporting Digital Elements settings found in the Report settings (the **SET R** command from a terminal or the **Report** branch of the Settings tree view of QuickSet). You can enter as many as 800 Relay Word bits from a maximum of 100 target rows. The # symbol places a blank column in the digital report. Use the # symbol to organize the digital section of the event report.

Digital Section IN*nnn* Times

Reported assertion times for input digital elements differ, although these elements have the same name in both high-resolution raw data reports and in the filtered event reports. When you enter an input (IN*nnn*) in the event digitals list, the relay displays the filtered input with time latency in the event report and the Compressed ASCII event report. However, in the binary COMTRADE file event report, the relay reports the actual high-sample rate capture time for relay inputs.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 9.11* for the locations of items included in an example summary section of an event report. The specific values available depend on the specific relay. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual to see what specific data are reported in the summary of a relay. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command.

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report.

```
Event: TRIP   Location: $$$$.$$      From: LOCAL     FLM: SE  Time Source: OTHER
Event Number: 10030      Shot 1P: 0   Shot 3P: 0        Freq: 60.00     Group: 1
Targets: INST COMM 87L
Breaker 1: CLOSED        Trip Time: 11:18:49.016
Breaker 2: NA

PreFault:     IA     IB     IC     IG    3I2       VA       VB       VC    V1mem

MAG(A/kV)    426    426    427      1      0  286.420  286.638  286.302  286.453

 ANG(DEG)     1.3 -118.7  121.3  130.6  -99.2      0.0   -120.0    120.0      0.0

 Fault:

MAG(A/kV)    426    426    427      1      1  286.397  286.632  286.298  286.450

ANG(DEG)     1.3 -118.7  121.3  106.1  -92.6      0.0   -120.0    120.0      0.0

                 87 Differential Currents

PreFault:     IA     IB     IC     IQ     IG
MAG(pu)     0.36   0.35   0.36   0.00   0.00
ANG(DEG)     1.4 -118.9  120.9   92.9   59.5

Fault:
MAG(pu)     0.00   0.00   0.00   0.00   0.00
ANG(DEG)   -20.6  -20.6  -20.6  -20.6  -20.6
```

Event Information

Prefault Data

Fault Data

Line-Current Differential Status

Figure 9.11 Example Summary Section of the SEL-411L Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 9.12* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command.

The settings portion of the event report lists important relay settings at the time the relay event triggered. The event report shows group, global, output, protection SELOGIC control equation settings and alias settings. For the group settings and the protection SELOGIC settings, the relay reports only the active group. The settings order in the event report is the same order as when you issue a **SHOW** command from a terminal.

```
Group 1
Line Configuration
CTRW    := 400      CTRX    := 400      PTRY    := 3636     VNOMY   := 115
PTRZ    := 3636     VNOMZ   := 115      Z1MAG   := 4.72     Z1ANG   := 82.60
Z0MAG   := 14.50    Z0ANG   := 75.70    EFLOC   := Y
  •
  •
  •

Global
General Global Settings
SID     := "Station A"
RID     := "Relay 1"
NUMBK   := 2
BID1    := "Breaker 1"
BID2    := "Breaker 2"
NFREQ   := 60       PHROT   := ABC      DATE_F  := MDY
FAULT   := NA
  •
  •
  •
```

Active Group Settings

Global Settings

Figure 9.12 Settings Section of the Event Report

Output Interface Board #1 OUT201 := 3PT OUT202 := BK1CL OUT203 := BK2CL OUT204 := NA OUT205 := NA OUT206 := NA OUT207 := NA OUT208 := NA • • •	Output Settings
Remote Analog Outputs RA001 := NA RA002 := NA • • • RA061 := NA RA062 := NA RA063 := NA RA064 := NA	Remote Analog Settings
Mirrored Bits Transmit Equations TMB1A := NA • • • TMB8B := NA	MIRRORED BITS Settings
Protection 1 Freeform Protection SELOGIC 1: ### PROTECTION FREEFORM AUTOMATION EXAMPLE 2: ### 3: ### SET CONTROL VARIABLE 1 4: ### ASSERTS WHEN PRIMARY POSITIVE SEQUENCE IS 5: ### GREATER THAN 90% OF 230 KV DIVIDED BY SQRT 3 6: PSV01 := V1M >= 119.5 #90% OF 230 KV DIVIDED BY SQRT 3	Active Protection Logic Settings
Alias Relay Aliases (Relay Word Bit or Analog Quantity name, 7 Character Alias [0-9 A-Z _]) 1: EN,"REL_EN"	Alias Settings

Figure 9.12 Settings Section of the Event Report (Continued)

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. QuickSet uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue ASCII command **CEV**. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII event report are similar to the event report, although the relay reports the items in a special order. CEV files (like COMTRADE files) include all eight Relay Word bits from each row of the Relay Word used as the base set for the relay (see *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for a list of these bits). Additionally, it includes the rows containing those Relay Word bits configured for inclusion by the ERDG setting. For the purpose of improving products and services, SEL sometimes changes the items and item order.

Event Summary

You can retrieve a summary version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports on page 9.6*). The summary information available depends on the specific relay. See *Section 7: Metering, Monitoring, and Reports* in the product-specific instruction manual for the details of the summary event report for a specific relay.

The relay can be configured to automatically send an event summary on serial ports (see *Automatic Messages on page 15.27*).

Viewing the Event Summary

Access the event summary from the communications ports and communications cards. View and download event summaries from Access Level 1 and higher. You can independently acknowledge a summary (with the **SUM ACK** command) at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve a complete set of summary reports. To acknowledge and remove a summary, you must first use the **SUM N(EXT)** command to view that summary.

You can use the **SUM** command to retrieve event summaries by date or date range, and by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History on page 9.27*.)

Table 9.2 lists the **SUM** commands. See *SUMMARY on page 14.52* for complete information on the **SUM** command.

Table 9.2 SUM Command

Command	Description
SUM	Return the most recent event summary (with header).
SUM *n*	Return a particular *n*[a] event summary (with header).
SUM ACK	Acknowledge the event summary on the present communications port.
SUM N	View the oldest unacknowledged event summary (**N** = next).

[a] The parameter n indicates event order or serial number.

You can also view event summaries using the Analytic Assistant tool built into QuickSet, or with SYNCHROWAVE Event.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue ASCII command CSU to view the Compressed ASCII summary report. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767 the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 9.13* for a sample event history.

The event history typically contains the following:

- ➤ Standard report header
  - ➢ Relay and terminal identification
  - ➢ Date and time of report
- ➤ Event number
- ➤ Event date and time
- ➤ Event type
- ➤ Location of fault (if applicable)
- ➤ Maximum phase current from summary fault data
- ➤ Active group at the trigger instant
- ➤ Targets

Figure 9.13 is a sample event history from a terminal.

```
Relay 1                                     Date: 03/16/2001  Time: 11:57:27.803
Station A                                   Serial Number: 2001001234
#       DATE        TIME      EVENT  LOCAT   CURR GRP TARGETS
10007 03/15/2001 23:30:49.026 BCG T   48.17  8892  1  INST TIME ZONE_1 B_PHASE
10006 03/15/2001 07:15:00.635 ABC T   22.82  8203  1  INST ZONE_1 A_PHASE bk1rs
10005 03/15/2001 06:43:53.428  TRIG  $$$$.$$    0  1
```

Event Number | Event Type | Fault Location | Active Group

Figure 9.13 Sample SEL-411L Event History

The event types in the event history are the same as the event types in the event summary.

The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **EVE** and **CEV** commands). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance. The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

Viewing the Event History

Access the history report from the communications ports and communications cards. View and download history reports from Access Level 1 and higher. You can also clear or reset history data from Access Levels 1 and higher. You can independently clear/reset history data at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete history reports. You can also clear all history data from all ports (with the **HIS CA** command).

Use the **HIS** command from a terminal to obtain the event history. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns. See *HISTORY on page 14.32* for information on the **HIS** command. *Table 9.3* lists the **HIS** commands.

Table 9.3 HIS Command

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*[a].
HIS *date1 date2*	Return the event summaries from date1 to date2, with date1 at the bottom of the list and date2 at the top of the list.
HIS C	Clear all event data on the present port.
HIS R	Clear all event data on the present port.
HIS CA	Clear event data for all ports.
HIS RA	Clear event data for all ports.

[a] Use the same date format as Global setting DATE_F.

You can use QuickSet to retrieve the relay event history. Use the **Tools > Events > Get Event Files** menu to view the Event History dialog box. See *Analyze Events on page 2.22* for information and examples.

CHISTORY

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. This is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report.

Items included in the Compressed ASCII history report are similar to those included in the history report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

History File Download

You can also download the history report file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS HISTORY.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CHISTORY.TXT <Enter>**. In addition, you can use QuickSet to download history files.

Sequential Events Recorder (SER)

The Sequential Events Recorder (SER) gives you detailed information on relay states and relay element operation. The SER captures and time-tags state changes of Relay Word bit elements and relay conditions. These conditions include power-up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, and SER autoremoval/reinsertion. The relay stores the latest 1000 SER entries to nonvolatile memory. *Figure 9.14* is a sample SER report.

The SER report contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- SER number
- SER date and time
- Relay element or condition
- Element state

```
Relay 1                                     Date: 03/16/2001  Time: 13:09:29.341
Station A                                   Serial Number: 2001001234
FID=SEL-411L-R101-V0-Z001001-D20010315
#     DATE        TIME           ELEMENT               STATE
6    03/15/2001  00:00:00.004  Power-up             Group 1
5    03/15/2001  00:00:00.022  Relay                Enabled
4    03/15/2001  00:30:00.021  GROUND O/C 1 LINE 1  51S1 PICKED UP
3    03/15/2001  00:30:03.221  GROUND O/C 1 LINE 1  51S1 TIMEOUT
2    03/15/2001  00:32:00.114  GROUND O/C 1 LINE 1  51S1 RESET
1    03/15/2001  00:32:00.114  GROUND O/C 1 LINE 1  51S1 DROPOUT
```

SER Number — Relay Element or Condition

Figure 9.14 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always #1. When using a terminal you can order the positions of the SER records in the SER report.

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats.

Access the SER report from the communications ports and communications cards in Access Level 1 and higher. You can independently clear/reset already viewed SER data at each communications port (with the **SER CV** or **SER RV** command) so that users at other ports (SCADA, Engineering, for example) can retrieve complete SER reports. The **SER CV** or **SER RV** command will not clear any SER data that has been recorded, but not viewed, on a particular serial port. To clear all SER data on a serial port, use the **SER C** or **SER R** command.

To clear all SER data from all serial ports, use the **SER CA** or **SER RA** command, available only from Access Levels P, A, O, and 2. This procedure would normally be used after relay commissioning or testing.

Use an ASCII terminal or QuickSet to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range. The relay labels each new SER record with a unique number.

Table 9.4 SER Commands

Command	Description
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than n, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than n, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.
SER *date1*[b]	Return the SER records on date *date1*.
SER *date1 date2*	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C or **SER R**	Clear SER records on the present port.
SER CA or **SER RA**	Clear SER data for all ports.
SER CV or **SER RV**	Clear viewed SER records on the present port.
SER D	List chattering SER elements that the relay is removing from the SER records.

[a] The parameters *m* and *n* indicate SER numbers that the relay assigns at each SER trigger.
[b] Use the same date format as Global setting DATE_F.

You can retrieve SER records with QuickSet. The **HMI > Meter and Control** menu item gives you the SER report. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS MENU.

CSER

The relay outputs a Compressed ASCII SER report for SCADA and other automation applications. Issue the CSE command to view the Compressed ASCII SER report. A sample of the SER report appears in *Figure 9.15*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII SER report are similar to the SER report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-411L-R101-V0-Z001001-D20010315","0dfc"
```
Report Header

```
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","ELEMENT","STATE","0FC8"
1,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_DROPOUT","09D2"
2,3,15,2001,00,32,00,114,"GROUND_O/C_1_LINE_1","51S1_RESET","08E7"
3,3,15,2001,00,30,03,221,"GROUND_O/C_1_LINE_1","51S1_TIMEOUT","09B0"
4,3,15,2001,00,30,00,021,"GROUND_O/C_1_LINE_1","51S1_PICK_UP","097B"
5,3,15,2001,00,00,00,222,"Relay","Enabled","09BA"
6,3,15,2001,00,00,00,004,"Power-up","Group 1","0A0A"
```
SER Data (six records)

Figure 9.15 Sample Compressed ASCII SER Report

SER File Download

You can also download the SER data as a file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS SER.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

Setting SER Points

NOTE: The relay is limited to storing SER points at a rate of approximately 6000 per hour. Be careful to select points that will not lead to this rate being exceeded.

You program the relay elements that trigger an SER record. You can select as many as 250 elements. These triggers, or points, can include control input and control output state changes, element pickups and dropouts, recloser state changes, and so on. Use the **SET R** command from a terminal, or use QuickSet **Report** branch of the Settings tree view to enter **SER Points**.

Use the text-edit line mode settings method to enter or delete SER elements. To set an SER element, enter the five items of this comma-delimited string (all but the first parameter are optional): Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm.

The relay defaults to the element name when you do not provide a reporting name. The default names for the set and clear states are Asserted and Deasserted, respectively. By default, SER Points are not configured for HMI alarm display. The relay always creates an SER record for power-up, relay enable and relay disable, any group change and settings change, diagnostic restart, and memory overflow.

Automatic Deletion and Reinsertion

The SER also includes an automatic deletion and reinsertion function. The relay automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with “chattering” information. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function, and select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element. The relay removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period. Once deleted from SER recording, the relay ignores the item for a 10 • SRDLTIM period. At the end of this period, the relay checks the chatter criteria and, if the point does not exceed the criteria, the relay automatically reinserts the item into SER recording. To see a list of deleted SER points, use the **SER D** command.

Signal Profiling

Use the analog signal profiling function to record and track values of as many as 20 analog quantities. This function provides data in CASCII that is compatible to import directly into applications like spreadsheets. Specify the specific analog quantities for profiling with the SPAQ Report settings. At the data acquisition rate of 5 minutes, the relay stores at least 10 days of all analog signals selected for profiling in nonvolatile memory. The report includes the time of acquisitions and the magnitude of each selected analog quantity. By defining conditions in the signal profiling enable SELOGIC variable setting (SPEN), you can record analog values at particular periods or conditions of interest.

SPAQgg (Analog Quantities for Signal Profiling)

Enter any analog quantity available in the relay from the Analog Quantity list in this freeform setting.

SPAR (Signal Profile Acquisition Rate)

Although you can select as many as 20 analog quantities, the signal acquisition rate is the same for all analog quantities. Select an acquisition rate of 1, 5, 15, 30, or 60 minutes.

SPEN (Signal Profile Enable)

Use this SELOGIC control equation to specify conditions under which the profiling must take place. If there are no conditions, be sure to set SPEN = 1, or else no data are recorded (default value of NA disables the function).

SECTION 10

Testing, Troubleshooting, and Maintenance

This section address the philosophy of relay testing, general approaches to testing and troubleshooting, troubleshooting common problems, and a few maintenance items. This section begins with guidelines for determining and establishing test routines for SEL-400 series relays. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The relay incorporates self-tests to help you diagnose potential difficulties should they occur. The subsection Relay Troubleshooting contains a quick-reference table for common relay operation problems.

Topics presented in this section include the following:

All SEL-400 series relays are factory calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

Testing Philosophy

Protective relay testing generally consists of three categories: acceptance testing, commissioning testing, and maintenance testing. The categories differ in testing complexity and according to when these activities take place in the life of the relay.

Each testing category includes particular details as to when to perform the test, the testing goals at that time, and the relay functions that you need to test. This information is a guide to testing SEL-400 series relays; be sure to follow the practices of your company for relay testing.

Acceptance Testing

SEL performs detailed acceptance testing on all new relay models and versions. We are certain that your relay meets published specifications. Even so, you can perform acceptance testing on a new relay model to become familiar with the relay operating theory and settings; this familiarity helps you apply the relay accurately and correctly. A summary of acceptance testing guidelines is presented in *Table 10.1*.

Table 10.1 Acceptance Testing

Details	Description
Time	Test when qualifying a relay model for use on the utility system.
Goals	a) Confirm that the relay meets published critical performance specifications such as operating speed and element accuracy. b) Confirm that the relay meets the requirements of the intended application. c) Gain familiarity with relay settings and capabilities.
Test	Test all protection elements and logic functions critical to your intended application.

Commissioning Testing

SEL performs a complete functional check and calibration of each SEL-400 series relay before shipment so that your relay operates correctly and accurately. You should perform commissioning tests to verify proper connection of the relay to the power system and all auxiliary equipment. Check control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection test to verify that the relay current and voltage inputs are the proper magnitude and phase rotation.

Brief fault tests confirm that the relay settings and protection scheme logic are correct. You do not need to test every relay element, timer, and function in these tests.

At commissioning, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation (see *Examining Metering Quantities on page 3.35*).

Use the **PUL** command to pulse relay control output operation. Use the **TAR** command to view relay targets and verify that control inputs are operational. Use **TEST DB**, **TEST DB2**, and **TEST FM** to check SCADA interfaces. (See *TEST DB on page 14.55*, *TEST DB2 on page 14.56*, and *TEST FM on page 14.57* for information on these relay commands.)

Table 10.2 lists guidelines for commissioning testing. For further discussion of these tests, see *Checking Relay Operation* in *Section 3: Testing* of the product-specific instruction manual.

Table 10.2 Commissioning Testing

Details	Description
Time	Test when installing a new protection system.
Goals	a) Validate all system ac and dc connections. b) Confirm that the relay functions as intended using your settings. c) Check that all auxiliary equipment operates as intended. d) Check SCADA interface.
Tests	Test all connected/monitored inputs and outputs, and the polarity and phase rotation of ac connections. Make simple checks of protection elements. Test communications interfaces.

TiDL Commissioning

The Time-Domain Link (TiDL) system uses a commissioning feature to identify that the connected remote Axion nodes meet the requirements of the supported topologies for the applied relay. These topologies are a balance between copper reduction and number of nodes. The nodes must be connected in one of the supported topologies so that the relay will map the voltages and currents accordingly.

The SEL-400 series relay will have a new interface on its back panel that replaces the original CT and PT input connections. These standard inputs are replaced with a remote module interface that supports eight fiber-optic ports, labeled **PORT 6A–PORT 6H** (see *Figure 10.1*).

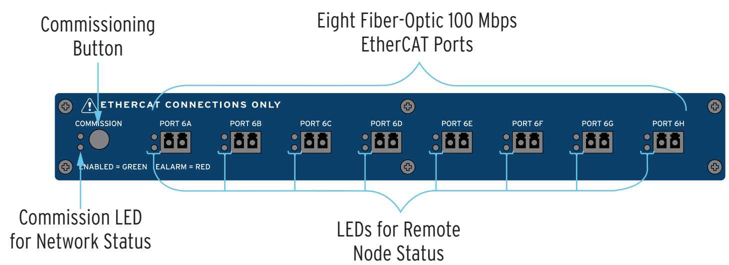

Figure 10.1 Remote Module Interface

Once all of the remote Axion nodes are connected to the relay, press the **COMMISSION** pushbutton on the remote module interface. This process will verify that the connected ports and Axion nodes are installed according to one of the supported topologies. Once the process is complete, the topology will be stored in memory. At each additional startup of the relay, the firmware will validate that the connected modules match those of the stored configuration. It will recognize if any of the CT/PT modules within the node have changed. If the topology needs to be changed (e.g., modules are added or replaced), the system will need to be recommissioned by pressing the **COMMISSION** pushbutton.

When the commissioning and validation of the topology is complete, the voltages and currents will be mapped according to the topology assignments (see *Section 2: Installation* in the product-specific instruction manual). Secondary injection testing will take place at each Axion node. Test sources will be required to inject voltages and currents into the Axion node to verify the correct installation and mapping. Monitoring of the voltages and currents will remain in the control house with the relay.

In a TiDL application, the relay will have I/O on both the main board (100-level inputs and outputs) and one additional I/O board (200-level inputs and outputs). All other I/O will be received from the remote Axion modules and are mapped to the 300-, 400-, and 500-level inputs and outputs in the relay.

Use the **METER** command on the relay to verify the ac current and voltage magnitude and phase rotation (see *Examining Metering Quantities on page 3.35*). Use the **PUL** command on the relay to pulse relay control output operation and monitor the outputs on the relay and at the Axion node. Using a test set, voltages and currents can be applied to the remote inputs on the Axion and then monitored on the relay interface.

Maintenance Testing

All SEL-400 series relays use extensive self-testing routines and feature detailed metering and event reporting functions. These features reduce your dependence on routine maintenance testing. When you want to perform maintenance testing, follow the recommendations in *Table 10.3*.

Table 10.3 Maintenance Testing

Details	Description
Time	Test at scheduled intervals or when there is an indication of a problem with the relay or power system.
Goals	a) Confirm that the relay is measuring ac quantities accurately. b) Check that scheme logic and protection elements function correctly. c) Verify that auxiliary equipment functions correctly.
Tests	Test all relay features/power system components that did not operate during an actual fault within the past maintenance interval.

You can use the relay reporting features as maintenance tools. Periodically compare the relay **METER** command output to other meter readings on a line to verify that the relay measures currents and voltages correctly and accurately. Use the circuit breaker monitor, for example, to detect slow breaker auxiliary contact operations and increasing or varying breaker pole operating times. For details on these features, see *Circuit Breaker Monitor on page 8.1*.

Each occurrence of a fault tests the protection system and relay application. Review relay event reports in detail after each fault to determine the areas needing your attention. Use the event report current, voltage, and relay element data to determine that the relay protection elements and communications channels operate properly. Inspect event report input and output data to determine whether the relay asserts outputs at the correct times and whether auxiliary equipment operates properly.

At each maintenance interval, the only items to be tested are those that have not operated (via fault conditions and otherwise) during the maintenance interval. The basis for this testing philosophy is simple: you do not need to perform further maintenance testing for a correctly set and connected relay that measures the power system properly and for which no relay self-test has failed.

SEL-400 series relays are based on microprocessor technology; the relay internal processing characteristics do not change over time. For example, if time-overcurrent element operating times change, these changes occur because of alterations to relay settings and/or differences in the signals applied to the relay. You do not need to verify relay element operating characteristics as a part of maintenance checks.

SEL recommends that you limit maintenance tests on SEL relays according to the guidelines listed in *Table 10.3*. You will spend less time checking relay operations that function correctly. You can use the time you save to analyze event data and thoroughly test systems needing more attention.

Testing Features and Tools

All SEL-400 series relays provide the following features that can assist you during relay testing:

- ➤ Metering
- ➤ High-resolution oscillography
- ➤ Event reports
- ➤ Event summary reports
- ➤ Sequential Events Recorder (SER) reports

Certain relay commands are useful in confirming relay operation. The following commands, for example, aid you in testing the relay:

- ➤ **TAR**
- ➤ **PUL**
- ➤ **TEST DB**
- ➤ **TEST DB2**
- ➤ **TEST FM**

In addition, the relay incorporates a low-level test interface where you can interrupt the connection between the relay input transformers and the input processing module. Use the low-level test interface to apply reduced-scale test quantities from the SEL-4000 Relay Test System; you do not need to use large power amplifiers to perform relay testing.

Metering

NOTE: Some relays support a single dc battery monitor. See the relay-specific instruction manual to determine whether one or two dc battery monitors are supported.

The specific metering data available depends on the relay model. See *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual for detailed information. In general, the metering data show the ac currents and voltages (magnitude and phase angle) connected to the relay in primary values. In addition, metering shows many other quantities including the power system frequency (FREQ) and the voltage input to the station dc battery monitors (Vdc1 and Vdc2). Compare these quantities against quantities from other devices of known accuracy. The metering data are available at the serial ports, from the ACSELERATOR QuickSet SEL-5030 Software HMI, and at the front-panel LCD METER menu. See *METER on page 14.37*, *Meter on page 4.16*, *QuickSet HMI on page 2.19*, *Examining Metering Quantities on page 3.35* for more information.

High-Resolution Oscillography

NOTE: Control Inputs are sampled at 2 kHz, and the raw binary data (prior to debounce timer conditioning) is available in high-resolution oscillography. The COMTRADE data labels for raw control input data are IN101–IN107, IN201–IN2*nn*, IN301–IN3*nn*,IN401–IN4*nn*, IN501–IN5*nn*, based on installed hardware, where *nn* = 01–08 or 01–24.

The relay takes an unfiltered data snapshot of the power system at each event trigger or trip. The relay samples power system data at high sample rates from 1 kHz to 8 kHz. You can use the ACSELERATOR Analytic Assistant SEL-5601 Software or other COMTRADE viewing program to export and view these raw data in a binary COMTRADE file format. Use high-resolution oscillography to capture fast power system transients or to examine low-frequency anomalies in the power system. See *Raw Data Oscillography on page 9.9* for more information.

Event Reports

NOTE: Control Inputs are sampled at 2 kHz, and then conditioned by a debounce timer. The resulting Relay Word bits are updated 8 times/cycle and are available in standard event report files.

The relay also generates a filtered-quantities event report in response to faults or disturbances. Each event report contains information on current and voltage, relay element states, control inputs, and control outputs. If you are unsure of the relay response or your test method, the event report provides you with information on the operating quantities that the relay used at the event trigger. The relay provides oscillographic displays of the filtered event report data, which give you a visual tool for testing relay operating quantities. You can use the serial ports and QuickSet to view event reports. See *Event Reports, Event Summaries, and Event Histories on page 9.13* for a complete discussion of event reports.

Event Summary Reports

The relay generates an event summary for each event report; use these event summaries to quickly verify proper relay operation. With event summaries, you can quickly compare the reported fault current and voltage magnitudes and angles against the reported fault location and fault type. If you question the relay response or your test method, you can obtain the full event report and the high-resolution oscillographic report for a more detailed analysis. See *Event Summary on page 9.26* for more information on the event summary.

SER Reports

The relay provides an SER report that time tags changes in relay elements, control inputs, and control outputs. Use the SER for convenient verification of the pickup and dropout of any relay element. For a complete discussion of the SER, see *Sequential Events Recorder (SER) on page 9.28*.

Test Commands

TAR Command

Use the **TAR** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. You can see relay targets at the serial ports, and from the front-panel LCD (see *TARGET on page 14.53* and *Operation and Target LEDs on page 4.33*).

PUL Command

Use the **PUL** command to test the control output circuits. The specified output closes if open, or opens if closed. You can use the **PUL** command at the serial ports, in the QuickSet HMI, and from the front-panel LCD (see *PULSE on page 14.45*, *QuickSet HMI on page 2.19*, and *Operation and Target LEDs on page 4.33*).

TEST DB Command

Use the **TEST DB** command for testing the relay database, which is used for Fast Message Data Access. The **TEST DB** command can be used to override any value in the relay database. Use the **MAP 1** command and the **VIEW 1** command to inspect the relay database (see *MAP on page 14.37*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Section 10: Communications Interfaces* in the product-specific instruction manual for more information.

TEST DB2 Command

Use the **TEST DB2** command to test the DNP3 and IEC 61850 interfaces. Values you enter are "override values." For more information on DNP3, see *Section 16: DNP3 Communication*. For more information on IEC 61850, see *Section 17: IEC 61850 Communication*.

TEST FM Command

Use the **TEST FM** command to override normal Fast Meter quantities for testing purposes. You can only override "reported" Fast Meter values (per-phase voltages and currents). You cannot directly test Fast Meter values that the relay derives from the reported values (power, sequence components, etc.). For more information on Fast Meter, see *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.

Test Methods

Use the following methods to conveniently test the pickup and dropout of relay elements and other relay functions:

- Target indications (element pickup/dropout)
- Control output closures
- SER reports

The tests and procedures in the following subsections are for 5 A relays. Scale values appropriately for 1 A relays.

Once you have completed a test, return the relay settings that you modified for the test to default or operational values.

Testing With Relay Word Bits

Use the communications port **TAR** command or the front panel to display the state of relay elements, control inputs, and control outputs. Viewing a change in relay element (Relay Word bit) status is a good way to verify the pickup settings you have entered for protection elements. See *Examining Relay Elements on page 3.43* for more information on examining relay elements using a terminal and from the front panel.

Testing With Control Outputs

You can set the relay to operate a control output to test a single element. Set the SELOGIC control equation for a particular output (OUT101–OUT108, for example) to respond to the Relay Word bit for the element under test. See *Operating the Relay Inputs and Outputs on page 3.61* for configuring control inputs and control outputs. *Section 11: Relay Word Bits* in the product-specific instruction manual lists the names of the relay element logic outputs.

Example: Testing the 50P1 Element With a Control Output

This procedure shows how to set control output OUT105 to test the SEL-451 50P1 Phase Instantaneous Overcurrent element.

For this test, you must have a computer with QuickSet for the relay, a variable current source for relay testing, and a control output closure indicating device such as a test set or a VOM (volt ohmmeter).

In this example, use QuickSet to configure the relay. You must have a computer that is communicating with the relay and running QuickSet (see *Making Settings Changes in Initial Global Settings on page 3.20*).

Step 1. Prepare to control the relay with QuickSet by establishing communication, checking passwords, and reading relay settings.

Step 2. Click the **Outputs > Main Board** branch of the QuickSet **Settings** tree structure to view output settings (shown in *Figure 10.2*).

The **Main Board Outputs** dialog box appears.

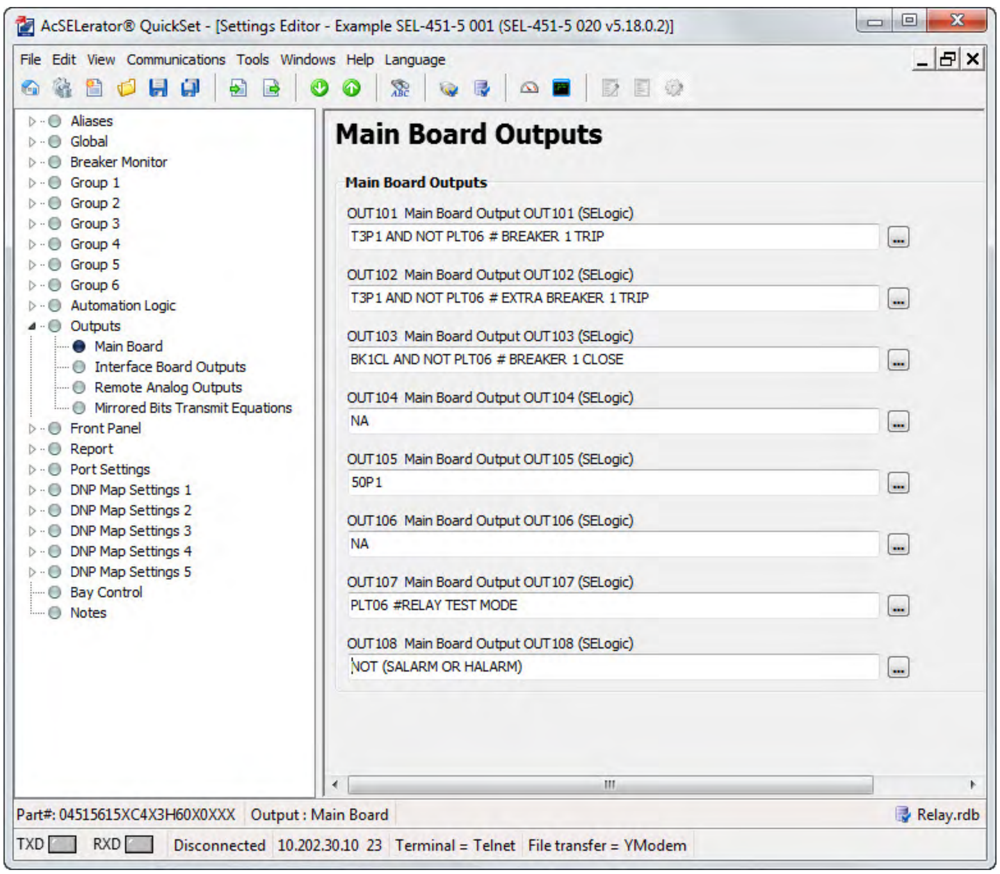

Figure 10.2 Setting Main Board Outputs: QuickSet

Step 3. Set OUT105 to respond to the 50P1 element pickup.

a. Move the cursor to the OUT105 Main Board Output105 (SELOGIC) text box and double-click the left (regular) mouse button.

b. Delete the NA default setting.

c. Type 50P1.

d. Press **<Tab>** or click in any other text box.

e. The relay checks the validity of the setting you entered.

An invalid setting (you could have mistyped the element name) causes the OUT105 text box to turn red.

If the setting is valid, the text box displays the new setting on a white background.

Step 4. Click **File > Save** to save the new settings in QuickSet.

Step 5. Upload the new settings to the SEL-451.

a. Click **File > Send**.

QuickSet prompts you for the settings class you want to send to the relay, as shown in the Group Select dialog box in *Figure 10.3*.

b. Click the Output check box.

c. Click **OK**.

The relay responds with the **Transfer Status** dialog box, as shown in *Figure 10.3*.

If you see no error message, the new settings are loaded in the relay.

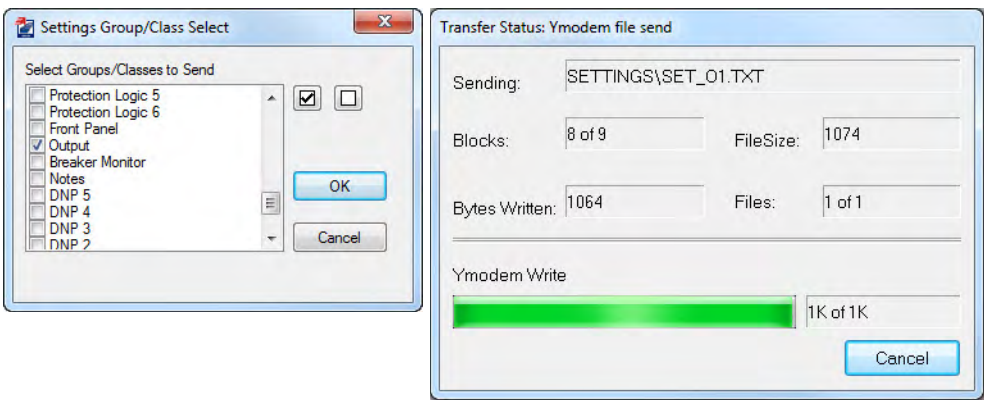

Figure 10.3 Uploading Output Settings to the SEL-451

Step 6. Connect an indicating device to OUT105 on the relay rear panel.

A VOM multi-tester on a low resistance scale can indicate an OUT105 control output closure.

Step 7. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 8. Increase the current source to produce a current magnitude greater than 15.00 A secondary in the relay (to test the element).

When the 50P1 element picks up, the relay changes the 50P1 Relay Word bit to logical 1 and closes the output contacts of control output OUT105.

The indicating device operates.

Testing With SER

You can set the relay to generate a report from the SER to test relay elements; include the element that you want to test in the SER **Points and Aliases** list. Set aliases for the element name, set state, and clear state in the relay SER to simplify reading the SER report. See *Sequential Events Recorder (SER) on page 9.28* for complete information on the SER.

Example: Testing the SEL-451 51S1 Element Using the SER

The SER gives exact time data for testing time-overcurrent element time-outs. Subtract the 51S1T assertion time from the 51S1 assertion time to check the operation time for this element. Use the factory defaults for the operating quantity, pickup level, curve, time dial, electromechanical reset, and torque control (*Table 10.4*).

The procedure in the following steps shows how to set the SER trigger lists to capture the selectable operating quantity time-overcurrent element 51S1 operating times. The procedure also shows how to set the torque control supervision for the 51S1 element.

Table 10.4 Selectable Operating Quantity Time-Overcurrent Element (51S1) Test Settings

Setting	Description	5A
51S1O	51S1 Operating Quantity (IA*n*, IB*n*, IC*n*, IMAX*n*, IA*n*R, IB*n*R, IC*n*R, IMAX*n*R, I1L, 3I2L, 3I0*n*)[a]	3I0L
51S1P	51S1 Overcurrent Pickup (0.25–16 A, secondary)	0.75
51S1C	51S1 Inverse-Time Overcurrent Curve (U1–U5, C1–C5)	U3
51S1TD	51S1 Inverse-Time Overcurrent Time Dial (0.50–15.00)	1.00
51S1RS	51S1 Inverse-Time Overcurrent EM Reset (Y, N)	N
51S1TC	51S1 Torque Control (SELOGIC control equation)	1

[a] *n* = L, 1, and 2 for Line, Circuit Breaker 1, and Circuit Breaker 2, respectively. R suffix selects rms quantities. For more information on rms, refer to RMS in the Glossary.

The relay uses *Equation 10.1* and *Equation 10.2* to determine the operating time for the 51S1 element. For a current input 50 percent greater than the default pickup, the test value, I_{TEST}, is:

$$\begin{aligned} I_{TEST} &= M \cdot (51S1P) \\ &= 1.5 \cdot (0.75\ A) \\ &= 1.125\ A \end{aligned}$$

Equation 10.1

where M is the pickup multiple and 51S1P is the element pickup value (see *Table 10.4*).

The operating time (t_p) for a time dial (TD) equal to 1 for the U3 (Very Inverse) Curve is:

$$\begin{aligned} t_p &= TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right) \\ &= 1 \bullet 0.0963 + \frac{3.88}{1.5^2 - 1} \\ &= 3.2 \text{ seconds} \end{aligned}$$

Equation 10.2

In this example, use QuickSet to configure the relay. You must have a computer that is communicating with the SEL-451 and running the QuickSet (see *Making Settings Changes in Initial Global Settings on page 3.20*). You also need a variable current source for relay testing.

Step 1. Prepare to control the relay with QuickSet by establishing communication, checking passwords, and reading relay settings.

Step 2. Set the selectable operating quantity time-overcurrent element for test operation.

a. Open the **Group 1 > Set 1> Relay Configuration > Time Overcurrent** branch of the **Settings** tree view (see *Figure 10.4*).

b. Verify that enable setting E51S (Selectable Inverse-Time Overcurrent Element) is set to 1, or greater.

c. In the **Time Overcurrent** dialog box, change setting **51S1O Operating Quantity** to **3I0L**.

d. Change the remaining element configurations to match *Table 10.4*.

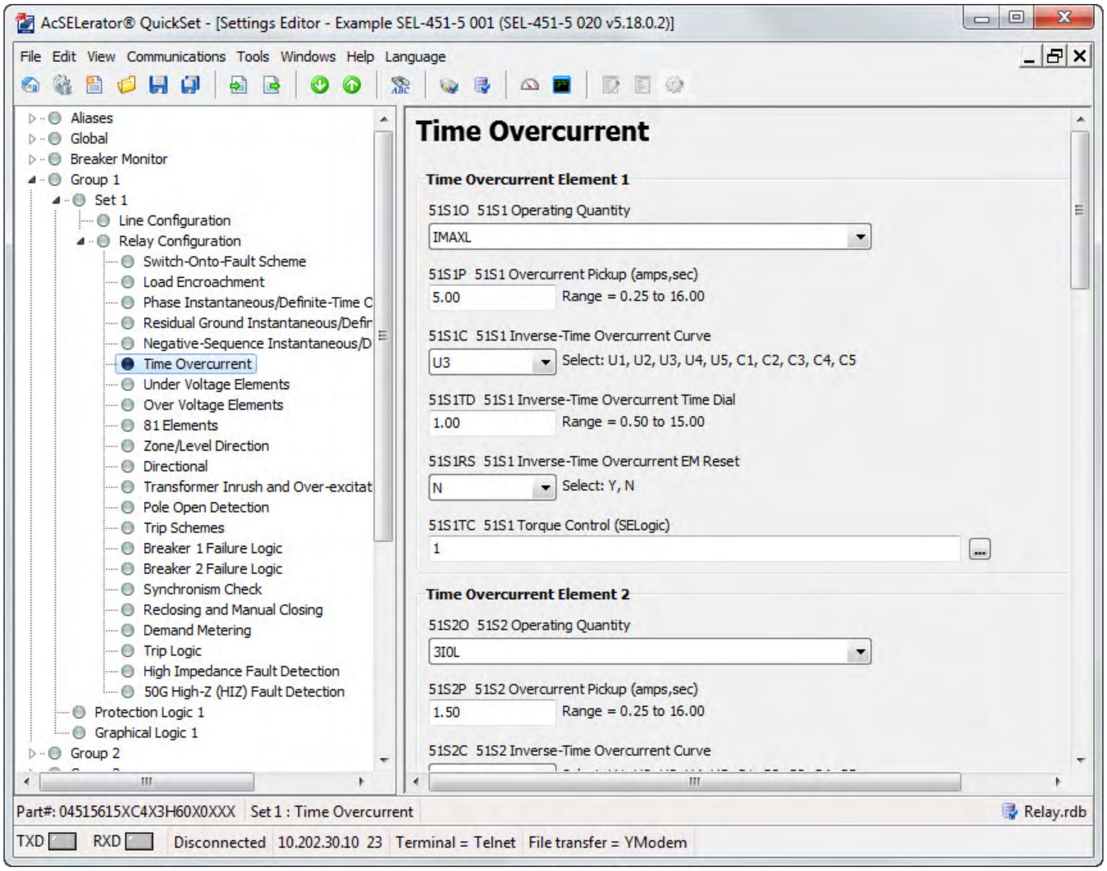

Figure 10.4 Checking the 51S1 Overcurrent Element: QuickSet

Step 3. View the SER settings.

a. Click the + next to the **Report** branch of the QuickSet **Settings** tree view structure shown in *Figure 10.5*.

b. Click on the **SER Points and Aliases** branch.

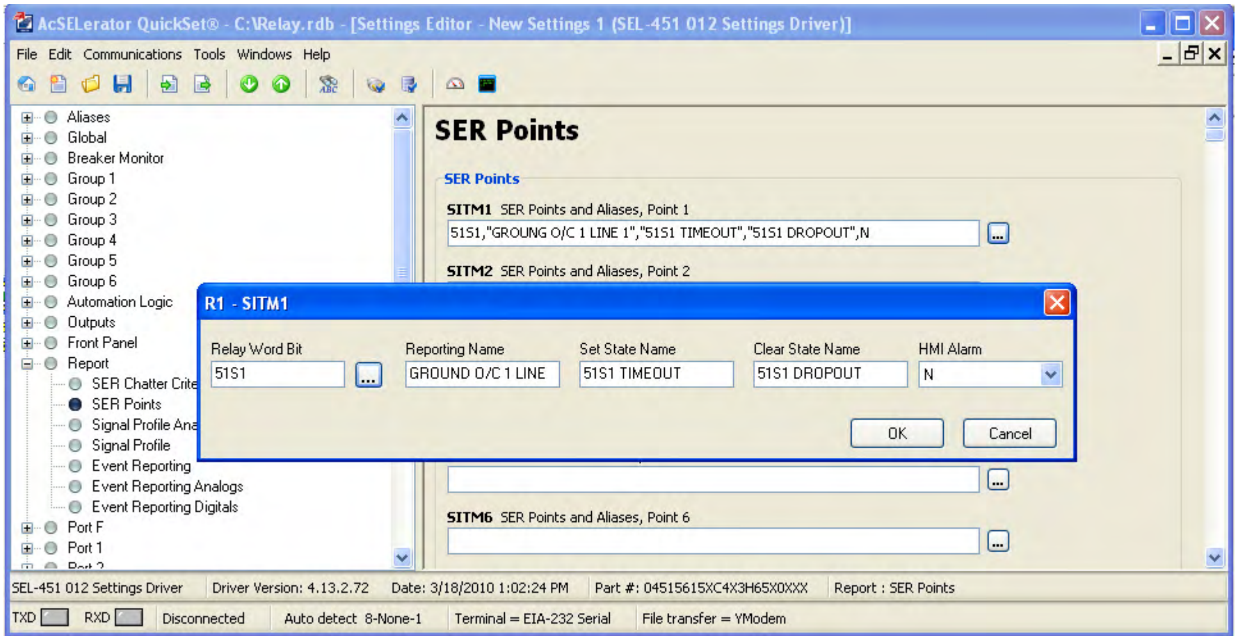

Figure 10.5 Setting SER Points and Aliases: QuickSet

Step 4. Enter SER element names and aliases.

a. Scroll down to find **SITM1 SER Points and Aliases, Point 1** entry field, and then click the [...] button beside the entry box.

b. Click the [...] button beside the **Relay Word Bit** entry field.

c. Select Overcurrent Element Bits.

d. Double-click on **51S1T** to copy the name into the **Relay Word Bit** field.

e. Type **GROUND O/C 1 LINE 1** in the **Reporting Name** field.

f. Type **51S1 TIMEOUT** in the **Set State Name** field.

g. Type **51S1 DROPOUT** in the **Clear State Name** field.

h. Click on the **OK** button.

i. Repeat *Step a–Step h* for **SITM2 SER Points and Aliases, Point 2**, with setting values **51S1, GROUND O/C 1 LINE 1, 51S1 PICKED UP, 51S1 RESET**. *Figure 10.5* shows the entry field for SITM2 just before pressing the **OK** button.

You can enter as many as 250 relay elements in the **SER Points and Aliases** list (see *Sequential Events Recorder (SER) on page 9.28*).

Step 5. Click **File > Save** to save the new settings in QuickSet.

Step 6. Upload the new settings to the SEL-451.

a. Click **File > Send**.

b. QuickSet prompts you for the settings class you want to send to the relay, as shown in the **Group Select** dialog box of *Figure 10.6*.

c. Select the check box for **Group 1** and for **Report**.

d. Click **OK**.

QuickSet responds with a **Transfer Status** dialog box as in *Figure 10.7*.

If you see no error message, the new settings are loaded in the relay.

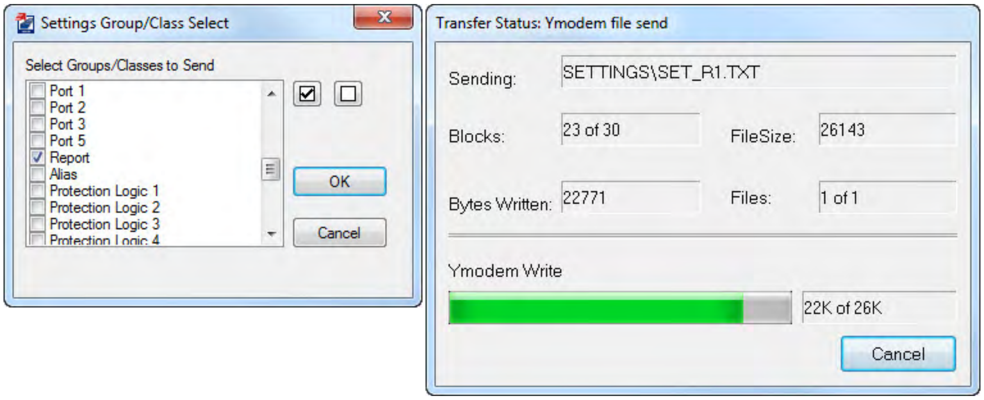

Figure 10.6 Uploading Group 1 and Report Settings to SEL-451

Step 7. Connect a test source to the relay.

a. Set the current output of a test source to zero output level.

b. Connect a single-phase current output of the test source to the IAW analog input.

Step 8. Test the element.

a. Increase the current source to produce a current magnitude of 1.125 A secondary in the relay.

b. Keep the current source at this level past the expected element time-out (longer than 3.2 seconds).

c. Return the current source to zero after the element times out.

Step 9. Select the **HMI** menu (top toolbar) to start the QuickSet HMI interface.

Step 10. View the SER report. Click the **SER** button of the HMI tree view.

QuickSet displays the SER report similar to *Figure 10.7*.

The time difference between SER entries **51S1 PICKED UP** and **51S1 TIMEOUT** is approximately 3.2 seconds.

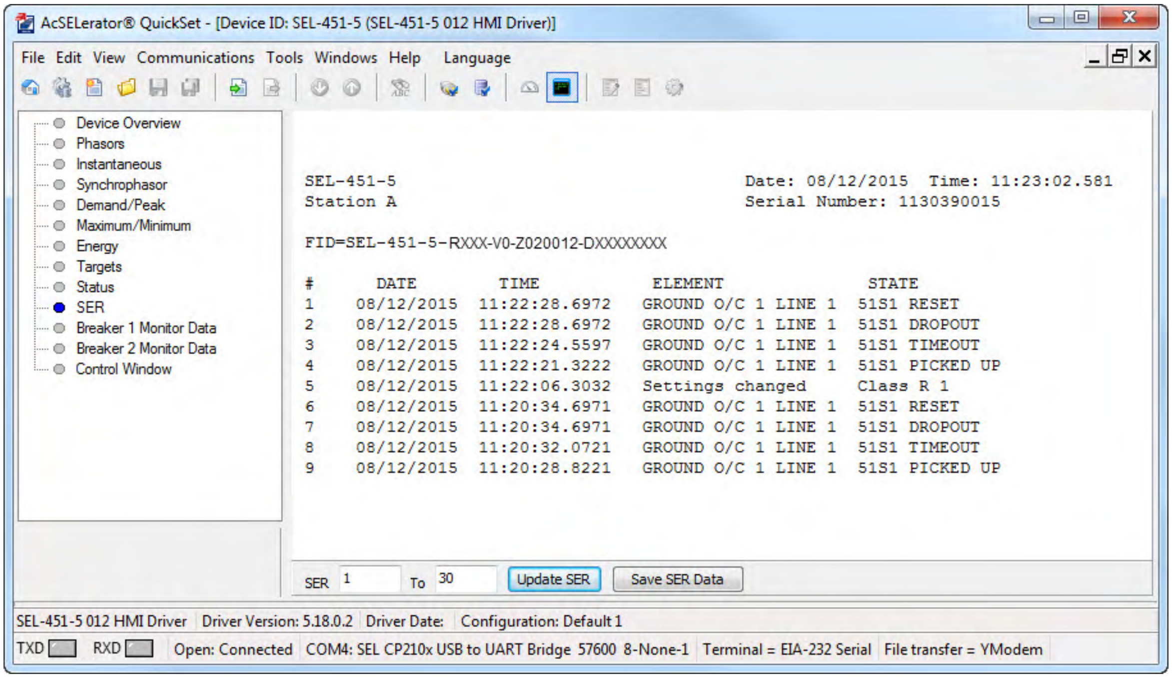

Figure 10.7 SER Report: QuickSet HMI

Relay Self-Tests

The relay continuously runs many self-tests to detect out-of-tolerance conditions. These tests run at the same time as relay protection and automation logic, but do not degrade relay performance.

The relay provides a number of alarms to indicate different conditions, as shown in *Table 10.5*.

Table 10.5 Alarm Relay Word Bits

Alarm Relay Word Bit	Description
HALARML	Latches for any relay failures.
HALARMP	Asserts for five seconds when a warning condition occurs.
HALARMA	Starts pulsing for five seconds every minute whenever a new warning condition occurs and continues to pulse until the RST_HAL logic reset is asserted.
RST_HAL	Resets the HALARMA operation (similar to the other logic resets in the relay).
HALARM	Equivalent to HALARML OR HALARMP.
SETCHG	Pulses for one second whenever settings are changed.
GRPSW	Pulses for one second whenever groups are switched.
ACCESS	This bit is set when a user is logged in at access Level B or higher.
BADPASS	Pulses for one second whenever a user enters three successive bad passwords.
SALARM	BADPASS OR SETCHG OR GRPSW.

The relay reports out-of-tolerance conditions as a status warning or status failure. For conditions that do not compromise relay protection, yet are beyond expected limits, the relay issues a status warning and continues to operate. A severe out-of-tolerance condition causes the relay to declare a status failure and enter a protection-disabled state. During a protection-disabled state, the relay suspends protection element processing and trip logic processing and de-energizes all control outputs. When disabled, the **ENABLED** front-panel LED is not illuminated.

The relay signals a status warning by pulsing the HALARMP, HALARMA, and HALARM Relay Word bits (hardware alarm) to logical 1 for five seconds. For a status failure, the relay latches the HALARML and HALARM Relay Word bits at logical 1. Some hardware failures prevent the relay from operating. In such cases, Relay Word bits HALARML and HALARM do not assert.

Once HALARMP pulses, Relay Word bit HALARMA continues to assert for approximately five seconds once per minute to indicate that a hardware warning has occurred. HALARMA continues to pulse until it is reset by pulsing SELOGIC control equation RST_HAL. Restarting the relay also resets HALARMA. HALARMP does not assert again for the same alarm condition, unless the condition is cleared and returns.

The relay will automatically restart as many as two times on certain diagnostic failures. In many instances, this will correct the failure. When this occurs, the relay will log a `Diagnostic Restart` in the SER.

To provide remote status indication, connect the b contact of OUT108 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM).

If you repeatedly receive status warnings, check relay operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Technical Support on page 10.31*).

The relay generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The relay issues a status message with a format identical to the **STATUS** command output, but includes the power supply information from the **STA A** response. The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands and the front-panel `RELAY STATUS` menu to display status warnings and status failures. See *STATUS on page 14.50*, *Checking Relay Status on page 3.11*, and *Relay Status on page 4.29* for more information on automatic status notifications and on viewing relay status.

The relay includes self-diagnostics that monitor settings, hardware, and communication. The settings diagnostic checks if an internal error may have caused the calibration settings to be lost or corrupted, which would introduce errors in the magnitude and angles of the voltages and currents measured. The hardware diagnostics monitor any component change that does not match the part number, as well as hardware failures in the power supply, processors, and digital samplers. For relays that support remote data acquisition, such as TiDL, the relay will monitor the connection to the remote data or the communication board in the relay that receives the remote data. Finally, the diagnostics monitor communications such as Ethernet, serial, and 87L connections. The **STATUS** command notifies the user if any of the diagnostics trigger a warning or a failure. In cases where the issue is a failure the relay will become disabled and protection will be inhibited.

Status

Figure 10.8 is a sample **STATUS** screen from the Status option of the QuickSet **HMI > Meter and Control** tree view (the terminal **STATUS** report is similar). *Figure 10.9* is the **STATUS A** report showing all status information on a terminal.

```
Status

SEL-451-5                                  Date: 08/12/2015  Time: 11:36:55.104
Station A                                  Serial Number: 1130390015

FID=SEL-451-5-RXXX-V0-Z020012-DXXXXXXXX      CID=0xfd1a

Failures
  No Failures

Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled
```

Figure 10.8 Relay Status: QuickSet HMI

```
=>>STA A <Enter>
Relay 1                                     Date: 03/15/2015 Time: 04:48:49.938
Station A                                   Serial Number: 0000000000
FID=SEL-451-5-Rxxx-V0-Zxxxxxx-Dyyyymmdd      CID=0xxxxx

Failures
  No Failures
Warnings
  No Warnings
Channel Offsets (mV)   W=Warn    F=Fail
  CH1  CH2  CH3  CH4  CH5  CH6  CH7  CH8  CH9 CH10 CH11 CH12  MOF
    0    0    0    0    0    0    0    0    0    0    0    0    0

Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.28   4.91   -4.93   14.70    -14.79
Temperature
   23.7 degrees Celsius
Communication Interfaces

Active High Accuracy Time Synchronization Source: IRIG-B
  IRIG-B Source PRESENT
SELogic Relay Programming Environment Errors
  No Errors
Relay Enabled
=>>
```

Figure 10.9 Relay Status From a STATUS A Command on a Terminal

CSTATUS

The relay also reports status information in the Compressed ASCII format when you issue the CST command. An example Compressed ASCII status message is shown in *Figure 10.10*.

```
"RID","SID","FID","yyyy",
"relay_name","station_name","SEL-451-x-Rxx-Vx-Zxxxxxx-Dxxxxxxxx","yyyy"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"
(Month),(Day),(Year),(Hour),(Min),(Sec),(MSec),"yyyy"

"CPU_RAM","CPU_PROG","SELBOOT","CPU_SET","DSP_RAM","DSP","DSP_CSUM","DSP_T_OUT","CPUDSP_RAM","FRNT_PNL","CAL_BOARDA","CCRD_
   CHG","COMM_CARD","ANA_CONV","IO_1","IO_2","yyyy"
"(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or
   F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","yyyy"
"ATOD_OFFST","MSTR_OFFST","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V_PS","TEMP_STA","TEMP","PRT_O_LOAD","LCD_ERROR","FPGA","
   yyyy"

"(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)","(Ok or F)",(Temp value),"(Ok or
   F)","(Ok or F)","(Ok or F)","yyyy"
"MBA","MBB","ACTTIM_SRC","SELOG_MATH","FM_TEST","DB_TEST","DB2_TEST","RLY_STA","PRT_F_TP","PRT_1_TP","PRT_2_TP","PRT_3_TP",
   "PRT_5_TP","yyyy"
(Inac or Ok or F),(Inac or Ok or F),(HIRIG or IRIG or " "),(Enabled or Disabled), (Enabled or Disabled), (Enabled or
   Disabled), (Enabled or Disabled),(F,0-5), (F,0-5), (F,0-5), (F,0-5), (F,0-5),"yyyy"
```

Figure 10.10 Example Compressed ASCII Status Message

Definitions for the items and fields in the Compressed ASCII configuration are listed below:

- *yyyy* is the checksum
- *x* is text in the FID (Firmware ID) string
- (description) is text that the relay supplies
- (Ok or W or F) is normal, warning, or failure, respectively

Firmware Version Number

At the top of each status report the relay displays the present firmware version number that identifies the software program that controls relay functions. The firmware version is the four-place designator immediately following the relay model number (the first characters in the firmware identification or FID string). The first character in the four-place firmware version number is R (representing Release).

Figure 10.8 and *Figure 10.9* show the location of the FID sting, with a blank or generic response. To see the actual FID string for the firmware version described in this manual, see *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific instruction manual for firmware version information.

Relay Troubleshooting

Inspection Procedure

Complete the following inspection procedure before disturbing the system. After you finish the inspection, proceed to *Troubleshooting Procedures on page 10.19*.

Step 1. Confirm that the power is on. Do not turn the relay off.

Step 2. Measure and record the control power voltage at the relay **POWER** terminals marked **+** and **–** on the rear-panel terminal strip.

Step 3. Measure and record the voltages at all control inputs.

Step 4. Measure and record the state of all control outputs.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedures

Troubleshooting procedures for common problems are listed in *Table 10.6* and *Table 10.7*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related ASCII commands are listed in bold capitals. See *Section 14: ASCII Command Reference* for details on SEL-400 series commands and *Section 12: Settings* for details on relay settings.

Table 10.6 Troubleshooting Procedures (Sheet 1 of 2)

Symptom/Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Verify that substation battery power is operational.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page 10.23*).
Poor HMI contrast.	Press and hold ESC for two seconds. Press Up Arrow and Down Arrow pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	See *Table 10.7* for guidance on the specific failure type. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108.
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse (see *Power Supply Fuse Replacement on page 10.23*).
Power supply failure.	LCD displays STATUS FAILURE screen. See *Table 10.7*.
Main board or interface board failure.	LCD displays STATUS FAILURE screen. See *Table 10.7*.
Other self-test failure.	LCD displays STATUS FAILURE screen. See *Table 10.7*.
System Does Not Respond to Commands	
NOTE: If Port setting PROTO := PMU, that serial port will not respond to ASCII commands. Additionally, a PROTO := PMU port will not respond to any messages when Global setting EPMU := N.	
No communication.	Confirm cable connections and types. If correct, type **<Ctrl+X> <Enter>**. This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings (see *Set/Show on page 4.25*).
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications (see *Serial Communication on page 15.2*).
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications (see *Serial Communication on page 15.2*).
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration (see *Serial Communication on page 15.2*).
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings.
Improper test settings.	Restore operating settings.

Table 10.6 Troubleshooting Procedures (Sheet 2 of 2)

Symptom/Cause	Diagnosis/Solution
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report (see *Examining Metering Quantities on page 3.35*).
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions (see *Installing Optional I/O Interface Boards on page 10.24*).
Check the relay self-test status.	Take preventive action as directed by relay Status Warning and Status Failure information (see *Checking Relay Status on page 3.11*).
Sequence of Events Recorder	
SER DATA LOSS Reported	This is caused by an internal buffer overrun, which can occur if SER points are being triggered faster than they can be processed. It will recover as soon as the SER processing can catch up. SER data loss can also be caused by excessive SER triggering (>6000 points per hour), causing the relay to temporarily suspend storing points. In this case, it will normally recover within an hour, but the SER DATA LOSS END message will not be reported until the first SER point is triggered after the suspension ends.
Tripping Output Relay Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Control output relay contacts have burned closed.	Remove relay power. Remove the control output connection. Check continuity—Form A contacts should be open and Form B contacts should be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Time/Date Errors	
External IRIG time source error.	Check IRIG-B time source or cables. Check **TIME Q** command or `HMI SET/SHOW | Date/Time` screen.
A low-priority time source error.	Check last update source (**TIME Q** command or `HMI SET/SHOW | Date/Time` screen) (see *Table 11.5 on page 11.8*).
Lithium clock battery failure.	Verify that the battery has failed before replacing the battery–it should last for 10 years if the relay is energized (see *Replacing the Lithium Battery on page 10.22*).
TiDL Applications	
Relay will not successfully commission.	Check the configuration of axion CT/PT modules and verify that they match a supported topology (see *Section 2: Installation* in the product-specific instruction manual).
Relay disabled.	Check the CT/PT modules for failure. If a module is identified as failed, replace the CT/PT module and then press the commissioning button on the back of the relay (see *TiDL Commissioning on page 10.3*).

Table 10.7 Troubleshooting for Relay Self-Test Warnings and Failures (Sheet 1 of 2)

Diagnostic Message	Diagnosis/Solution
Memory Failures	
RAM Failure[a]	This indicates a failure of a memory device. Contact the SEL factory or your Technical Service Center.
Flash Failure	
Settings Failed	
Default Settings Failure	
Default Cal Settings	This indicates that something has occurred that has caused the relay to lose its calibration. Contact the SEL factory or your Technical Service Center.

Table 10.7 Troubleshooting for Relay Self-Test Warnings and Failures (Sheet 2 of 2)

Diagnostic Message	Diagnosis/Solution
Line Current Differential Warnings	
87L Watchdog Alarm	This alarm indicates that the relay has received more than three unwarranted 87L pickup operations associated with 87L communication channel impairments. This logic asserts Relay Word bit 87ALARM and does not inhibit 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command.
87L Watchdog Error 1	This error indicates that the relay has received more than five unwarranted 87L pickup operations associated with 87L communication channel impairments. This logic asserts Relay Word bit 87ERR1 and inhibits 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command.
87L Watchdog Error 2	This error indicates that the relay has received more than ten unwarranted 87L pickup operations associated with 87L communications channel impairments and non-channel related issues. This logic asserts Relay Word bit 87ERR2 and inhibits 87L protection. This alarm can be reset at Access Level 2 by issuing a **COM 87L WD C** command. **NOTE:** In firmware R105 and older, this alarm can only be reset at Access Level C.
87L Watchdog Reset	This warning occurs when the **COM 87L WD C** command is issued.
Hardware Changes	
Card or Board Change	This indicates that the installed hardware does not match the part number. If the hardware was intentionally changed, use the **STA** command from Access Level 2 to accept the new hardware configuration. If the hardware was not changed, make sure all connections are fully seated and then restart the relay. If the error persists, contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the Status Warning. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the Status Warning. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
FPGA Failure	
FPGA diagnostics failed during either power up or run time.[a]	In this rare event, the relay will automatically restart. If the failure occurs three times in seven days, the LCD displays the FPGA FAIL screen. Contact the SEL factory or your Technical Service Center. **NOTE:** In older firmware versions, the relay did not automatically restart. Contact the SEL factory or your Technical Service Center.
Serial Port Power Overload	
+5V EIA-232 Overload	The relay rear serial ports are capable of providing +5V power to an external transceiver, but have a limited power output. This warning indicates that the power limit has been exceeded and the current has been limited. Check what is connected to the serial ports to ensure that there is no unintentional load on the +5V outputs.
All Other Warnings and Failures	
	Contact the SEL factory or your Technical Service Center.

[a] The relay will automatically restart for some of these failures. Contact the factory if the failure recurs.

Maintenance

Instructions for Cleaning

Use care when cleaning the relay. Use a mild soap or detergent solution and a damp cloth to clean the chassis. Do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any surface.

Replacing the Lithium Battery

⚠**CAUTION**
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

⚠**CAUTION**
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You can replace the lithium battery in the relay. Perform the following steps to replace the lithium battery.

Step 1. Remove the relay from service.

a. Follow your company standard procedure for removing a relay from service.

b. Disconnect power from the relay.

c. Remove the relay from the rack or panel.

d. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 2. Remove the front panel from the relay.

Step 3. Disconnect the front-panel cable from the front panel.

Step 4. Disconnect the power cable, interface board cable(s), and input board analog cable from the main board.

Step 5. Pull out the drawout tray containing the main board. In some SEL-400 series relays, the main board is not in a drawout tray. In these cases, you will need to remove the top cover to access the battery.

Step 6. Locate the lithium battery.

The lithium battery is at the front of the main board.

Step 7. Remove the spent battery from beneath the clip of the battery holder.

Step 8. Replace the battery with an exact replacement.

Use a 3 V lithium coin cell, Ray-O-Vac No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 9. Reinstall the relay main board drawout tray.

Step 10. Reattach the power cable, interface board cable(s), and input board analog cable.

Step 11. Reconnect the front-panel cable to the front panel.

Step 12. Reattach the front panel.

Step 13. Set the relay date and time via the communications ports or front panel (see *Making Simple Settings Changes on page 3.15*).

Step 14. Follow your company's standard procedure to return the relay to service.

Power Supply Fuse Replacement

⚠**DANGER**
Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.

⚠**WARNING**
Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.

⚠**CAUTION**
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

You can replace a bad fuse in a relay power supply, or you can return the relay to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the relay.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORT** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 10. Remove the screw terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses, 200-addresses, and 300-addresses screw terminal connectors.

b. Pull straight back to remove.

Step 11. Remove the top chassis plate by unscrewing seven screws from the chassis.

Step 12. Pull out the drawout tray containing the main board.

Step 13. Pull out the drawout tray containing the I/O interface board(s).

Step 14. Locate the power supply. Fuse F1 is at the rear of the power supply circuit board (see *Figure 10.11*).

Step 15. Examine the power supply for blackened parts or other damage. If you can see obvious damage, reinstall all boards and contact SEL to arrange return of the relay for repair.

Step 16. Remove the spent fuse from the fuse clips.

Step 17. Replace the fuse with an exact replacement (see Section 2: Installation in the product-specific instruction manual for the proper fuse for your power supply).

Step 18. Reinstall the interface board.

Step 19. Reinstall the main board, and reconnect the power, the interface board, and the analog input board cables.

Step 20. Replace the chassis top on the relay and secure it with seven screws.

Step 21. Reconnect the cable removed in *Step 8* and reinstall the relay front-panel cover.

Step 22. Reattach the rear-panel connections.

Affix the screw terminal connectors to the appropriate 100-addresses, 200-addresses, and 300-addresses locations on the rear panel.

Step 23. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 24. Follow your company standard procedure to return the relay to service.

NOTE: Some versions of this relay will have the PS50 power supply. The fuse is located in the same location as the PS30, but it is rotated 90 degrees.

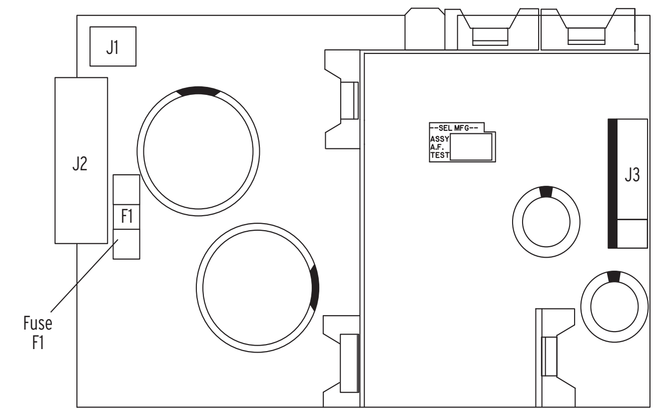

Figure 10.11 PS30 Power Supply Fuse Location

Installing Optional I/O Interface Boards

Perform the following steps to install SEL-400 series relay I/O interface boards.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Step 1. Follow your company standard to remove the relay from service. It will be necessary to remove power from the relay as part of this process.

Step 2. Disconnect power from the relay. Isolate any contact inputs or outputs that will be affected by the installation of the I/O interface board.

Step 3. Retain the **GND** connection, located to the right of the power supply terminals to the relay, and ground the equipment to an ESD mat, or other grounding point.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-terminal block connectors for the I/O board that is being installed. Two screws are used to retain each connector. Once these screws are loosened, pull the connector firmly to remove it from the rear of the relay. Note that these connectors are keyed to their mating connectors in the relay.

Figure 10.12 SEL-400 Series Relay Rear Panel

Step 6. Remove the front panel.

a. Unscrew the front cover of the relay.

b. Slowly pull the front cover off of the relay.

There will be a short ribbon cable between the front panel of the relay and the main board of the relay that will prevent the relay front panel from being pulled more than five inches from the relay. Do not let the relay front panel hang from this ribbon cable.

c. Remove the ribbon cable at the front panel by pushing the cable retention levers toward the back of the front panel, as shown in *Figure 10.13*.

If your front panel is equipped with auxiliary trip and close pushbuttons, remove the connectors to the pushbuttons connected at the front panel and the expansion I/O board.

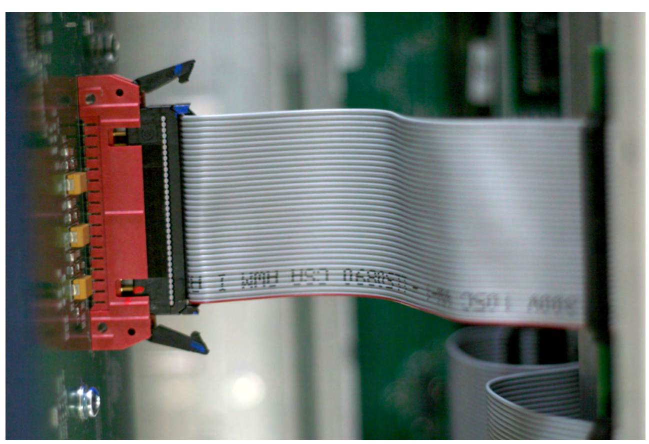

Figure 10.13 Front-Panel Ribbon Cable Connector With Clasps Open

Step 7. Remove the power supply, expansion I/O and calibration board ribbon cables from their connectors on the main board (see *Figure 10.14*).

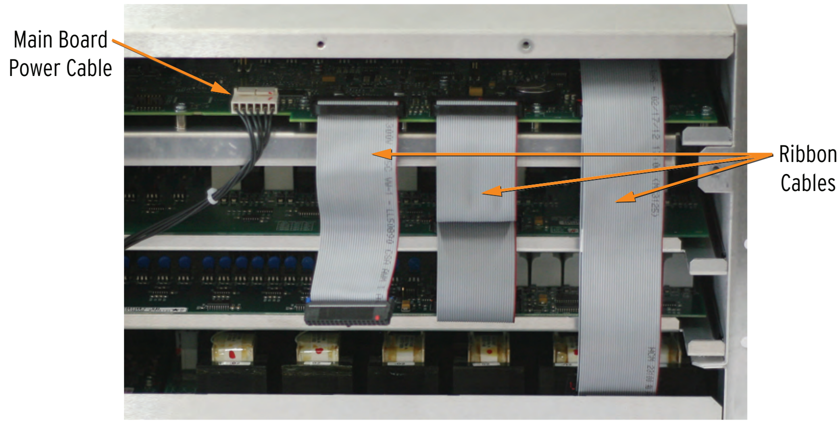

Figure 10.14 Main Board Cable Connections

Step 8. Remove the main board power cable (white connector) from the main board by lifting up the retaining tabs on top of the header and sliding the connector out.

Do not bend the retaining tabs any higher than is necessary to remove the connector as this could damage the tabs.

Step 9. Use the Jumper Configuration table shown in *Figure 10.15* to confirm that the jumper arrangement on the I/O board matches the correct jumper configuration for the interface board being installed. For example, the jumper configuration in *Figure 10.15 (a)* is for an interface board being installed at the 300 level (i.e., the jumpers are set to ON, OFF, ON, OFF).

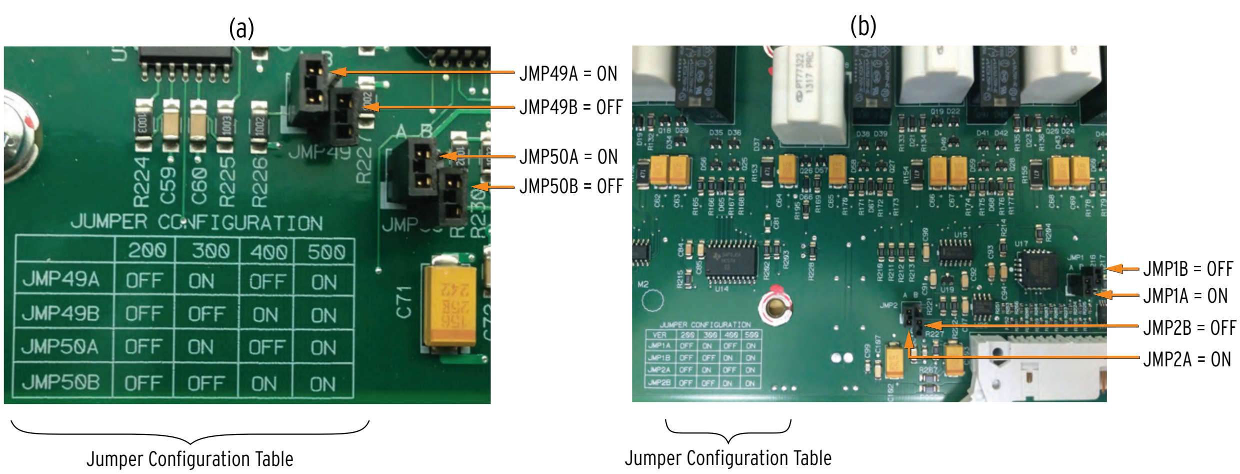

Figure 10.15 I/O Board Jumper Configuration

Step 10. Install the drawout tray with the I/O interface board.

a. Position the drawout tray edges into the left-side and right-side internally mounted slots.

b. Slide the I/O interface board into the relay by pushing the front edge of the board drawout tray.

c. Apply firm pressure to fully seat the I/O interface board.

If you encounter resistance, STOP and withdraw the board.

Inspect the drawout tray edge guide slots for damage.

If you see no damage, take all of the precautions outlined above and try again to insert the board.

Step 11. Confirm screw-terminal connector keying.

a. Inspect the screw-terminal connector receptacles on the rear of the I/O interface board.

Figure 10.16 shows the I/O board section without terminal blocks. The yellow dividers are the connector keying for each terminal block.

b. Refer to *Figure 10.17* for the corresponding key positions inside the receptacle.

Figure 10.16 Screw-Terminal Connector Receptacles

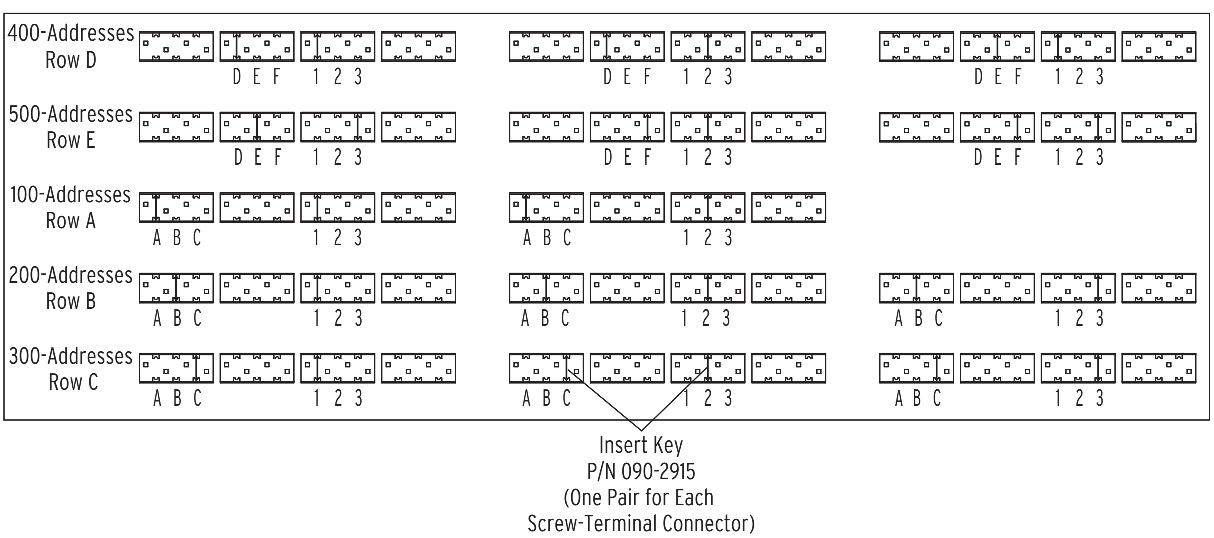

Figure 10.17 Screw-Terminal Connector Keying

c. If the keys inside the I/O interface board receptacles are not in the positions indicated in *Figure 10.17*, grasp the key edge with long-nosed pliers to remove the key and reinsert the key in the correct position.

d. Break the webs of the screw-terminal connectors in the position that matches the receptacle key, as shown in *Figure 10.18*.

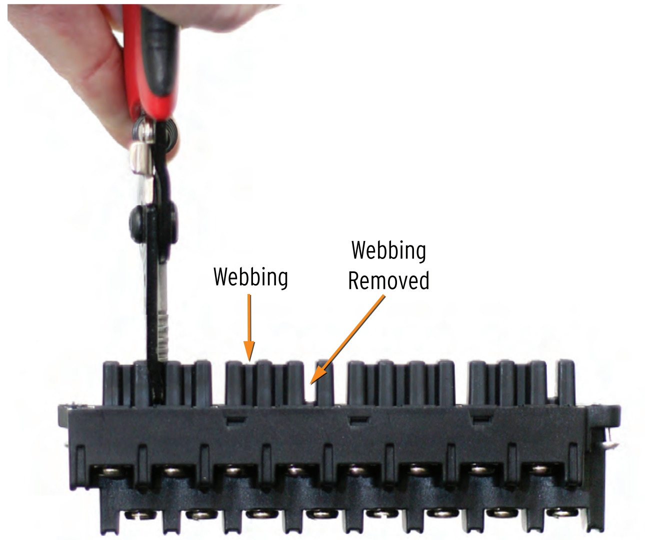

Figure 10.18 Screw-Terminal Connector With Webs

Step 12. Attach the screw-terminal connector.

a. Mount the screw-terminal connectors to the rear panel of the relay.

b. Tighten the screw-terminal connector mounting screws to between 7 in-lb and 12 in-lb (0.8 Nm to 1.4 Nm).

Step 13. Reconnect the power, the interface board, and the analog input board cables to the relay main board.

Step 14. Reconnect the cables removed in *Step 6–Step 8* and reinstall the relay front-panel cover.

Step 15. Apply power.

Step 16. Reconnect any serial cables that you removed from the communications ports in the disassembly process.

Step 17. Establish a terminal emulation session with the relay using QuickSet SEL-5030 Software or other terminal emulation program.

Step 18. Using the terminal emulation program, enter Access Level 2.

Step 19. From Access Level 2, issue the **STA** command, and answer **Y <Enter>** if prompted to accept the new hardware configuration. (Note: If the I/O board was replaced with exactly the same board, you will not be prompted to accept new hardware.)

Step 20. Inspect the relay targets to confirm that the relay reads the I/O interface board(s).

a. Verify the I/O interface board control inputs and outputs in the target listings by using a terminal or the QuickSet software.

b. Use a communications terminal to issue the following commands.

TAR IN*n*01 <Enter>

TAR OUT*n*01 <Enter>

n = 1–5 for boards in the 100–500 address slots

Step 21. Follow your company's standard procedure to return the relay to service.

Troubleshooting

Step 1. If the I/O board jumpers were not correctly configured in *Step 9* and *Step 10*, the front panel will display the error `RELAY DISABLED SETTINGS FAILED`. You will also receive a `SETTINGS FAILED` failure in the terminal emulation window following an **STA** command, as shown in *Figure 10.19*.

```
Level 2
=>>sta

Relay 1                                 Date: 01/10/2000   Time: 18:13:10.769
Station A                               Serial Number: 1130320464

FID=SEL-487B-1-R305-V0-Z007005-D20121221    CID=0XF3A0

Failures
  SETTINGS FAILED


Warnings
  No Warnings

SELogic Relay Programming Environment Errors
  No Errors

Relay Disabled
```

Figure 10.19 I/O Board Installation Error Message in the Terminal Window

Step 2. Disconnect power to the relay and return to *Step 8* to verify you have correctly configured the jumpers (*Step 9*). If the jumpers are not correct, repeat the I/O board installation instructions, beginning with *Step 9*.

Step 3. If the jumpers are correct, enter the CAL level.

a. Enter the **VEC D** command.

b. If you see the error `SETTINGS FAILURE in C n`

(*n* = 1–4), enter the **SET C *n*** command.

c. When prompted to do so, save the settings.

d. Return to Access Level 2, and enter the **STA** command to verify that the status is free of warnings.

If the problem persists, please contact your SEL representative.

TiDL Module Replacement

NOTE: The modules are hot pluggable; however, if a module is removed, the TiDL system will be disabled, the same as powering off the unit.

To replace a module in the SEL-2240 Axion, perform the following steps:

Step 1. De-energize any power source connected to the power coupler(s) in the Axion node.

Step 2. Loosen the chassis retaining screw at the top of the module.

Step 3. Tip the top of the module away from the chassis and lift it from the bottom lip.

Step 4. Install the new module, inserting the bottom lip first by using the notch on the module to help with alignment (see *Figure 10.20*). Then push in the top of the module to align with the chassis slot and tighten the retaining screw (see *Figure 10.21*).

Figure 10.20 Axion Notch Alignment

Figure 10.21 Axion Retaining Screw

Step 5. Make all necessary connections to the module.

Step 6. If in *Step 1* you chose to disconnect power, apply power to the Axion module and then skip to *Step 8*. Otherwise, proceed to *Step 7*.

Step 7. Cycle power to the SEL relay.

Step 8. When startup is complete, press and hold the **COMMISSION** button on the back of the relay for two seconds for the relay to verify the connected topology.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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SECTION 11

Time and Date Management

SEL-400 series relays can determine the time from a variety of sources, including IRIG-B, PTP (IEEE 1588), Simple Network Time Protocol (SNTP), DNP3, MIRRORED BITS, terminal **TIME** and **DATE** commands, and HMI settings. (Refer to the appropriate sections in the product-specific instruction manual to learn about using these various time sources.) Most of these sources provide only an approximate measure of time. For high-accuracy time synchronization, which is needed to support synchrophasors and to ease comparison of system-wide events, a high-accuracy time source must be provided, such as IRIG-B with C37.118 extensions or PTP with power system profile. This section focuses on issues related to high-accuracy timekeeping. The relay records power system events with very high accuracy when you provide high-accuracy clock input signals. Relays placed at key substations can give you information on power system operating conditions in real time.

NOTE: Not all SEL-400 series relays support synchrophasors.

Based on the high-accuracy time input, the relay calculates synchrophasors for currents and line voltages (for each phase and for positive-sequence), as specified in IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems. You can then perform detailed analysis and calculate load flow from the synchrophasors. See *Section 18: Synchrophasors* for more information about phasor measurement functions in the relay.

This section presents details on these measurements as well as suggestions for further application areas. The topics of this section are the following:

IRIG-B Timekeeping

The relay is capable of high-accuracy timekeeping when supplied with an IRIG-B signal. When the supplied clock signal is sufficiently accurate, the relay can act as a phasor measurement unit (PMU) and transmit synchrophasor data representative of the power system at fixed time periods to an external data processor. The relay can also record COMTRADE event report data using the high-accuracy time stamp.

The relay has two input connectors that accept IRIG-B demodulated time-code format: the IRIG-B pins of Serial Port 1, and the IRIG-B BNC connector. See *Section 2: Installation* in the product-specific instruction manual for more information on connecting these inputs.

NOTE: The SEL-2407 Satellite-Synchronized Clock meets both the relay accuracy and IEEE C37.118 requirements for a high-accuracy time source.

The IRIG-B inputs can be used for high-accuracy timekeeping purposes with as high as 1 ms accuracy with an appropriate time source. See *Table 11.1* for relay timekeeping mode details.

Table 11.1 Relay Timekeeping Modes

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)	PTP	HPTP
Best accuracy (condition)	Depends on last method of setting, or synchronization[a]	500 µs (when time-source jitter is less than 3 ms)	1 µs (when time-source jitter is less than 500 ns, and time-error is less than 1 µs)[b]	Determined by PTP master (Master clock sync and announce interval <= 4s)	1 µs (Master clock sync and announce interval <= 4 s, and TQUAL <1 µs)
IRIG-B connection required	None	BNC connector (preferred), or Serial Port 1	BNC connector (preferred), or Serial Port 1	PTP time source connected	PTP time source connected
Relay Word bits	TIRIG = 0 TSOK = 0 BNC_TIM = 0 SER _TIM = 0 BNC_OK = 0 SER_OK = 0	TIRIG = 1 TSOK = 0 BNC_TIM = 1 or SER_TIM = 1 BNC_OK = 0 SER_OK = 0	TIRIG = 1 TSOK = 1 BNC_TIM = 1 or SER_TIM = 1 BNC_OK = 1 or SER_OK = 1	TPTP = 1 TSOK = 0	TPTP = 1 TSOK = 1

[a] The internal clock in the relay can be synchronized via SNTP, DNP3, SEL-2030 Communications Processor, or MIRRORED BITS communications.

[b] The time source must include the IEEE C37.118 IRIG-B control bit assignments and the Global setting IRIGC must be set to C37.118 to provide the time-error estimate for the clock. In products that support line-current differential protection, the jitter requirement for HIRIG is 50 ns.

NOTE: If the time-code signal connected to the BNC connector degrades in quality, the relay will not switchover to the IRIG-B pins of Serial Port 1. The relay will only switch to Serial Port 1 if the signal on the BNC connector completely fails or the accuracy is better on Serial Port 1 than on the BNC input (e.g., the cable is unplugged).

Only one IRIG-B time source can be used by the relay, and the signal connected to the IRIG-B BNC connector takes priority over the Serial Port 1 IRIG-B pins. If a signal is detected on the IRIG-B BNC input, the IRIG-B pins of Serial Port 1 will be ignored, unless the Serial Port 1 IRIG-B has better quality than the BNC input.

The relay determines the suitability of the IRIG-B signal connected to the BNC connector for high-accuracy timekeeping by applying two tests:

➤ Measuring whether the jitter between positive-transitions (rising edges) of the clock signal is less than 500 ns.

➤ Decoding the time-error information contained in the IR IG-B control field and determining that analog quantity TQUAL is less than 10^{-6} seconds (1 µs).

If a valid source is detected on the BNC or serial port IRIG inputs, then BNC_TIM or SER_TIM will be set, respectively. Similarly, if a high-quality source is detected on the BNC or serial port IRIG inputs, then BNC_OK or SER_OK will be set, respectively.

PTP Timekeeping

In addition to IRIG-B, Precision Time Protocol (PTP), as specified in IEEE 1588-2008, can be used for high-accuracy timekeeping. The relay can only be synchronized by a grandmaster on the PTP timescale, not an arbitrary (ARB) timescale. With the ARB timescale, the epoch is set by an administrative procedure and can change at any time during normal operation. The PTP timescale uses the PTP epoch of January 1 1970 00:00:00 TAI (International Atomic Time), which corresponds to December 31 1969 23:59:51.999918 UTC (Coordinated Universal Time). Its unit of time is the SI second and accounts for leap seconds. As of June 2016, TAI is 36 seconds ahead of UTC.

The offset between TAI and UTC time is included in the PTP announce message, along with a flag that indicates whether or not the offset is valid. The relay will use the offset sent by the Grand Master (GM) clock to determine UTC time regardless of validity. Because of this, all SEL devices (and other slave devices that share this behavior) synchronized with the GM will retain relational accuracy with each other even if, in certain cases, the GM may be incorrect in relation to UTC.

The announce message may also include the current TAI to Local offset value (required in the C37.238 profile). In accordance with IEEE 1588-2008 16.3.3.4, this value must include the TAI to UTC offset to reflect local time at the node, or slave device. If the relay receives a TAI to Local offset value that does not include the TAI to UTC offset, it may incorrectly calculate UTC and Local time. Also, if the announce message does not include the TAI to Local offset value, the relay will use its configured Time and Date settings (UTCOFF, BEG_DST, and END_DST) to calculate local time. This is one reason that the relay Time and Date settings must match the settings in the GM clock, or devices that are synchronized may have issues with time alignment.

To use PTP, the relay part number must include the Ethernet card option that supports PTP and PTP must be enabled in Port 5 settings (EPTP = Y) and properly configured. The relay must be connected to a network containing an appropriate PTP master, and all intervening switches must be IEEE 1588 aware. For all SEL-400 series relays, PTP is only available on Ethernet Ports 5A and 5B. PTPPORT is an analog quantity that can be used to identify the active port. PTPPORT = 1 if Port A is the active port, PTPPORT = 2 if Port B is the active port, and PTPPORT = 0 if PTP is not synchronized. See *Precision Time Protocol (PTP) on page 15.15* for more information on configuring the relay and the Ethernet network for PTP.

To achieve basic synchronization to PTP, the master clock sync and announce interval must not exceed four seconds. The Relay Word bit PTP_TIM indicates that this basic level of synchronization has been achieved. If the master clock reports an accuracy of 1 µs or better and the network is not introducing excessive jitter in the time-synchronized messages, PTP_OK will be set indicating the presence of high-accuracy time synchronization. The analog quantity PTPSTEN can be used to indicate the state of the PTP Port as follows: 1 = Initializing, 2 = Faulty, 3 = Disabled, 4 = Listening, 8 = Uncalibrated, 9 = Slave.

Depending on the Port 5 configurations, the supported PTP profile may be restricted to C37.238 power profile. When PTP time synchronization is configured on the process bus ports (NETPORT = C or D), the only available PTP profile is C37.238. Refer to *Station Bus and Process Bus on page 17.19* for definitions of a process bus.

PTP Over PRP Networks

SEL-400 series relays support PTP time synchronization over a PRP network. When the relay operates in this network mode, the only available PTP profile is C37.238.

The SEL-400 series relays support PTP time synchronization over Parallel Redundancy Protocol (PRP) networks. In a PRP network, a dual attached node (DAN) receives a pair of duplicated packets. It processes the first frame and discards the duplicated frame based on the information in the redundancy controller trailer (RCT).

This method of using RCTs to distinguish packets does not apply to PTP messages. PTP messages that transverse through two distinct networks suffer a different amount of delays. *Figure 11.1* shows that path delays via LAN A and LAN B are different. These delays include link delays and residence time. PTP-capable Ethernet switches in these LANs should update PTP messages with the actual residence time and request/reply to path delay messages. It should not alter PTP messages by appending RCTs. The dual attached slave clock receives two different sets of PTP messages, as shown in *Figure 11.1*. The two ports independently determine its port state.

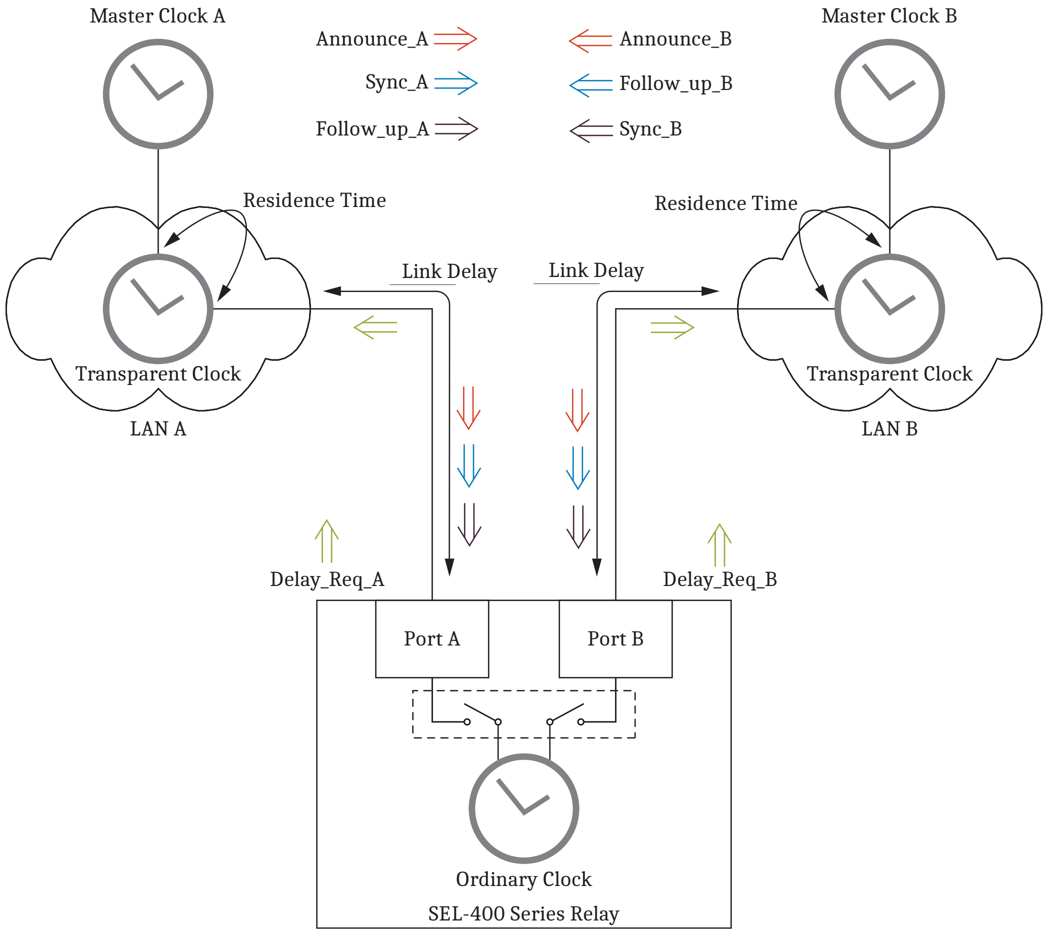

Figure 11.1 PTP Time Synchronization Over a PRP Network

The relay can only synchronize to a PTP clock. If two PTP masters are available. SEL-400 series relays first use the Best Master Clock Algorithm (BMCA) to select the best master. If the locally derived offsets between the relay and the BMCA- selected master is less or equal to 1 µs, the relay synchronizes itself with the BMCA-selected master time information. Otherwise, the relay uses the time information from the other master if this master has locally derived offsets less than or equal to 1 µs. If not, the relay continues using the BMCA-selected master. SEL-400 series relays use the analog quantity PTPPORT to indicate the port to which the relay is synchronized. If PTPPORT = 1, the relay is synchronized via Ethernet Port 5A. If PTPPORT = 2, the relay is synchronized via Ethernet Port 5B. The ASCII command **COM PTP** also displays the port status in *COM PTP on page 14.14*. If a port is selected to synchronize the relay, the port status is ACTIVE; otherwise, it is PASSIVE.

Time Source Selection

IRIG-B via BNC connection, IRIG-B via Serial Port 1, and PTP can all be connected to the relay. Each of these can provide a high-quality time value. The relay selects between these sources using the following priority scheme:

1. IRIG-B BNC high quality (BNC_OK = 1)
2. IRIG-B serial port high quality (SER_OK = 1)

3. PTP high quality (PTP_OK = 1)
4. PTP nominal quality (PTP_TIM = 1)
5. IRIG-B BNC nominal quality (BNC_TIM = 1)
6. IRIG-B serial port nominal quality (SER_TIM = 1)

The **TIME** command indicates what source is being used. This is also available in the analog quantity CUR_SRC as shown in *Table 11.2*.

Table 11.2 CUR_SRC Encoding

Source	CUR_SRC value
BNC IRIG-B	1
Serial Port IRIG-B	2
PTP	4
None of the above	8

If IRIG-B and PTP are not available, then the time can be set via any low-priority time source: SNTP, DNP3, **TIME** and **DATE** commands, front-panel set date/time, and extended MIRRORED BITS.

Time Quality Indications

Analog Quantities and Relay Word Bits

You can check the status of timekeeping by checking the relevant analog quantities or relay word bits. Once a time source is connected, wait at least 20 seconds to allow for a solid synchronization to take place.

If you are using a time source that provides time-quality information (IRIG-B with C37.118 or PTP), then the presently reported time quality is available via the TQUAL analog quantity and the TQUAL1, TQUAL2, TQUAL4, and TQUAL8 Relay Word bits. *Table 11.3* and *Table 11.4* show how these are encoded for IRIG and the two supported PTP Profiles.

Table 11.3 Time Quality Encoding (PTP Default Profile or IRIG)

PTP v2 Default Profile Or IRIG (PTPPRO = Default)					
Master Clock Accuracy (ns)	TQUAL8	TQUAL4	TQUAL2	TQUAL1	TQUAL (seconds)
Clock failure, time not reliable	1	1	1	1	1038
10 seconds	1	0	1	1	10
1 second	1	0	1	0	1
100 milliseconds	1	0	0	1	0.1
10 milliseconds	1	0	0	0	0.01
1 millisecond	0	1	1	1	0.001
100 microseconds	0	1	1	0	0.0001
10 microseconds	0	1	0	1	0.00001
1 microsecond	0	1	0	0	0.000001
100 nanoseconds	0	0	1	1	0.0000001
10 nanoseconds[a]	0	0	1	0	0.00000001
1 nanosecond[a]	0	0	0	1	0.000000001

[a] This does not apply to PTP default Profile.

Table 11.4 Time Quality Encoding (PTP Power Profile)

PTP v2 Power Profile (PTPPRO = C37.238)					
Time_inaccuracy = Grandmaster timeinaccuracy + Network timeinaccuracy (ns)	TQUAL8	TQUAL4	TQUAL2	TQUAL1	TQUAL (seconds)
Grandmaster timeinaccuracy = 4294967295 or Network timeinaccuracy = 4294967295	1	1	1	1	Grandmaster timeinaccuracy + Network timeinaccuracy
1,000,000,000 ≤ time_inaccuracy < 10,000,000,000	1	0	1	1	
100,000,000 ≤ time_inaccuracy < 1,000,000,000	1	0	1	0	
10,000,000 ≤ time_inaccuracy < 100,000,000	1	0	0	1	
1,000,000 ≤ time_inaccuracy < 10,000,000	1	0	0	0	
100,000 ≤ time_inaccuracy < 1,000,000	0	1	1	1	
10,000 ≤ time_inaccuracy < 100,000	0	1	1	0	
1,000 ≤ time_inaccuracy < 10,000	0	1	0	1	
100 ≤ time_inaccuracy < 1,000	0	1	0	0	
10 ≤ time_inaccuracy < 100	0	0	1	1	
1 ≤ time_inaccuracy < 10	0	0	1	0	
time_inaccuracy = 0	0	0	0	0	

PTP supports two power profiles and is set by the PORT 5 setting PTPPRO. The two profiles are DEFAULT and C37.238. PTP reports the time quality through TQUAL1, TQUAL2, TQUAL4, and TQUAL8 Relay Word bits, which are the same bits used if IRIG-B is the time source. If PTPPRO = DEFAULT, the time quality is reported based only on the accuracy of the master clock. If PTPPRO = C37.238, the time quality is reported based on the accuracy of the master clock (Grandmaster timeinaccuracy) plus the inaccuracy of the network (Network timeinaccuracy). For this profile, if either Grandmaster timeinaccuracy or Network timeinaccuracy is the maximum value, the relay will set all TQUAL bits to 1.

NOTE: If the Global setting IRIGC is changed from NONE to C37.118, the relay asserts TGLOBAL before completely assessing the time-synchronization state. The assessment completes and TGLOBAL has the correct value approximately 5 seconds after you make such a settings change.

If the relay is synchronized to an IRIG-B or PTP time source, the TSYNC bit will be set. If the quality of this synchronization is 1 µs or better, then TSOK is set, indicating this bit has sufficient accuracy for synchrophasors. TGLOBAL will assert if a high-accuracy source is being used and the source indicates it is providing 1 µs or better accuracy, and the Global setting IRIGC = C37.118 for BNC IRIG. If the relay is synchronized to IRIG-B without the quality extensions indicated by the Global setting IRIGC, or PTP without the grandmaster clock sending announce and synchronization messages at least every four seconds, TLOCAL bit will be asserted.

As an example of checking IRIG status, use the command **TAR TIRIG** to view the relevant Relay Word bits, as shown in *Figure 11.2*. Only the state of the TIRIG and TSOK Relay Word bits are discussed in the troubleshooting steps below. The other Relay Word bits of interest to this discussion are TUPDH, which indicates that the relay internal clock is presently being updated by the HIRIG source, TSYNCA, which acts as an alarm bit that asserts when the relay is not synchronized to either an internal or an external source. TSYNCA will only assert briefly when the HIRIG time source is connected or disconnected.

```
=>TAR TIRIG <Enter>

*       *       TIRIG   TUPDH   TSYNCA  TSOK    PMDOK   FREQOK
0       0       1       1       0       1       1       0
=>
```

Figure 11.2 Confirming the High-Accuracy Timekeeping Relay Word Bits

The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the high-accuracy IRIG timekeeping mode (HIRIG).

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG time-keeping mode. Following is a list of possible reasons for not entering HIRIG mode:

- ➤ The IRIG-B clock does not use the IEEE C37.118 control bit assignments, or the IRIG-B signal is not of sufficient accuracy.
- ➤ The termination resistor, required by some IRIG clocks, is not installed.
- ➤ The time-source clock is reporting that its time error is greater than 1 µs.

If neither TSOK nor TIRIG is asserted, the relay is not in an IRIG time-source mode. Following is a list of possible reasons for not entering IRIG mode:

- ➤ The IRIG-B clock signal is not of sufficient accuracy or is improperly configured.
- ➤ The termination resistor, required by some IRIG clocks, is not installed.

NOTE: At startup, TPTP can assert as fast as 1.5 seconds after PTP_TIM asserts.

TBNC asserts when BNC IRIG is used to update the relay master time. Likewise, TSER asserts when serial IRIG is selected and TPTP asserts when PTP is the active source updating the relay master time. At any given time, only one of these three bits can equal logical 1.

Global Time Source vs Local Time Source

An SEL-400 series relay indicates that it is synchronized with either a Global or local time source according to the logic as shown in *Figure 11.3*. When CUR_SRC is IRIG or PTP and TSOK is asserted, the relay determines the status of TGLOBAL or TLOCAL following the logic diagram in *Figure 11.3*. TGLOBAL asserts when the relay is synchronized to high-accuracy IRIG-B (accuracy ≤ 1 us and IRIGC = C37.118) or PTP (accuracy ≤ 1 us, master_clock_class = 6). A holdover timer keeps TGLOBAL asserted for five seconds if the relay loses its global time source after being synchronized. TLOCAL asserts when the relay is synchronized to high-accuracy IRIG-B (accuracy ≤ 1 us and IRIGC = None) or PTP (accuracy ≤ 1 us) and TGLOBAL is not asserted.

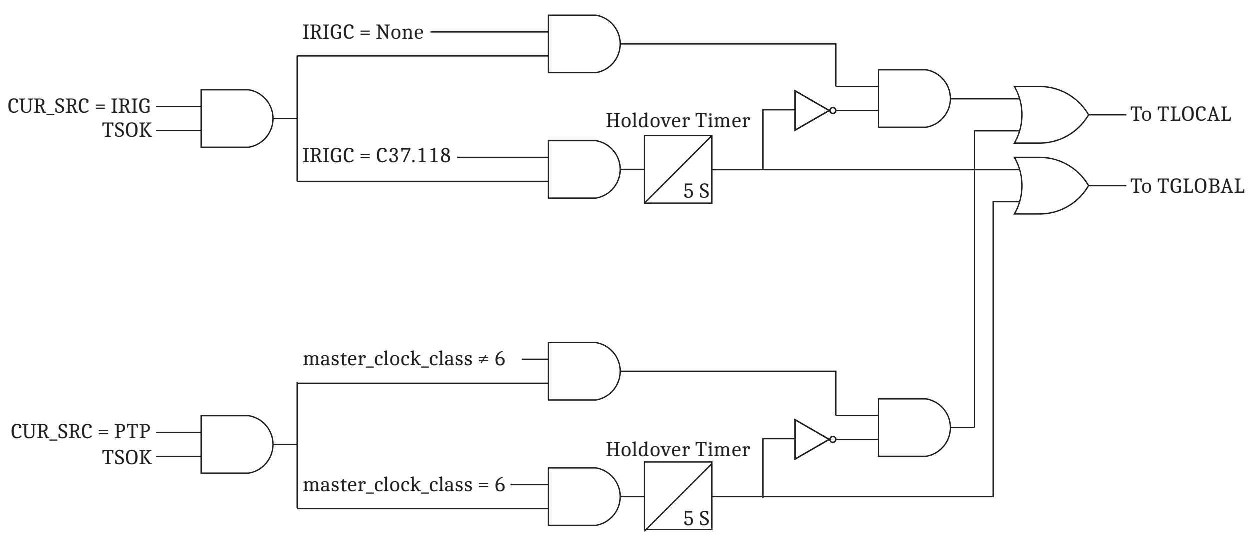

Figure 11.3 TLOCAL and TGLOBAL Logic

TIME Q Command

The **TIM Q** command provides details about relay timekeeping (see *Table 11.3* and *Table 11.4*). The internal clock of the relay is initially calibrated at the SEL factory. An external IRIG or PTP source is required to eliminate clock drift. The `Time Source` field provides the present high-accuracy timing input source; entries for this line are HIRIG, HPTP, or OTHER. The `Last Update Source` reports the source from which the relay referenced the last time value measurement. Entries for this line can be high-priority or low-priority sources. *Table 11.5* lists the possible `Last Update Source` values for the relay.

```
=>>TIM Q <Enter>

Relay 1                                    Date: 02/24/2016  Time: 15:08:41.468
Station A                                  Serial Number: 0000000000

Time Source: HPTP
Last Update Source: HPTP
Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Time Traceable : TRUE
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0

Time Mark Period:  1000.000061 ms

Internal Clock Period:  19.999935 ns

=>>
```

Figure 11.4 Sample TIM Q Command Response

Table 11.5 Date/Time Last Update Sources

Time Input Source Mode	Priority	Time Source
HIRIG	High	Time/date from the high-accuracy IRIG-B input
SNTP	Low	Simple Network Time Protocol
IRIG	High	Time/date from the IRIG-B format time base signal
HPTP	High	Time/date from a high-accuracy PTP source
PTP	High	Time/date from a PTP source
DNP	Low	Time/date from the DNP3 communications port
MIRRORED BITS	Low	Time/date from the Mirrored Bit port
SNTP	Low	Time/date from SNTP server
ASCII TIME	Low	Time from the relay serial ports
ASCII DATE	Low	Date from the relay serial ports
NONV CLK	Low	Time/date from the nonvolatile memory clock
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen

The `Time Mark Period` value indicates the instantaneous period in which the relay measures the time-source inputs. The relay displays the time mark periods showing the present time precision derived from the applied time-source signals.

The **TIME Q** command is also helpful for troubleshooting IRIG and PTP problems. If the `Time Mark Period` value changes significantly between successive **TIME Q** commands, there may be too much noise in the time signal for the relay timekeeping function.

Adaptive Internal Clock Period Adjustment

The Internal Clock Period, as shown in the **TIME Q** command response in *Figure 11.4*, is the internal relay timekeeping period. The relay adjusts this master internal clock when you apply HIRIG or HPTP mode timekeeping, adapting the internal relay clock for your installation temperature conditions. If you lose the timing lock, the relay internal clock operates at this precisely adapted clock period until HIRIG or HPTP mode is restored. Time tags for event reports during a loss of high-accuracy timekeeping remain very accurate. Lower-accuracy time sources do not adaptively adjust the internal relay clock period.

COM PTP Command

The **COM PTP** command provides a report of the PTP data sets maintained by the device as well as statistics for the measured time offsets with the parent (master) clock. The PTP data sets contain information about the state, identity, and configuration of the local, parent, and grandmaster clocks in addition to properties of the time being distributed by the grandmaster clock. See *COM PTP on page 14.14* for more information on this command.

Daylight-Saving Time (DST)

The status of DST time can be determined by one of three possible high-priority sources (BNC, SER, or PTP). The daylight-saving time pending Relay Word bit (DSTP) is valid only when IRIG is the active source. When PTP is selected, it sets the DSTP bit to zero at all times. If no high-priority source with daylight-saving time information is available, the DST bit is determined based on the BEG_DST and END_DST Global settings.

When using PTP as the Time Synchronization source, the PTP master may not provide valid DST information as the relay powers up. To ensure the relay powers up with the correct time when synced to a PTP source, you must ensure that the relay Time and Date Management settings and the PTP master configuration are in agreement.

Time-Synchronized Events

Time-Synchronized Triggers

You can program the relay to perform data captures at *specific* times. Relays that are time-locked using HIRIG mode provide high-accuracy time-synchronized data captures. When you use this method on multiple relays, the actual trigger times can differ by as much as 5 ms, but the information in the binary COMTRADE file outputs from each relay is time-stamped at very high accuracy. Do not assume that the relay triggers are locked with high accuracy; rather, compare corresponding time-stamped data points from each COMTRADE file.

Time Triggering the Relay

NOTE: The **MET PM *time*** command can be used to capture synchrophasor data at a specific time if synchrophasors are enabled with Global setting EPMU := Y.

Perform the following steps to trigger an event data capture in the relay at a specific time. These settings cause the relay to initiate a data capture at 12:00:30 p.m. Use other SELOGIC control equations in a similar manner to trigger relay event recordings.

Step 1. Start ACSELERATOR QuickSet SEL-5030 Software and establish communications with the relay.

Step 2. Click **Settings > Read** to read the present configuration in the relay.

The relay sends all configuration and settings data to QuickSet.

Step 3. Click the **+** mark next to the **Group** you want to program on the Settings tree view.

This example uses **Group 1**.

You will see the **Protection Free-Form Logic Settings** dialog box.

Step 4. Enter time trigger settings:

a. Click the ... button beside the first unused Protection SELOGIC control equation row entry field to start the **Expression Builder**.

b. On the left side of the SELOGIC control equation, select **Math Variables** and double-click **PMV64**.

c. On the right side of the equation, select **Analog Quantities > Time and Date Management**.

d. Double-click **THR** (Time in Hours).

e. Use the **#** character to add a comment to the line.

f. When finished, click **Accept**.

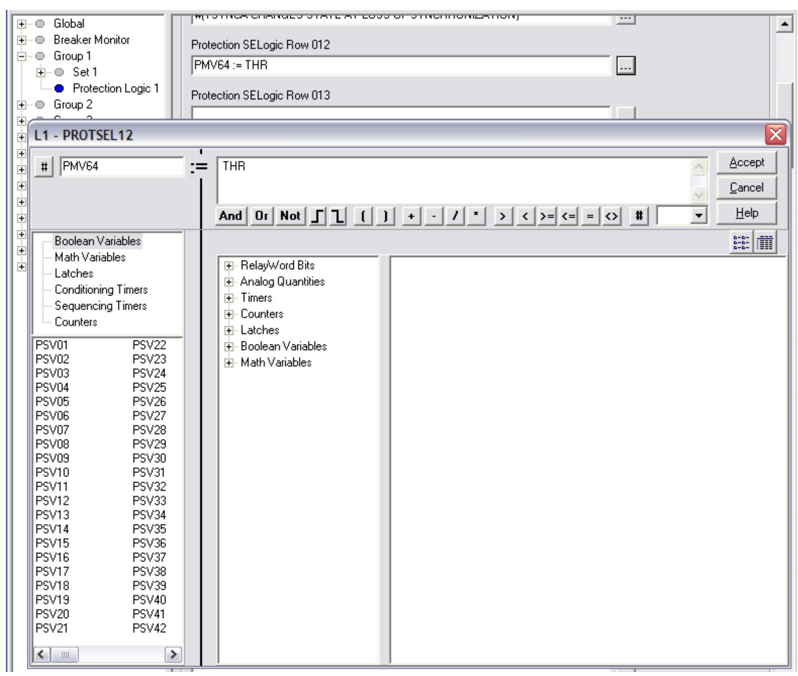

Figure 11.5 Setting PMV64 With the Expression Builder Dialog Box

Step 5. In a similar manner, build a freeform SELOGIC control equation program in **Protection Logic** that causes protection freeform SELOGIC control equation variable PSV02 to assert to logical 1 at 12:00:30.005 p.m. Use the following expressions:

NOTE: In this example, the event report trigger will occur between 12:30:00.002 and 12:30:00.005 because of the method of relay protection logic processing.

PMV64 := THR # Clock hours

PMV63 := TMIN # Clock minutes

PMV62 := TSEC # Clock seconds

PSV02 := (PMV64=12) AND (PMV63=00) AND (PMV62=30) # Set PSV02 at 12:00:30

Step 6. Select settings.

a. Click the **+** mark next to **Relay Configuration**.

b. Click the **Trip Logic** and **ER Trigger** branch.

You will see the **Trip Logic** and **ER Trigger Settings** dialog box.

Step 7. Click in the **ER Event Report Trigger Equation** (SELOGIC) text box and add **OR R_TRIG PSV02** to the end of elements already in this SELOGIC control equation.

Step 8. Click **File > Save** to save the new settings in QuickSet.

NOTE: You should be careful to remove this event report trigger once you have completed your testing. Otherwise, the relay will continue to trigger new events every day at the programmed time.

Step 9. Upload the new settings to the relay:

a. Click **File > Send**.

QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Group 1** (or the settings group that you are programming).

c. Click **OK**.

If you see no error message, the new settings are loaded in the relay.

COMTRADE File Information

Retrieve the COMTRADE files for the time-triggered data captures from each relay with the **FILE READ** command.

Parse the binary COMTRADE data for the power system currents and voltages you need to calculate system quantities.

Fault Analysis

Use the relay measurement and communications capabilities to obtain precise simultaneous measurements from the power system at different locations. Combining system measurements from a number of key substations gives you a snapshot picture of the phasor relationships in the power system at a particular time. You can perform extensive fault analysis by evaluating the simultaneous measurements gathered at a central computer or data server.

Install at least two relays in the power system to implement dynamic phasor determination. *Figure 11.6* shows an example of a 230 kV overhead transmission line with a relay at each terminal. Connect GPS clocks (such as the SEL-2407) at each substation to provide high-accuracy time-signal inputs for each relay.

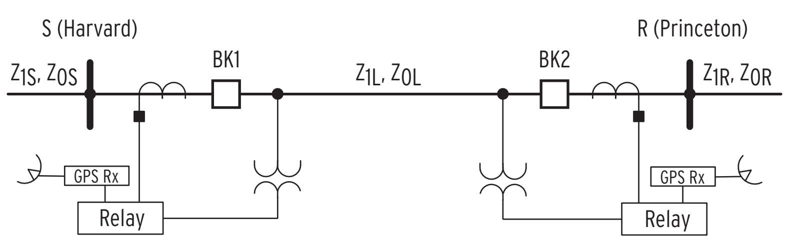

Figure 11.6 230 kV Transmission Line System

With synchronized and time-stamped binary COMTRADE data, you can develop automated computer algorithms for comparing these data from different locations in the power system.

In particular, you can use fault data extracted from two relays. Use third-party software to filter the binary COMTRADE data so that the signals are composed of fundamental quantities only (50 Hz or 60 Hz). You can also use third-party software to convert the binary COMTRADE data to ASCII COMTRADE files. Use the Phasor Diagram in the SEL-5601 SYNCHROWAVE Event to select the appropriate prefault and post-fault quantities.

Power Flow Analysis

Use SEL-400 series relays to develop instantaneous power flow data. Obtain the voltage and current phasors from different power system buses at the same instant and use these measurements to determine power flow at that instant. Use the synchronized phasor measurement capabilities of the relay and the **METER PM** command or a Synchrophasor Protocol to collect synchronized voltage and current data. Use this information to confirm your power flow models.

For example, consider four SEL-421 Relays installed in the power system as shown in *Figure 11.7*. Substations S and R provide generation for the load at Substation T.

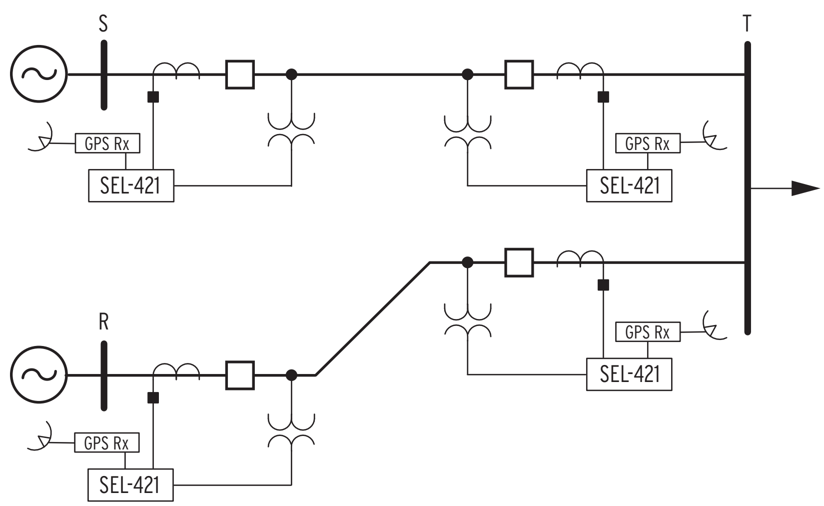

Figure 11.7 500 kV Three-Bus Power System

Table 11.8 lists the voltage and current measured by the four SEL-421 Relays at one particular time.

Table 11.6 SEL-421 Voltage and Current Measurement (Sheet 1 of 2)

Voltage		Current	
SEL-421 at Substation S			
V_{AS}	288.675 kV ∠0°	I_{AS}	238.995 A ∠41.9°
V_{BS}	288.675 kV ∠240°	I_{BS}	238.995 A ∠–78.1°
V_{CS}	288.675 kV ∠120°	I_{CS}	238.995 A ∠161.9°
SEL-421 at Substation R			
V_{AR}	303.109 kV ∠–0.2°	I_{AR}	234.036 A ∠–44.2°
V_{BR}	303.109 kV ∠239.8°	I_{BR}	234.036 A ∠195.8°
V_{CR}	303.109 kV ∠119.8°	I_{CR}	234.036 A ∠75.8°

Table 11.6 SEL-421 Voltage and Current Measurement (Sheet 2 of 2)

Voltage		Current	
SEL-421 at Substation T Looking Toward Substation S			
V_{AT-S}	295.603 kV ∠–1.6°	I_{AT-S}	238.995 A ∠–138.1°
V_{BT-S}	295.603 kV ∠238.4°	I_{BT-S}	238.995 A ∠101.9°
V_{CT-S}	295.603 kV ∠118.4°	I_{CT-S}	238.995 A ∠–18.1°
SEL-421 at Substation T Looking Toward Substation R			
V_{AT-R}	295.603 kV ∠–1.6°	I_{AT-R}	234.036 A ∠135.8°
V_{BT-R}	295.603 kV ∠238.4°	I_{BT-R}	234.036 A ∠15.8°
V_{CT-R}	295.603 kV ∠118.4°	I_{CT-R}	234.036 A ∠–104.2°

Use *Equation 11.1* to calculate the generation supplied from Substation S and Substation R, plus the load at Substation T.

$$\begin{aligned} S_{3\phi} &= P_{3\phi} + jQ_{3\phi} \\ &= \sqrt{3} \bullet V_{pp} \bullet I^*_L \\ &= 3 \bullet V_p \bullet I^*_L \end{aligned}$$

Equation 11.1

where:

$S_{3\phi}$ = Three-phase complex power (MVA)
$P_{3\phi}$ = Three-phase real power (MW)
$Q_{3\phi}$ = Three-phase imaginary power (MVAR)
V_{pp} = Phase-to-phase voltage
V_p = Phase-to-neutral voltage
I^*_L = Complex conjugate of the line current

The complex power generation supplied by Substation S is:

$$\begin{aligned} S_S &= (3 \bullet 288.675 \text{ kV}\angle 0°) \bullet (238.995 \text{ A}\angle{-41.9°}) \\ &= 154.1 \text{ MW} - j138.2 \text{ MVAR} \end{aligned}$$

The complex power generation supplied by Substation R is:

$$\begin{aligned} S_R &= (3 \bullet 303.109 \text{ kV}\angle{-0.2°}) \bullet (234.036 \text{ A}\angle 44.2°) \\ &= 152.6 \text{ MW} + j148.3 \text{ MVAR} \end{aligned}$$

The load at Substation T supplied by Substation S is:

$$\begin{aligned} S_{T-S} &= (3 \bullet 295.603 \text{ kV}\angle{-1.6°}) \bullet (238.995 \text{ A}\angle 138.1°) \\ &= -153.7 \text{ MW} + j145.9 \text{ MVAR} \end{aligned}$$

The load at Substation T supplied by Substation R is:

$$\begin{aligned} S_{T-R} &= (3 \bullet 295.603 \text{ kV}\angle{-1.6°}) \bullet (234.036 \text{ A}\angle{-135.8°}) \\ &= -152.8 \text{ MW} - j140.5 \text{ MVAR} \end{aligned}$$

The total load at Substation T is:

$$\begin{aligned} S_T &= S_{T-S} + S_{T-R} \\ &= -306.5 \text{ MW} + j5.4 \text{ MVAR} \end{aligned}$$

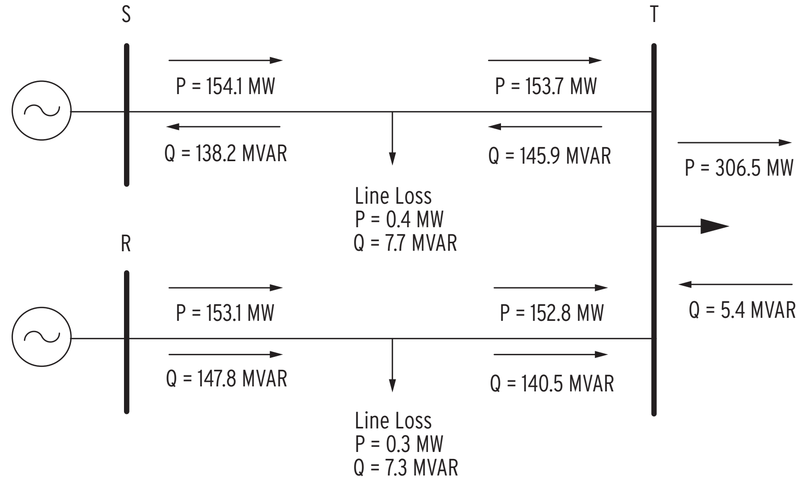

Figure 11.8 Power Flow Solution

Use the power flow solution to verify the instantaneous positive-sequence impedances of your system transmission lines.

State Estimation Verification

Electric utility control centers have used state estimation to monitor the state of the power system for the past 20 years. The state estimator calculates the state of the power system using measurements such as complex power, voltage magnitudes, and current magnitudes received from different substations. State estimation uses an iterative, nonlinear estimation technique. The state of the power system is the set of all positive-sequence voltage phasors in the network. Typically, several seconds or minutes elapse from the time of the first measurement to the time of the first estimation. Therefore, state estimation is a steady-state representation of the power system.

Consider using precise simultaneous positive-sequence voltage measurements from the power system to verify your state estimation model. Take time-synchronized high-resolution positive-sequence voltage measurements at all substations. Send the relay synchrophasor messages to a central database to determine the power system state.

Power system contingency analysis models rely on state-estimation techniques, and may have inaccuracies caused by incorrect present-state information, or errors in system characteristics, such as incorrect line and source impedance estimates. The simultaneous event-report triggering technique described earlier in this section can be used to verify present models.

NOTE: Not all SEL-400 series relays support synchrophasors.

With SEL-400 series relays acting as phasor measurement units (PMUs) installed in several substations, synchrophasor measurements can be transmitted to a central processor in near-real time, providing very accurate snapshots of the power system. This type of data processing system provides system-state measurements that are a few seconds old, rather than state estimates that may be several minutes old. In addition, the synchrophasor results are real measurements, rather than estimates.

See *Section 18: Synchrophasors* for information on the PMU settings and the communications protocols available for synchrophasor data collection.

SECTION 12

Settings

This section contains tables of relay settings that are common to most SEL-400 series relays. See the product-specific instruction manuals for details of all settings available in the relay.

The relay hides some settings based upon other settings. If you set an enable setting to OFF, for example, the relay hides all settings associated with that enable setting. This section does not explain rules for hiding settings; these rules are discussed in *Section 6: Protection Application Examples* in the product-specific instruction manuals, where appropriate.

⚠WARNING
Isolate the relay trip circuits while changing settings. When changing settings for multiple classes, it is possible to be in an intermediate state that will cause an unexpected trip.

The settings prompts in this section are similar to the ASCII terminal and ACSELERATOR QuickSet SEL-5030 software prompts. The prompts in this section are unabbreviated and show all possible setting options.

This section describes how settings are organized, explains the concept of settings groups, and then describes some common relay settings:

Settings Structure

The settings structure assigns each relay setting to a specific location based on the setting type. A top-down organization allocates relay settings into these layers:

➤ Class
➤ Instance
➤ Category
➤ Setting

Examine *Figure 12.1* to understand the settings structure in a typical SEL-400 series relay. The top layer of the settings structure contains classes and instances. Class is the primary sort level; all classes have at least one instance, and some classes have multiple instances. Typical settings classes and related instances are listed in *Table 12.1*.

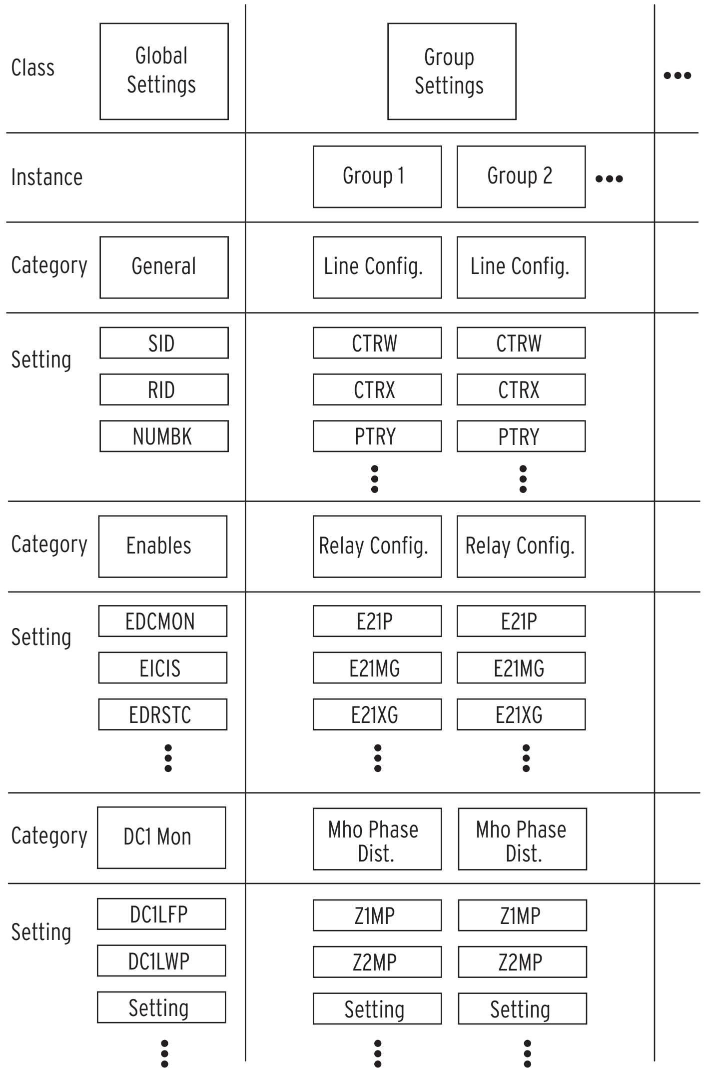

Figure 12.1 Typical Relay Settings Structure Overview

Table 12.1 Typical Settings Classes and Instances (Sheet 1 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Global	Relay-wide applications settings	Global	SET G	P, A, O, 2	
Group	Individual scheme settings	Group 1 • • • Group 6	Group 1 settings • • • Group 6 settings	SET 1, SET S 1 • • • SET 6, SET S 6	P, 2
Breaker Monitor	Circuit breaker monitoring	Breaker Monitor		SET M	P, 2
Bay Control	Bay Control Settings	1		SET B 1	P, A, O, 2

Table 12.1 Typical Settings Classes and Instances (Sheet 2 of 2)

Class	Description	Instance	Description	ASCII Command	Access Level
Port	Communications port settings	PORT F PORT 1 • • • PORT 3 PORT 5	Front-panel port PORT 1 settings • • • PORT 3 settings Ethernet card settings	SET P F SET P 1 • • • SET P 3 SET P 5	P, A, O, 2
Report	Event report and SER settings	Report		SET R	P, A, O, 2
Front Panel	Front-panel HMI settings	Front Panel		SET F	P, A, O, 2
Protection SELOGIC control equations	Protection-related SELOGIC control equations	Group 1 • • • Group 6	Group 1 protection SELOGIC control equations • • • Group 6 protection SELOGIC control equations	SET L 1 • • • SET L 6	P, 2
Automation SELOGIC control equations	Automation-related SELOGIC control equations	Block 1 • • • Block 10	Block 1 automation SELOGIC control equations • • • Block 10 automation SELOGIC control equations	SET A 1 • • • SET A 10	A, 2
DNP3	Distributed Network Protocol data remapping	Map1 • • • Map 5		SET D 1 • • • SET D 5	P, A, O, 2
Output SELOGIC control equations	Relay control output settings and MIRRORED BITS communications transmit equations	Output		SET O	O, 2
Alias	Set aliases	Analog or digital quantities		SET T	P, A, O, 2
Notes	Freeform programming to leave notes in the relay	Notes	100 lines	SET N	P, A, O, 2

Note that some settings classes have only one instance and you do not specify the instance designator when accessing these classes. An example is the Global settings class. You can view or modify Global settings with a communications terminal by entering **SET G** as shown in the ASCII Command column of *Table 12.1*. The relay presents the Global settings categories at the **SET G** command; no instance numbers follow **SET G**. Conversely, the Port settings command has five instances (PORT F, PORT 1, PORT 2, PORT 3, and PORT 5). To access the PORT 1 settings, type **SET P 1 <Enter>**. If you do not specify which port to set, the relay defaults to the active port (the port you are presently using).

The Group settings can have the optional one-letter acronym S attached to the command; you can enter SET 1 or SET S 1 for Group 1 settings, SET 2 or SET S 2 for Group 2 settings, etc. If you do not specify which group to set, the relay defaults to the present active group. If Group 6 is the active group, and you type **SET <Enter>**, for example, you will see the settings prompts for the Group 6 settings.

Multiple Setting Groups

SEL-400 series relays have six independent setting groups. Each setting group has complete relay settings and protection SELOGIC settings. The active setting group can be:

- Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page 14.31*.
- Shown or selected from the front-panel LCD with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item as described in *Figure 4.31 on page 4.28*.
- Selected with SELOGIC control equation settings SS1 through SS6. Settings SS1 through SS6 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.
- Shown with DNP3 Objects 20 and 22 and selected with Objects 40 and 41.

Setting Groups: Application Ideas

Setting groups can be used for such applications as:

- Environmental conditions such as winter storms, periods of high summer heat, etc.
- Hot-line tag that disables closing and sensitizes protection
- Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 indicate the active setting group, as shown in *Table 12.2*.

Table 12.2 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
CHSG	Indication that a group switch timer is operating or a group switch change is underway
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

The Global settings class contains the SELOGIC control equation settings SS1 through SS6, as shown in *Table 12.3*.

NOTE: The settings group switching settings are checked once per cycle. When setting TGR := 0, in order for a transient assertion to be recognized, it should be conditioned to remain asserted for at least 1 cycle.

Table 12.3 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS6

Setting	Definition
SS1	Go to (or remain in) setting Group 1
SS2	Go to (or remain in) setting Group 2
SS3	Go to (or remain in) setting Group 3
SS4	Go to (or remain in) setting Group 4
SS5	Go to (or remain in) setting Group 5
SS6	Go to (or remain in) setting Group 6

The operation of these settings is explained with the following example.

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR (Global settings):

TGR	Group Change Delay Setting	(settable from 0 to 54000 cycles)

NOTE: The CHSG Relay Word bit does not operate for settings changes initiated by the serial port or front panel methods.

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group. Relay Word bit CHSG asserts when the TGR timer is picked-up and timing, and also when a setting group change has been initiated.

Active Setting Group Changes

The relay is disabled for less than one second while in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01 through LB32), remote bit (RB01 through RB32), and latch bit (PLT01 through PLT32) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group.

After a group change, an automatic message will be sent to any serial port that has setting AUTO := Y (see *Table 12.7*).

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6, the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

Port Settings

Table 12.4 Port Settings Categories

Settings	Reference
Protocol Selection	See *Table 12.5*.
Communications Settings	See *Table 12.6*.
SEL Protocol Settings	See *Table 12.7*.
Fast Message Read Data Access	See *Table 12.8*.
IP Configuration	See *Table 12.9*.
FTP Configuration	See *Table 12.10*.
HTTP Server Configuration	See *Table 12.11*.
Telnet Configuration	See *Table 12.12*.
IEC 61850 Configuration	See *Table 12.13*.
SV Receiver Configuration	See *Table 12.14*
SV Transmitter Configuration	See *Table 12.15*
DNP3 Protocol Settings	See *Table 12.16*.
DNP3 Protocol LAN/WAN Settings	See *Table 12.17*.
Phasor Measurement Configuration	See *Table 12.18*.
MIRRORED BITS Protocol Settings	See *Table 12.19*.
RTD Protocol Settings	See *Table 12.20*.
PMU Protocol Settings	See *Table 12.21*.
Simple Network Time Protocol (SNTP) Selection	See *Table 12.22*.

Table 12.5 Protocol Selection

Label	Prompt	Default Value
EPORT[a]	Enable Port (Y, N)	Y
MAXACC	Maximum Access Level (1, B, P, A, 0, 2, C)	C
PROTO[b]	Protocol (SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU)	SEL

[a] Setting EPORT to N on Port 1 has no effect on the operation of IRIG-B on Port 1.
[b] Does not apply to Ethernet (Port 5). Subsequent SEL protocol settings apply to Telnet.

Make *Table 12.6* settings for serial ports if preceding setting PROTO ≠ RTD.

Table 12.6 Communications Settings

Label	Prompt	Default Value
MBT[a]	Using Pulsar 9600 modem? (Y, N)	N
SPEED[b]	Data Speed (300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, SYNC[c])	9600
DATABIT[d]	Data Bits (7, 8 bits)	8
PARITY[c]	Parity (Odd, Even, None)	N
STOPBIT[e]	Stop Bits (1, 2 bits)	1
RTSCTS[f]	Enable Hardware Handshaking (Y, N)	N

[a] Only applicable if PROTO := MBA, MBB, MBGA, or MBGB.
[b] For PROTO := MBA, MBB, MBGA, or MBGB, 57600 not available.
[c] SYNC option only available for PROTO := MBA, MBB, MBGA, or MBGB on rear-panel serial ports.
[d] For PROTO := SEL only.
[e] For PROTO := SEL, MBA, MBB, or PMU only.
[f] For PROTO := SEL or PMU only.

Make *Table 12.7* settings if Port setting PROTO := SEL, DNP, or PMU.

Table 12.7 SEL Protocol Settings

Label	Prompt	Default Value
TIMEOUT[a]	Port Time-Out (OFF, 1–60 minutes)	5
AUTO[b]	Send Auto-Messages to Port (Y, N)	Y
FASTOP[c]	Enable Fast Operate Messages (Y, N)	N
TERTIM1[a]	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN[a]	Termination String-Disconnect Sequence (9 characters maximum)[d]	"\005"
TERTIM2[a]	Final Delay-Disconnect Sequence (0–600 seconds)	0

[a] Hidden for PROTO := PMU.
[b] Hidden for PROTO := DNP or PMU.
[c] Hidden for PROTO := DNP.
[d] TERSTRN set at /005 is <Ctrl+E>.

NOTE: Not all of these settings are available in every SEL-400 series relay. Just those that apply to features in the relay are available.

Table 12.8 Fast Message Read Data Access (Sheet 1 of 2)

Label	Prompt	Default Value
FMRENAB	Enable Fast Message Read Data Access (Y/N)	Y
FMRLCL	Enable Local Region for Fast Message Access (Y/N)	N
FMRMTR	Enable Meter Region for Fast Message Access (Y/N)	Y
FMRDMND	Enable Demand Region for Fast Message Access (Y/N)	Y
FMRTAR	Enable Target Region for Fast Message Access (Y/N)	Y

Table 12.8 Fast Message Read Data Access (Sheet 2 of 2)

Label	Prompt	Default Value
FMRHIS	Enable History Region for Fast Message Access (Y/N)	N
FMRBRKR	Enable Breaker Region for Fast Message Access (Y/N)	N
FMRSTAT	Enable Status Region for Fast Message Access (Y/N)	N
FMRANA	Enable Analog Region for Fast Message Access (Y/N)	Y

Make *Table 12.9* settings on the Ethernet port (Port 5).

Table 12.9 IP Configuration

Label	Prompt	Default Value
IPADDR	Device IP Address / CIDR Prefix (w.x.y.z/t)	192.168.1.2/24
DEFRTR	Default router (w.x.y.z)	192.168.1.1
ETCPKA	Enable TCP Keep-Alive (Y,N)	Y
KAIDLE	TCP Keep-Alive Idle Range (1–20 seconds)	10
KAINTV	TCP Keep-Alive Interval Range (1–20 seconds)	1
KACNT	TCP Keep-Alive Count Range (1–20)	6
BUSMODE[a]	Bus Operating Mode (INDEPEND, MERGED)	INDEPEND
NETMODE	Operating Mode (FIXED, FAILOVER, SWITCHED, PRP...)	FAILOVER
NETPORT	Primary Network Port (A, B, C, D)[b]	C
PRPTOUT	PRP Entry Timeout (100–10000 milliseconds)	500
PRPINTV	PRP Supervision TX Interval (1–10 seconds)	2
PRPADDR	PRP Destination Addr LSB (0–255)	0
FTIME	Failover Time-Out (0–65535 milliseconds)	5
NETASPD[c]	Port 5A Speed (Auto, 10, 100)	Auto
NETBSDP[c]	Port 5B Speed (Auto, 10, 100)	Auto
NETCSPD[c]	Port 5C Speed (Auto, 10, 100)	Auto
NETDSPD[c]	Port 5D Speed (Auto, 10, 100)	Auto

[a] Available on devices with IEC 61850 Sampled Values (SV) publication or subscription capability.
[b] The specific options available depend on the physical ports installed in the hardware.
[c] This setting applies only if the port is installed and it is a twisted-pair port (10/100BASE-T).

NOTE: SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP user name "anonymous". If you enable anonymous FTP logins, you are allowing unrestricted access to the SEL-400 series relay and host files.

Table 12.10 FTP Configuration

Label	Prompt	Default
FTPSERV[a]	Enable FTP Server (Y, N)	N
FTPCBAN	FTP Connect Banner	FTP SERVER:
FTPIDLE[a]	Idle Time-Out (5–255 minutes)	5
FTPANMS[a]	Enable Anonymous FTP login (Y, N)	N
FTPAUSR	Anonymous User Access Level	0

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Table 12.11 HTTP Server Configuration

Label	Prompt	Default Value
EHTTP	Enable HTTP Server (Y,N)	N
HTTPPOR	HTTP Port Number (1–65534)	80
HIDLE	HTTP Session Idle Timeout in minutes (1–30)	5

Table 12.12 Telnet Settings

Label	Prompt	Default
ETELNET	Enable Telnet (Y, N)	N
TCBAN	Telnet Connect Banner	TERMINAL SERVER:
TPORT[a]	Telnet Port (23, 1025–65534)	23
TIDLE	Telnet Port Time-Out (1–30 minutes)	15

[a] If you change these settings and accept the new settings, the relay closes all active network connections and briefly pauses network operation.

Table 12.13 IEC 61850 Configuration

Label	Prompt	Default
E61850	Enable IEC 61850 Protocol (Y, N)	N
EGSE[a]	Enable IEC 61850 GSE (Y, N)	N
EMMSFS[a]	Enable MMS File Services (Y, N)	N

[a] Settings EGSE and EMMSFS are hidden when E61850 is set to N.

Make the *Table 12.14* settings in relays that support IEC 61850-9-2 Sampled Values (SV) subscriptions.

Table 12.14 SV Receiver Configuration

Label	Prompt	Default Value
SVRXEN	Enable SV Reception (Number of streams 0–7)	0
SVRADR*s*[a]	SV Stream *s* Subscribed MAC Address[b]	01-0C-CD-04-00-0*s*
RAPPID*s*[a]	SV Stream *s* Rx APPID (0x4000–0x7FFF)[c]	0x4000
SVR*s*ICH[a]	SVRX*s* Channel Current Terminal (OFF,W,X)	W
SVR*s*VCH[a]	SVRX*s* Channel Voltage Terminal (OFF,Y,Z)	Y

[a] *s* represents the subscription number. Seven subscriptions are supported. Only settings for subscriptions enabled by SVRXEN will be visible.
[b] Layer 2 multicast address only. Broadcast address is not allowed.
[c] The 0x prefix is used to indicate that this setting is in hexadecimal.

Make *Table 12.15* settings in relays that support IEC 61850-9-2 SV publications.

Table 12.15 SV Transmitter Configuration (Sheet 1 of 2)

Label	Prompt	Default Value
SVTXEN	Enable SV Transmission (Number of streams 0–7)	0
SVTADR*p*[a]	SVT *p* Destination MAC Address[b]	01-0C-CD-04-00-0*p*
TAPPID*p*[a]	SV Stream *p* Tx APPID (0x4000–0x7FFF)[c]	0x4000
TSVID*p*[a]	SVID *p* (String of 63 characters a–z,A–Z,_,0–9)	"4000"
TVLAN*p*[a]	SV *p* Transmit VLAN ID (0x000–0xFFF)[c]	0x000
TPRIO*p*[a]	SV *p* Transmit VLAN Priority (0–7)	4

Table 12.15 SV Transmitter Configuration (Sheet 2 of 2)

Label	Prompt	Default Value
SVT*p*ICH[a]	SVTX*p* Channel Current Terminal (W,X)	W
SVT*p*VCH[a]	SVTX*p* Channel Voltage Terminal ([range])	Y

[a] *p* represents the publication number. Seven publications are supported. Only settings for publications enabled by SVTXEN will be visible.

[b] Layer 2 multicast address only. Broadcast address is not allowed.

[c] The 0x prefix is used to indicate that this setting is in hexadecimal.

Make *Table 12.16* settings if Port setting PROTO := DNP.

Table 12.16 DNP3 Serial Protocol Settings (Sheet 1 of 2)

Label	Prompt	Default Value
DNPADR	DNP Address (0–65519)	0
DNPID	DNP ID for Object 0, Var 246 (20 characters)	"Relay 1-DNP"
DNPMAP	DNP Session Map (1–5)	1
ECLASSB	Class for Binary Event Data (OFF, 1–3)	1
ECLASSC	Class for Counter Event Data (OFF, 1–3)	OFF
ECLASSA	Class for Analog Event Data (OFF, 1–3)	2
ECLASSV	Class for Virtual Terminal Data (OFF, 1–3)	OFF
TIMERQ	Time-Set Request Interval (I, M, 1–32767 minutes)	I
DECPLA	Currents Scaling (0–3 decimal places)	1
DECPLV	Voltages Scaling (0–3 decimal places)	1
DECPLM	Misc Data Scaling (0–3 decimal places)	1
STIMEO	Select/Operate Time-Out (0.0–60.0 seconds)	1.0
DRETRY	Data Link Retries (OFF, 1–15)	OFF
DTIMEO	Data Link Time-Out (0.0–30.0 seconds)	1
MINDLY	Minimum Delay from DCD to TX (0.00–1.00 seconds)	0.05
MAXDLY	Maximum Delay from DCD to TX (0.00–1.00 seconds)	0.10
PREDLY	Settle Time-RTS On to TX (OFF, 0.00–30.00 seconds)	0.00
PSTDLY	Settle Time-TX to RTS Off (0.00–30.00 seconds)	0.00
DNPCL	Enable Control Operations (Y, N)	N
AIVAR	Default Variation for Analog Inputs (1–6)	2
ANADBA	Analog Reporting Deadband for Currents (0–32767)	100
ANADBV	Analog Reporting Deadband for Voltages (0–32767)	100
ANADBM	Analog Reporting Deadband (0–32767)	100
ETIMEO	Event Message Confirm Time-Out (1–50 seconds)	2
UNSOL	Enable Unsolicited Reporting (Y, N)	N
PUNSOL	Enable Unsolicited Reporting at Power-Up (Y, N)	N
REPADR	DNP Address to Report to (0–65519)	1
NUMEVE	Number of Events to Transmit On (1–200)	10
AGEEVE	Age of Oldest Event to Transmit On (0–99999)	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	3
UTIMEO	Unsolicited Message Offline Time-Out (OFF, 1–5000 sec)	60
EVEMOD	Event Mode (SINGLE, MULTI)	SINGLE

Table 12.16 DNP3 Serial Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
MODEM	Modem Connected to Port (Y, N)	N
MSTR	Modem Startup String (30 chars max)	"E0X0&D0S0=4"
PH_NUM1	Phone Number for Dial-Out (30 chars max)	""
PH_NUM2	Backup Phone Number for Dial-Out (30 chars max)	""
RETRY1	Retry Attempts for Phone 1 Dial-Out (1–20)	5
RETRY2	Retry Attempts for Phone 2 Dial-Out (1–20)	5
MDTIME	Time to Attempt Dial (5–300 seconds)	60
MDRET	Time Between Dial-Out Attempts (5–3600 seconds)	120

Make *Table 12.17* settings if configuring DNP3 LAN/WAN.

Table 12.17 DNP3 LAN/WAN Settings (Sheet 1 of 2)

Label	Prompt	Default Value
EDNP	Enable DNP Sessions (0–6)	0
DNPADR	DNP Address (0–65519)	0
DNPPNUM	DNP TCP and UDP Port (1025–65534)	20000
DNPID	DNP ID for Object 0, Var 246 (20 characters)	"RELAY1-DNP"
Ethernet DNP3 Master *n* Configuration, *n* = 1 to value of EDNP, max 6[a]		
DNPIP*n*	IP Address (w.x.y.z)	192.168.1.[100+n]
DNPTR*n*	Transport Protocol (UDP, TCP)	TCP
DNPUDP*n*[b]	UDP Response Port (REQ, 1025–65534)	20000
DNPMAP*n*	DNP Session Map (1–5)	1
CLASSB*n*	Class for Binary Event Data (OFF,1–3)	1
CLASSC*n*	Class for Counter Event Data (OFF,1–3)	OFF
CLASSA*n*	Class for Analog Event Data (OFF,1–3)	2
TIMERQ*n*	Time-Set Request Interval (I,M,1–32767 mins)	I
DECPLA*n*	Currents Scaling (0–3 decimal places)	1
DECPLV*n*	Voltages Scaling (0–3 decimal places)	1
DECPLM*n*	Misc Data Scaling (0–3 decimal places)	1
STIMEO*n*	Select/Operate Time-Out (0.0–60.0 seconds)	1.0
DNPINA*n*[c]	Seconds to Send Data Link Heartbeat (0–7200)	120
DNPCL*n*	Enable Control Operations (Y, N)	N
AIVAR*n*	Default Variation for Analog Inputs (1–6)	2
ANADBA*n*[d]	Analog Reporting Dead band for Currents (0–32767)	100
ANADBV*n*[d]	Analog Reporting Dead band for Voltages (0–32767)	100
ANADBM*n*[d]	Analog Reporting Dead band (0–32767)	100
ETIMEO*n*	Event Message Confirm Time-Out (1–50 seconds)	2
UNSOL*n*[e]	Enable Unsolicited Reporting (Y,N)	N
PUNSOL*n*[f]	Enable Unsolicited Reporting at Power-Up (Y, N)	N
REPADR*n*	DNP Address to Report to (0–65519)	1
NUMEVE*n*[f]	Number of Events to Transmit On (1–200)	10
AGEEVE*n*[f]	Age of Oldest Event to Transmit On (0–99999)	2

Table 12.17 DNP3 LAN/WAN Settings (Sheet 2 of 2)

Label	Prompt	Default Value
URETRY*n*[f]	Unsolicited Message Max Retry Attempts (2–10)	3
UTIMEO*n*[f]	Unsol. Message Offline Time-Out (1–5000 sec)	60
EVEMOD*n*	Event Mode (SINGLE, MULTI)	SINGLE

[a] Hidden if EDNP := 0.
[b] Hidden if DNPTR*n* := TCP.
[c] Hidden if DNPTR*n* := UDP.
[d] Hidden if CLASSA*n* := OFF.
[e] Hidden if CLASSA*n* := CLASSB*n* := CLASSC*n* := OFF.
[f] Hidden if UNSOL*n* := N.

Table 12.18 Phasor Measurement Configuration

Setting	Prompt	Default
EPMIP	Enable C37.118 Communications (Y, N)[a]	N
PMOTS1	PMU Output 1 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC1	PMU Output 1 Data Configuration (1–5)	1
PMOIPA1	PMU Output 1 Client IP Address (w.x.y.z)[b]	192.168.1.3
PMOTCP1	PMU Output 1TCP/IP Port Number (1–65534)[b, c, d]	4712
PMOUDP1	PMU Output 1 UDP/IP Data Port Number (1–65534)[b, e]	4713
PMOTS2	PMU Output 2 Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC2	PMU Output 2 Data Configuration (1–5)	1
PMOIPA2	PMU Output 2 Client IP Address (w.x.y.z)[f]	192.168.1.4
PMOTCP2	PMU Output 2 TCP/IP Port Number (1–65534)[d, f, g]	4722
PMOUDP2	PMU Output 2 UDP/IP Data Port Number (1–65534)[f, h]	4714

[a] Set EPMIP := Y to access remaining settings.
[b] Setting hidden when PMOTS1 := OFF.
[c] Setting hidden when PMOTSI := UDP_S.
[d] Port # must be unique compared to TPORT and DNPPNUM.
[e] Setting hidden when PMOTS1 := TCP.
[f] Setting hidden when PMOTS2 := OFF.
[g] Setting hidden when PMOTS2 := UDP_S.
[h] Setting hidden when PMOTS2 := TCP.

Make *Table 12.19* settings if Port setting PROTO := MBA, MBB, MBGA, or MBGB.

Table 12.19 MIRRORED BITS Protocol Settings (Sheet 1 of 2)

Label	Prompt	Default Value
TX_ID	MIRRORED BITS ID of This Device (1–4)	2
RX_ID	MIRRORED BITS ID of Device Receiving From (1–4)	1
RBADPU	Outage Duration to Set RBAD (0–10000 seconds)	10
CBADPU	Channel Unavailability to Set CBAD (1–100000 ppm)	20000
TXMODE	Transmission Mode (N-Normal, P-Paced)	N
MBNUM	Number of MIRRORED BITS Channels (0–8)	8
RMB1FL	RMB1 Channel Fail State (0, 1, P)	P
RMB1PU	RMB1 Pickup Time (1–8 messages)	1
RMB1DO	RMB1 Dropout Time (1–8 messages)	1
RMB2FL	RMB2 Channel Fail State (0, 1, P)	P

Table 12.19 Mirrored Bits Protocol Settings (Sheet 2 of 2)

Label	Prompt	Default Value
RMB2PU	RMB2 Pickup Time (1–8 messages)	1
RMB2DO	RMB2 Dropout Time (1–8 messages)	1
RMB3FL	RMB3 Channel Fail State (0, 1, P)	P
RMB3PU	RMB3 Pickup Time (1–8 messages)	1
RMB3DO	RMB3 Dropout Time (1–8 messages)	1
RMB4FL	RMB4 Channel Fail State (0, 1, P)	P
RMB4PU	RMB4 Pickup Time (1–8 messages)	1
RMB4DO	RMB4 Dropout Time (1–8 messages)	1
RMB5FL	RMB5 Channel Fail State (0, 1, P)	P
RMB5PU	RMB5 Pickup Time (1–8 messages)	1
RMB5DO	RMB5 Dropout Time (1–8 messages)	1
RMB6FL	RMB6 Channel Fail State (0, 1, P)	P
RMB6PU	RMB6 Pickup Time (1–8 messages)	1
RMB6DO	RMB6 Dropout Time (1–8 messages)	1
RMB7FL	RMB7 Channel Fail State (0, 1, P)	P
RMB7PU	RMB7 Pickup Time (1–8 messages)	1
RMB7DO	RMB7 Dropout Time (1–8 messages)	1
RMB8FL	RMB8 Channel Fail State (0, 1, P)	P
RMB8PU	RMB8 Pickup Time (1–8 messages)	1
RMB8DO	RMB8 Dropout Time (1–8 messages)	1
MBTIME	Accept Mirrored Bits Time Synchronization (Y, N)	N
MBNUMAN	Number of Analog Channels (0–7)	0
MBANA1	Selection for Analog Channel 1 (analog label)	[a]
MBANA2	Selection for Analog Channel 2 (analog label)	[a]
MBANA3	Selection for Analog Channel 3 (analog label)	[a]
MBANA4	Selection for Analog Channel 4 (analog label)	[a]
MBANA5	Selection for Analog Channel 5 (analog label)	[a]
MBANA6	Selection for Analog Channel 6 (analog label)	[a]
MBANA7	Selection for Analog Channel 7 (analog label)	[a]
MBNUMVT	Number of Virtual Terminal Channels (OFF, 0–7)	OFF

[a] The default value of the MBANA*n* settings is relay specific. See the product-specific instruction manual to find these defaults.

Make *Table 12.20* settings if Port setting PROTO := RTD.

Table 12.20 RTD Protocol Settings

Label	Prompt	Default Value
RTDNUM	RTD Number of Inputs (0–12)	12
RTD*n*TY[a]	RTD *n* Type (NA, PT100, NI100, NI120, CU10)[b]	PT100

[a] Where n is the number of RTD inputs enabled in the RTDNUM setting.

[b] NA designates an input that is not connected to an RTD device.

Table 12.21 PMU Protocol Settings

Label	Prompt	Default Value
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[a]	Remote PMU Hardware ID (1–65534)	1
PMODC	PMU Output Data Configuration (1–5)	1

[a] Setting hidden when PMUMODE := SERVER.

Table 12.22 Simple Network Time Protocol (SNTP) Selection

Setting	Prompt	Default
ESNTP	SNTP Enable (OFF, UNICAST, MANYCAST, BROADCAST)	OFF
SNTPRAT[a]	SNTP Request Update Rate (15–3600 seconds)	60
SNTPTO	SNTP Timeout (5–20 seconds)	5
SNTPPIP	SNTP Primary Server IP Address (w.x.y.z)[b]	192.168.1.110
SNTPBIP	SNTP Backup Server IP Address (w.x.y.z)[c]	192.168.1.111
SNTPPOR[d]	SNTP IP Local Port Number (1–65534)	123

[a] This setting is hidden if ESNTP = OFF, and hidden and forced to 5 if ESNTP = BROADCAST.
[b] Where w: 0–126, 128–239, x: 0–255, y: 0–255, z: 0–255.
[c] Where w: 0–126, 128–223, x: 0–255, y: 0–255, z: 0–255.
[d] This setting is hidden if ESNTP ≠ UNICAST.

Table 12.23 PTP Settings

NOTE: PTP is only supported on Ethernet Ports 5A and 5B. Most SEL-400 series relays only support 2 ports at a time, and must have Port 5A and Port 5B selected by the MOT option in these relays. Relays that support 4 ports will still have PTP on Port 5A and Port 5B but will not require selection of a different MOT option to have PTP available.

Setting	Prompt	Default
EPTP	Enable PTP (Y, N)[a]	N
PTPPRO	PTP Profile (DEFAULT, C37.238)[b]	DEFAULT
PTPTR	PTP Transport Mechanism (UDP, LAYER2)[c]	UDP
DOMNUM	PTP Domain Number (0–255)	0
PTHDLY	PTP Path Delay Mechanism (P2P, E2E, OFF)[d]	E2E
PDINT	Peer Delay Request Interval (1, 2, 4, ...64 s)[e]	1
AMNUM	PTP Number of Acceptable Masters (OFF, 1–5)	OFF
AMIP*n*	PTP Acceptable Master *n* IP (w.x.y.z)[f]	192.168.1.12*n*
AMMAC*n*	PTP Acceptable Master *n* MAC (xx:xx:xx:xx:xx:xx)[g]	00.30.A7:00:00:0[p]
ALTPRI*n*	PTP Alternate Priority1 for Master n (0–255)[h]	0
PVLAN	PTP VLAN Identifier (0–4094)[i]	0
PVLANPR	PTP VLAN Priority (0–7)[i]	4

[a] This setting is not available if the hardware does not support Ports 5A and 5B or if the ports are used in SWITCHED mode.
[b] Hidden and forced to C37.238 if Port 5A or 5B is used for the process bus (87L or IEC 61850-9-2 Sampled Values).
[c] Hide if PTPPRO = C37.238.
[d] If PTPPRO = C37.238, E2E is removed from the setting range.
[e] Hide if PTHDLY = E2E or OFF.
[f] Hide if AMNUM = OFF or if PTPTR = LAYER2.
[g] Hide if AMNUM = OFF or if PTPTR = UDP.
[h] Hide if AMNUM = OFF.
[i] Hide if PTPPRO = DEFAULT.

DNP3 Settings—Custom Maps

Table 12.24 DNP3 Settings Categories

Settings	Reference
DNP3 Fault Location Min and Max	*Table 12.25*
Binary Input Map	*Table 12.26*
Binary Output Map	*Table 12.26*
Counter Map	*Table 12.26*
Analog Input Map	*Table 12.26*
Analog Output Map	*Table 12.26*

The fault location minimum and maximum settings determine what fault data are sent to a DNP3 master. This affects all DNP3 sessions using the current DNP3 map.

NOTE: MINDIST and MAXDIST only apply to relays that provide a fault location.

Table 12.25 Minimum and Maximum Fault Location

Label	Prompt	Default Value
MINDIST	Min Fault Location to Capture (OFF, –1000.0 to 1000.0)	OFF
MAXDIST	Max Fault Location to Capture (OFF, –1000.0 to 1000.0)	OFF

The remainder of this settings class consists of a set of freeform categories for configuring the map for the various DNP3 data types. The category headers indicate the syntax of the entries. *Table 12.26* shows these headers. All entries require a data label. The dead-band and scale-factor parameters are optional. The defaults are relay specific, so refer to the product-specific instruction manual to see the defaults for these settings.

Table 12.26 DNP3 Map Category Headers

Binary Input Map (Binary Input Label)
Binary Output Map (Binary Output Label)
Counter Map (Counter Label, Deadband)
Analog Input Map (Analog Input Label, Scale Factor, Deadband)
Analog Output Map (Analog Output Label)

Front-Panel Settings

Table 12.27 Front-Panel Settings Categories (Sheet 1 of 2)

Settings	Reference
Front-Panel Settings	*Table 12.28*
Selectable Screens for the Front Panel	*Table 12.29*
Selectable Operator Pushbuttons	*Table 12.30*
Front-Panel Event Display	*Table 12.31*
Display Points	
Local Control	

Table 12.27 Front-Panel Settings Categories (Sheet 2 of 2)

Settings	Reference
Local Bit SELOGIC	*Table 12.32*
SER Parameters	*Table 12.33*

The defaults for the pushbuttons and targets in the Front-Panel Settings category are relay specific. See the product-specific instruction manual to find these defaults.

Table 12.28 Front-Panel Settings (Sheet 1 of 3)

Label	Prompt
FP_TO	Front Panel Display Time-Out (OFF,1–60 min)
EN_LEDC	Enable LED Asserted Color (R,G)
TR_LEDC	Trip LED Asserted Color (R,G)
PB1_LED	Pushbutton LED 1 (SELOGIC Equation)
PB1_COL	PB1_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB2_LED	Pushbutton LED 2 (SELOGIC Equation)
PB2_COL	PB2_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB3_LED	Pushbutton LED 3 (SELOGIC Equation)
PB3_COL	PB3_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB4_LED	Pushbutton LED 4 (SELOGIC Equation)
PB4_COL	PB4_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB5_LED	Pushbutton LED 5 (SELOGIC Equation)
PB5_COL	PB5_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB6_LED	Pushbutton LED 6 (SELOGIC Equation)
PB6_COL	PB6_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB7_LED	Pushbutton LED 7 (SELOGIC Equation)
PB7_COL	PB7_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB8_LED	Pushbutton LED 8 (SELOGIC Equation)
PB8_COL	PB8_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB9_LED[a]	Pushbutton LED 9 (SELOGIC Equation)
PB9_COL[a]	PB9_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB10LED[a]	Pushbutton LED 10 (SELOGIC Equation)
PB10COL[a]	PB10_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB11LED[a]	Pushbutton LED 11 (SELOGIC Equation)
PB11COL[a]	PB11_LED Assert and Deassert Color (Enter 2: R,G,A,O)
PB12LED[a]	Pushbutton LED 12 (SELOGIC Equation)
PB12COL[a]	PB_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T1_LED	Target LED 1 (SELOGIC Equation)
T1LEDL	Target LED 1 Latch (Y, N)
T1LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T2_LED	Target LED 2 (SELOGIC Equation)
T2LEDL	Target LED 2 Latch (Y, N)
T2LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)

Table 12.28 Front-Panel Settings (Sheet 2 of 3)

Label	Prompt
T3_LED	Target LED 3 (SELOGIC Equation)
T3LEDL	Target LED 3 Latch (Y, N)
T3LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T4_LED	Target LED 4 (SELOGIC Equation)
T4LEDL	Target LED 4 Latch (Y, N)
T4LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T5_LED	Target LED 5 (SELOGIC Equation)
T5LEDL	Target LED 5 Latch (Y, N)
T5LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T6_LED	Target LED 6 (SELOGIC Equation)
T6LEDL	Target LED 6 Latch (Y, N)
T6LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T7_LED	Target LED 7 (SELOGIC Equation)
T7LEDL	Target LED 7 Latch (Y, N)
T7LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T8_LED	Target LED 8 (SELOGIC Equation)
T8LEDL	Target LED 8 Latch (Y, N)
T8LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T9_LED	Target LED 9 (SELOGIC Equation)
T9LEDL	Target LED 9 Latch (Y, N)
T9LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T10_LED	Target LED 10 (SELOGIC Equation)
T10LEDL	Target LED 10 Latch (Y, N)
T10LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T11_LED	Target LED 11 (SELOGIC Equation)
T11LEDL	Target LED 11 Latch (Y, N)
T11LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T12_LED	Target LED 12 (SELOGIC Equation)
T12LEDL	Target LED 12 Latch (Y, N)
T12LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T13_LED	Target LED 13 (SELOGIC Equation)
T13LEDL	Target LED 13 Latch (Y, N)
T13LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T14_LED	Target LED 14 (SELOGIC Equation)
T14LEDL	Target LED 14 Latch (Y, N)
T14LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T15_LED	Target LED 15 (SELOGIC Equation)
T15LEDL	Target LED 15 Latch (Y, N)
T15LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T16_LED	Target LED 16 (SELOGIC Equation)
T16LEDL	Target LED 16 Latch (Y, N)

Table 12.28 Front-Panel Settings (Sheet 3 of 3)

Label	Prompt
T16LEDC	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T17_LED[b]	Target LED 17 (SELOGIC Equation)
T17LEDL[b]	Target LED 17 Latch (Y, N)
T17LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T18_LED[b]	Target LED 18 (SELOGIC Equation)
T18LEDL[b]	Target LED 18 Latch (Y, N)
T18LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T19_LED[b]	Target LED 19 (SELOGIC Equation)
T19LEDL[b]	Target LED 19 Latch (Y, N)
T19LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T20_LED[b]	Target LED 20 (SELOGIC Equation)
T20LEDL[b]	Target LED 20 Latch (Y, N)
T20LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T21_LED[b]	Target LED 21 (SELOGIC Equation)
T21LEDL[b]	Target LED 21 Latch (Y, N)
T21LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T22_LED[b]	Target LED 22 (SELOGIC Equation)
T22LEDL[b]	Target LED 22 Latch (Y, N)
T22LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T23_LED[b]	Target LED 23 (SELOGIC Equation)
T23LEDL[b]	Target LED 23 Latch (Y, N)
T23LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)
T24_LED[b]	Target LED 24 (SELOGIC Equation)
T24LEDL[b]	Target LED 24 Latch (Y, N)
T24LEDC[b]	T_LED Assert and Deassert Color (Enter 2: R,G,A,O)

[a] PB9–PB12 settings are only available on 12 pushbutton models.
[b] T17–T24 settings are only available on 12 pushbutton models.

Table 12.29 Selectable Screens for the Front Panel (Sheet 1 of 2)

NOTE: The specific settings available in this category for a relay depends on the features of that relay.

NOTE: In some relays, rather than picking from a list of screens, as shown here, there is a freeform settings block in which you can list the screens you want in the order you want them displayed.

Label	Prompt	Default Value
SCROLD	Front-Panel Display Update Rate (OFF, 1–15 sec)	5
ONELINE	One-Line Bay Control Diagram (Y,N)	Y
RMS_V	RMS Line Voltage Screen (Y,N)	N
RMS_I	RMS Line Current Screen (Y,N)	Y
RMS_VPP	RMS Line Voltage Phase to Phase Screen (Y,N)	N
RMS_W	RMS Active Power Screen (Y,N)	N
FUNDVAR	Fundamental Reactive Power Screen (Y,N)	N
RMS_VA	RMS Apparent Power Screen (Y,N)	N
RMS_PF	RMS Power Factor Screen (Y,N)	N
RMS_BK1	RMS Breaker 1 Currents Screen (Y,N)	N
RMS_BK2	RMS Breaker 2 Currents Screen (Y,N)	N

Table 12.29 Selectable Screens for the Front Panel (Sheet 2 of 2)

Label	Prompt	Default Value
STA_BAT	Station Battery Screen (Y,N)	N
FUND_VI	Fundamental Voltage and Current Screen (Y,N)	Y
FUNDSEQ	Fundamental Sequence Quantities Screen (Y,N)	N
FUND_BK	Fundamental Breaker Currents Screen (Y,N)	N
DIFF_L	Differential Metering Local Currents Screen (Y,N)	Y
DIFF_T	Differential Metering Total Currents Screen (Y,N)	Y
DIFF	Differential Metering (Y,N)	Y
ZONECFG	Terminals Associated with Zones (Y,N)	Y

Table 12.30 Selectable Operator Pushbuttons

Label	Prompt	Default Value
PB1_HMI	Pushbutton 1 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB2_HMI	Pushbutton 2 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB3_HMI	Pushbutton 3 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB4_HMI	Pushbutton 4 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB5_HMI	Pushbutton 5 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB6_HMI	Pushbutton 6 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB7_HMI	Pushbutton 7 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB8_HMI	Pushbutton 8 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB9_HMI[c]	Pushbutton 9 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB10HMI[c]	Pushbutton 10 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB11HMI[c]	Pushbutton 11 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF
PB12HMI[c]	Pushbutton 12 HMI Screen (OFF,AP,DP,EVE,SER)[a, b]	OFF

[a] PB*n*_HMI can only be set to DP if a valid display point has been set.
[b] Each instance (AP, DP, EVE, SER) can only be set to a single operator pushbutton.
OFF = No HMI Pushbutton Operation
AP = Alarm Points
DP = Display Points
EVE = Event Summaries
SER = SER HMI Display
[c] PB9–PB12 settings are only available on 12-pushbutton models.

Table 12.31 Front-Panel Event Display

Label	Prompt	Default Value
DISP_ER	Enable HMI Auto Display of Events Summaries (Y,N)	Y
TYPE_ER	Types of Events for HMI Auto Display (ALL,TRIP)[a]	ALL
NUM_ER	Operator Pushbutton Events to Display (1–100)[b]	10[c]

[a] Setting is only available if DISP_ER := Y.
[b] Setting is only available if an operator pushbutton has been set to EVE.
[c] Some relays default NUM_ER to 3.

Boolean display points are selected using freeform settings fields. Two types of display points can be entered: Boolean and analog. For Boolean display points, the entry syntax is:

Bit name, "Label", "Set String", "Clear String", Text Size"

For an analog display point, the syntax is:

Analog name, "User Text and Formatting", "Text Size"

See the Front-Panel Operations section for more information on configuring display points.

Local control bits are configured using the Local Control category. This is a freeform category. Each entry has the following syntax:

Local bit name, "Label", "Set State", "Clear State", Pulse enable

See *Local Control on page 4.20* for more information on configuring local control bits.

Table 12.32 Local Bit SELOGIC[a]

Label	Prompt	Default Value
LB_SPmm	Local Bit Supervision (SELOGIC Equation, NA)	1
LB_DPmm	Local Bit Status Display (SELOGIC Equation, NA)	LBmm

[a] Settings in Table *Table 12.32* appear if the associated local bit is defined. If no local bits are defined, the whole category is hidden.

Table 12.33 SER Parameters

Label	Prompt	Default Value
SER_PP	Five Events per SER Events page? (Y for 5, N for 3)	N

Alias Settings

Although SEL-400 series relays provide extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names to improve the readability of the program. These aliases can be used in settings and SELOGIC equations and are used in most relay reports. Assign a valid seven-character alias name to any Relay Word bit or any Analog Quantity. (Some SEL-400 series relays support aliasing additional types of data.)

Invalid alias names include the following keywords used by settings and SELOGIC control equations:

- END
- INSERT
- DELETE
- LIST
- NA
- OFF

SELOGIC control equation operators (e.g., NOT, AND, OR, COS) cannot be used as alias names. A quantity may only be assigned one alias. An alias cannot match an existing relay word or analog quantity name.

Alias names are valid when the following are true:

- They consist of a maximum of seven characters.
- They are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

For example, the default name for contact output OUT101 is OUT101. You could change the default name to an alias, BK1_TR, for example.

Alias settings consists of a single freeform settings category. As many as 200 aliases may be assigned. The default alias configuration is relay specific. See the relay instruction manual for the default aliases. *Figure 12.2* shows an example using the **SET T** command to set two aliases.

```
=>>SET T <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
? <Enter>
2:
?  OUT101, BK1_TR
3:
? END <Enter>

Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])
1: EN,"RLY_EN"
2: OUT101,"BK1_TR"
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 12.2 Changing a Default Name to an Alias

Protection Freeform SELOGIC Control Equations

Protection freeform SELOGIC control equations are in Classes 1 through 6 corresponding to settings Groups 1 through Group 6 (see *Multiple Setting Groups on page 12.4*).

As many as 250 lines of freeform equations may be entered in each of six settings groups, although the actual maximum capacity may be less. See *SELOGIC Control Equation Capacity on page 13.5* for more information. The default configuration of the protection SELOGIC control equations is relay specific. See the product-specific instruction manual to see the defaults.

Automation Freeform SELOGIC Control Equations

NOTE: Some versions of some SEL-400 series relays have only one automation setting block with a capacity of 100 lines of automation freeform SELOGIC control equations.

Automation freeform SELOGIC control equations are in Blocks 1 through 10.

SEL-400 series relays do not contain any automation freeform SELOGIC settings in the factory-default settings.

The relay has a capacity of 100 lines of automation freeform SELOGIC control equations in each of 10 automation setting blocks. See *SELOGIC Control Equation Capacity on page 13.5* for more information.

Output Settings

Table 12.34 Output Settings Categories

Settings	Reference
Main Board	
Interface Board #1	
Interface Board #2	
Interface Board #3	
Interface Board #4	
Remote Analog Outputs	*Table 12.35*
MIRRORED BITS Transmit Equations	*Table 12.36*
87L Communications Bits[a]	*Table 12.37*

[a] Only available in products that support 87L communication.

The Main Board output settings consists of SELOGIC control equations OUT101–OUT108. The defaults are relay specific; see the relay-specific instruction manual to see the defaults. Some SEL-400 series relays do not have any main board outputs, in which case this category is not available.

NOTE: In TiDL relays, Interface Boards 2–4 are always considered to be available. Depending on the Axion modules connected, these outputs may or may not be physically present.

The Interface Board output settings consists of SELOGIC control equations OUT*x*01–OUT*x*16 where *x* = 2–5, corresponding to Interface Boards 1 to 4. The category for any interface board is only available if the interface board is installed. The defaults are relay specific; see the relay-specific instruction manual to see the defaults.

Make *Table 12.35* settings if an Ethernet card is present and IEC 61850 is ordered.

Table 12.35 Remote Analog Outputs

Label	Prompt	Default Value
RAO01 • • • RAO64	 • • •	NA • • • NA

Table 12.36 MIRRORED BITS Transmit Equations

Label	Prompt	Default Value
TMB1A • • • TMB8A	 • • •	NA • • • NA
TMB1B • • • TMB8B		NA • • • NA

NOTE: This category is only available in relays that support 87L communications.

Table 12.37 87L Communications Bits

Label[a, b]	Prompt	Default Value
87T*x*P1	•	NA
87T*x*P2	•	NA
87T*nn*E	•	NA

[a] *x* = 1–4. These settings are hidden when E87CH = N or 2E or 3E or 4E. Also hidden if there is no serial communications card installed.

[b] *nn* = 01–32. These settings are visible when E87CH = 2E, 3E, or 4E, and are hidden in all other cases.

Report Settings

Table 12.38 Report Settings Categories

Settings	Reference
SER Chatter Criteria	*Table 12.39*
SER Points	
Signal Profile	*Table 12.40*
Event Reporting	*Table 12.41*
HIF Event Reporting	
Event Reporting Analog Quantities	
Event Reporting Digital Elements	

Table 12.39 SER Chatter Criteria

Label	Prompt	Default Value
ESERDEL	Automatic Removal of Chattering SER Points (Y, N)	N
SRDLCNT[a]	Number of Counts Before Auto-Removal (2–20)	5
SRDLTIM[a]	Time for Auto-Removal (0.1–30 seconds)	1.0

[a] Setting is only available if ESERDEL := Y.

The SER Points category is a freeform category for listing points to record in the SER. Each point can be given a reporting name, a set state name, and a clear state name. You can also indicate whether or not to make this point visible as an alarm point on the front-panel LCD. The syntax for entry is:

> Relay Word Bit Label, "Reporting Name", "Set State Name", "Clear State Name", HMI Alarm Indication

Each of the names may consist of any printable ASCII character. The HMI alarm condition is a Y/N choice. By default, there are no SER points configured.

The signal profile settings category consists of a freeform block for selecting analog quantities to include in the signal profile followed by the settings described in *Table 12.40*. Any of the analog quantities listed in *Section 12:Analog Quantities* in the product-specific instruction manual may be selected. As many as 20 analog quantities can be included in the signal profile.

Table 12.40 Signal Profile

Label	Prompt	Default Value
SPAR	Signal Profile Acq. Rate (1,5,15,30,60 min)	5
SPEN	Signal Profile Enable (SELOGIC Eqn.)	0

Table 12.41 Event Reporting

Label	Prompt	Default Value
ERDIG	Store Selected (S) or All (A) Relay Word Bits	S
SRATE	Sample Rate of Event Report (1, 2, 4, 8 kHz)	2
LER[a]	Length of Event Report (0.25–3.00 seconds); SRATE := 8	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 8	0.10
LER[a]	Length of Event Report (0.25–6.00 seconds); SRATE := 4	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 4	0.10
LER[a]	Length of Event Report (0.25–12.00[c] seconds); SRATE := 2	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 2	0.10
LER[a]	Length of Event Report (0.25–24.00[d] seconds); SRATE := 1	0.50
PRE[b]	Length of Pre-Fault (0.05–0.25 seconds); SRATE := 1	0.10

[a] The upper end of the range is reduced by a factor of 4 if ERDIG is set to A.
[b] The upper limit for PRE is the set LER minus 0.05 s.
[c] In the SEL-411L, the upper bound is 9.00 s.
[d] In the SEL-411L, the upper bound is 12.00 s.

The Event Report Analog Quantities category is a freeform category in which you can select as many as 20 analog quantities to report in the relay event reports. By default, no analog quantities are configured.

The Event Reporting Digital Elements category is a freeform settings area in which as many as 800 relay words from as many as 100 relay word bit rows may be selected. See the product-specific instruction manual for the default configuration. The 100 row limit includes the base set of Relay Word bits always included in oscillography and event reports as described in *Section 7: Metering, Monitoring, and Reporting* in the product-specific instruction manual.

Notes Settings

Avoid losing important information about the relay. Use the Notes settings like a text pad to leave notes about the relay in the Notes area of the relay. Notes entries are in a single block of 100 lines. By default, there is no text stored in the Notes settings.

SECTION 13

SELOGIC Control Equation Programming

This section describes use of SELOGIC control equations and programming to customize relay operation and automate substations. This section covers the following topics:

Separation of Protection and Automation Areas

SEL-400 series relays act as protective relays and as smart nodes in distributed substation automation. The relay collects data, coordinates inputs from many interfaces, and automatically controls substation equipment. The relay performs protection and automation functions but keeps programming of these functions separate. For example, someone modifying or testing a capacitor bank control system or station restoration system created in automation programming should not be able to corrupt programming for protection tasks. Similarly, extended protection algorithms must operate at protection speeds unaffected by the volume of automation programming.

SEL-400 series relays contain several separate programming areas discussed in SELOGIC Control Equation Setting Structure. Separate access levels and passwords control access to each programming area and help eliminate accidental programming changes. For example, use Access Level P to modify protection configuration and protection freeform SELOGIC control equation programming and Access Level A to access automation programming. If you want unlimited access to both automation and protection configuration and programming, use Access Level 2.

NOTE: If you want unlimited access to both automation and protection configuration and programming, log in to Access Level 2.

Protection and automation areas must interact and exchange information. Protection and automation interact and exchange information through separate storage areas (variables) for results of automation and protection programming. The relay combines the results in the output settings that drive relay outputs to control substation equipment. Separation of protection and automation storage areas is illustrated in *Figure 13.1*.

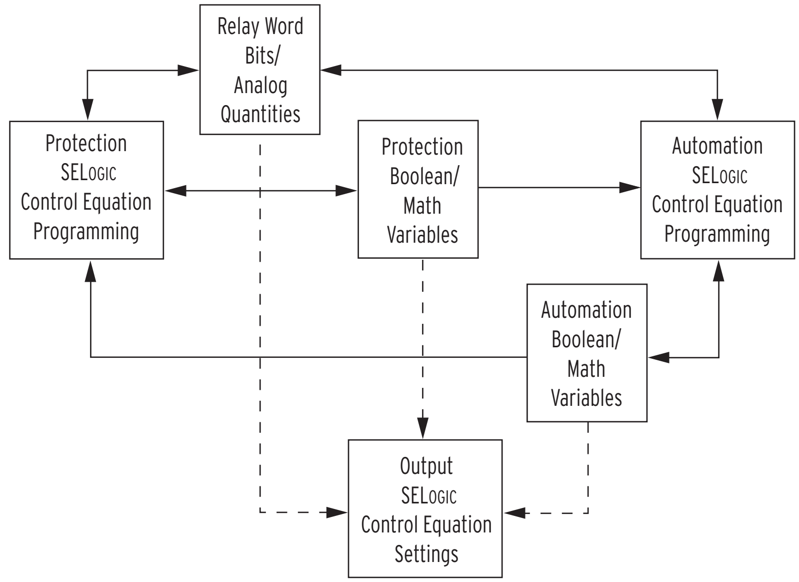

Figure 13.1 Protection and Automation Separation

Figure 13.1 illustrates how the SEL-400 series relays keep protection and automation programming separate while still exchanging information. The arrows indicate data flow between components. The Relay Word Bits and Analog Quantities are visible to protection, automation, and output programming. Protection programming uses the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables as inputs, but only writes and stores information to the Protection Variables. Similarly, automation programming uses data from all parts of the relay, but only stores data in the Automation Variables.

The Output SELOGIC control equation settings use the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables to control outputs and other information leaving the relay. Use the output settings to create a custom combination of the results of protection and automation operations. For example, an OR operation will activate an output when protection or automation programming results necessitate activating the output. You can use more complicated logic to supervise control of the output with other external and internal information. For example, use a command from the SCADA master to supervise automated control of a motor-operated disconnect in the substation.

SELOGIC Control Equation Setting Structure

SEL-400 series relays use SELOGIC control equations in three major areas. First, you can customize protection operations with SELOGIC control equation settings and freeform programming. Second, there is a freeform programming area for more sophisticated automation SELOGIC control equation programming. Third, there is a fixed area for relay output programming. The SELOGIC control equation programming areas are shown in *Figure 13.2*. There are also a small number of fixed SELOGIC control equations in other settings areas including front-panel settings that allow you to customize relay features not directly related to protection or automation.

NOTE: Some versions of some SEL-400 series relays only support one block of Automation SELOGIC Control Equations.

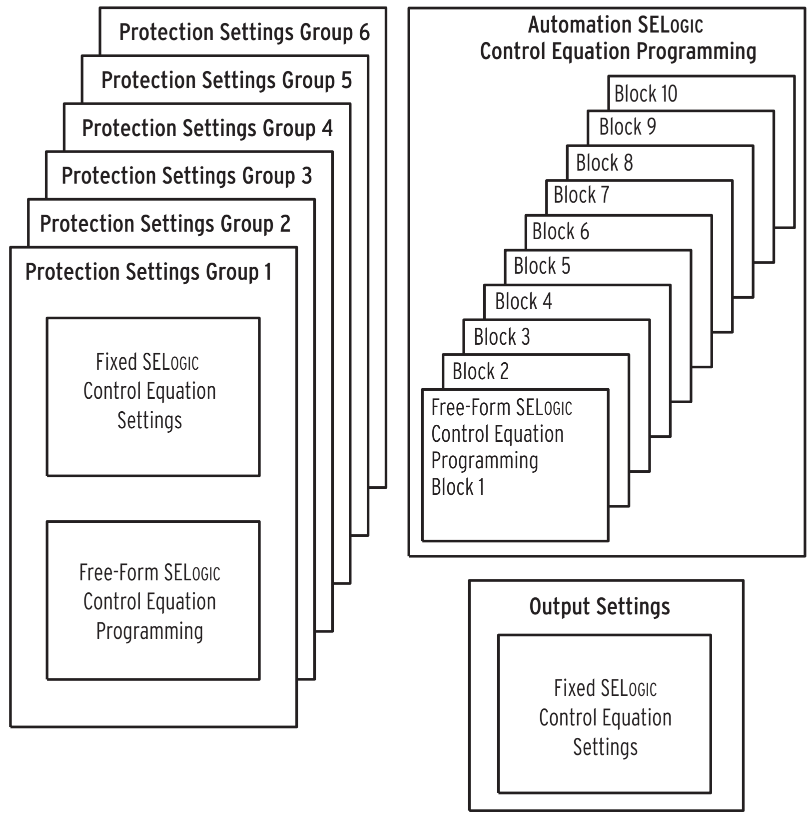

Figure 13.2 SELOGIC Control Equation Programming Areas

Protection

Protection SELOGIC control equation programming includes a fixed area and a freeform area. You can configure many protection settings within the relay (for example TR) with fixed SELOGIC control equation programming. Use these settings to control protection operation and customize relay operation. The programming and operation of fixed SELOGIC control equations in this area is very similar to programming in SEL-300 series relays.

There is a freeform SELOGIC control equation programming area associated with protection. Because this area operates at the protection processing interval along with protection algorithms and outputs, use this area to extend and customize protection operation. Protection freeform SELOGIC control equation programming includes a complete set of timers, counters, and variables.

For all protection settings, including protection SELOGIC control equation programming, there are six groups of settings that you activate with the protection settings group selection. Only one group is active at a time. When you switch groups, for example, you can activate completely different programming that corresponds to the conditions indicated by the active group. See *Multiple Setting Groups on page 12.4* for more information.

If you want the programming to operate identically in all groups, develop the settings in one group and copy these to all groups. You can copy settings using the **COPY** command documented in *COPY on page 14.17*. You can also perform cut-and-paste operations in the ACSELERATOR QuickSet SEL-5030 software.

NOTE: Perform operations that are not time critical in automation SELOGIC control equation programming. You can use this automation to reduce the demand and complexity of protection SELOGIC control equation programming.

All of the SELOGIC control equation programming in the protection area executes at the same deterministic interval as the protection algorithms. Because of this type of programming execution, you can use protection freeform and fixed programming to extend and customize protection operation.

Automation

Automation SELOGIC control equation programming is a large freeform programming area that provides as many as ten blocks. The relay executes each block sequentially from the first block to the last. You do not need to fill a block completely or enter any equations in a block before starting to write SELOGIC control equations in the following blocks.

SEL-400 series relays dedicate a minimum processing time when executing automation SELOGIC control equations. If the processing load is light, the relay uses more processing time for executing automation programming. This means that the overall execution time fluctuates. You can display the average and peak execution time with the **STATUS S** ASCII command. Use the **STATUS SC** command to reset the peak execution time.

NOTE: Organize automation SELOGIC control equation programming into blocks based on function. It is easier to edit and troubleshoot small partially filled blocks that contain related programming.

Use automation SELOGIC control equation programming to automate tasks that do not require time-critical, deterministic execution. For example, if you are coordinating control inputs from a substation HMI and SCADA master, use automation freeform SELOGIC control equations and set the output contact setting to the automation SELOGIC control equation variable that contains the result.

Perform time-critical tasks with protection freeform SELOGIC control equations. For example, if you require a SELOGIC control equation for TR (trip) that contains more than 15 elements, you must perform that calculation in several steps. Because detection of a TR condition is a time-critical activity, perform the calculation with protection freeform SELOGIC control equations and set TR to the protection SELOGIC control equation variable that contains the result.

Because automation runs at a slower rate than protection, you must be careful when using protection bits within automation equations. Protection bits can assert and deassert again too fast for automation equations to consistently see them. Therefore, you may need to hold protection bits asserted for a second, by using conditioning timers, before using them in SELOGIC equations.

Outputs

To provide protection and automation area separation, the output settings are in a fixed SELOGIC control equation area separate from protection and automation programming. You can take advantage of this separation to combine protection and automation in a manner that best fits your application. Outputs include the relay control outputs, outgoing MIRRORED BITS points, and remote analog outputs. The relay executes output logic and processes outputs at the protection processing interval.

SELOGIC Control Equation Capacity

SELOGIC control equation capacity is a measure of how much remaining space you have available for programming. In both protection and automation, SELOGIC control equation capacity includes execution capacity and settings storage capacity.

The relay will reject any setting that exceeds the available settings storage capacity and execution capacity. You can then accept the previous settings you have entered and examine your settings.

Protection

SEL-400 series relays typically provide storage space for as many as 250 lines of protection freeform programming. See the product-specific instruction manual for the number of lines limit for any specific product. Because the relay executes protection fixed and freeform logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. The relay calculates total capacity in terms of settings capacity and execution capacity.

NOTE: The SEL-487B supports 100 lines of protection freeform programming.

Rather than limit parameters to guarantee that your application not exceed the maximum processing requirements, the relay measures and calculates the available capacity when you enter SELOGIC control equations. The relay will not allow you to enter programming that will cause the relay to be unable to complete all protection SELOGIC control equations each protection processing interval.

There are six protection settings groups. Only one protection settings group can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global Settings, Protection Group Settings, Protection Freeform Settings, Output Settings, and several other settings areas. The relay calculates protection capacities based on the total amount of SELOGIC control equation programming executed when the protection settings group is active. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for protection fixed and freeform logic.

Automation

SEL-400 series relays provide storage space for as many as 10 blocks of as many as 100 lines of automation freeform programming each. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for automation freeform logic.

There is a maximum execution capacity and settings storage capacity. If you enter a setting that exceeds maximum capacity, the relay will reject the setting. You will have the opportunity to reenter the setting or save any other settings you entered during that session.

SELOGIC Control Equation Programming

There are two major areas where SEL-400 series relays use SELOGIC control equations. First, fixed SELOGIC control equations define the operation of fixed protection elements or outputs. As with SEL-300 series relay programming, protection programming and outputs use fixed SELOGIC control equations. Second, you can use freeform SELOGIC control equations for freeform programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

Fixed SELOGIC Control Equations

Fixed result SELOGIC control equations are equations in which the left side (result storage location), or LVALUE, is fixed. Programming in SEL-300 series relays consists of all fixed SELOGIC control equations. Fixed equations include protection and output settings that you set with SELOGIC control equations.

Fixed SELOGIC control equations are Boolean equations. Fixed result control equations can be as simple as a single element reference (for example PSV01) or can include a complex equation. An example of fixed programming is shown in *Example 13.1*.

Example 13.1 Fixed SELOGIC Control Equations

The following equations are examples of fixed SELOGIC control equations for relay Output OUT101. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

OUT101 := **1** # Turn on OUT101

OUT101 := **NA** # Do not evaluate an equation for OUT101

OUT101 := **OUT102 AND RB02** # Turn on OUT101 if OUT102 and RB02 are on

Fixed SELOGIC control equations include expressions that evaluate to a Boolean value, True or False, represented by a logical 1 or logical 0.

OUT101 := **PSV04** # Turn on OUT101 if protection PSV04 is on

More complex programming in the freeform area controls OUT101. The result of the freeform programming is available as an element in a fixed equation.

OUT101 := **AMV003 > 5** # Turn on OUT101 if AMV003 is greater than 5

While you cannot perform mathematical operations in fixed programming, you can perform comparisons on the results of mathematical operations performed elsewhere.

Freeform SELOGIC Control Equations

Freeform SELOGIC control equations provide advanced relay customization and automation programming. There are freeform SELOGIC control equation programming areas used for protection and automation. You can use freeform SELOGIC control equation programming to enter program steps sequentially so that the relay will perform steps in the order that you specify. You can refer to storage locations multiple times and build up intermediate results in successive equations. You can also enter entire line comments to help document programming. Mathematical operations are available only in freeform SELOGIC control equation programming areas. An example of freeform SELOGIC control equation programming is shown in *Example 13.2*.

Example 13.2 Freeform SELOGIC Control Equations

The following equations are examples of freeform SELOGIC control equations. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

Freeform equation example programming

#

Is 80% of A-Phase fundamental voltage greater than 12kV?

PMV01 := **VAFM * 0.8** # 80% of A-Phase fundamental voltage

PSV04 := **PMV01 >= 12000** # True if A-Phase fundamental voltage is greater than or equal to 12000

Use comments to group settings in the freeform SELOGIC control equations by task and to document individual equations. In this example, an intermediate calculation generates the value we want to test to determine if PSV04 will be turned on.

Assignment Statements

Both fixed and freeform SELOGIC control equations are a basic type of computer programming statement called an assignment statement. Assignment statements have a basic structure similar to that shown below:

LVALUE := Expression

Starting at the left, the LVALUE is the location where the result of an evaluation of the expression on the right will be stored. The := symbol marks the statement as an assignment statement and provides a delimiter or separator between the LVALUE and the expression. Type the := symbol as a colon and equal sign. The assignment symbol is different than a single equal sign (=) to avoid confusion with a logical comparison between two values. The type of LVALUE must match the result of evaluating the expression on the right.

There are two basic types of assignment statements that form SELOGIC control equations. In the first type, Boolean SELOGIC control equations, the relay evaluates the expression on the right to a result that is a logical 1 or a logical 0. The LVALUE must be some type of Boolean storage location or setting that requires a Boolean value. For example, the setting for the Protection Conditioning Timer 7 Input, PCT07IN, requires a value of 0 or 1, which you set with a Boolean SELOGIC control equation.

The second type is a math SELOGIC control equation. Use the math SELOGIC control equation to perform numerical calculations on data in the relay. For example, in protection freeform programming in an SEL-451, enter AMV034 := 5 * BK1IAFM to store the product of 5 and the Circuit Breaker 1 A-Phase current in automation math variable 34. *Example 13.3* lists several examples of Boolean and math SELOGIC control equations.

Example 13.3 Boolean and Math SELOGIC Control Equations

The equations below are examples of Boolean SELOGIC control equations.

Example Boolean SELOGIC control equations

PSV01 := **IN101** # Store the value of IN101 in PSV01

PSV02 := **IN101 AND RB03** # Store result of logical AND in PSV02

PST01IN := **IN104** # Use IN104 as the input value for PST01

PSV03 := **PMV33 >= 7** # Set PSV03 when PMV33 greater than or equal to 7

The lines below are examples of math SELOGIC control equations.

Example math SELOGIC control equations

PMV01 := **5** # Store the constant 5 in PMV01

PMV02 := **0.5 * VAFM** # Store the product of A-Phase voltage and 0.5 in PMV02

Comments

Include comment statements in SELOGIC control equations to help document SELOGIC control equation programming. The relay provides the following two type of comments:

- ➤ in-line comments: (*comment*)
- ➤ end-of-line comments: #xxx

Example of in-line comment:

PCT01IN := (*this is an in-line comment*) PMV04 (*this is an in-line comment *)

Example of end-of-line comment:

PCT01IN := **10** # this is an end-of-line comment

If you begin a SELOGIC control equation with an end-of-line comment character, then the entire line is a comment.

NOTE: During troubleshooting or testing, reenter a line and insert the comment character to disable it. Enter the line without the comment character to enable the line later when you want it to be executed.

Comments are a powerful documentation tool for helping both you and others understand the intent of programming and configuration of the settings. You can use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Elements

SELOGIC control equation elements are a collection of storage locations, timers, and counters that you can use to customize the operation of your relay and to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 13.1*. The specific number of the various types of elements varies between SEL-400 series relays. See the product-specific instruction manual to determine the number of each type of element in that relay.

Table 13.1 Summary of SELOGIC Control Equation Elements

Element	Description
Relay Word bits	Boolean value data
Analog quantities	Received, measured, and calculated values
Special condition bits	Bits that indicate special SELOGIC control equation execution conditions
SELOGIC control equation variables	Storage locations for the results of Boolean SELOGIC control equations
SELOGIC control equation math variables	Storage locations for the results of math SELOGIC control equations
Latch bits	Nonvolatile storage for the results of Boolean SELOGIC control equations
Conditioning timers	Pickup and dropout style timers similar to those used in SEL-300 series relays
Sequencing timers	On-delay timers similar to those used in programmable logic controllers
Counters	Counters that count rising edges of Boolean value inputs

Relay Word Bits and Analog Quantities

Data within the relay are available for use in SELOGIC control equations. Relay Word bits are binary data that include protection elements, input status, and output status. See *Section 11: Relay Word Bits* in each product-specific instruction manual to view a list of Relay Word bits available within that relay. Analog quantities are analog values within the relay including measured and calculated values. *Section 12: Analog Quantities* in each product-specific instruction manual contains a list of analog quantities available within the relay.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the relay. You can use these bits in SELOGIC control equation programming to react to these conditions. You can also send these bits to other devices through relay interfaces including MIRRORED BITS communications and DNP3. The special condition bits are shown in *Table 13.2*

The relay sets the first execution bits AFRTEXA, AFRTEXP, and PFRTEX momentarily to allow you to detect changes in the relay operation. The relay sets these bits and clears them as described in *Table 13.2*, *Table 13.3*, and *Table 13.4*. You can use these bits to force logic and calculations to reset or take a known state on power-up or settings change operations.

Table 13.2 First Execution Bit Operation on Power-Up

Name	Description
AFRTEXA	Relay sets on power-up and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on power-up. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on startup. Relay clears after protection runs for 1 cycle.

Table 13.3 First Execution Bit Operation on Automation Settings Change

Name	Description
AFRTEXA	Relay sets on settings change and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on settings change. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on settings change. Relay clears after protection runs for 1 cycle.

Table 13.4 First Execution Bit Operation on Protection Settings Change, Group Switch, and Source Selection

Name	Description
AFRTEXA	Relay does not set.
AFRTEXP	Relay sets when listed event occurs. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets when listed event occurs. Relay clears after protection runs for 1 cycle.

SELOGIC Control Equation Variables

There are two types of SELOGIC control equation variables: Boolean and math.

SELOGIC Control Equation Boolean Variables

SELOGIC control equation Boolean variables are binary storage locations. Each variable equals either logical 1 or logical 0. This manual refers to these variables and the relay displays these as 1 and 0, respectively. Think also of the states 1 and 0 as True and False, respectively, when you evaluate Boolean logic statements. The quantities of SELOGIC control equation Boolean variables available in the different programming areas are listed in *Table 13.5*.

Table 13.5 SELOGIC Control Equation Boolean Variable Quantities

Type	Typical Quantity	Name Range
Protection SELOGIC control equation Boolean variables	64	PSV01–PSV64
Automation SELOGIC control equation Boolean variables	256	ASV001–ASV256

Use the SELOGIC control equation Boolean variables in freeform logic statements in any order you want. Use a SELOGIC control equation Boolean variable more than once in freeform logic programming, and use SELOGIC control equation Boolean variables as arguments in SELOGIC control equations. *Example 13.4* illustrates SELOGIC control equation variable usage. You can view the status of individual control equation Boolean bits in the Relay Word using the **TARGET** command. Use the **TAR PSV*nn*** command or the **TAR ASV*nnn*** command to view the Relay Word row containing the protection or automation Boolean bit specified by the number *nn*. You can also view the status of Boolean bits through the relay LCD front-panel display by selecting RELAY ELEMENTS from the Main Menu and scrolling through the rows of Relay Word bits.

Example 13.4 SELOGIC Control Equation Boolean Variables

The equations below show freeform SELOGIC control equation programming examples that use SELOGIC control equation Boolean variables. Each line has a comment after the # that provides additional detail.

PSV01 := **1** # Set PSV01 to 1 always

PSV09 := **PSV54 AND ASV005** # Set to result of Boolean AND

PSV02 := **PMV05 > 5** # Set if PMV05 is greater than 5

You can use SELOGIC control equation variables more than once in freeform programming. The SELOGIC control equations below use ASV100 and ASV101 to calculate intermediate results.

Remote control 1

ASV100 := **RB14 AND ALT01** # Supervise remote control with ALT01

ASV101 := **RB15 AND PLT07** # Supervise remote control with PLT07

ASV201 := **ASV100 OR ASV101** # Store desired control in ASV201

Remote control 2

ASV100 := **RB18 AND ALT09** # Supervise remote control with ALT09

ASV101 := **RB19 AND PLT13** # Supervise remote control with PLT13

ASV202 := **ASV100 OR ASV101** # Store desired control in ASV202

SELOGIC Control Equation Math Variables

SELOGIC control equation math variables are math calculation storage results. As with protection and automation SELOGIC control equation Boolean variables, there are separate storage areas for protection and automation math calculations. The quantities of SELOGIC control equation math variables available in the SEL-400 series relays are shown in *Table 13.6*.

Table 13.6 SELOGIC Control Equation Math Variable Quantities

Type	Typical Quantity	Name Range
Protection SELOGIC control equation math variables	64	PMV01–PMV64
Automation SELOGIC control equation math variables	256	AMV001–AMV256

Use math variables in freeform programming to store the results of math calculations as arguments in math calculations and comparisons. *Example 13.5* illustrates SELOGIC control equation math variable usage. You can view the results of protection and automation math variables using the **METER** command. Use the **MET PMV** command to see all protection math variable results (PMV01–PMV64). Similarly, use the **MET AMV** command to see all automation math variable results (AMV001–AMV256).

Example 13.5 SELOGIC Control Equation Math Variables

The equations below show freeform SELOGIC control equation programming examples that use SELOGIC control equation math variables using analog quantities available in the SEL-421. Each line has a comment after the # that provides additional description.

PMV01 := **378.62** # Store 387.62 in PMV01

PMV09 := **5 + VAFM** # Store sum of 5 and A-Phase voltage in kV in PMV09

You can use SELOGIC control equation math variables more than once in freeform programming. Use AMV010 in the following SELOGIC control equations to calculate intermediate results.

Determine if any phase voltage is greater than 13 kV

A-Phase

AMV010 := **VAFIM/1000** # VA in kV

ASV010 := **AMV010 > 13** # Set if greater than 13 kV

B-Phase

AMV010 := **VBFIM/1000** # VB in kV

ASV011 := **AMV010 > 13** # Set if greater than 13 kV

C-Phase

AMV010 := **VCFIM/1000** # VC in kV

ASV012 := **AMV010 > 13** # Set if greater than 13 kV

Combine phase results

ASV013 := **ASV010 OR ASV011 OR ASV012**

Latch Bits

Latch bits are nonvolatile storage locations for Boolean information. Latch bits are in several settings areas of the relay, as shown in *Table 13.7*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 13.8*.

Table 13.7 Latch Bit Quantities

Type	Typical Quantity	Name Range
Protection freeform latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 13.8 Latch Bit Parameters

Type	Item	Description	Setting	Name Examples
Input	Reset	Reset latch when on	Boolean SELOGIC control equation	PLT01R ALT01R
Input	Set	Set latch when on	Boolean SELOGIC control equation	PLT01S ALT01S
Output	Latched Value	Latched Value of 0 or 1	Value for use in Boolean SELOGIC control equations	PLT01 ALT24

Latch bits provide nonvolatile storage of binary information. A latch can have the value of logical 0 or logical 1. Latch bits also retain their state through changes in the active protection settings group. Because storage of latch bits is in nonvolatile memory, the state of latch bits remains unchanged indefinitely, even when power is lost to the relay.

As with logic latches used in digital electronics, each latch bit has a Set input and a Reset input. The relay evaluates the latch bit value at the end of each logic processing interval using the values for Set and Reset calculated during the processing interval. Latch bits are reset dominant. If the Set and Reset inputs are both asserted, the relay will reset the latch.

Latch bits are available in two different programming areas of the relay. First, there are 32 latch bits, PLT01–PLT32, that are associated with protection settings. Second, there are 32 latch bits, ALT01–ALT32, available in automation freeform programming. You can view the status of individual latch bits in the Relay Word using the **TARGET** command. Use the **TAR PLT*nn*** command or the **TAR ALT*nn*** command to view the Relay Word row containing the protection or automation latch bit specified by the two-digit number, *nn*. You can also view the status of latch bits through the relay LCD front-panel display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

Protection Latch Bits

Program the 32 latch bits, PLT01–PLT32, in the protection freeform SELOGIC control equation programming area. There is a separate protection freeform SELOGIC control equation programming area associated with each protection settings group. The latches in protection can have separate programming for Set and Reset in each protection settings group. While each protection latch value remains unchanged for a change in the active protection settings group, you can enter different Set and Reset programming for each protection settings group.

There are Set and Reset settings for each latch bit available in each group. For example, PLT01R and PLT01S are available in all six freeform settings groups and all control the same Latch Bit, PLT01. This structure allows you to either program each latch to operate in the same way for each group or behave differently based on the active protection settings group. For example, you could program the protection latch to set on IN107 when Protection Settings Group 1 is active and program the latch to set on IN106 when Protection Settings Group 2 is active. If you do not enter a setting for the Reset and Set in a protection settings group, the latch bit will remain unchanged when that protection settings group is active. *Example 13.6* illustrates protection latch bit usage.

Example 13.6 Protection Latch Bits

This example studies the factory settings for the HOT LINE TAG operator control logic in the SEL-451. Protection Latch Bit 4 (PLT04) is used as a close enable signal, which is deasserted during Hot Line Tag conditions. When the HOT LINE TAG operator control is pressed, Relay Word bit PB5_PUL pulses for one processing interval, and one of two actions will occur, depending on the previous state of PLT04:

- If PLT04 was previously asserted, the PB5_PUL is ANDed with PLT04 in the PLT04R SELOGIC equation, causing PLT04 to deassert. In this state, closing is blocked.
- If PLT04 was previously deasserted, the PB5_PUL is ANDed with NOT PLT04 in the PLT04S SELOGIC equation, causing PLT04 to assert. In this state, closing is permitted.

The settings below are duplicated in the Protection SELOGIC control equation freeform programming areas corresponding to each of six setting groups:

Store HOT LINE TAG state in PLT04, controlled by front panel pushbutton

#

PLT04S := PB5_PUL AND NOT PLT04

PLT04R := PB5_PUL AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)

#

PLT04 defeats the RECLOSE ENABLED operator control function

PLT02R := PB2_PUL AND PLT02 OR **NOT PLT04** # HOT LINE TAG DISABLES RECLOSE

In the factory settings for PLT04S and PLT04R, rising edge operators are not required because Relay Word bit PB5_PUL only asserts for one processing interval. If the application required control input IN103 to set or clear the Hot Line Tag function in addition to the operator control pushbutton, the settings would look like this:

PLT04S := (PB5_PUL OR R_TRIG IN103) AND NOT PLT04

PLT04R := (PB5_PUL OR R_TRIG IN103) AND PLT04 # HOT LINE TAG (WHEN PLT04 DEASSERTED)

If the R_TRIG operators were not present, Protection Latch Bit 4 (PLT04) would oscillate whenever IN103 was asserted, and the final state after IN103 deasserts would be indeterminate. To prevent contact bounce sensed by Control Input IN103 from triggering multiple rising edges, make appropriate debounce time settings.

Protection Latch Bit 4 (PLT04) appears in the factory settings for several SELOGIC control equations in the SEL-451:

- In the Protection SELOGIC control equation freeform programming area, PLT04 defeats the RECLOSE ENABLED operator control function

  PLT02R := PB2_PUL AND PLT02 OR **NOT PLT04** # HOT LINE TAG DISABLES RECLOSE

- In the front-panel settings, PB5_LED follows the inverted state of PLT04:

  PB5_LED := **NOT PLT04** #HOT LINE TAG

Example 13.6 Protection Latch Bits (Continued)

- In group settings, PLT04 supervises close and reclose conditions:
  - Autoreclose enable

    E3PR1 := PLT02 **AND PLT04**
  - Autoreclose drive-to-lockout

    79DTL := NOT (PLT02 **AND PLT04**) AND (3PT OR NOT 52AA1)
  - Manual close

    BK1MCL := (CC1 OR PB7_PUL) **AND PLT04**

The above settings allow the HOT LINE TAG operator control pushbutton to enable or disable close operations in the SEL-451. Any changes to these factory settings should be carefully designed and tested to ensure proper operation.

Evaluation of the latch bit value occurs at the end of the protection SELOGIC control equation execution cycle. The values evaluated for Reset (PLT*nn*R) and Set (PLT*nn*S) during SELOGIC control equation execution remain unchanged until after the evaluation of all SELOGIC control equations, when the relay evaluates the latch bit value (PLT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the protection freeform area dominates, and the relay uses this equation to evaluate the latch.

Automation Latch Bits

The automation latch bits, ALT01–ALT32, are available in automation freeform settings. Write freeform SELOGIC control equations to set and reset these bits. As with protection latch bits, the relay stores automation latch bits in nonvolatile memory and preserves these through a relay power cycle and group change operations. With protection latch bits, you can implement Set and Reset programming for each protection settings group. Automation SELOGIC control equation programming, however, has only one programming area active for all protection settings groups.

The relay evaluates the latch bit value at the end of the automation freeform SELOGIC control equation execution cycle. The values for Reset (ALT*nn*R) and Set (ALT*nn*S) remain unchanged until evaluation of all SELOGIC control equations, when the relay evaluates the latch (ALT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the automation freeform area dominates, and the relay uses this equation to evaluate the latch.

Conditioning Timers

Use conditioning timers to condition Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state. Conditioning timers are available in the protection freeform area, as shown in *Table 13.9*. Conditioning timers have the three input parameters and one output shown in *Table 13.10*.

NOTE: Times for protection timers must not exceed 2,000,000 cycles for proper operation.

Table 13.9 Conditioning Timer Quantities

Type	Typical Quantity	Name Range
Protection freeform conditioning timers	32	PCT01–PCT32

Table 13.10 Conditioning Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PCT01IN
Input	Pickup Time	Time that the input must be on before the output turns on	Time value in cycles	PCT01PU
Input	Dropout Time	Time that the output stays on after the input turns off	Time value in cycles	PCT01DO
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PCT01Q

A conditioning timer output turns on and becomes logical 1, after the input turns on and the Pickup Time expires. An example timing diagram for a conditioning timer, PCT01, with a Pickup Time setting greater than zero and a Dropout Time setting of zero is shown in *Figure 13.3*. In the example timing diagram, the Input, PCT01IN, turns on and the timer Output, PCT01Q, turns on after the Pickup Time, PCT01PU, expires. Because the Dropout Time setting is zero, the Output turns off when the Input turns off.

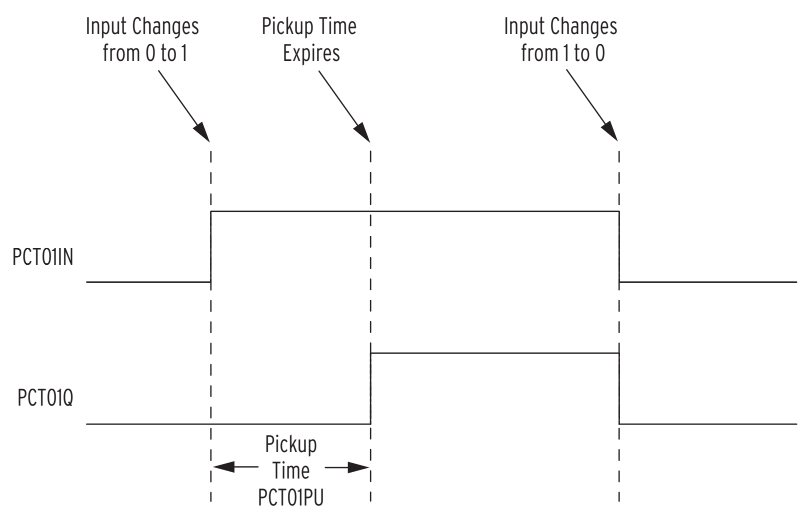

Figure 13.3 Conditioning Timer With Pickup and No Dropout Timing Diagram

If the Pickup Time is not satisfied, the timer Output never turns on, as illustrated in *Figure 13.4*. If the input reasserts again, one or more processing intervals later, the conditioning timer pickup timer begins timing again from zero.

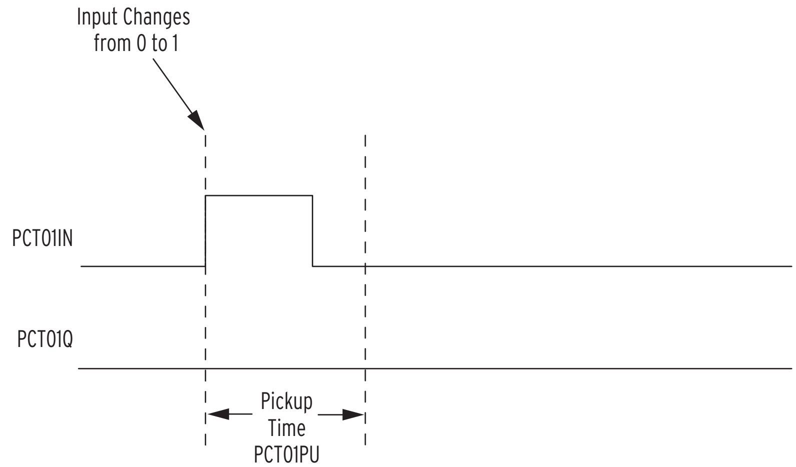

Figure 13.4 Conditioning Timer With Pickup Not Satisfied Timing Diagram

A conditioning timer output turns off when the input turns off and the Dropout Time expires. An example timing diagram for a conditioning timer, PCT02, with a Pickup Time setting of zero and a Dropout Time setting greater than zero is shown in *Figure 13.5*. Because the Pickup Time, PCT02PU, setting is zero, the Output, PCT02Q, turns on when the Input, PCT02IN, turns on. The Output turns off after the Input turns off and the Dropout Time, PCT02DO, expires. If the input reasserts before the dropout time expires, the dropout timer resets so it begins timing again from zero when the input drops out again.

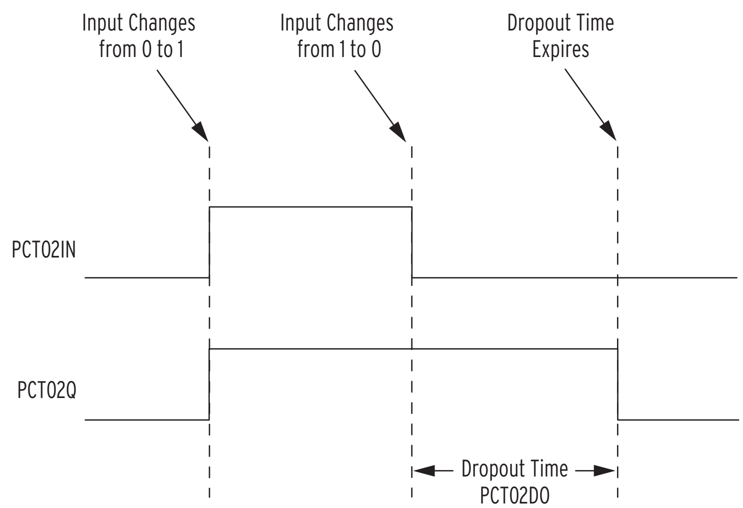

Figure 13.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown above, *Figure 13.6* illustrates conditioning timer operation for use of both the pickup and dropout characteristics. The Output, PCT03Q, turns on after the Input, PCT03IN, turns on and the Pickup Time, PCT03PU, expires. The Output turns off after the Input turns off and the Dropout Time, PCT03DO, expires.

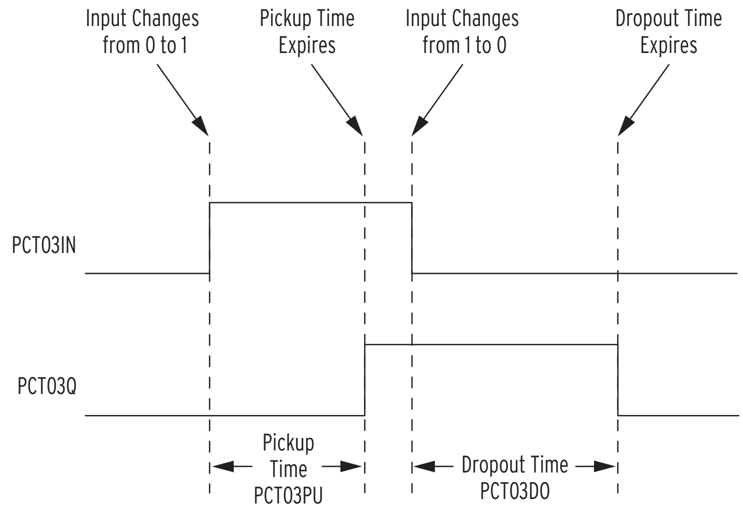

Figure 13.6 Conditioning Timer With Pickup and Dropout Timing Diagram

Set the conditioning timer settings for Pickup and Dropout in cycles and fractions of a cycle (represented in decimal form). The relay processes conditioning timers once for each protection processing interval. The relay asserts the timer output on the first processing interval when the elapsed time exceeds the setting. In most SEL-400 series relays, the protection processing interval is 1/8 cycle (or 0.125 cycles). See the product-specific instruction manual to determine the specific processing interval. Actual settings, programming, and operation are illustrated in *Example 13.7*.

Example 13.7 Conditioning Timer Programming and Operation

This example uses protection freeform conditioning timer seven, PCT07. The freeform settings are as shown here:

PCT07PU := **5.3** # Pickup set to 5.3 cycles

PCT07D0 := **6.0** # Dropout set to 6.0 cycles

PCT07IN := **IN101** # Operate on the first input on the main board

PSV29 := **PCT07Q** # Protection SELOGIC control equation variable follows the timer output

The operation of the timer when IN101 turns on for 7 cycles is shown in the timing diagram in *Figure 13.7*. Because the pickup setting is an uneven number of protection processing intervals (1/8 cycle), the pickup occurs on the first 1/8th cycle after the Pickup Time of 5.3 cycles expires.

Example 13.7 Conditioning Timer Programming and Operation (Continued)

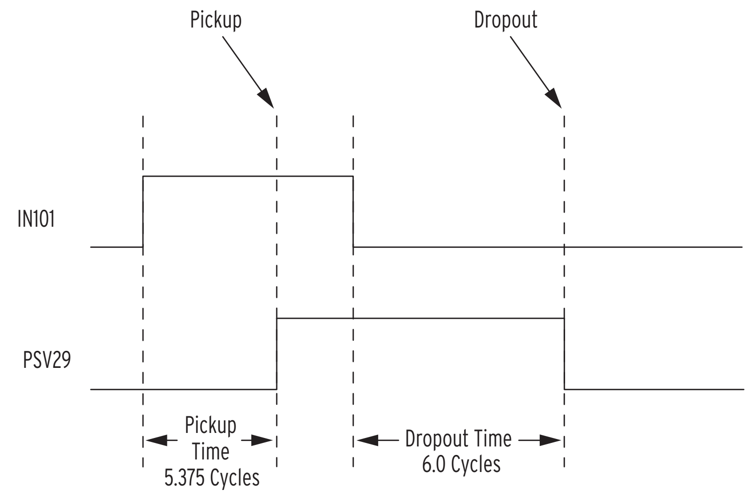

Figure 13.7 Conditioning Timer Timing Diagram for *Example 13.7*

In protection freeform programming, the relay evaluates the timer at execution of the timer Input SELOGIC control equation (PCT*nn*IN). The relay loads the Pickup Time (PCT*nn*PU) and Dropout Time (PCT*nn*DO) into the timer when the relay observes the appropriate edge in the input. If you enter a math expression for Pickup Time or Dropout Time, the relay uses the value calculated before the Input SELOGIC control equation. If your Pickup Time or Dropout Time equation is below the Input equation (has a higher expression line number), the relay will use the value calculated on the previous SELOGIC control equation execution interval. Because the relay calculates the last value for pickup or dropout in this manner, we recommend for most applications that you enter the Pickup Time, Dropout Time, and Input statements together in the order shown in *Example 13.7*. You can view the status of the protection conditioning timer output Relay Word bits using the **TAR PCT*nn*Q** command, where *nn* is the number of the protection conditioning timer. You can also view the status of these timer elements through the relay front-panel LCD display by selecting `RELAY ELEMENTS` from the Main Menu and scrolling through the rows of Relay Word bits.

Sequencing Timers

NOTE: Times for protection timers must not exceed 2,000,000 cycles for proper operation.

Sequencing timers are useful for sequencing operation. There are two main differences between sequencing timers and conditioning timers. First, sequencing timers integrate pulses of the input to count up a total time. Second, the elapsed time a sequencing timer counts is visible; you can use this time in other SELOGIC control equation programming or make this time visible through one of the relay communications protocol interfaces. Sequencing timers are available in the protection freeform area and automation freeform area as shown in *Table 13.11*. Sequencing timers have three input parameters and two outputs listed in *Table 13.12*.

Table 13.11 Sequencing Timer Quantities

Type	Typical Quantity	Name Range
Protection freeform sequencing timers	32	PST01–PST32
Automation freeform sequencing timers	32	AST01–AST32

Table 13.12 Sequencing Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PST01IN AST07IN
Input	Preset Time	Time the input must be on before the output turns on	Time value. Protection uses cycles, while automation uses seconds.	PST01PT AST07PT
Input	Reset	Timer reset	Boolean SELOGIC control equation setting	PST01R AST07R
Output	Elapsed Time	Time accumulated since the last reset	Value for math SELOGIC control equations. Protection uses cycles, while automation uses seconds.	PST01ET AST07ET
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PST01Q AST07Q

A sequencing timer counts time by incrementing the Elapsed Time when SELOGIC control equation execution reaches the Input equation if the Reset is off and the Input is on. The Output turns on when the Elapsed Time reaches or exceeds the Preset Time. Whenever the Reset is on, the relay sets the Output to zero, then clears the Elapsed Time, and stops accumulating time (even if Input is on).

Figure 13.8 is a timing diagram for typical sequencing timer operation.

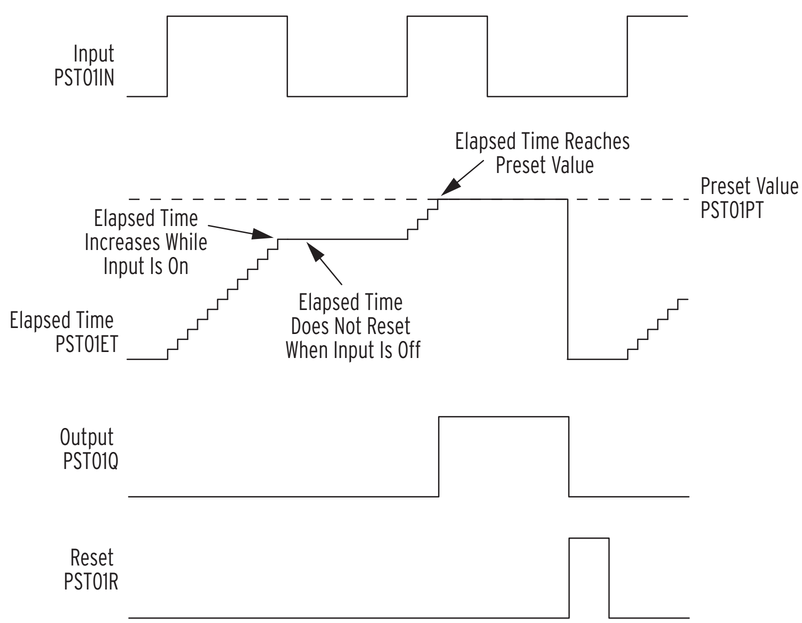

Figure 13.8 Sequencing Timer Timing Diagram

Timers in protection programming operate in cycles, while timers in automation programming operate in seconds. As with sequencing timers, operation depends on the logic processing interval. For example, in most SEL-400 series relays the logic processing interval is 1/8 cycle, so the relay effectively rounds up all operation to the nearest 0.125 cycles. With automation programming, the execution interval depends on the amount of automation programming. Determine the average automation execution interval with the **STATUS S** command.

The automation timers operate using a real time clock. Each time the relay evaluates the Input (AST*nn*IN) the relay adds the elapsed time since the last execution to the Elapsed Time (AST*nn*ET). The accuracy of the timer in stopping and starting when the input of the timer turns on averages half an automation execution cycle. If you change automation freeform programming, you must also check the new automation average execution cycle to verify that you will obtain satisfactory accuracy for your application. *Example 13.8* describes typical timer programming and describes the resulting operation.

Example 13.8 Automation Sequencing Timer Programming

The equations below are an example of programming for an automation sequencing timer, AST01. Each timer input is programmed as a separate statement in automation SELOGIC control equation programming.

Example programming of sequencing timer to time Input IN101 and IN102

AST01PT := **7.5** # Timer Preset Time of 7.5 seconds

AST01R := **RB03** # Reset timer when RB03 turns on

AST01IN := **IN101 AND IN102** # Timing time when IN101 and IN102 are on

ASV001 := **AST01Q** # ASV001 tracks output of timer

AMV256 := **AST01ET** # AMV256 tracks timing progress

In this example, timer AST01 times the quantity IN101 AND IN102 and turns on when the total time reaches 7.5 seconds. If the Input, AST01IN, is on for approximately 1 second every minute, the Output, AST01Q, will turn on during the eighth minute, when the accumulated elapsed time exceeds 7.5 seconds.

In freeform programming, the relay evaluates the timer at the timer Input SELOGIC control equation (PST*nn*IN or AST*nn*IN). If you enter an expression for the timer Reset (PST*nn*R or AST*nn*R) or Preset Time (PST*nn*PT or AST*nn*PT), the values for Reset and Preset Time that the relay uses are the last values that the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset Time value in this manner, we recommend for most applications that you enter the Preset Time, Reset, and Input statements together in the order shown in Example 3.8. You can view the current state of the timer by assigning the elapsed time output of the sequencing timer to a math variable. *Example 13.8* shows how you would assign the elapsed time output for automation sequence timer AST01 to automation math variable AMV256. To see the elapsed time value, issue the **MET AMV** command to display the values of the automation math variables. Likewise, you can assign the elapsed time output of a protection sequence timer to a protection math variable.

The elapsed time output is stored in volatile memory. Elapsed time resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that reboots the relay.

Counters

NOTE: Preset values for counters must not exceed 8,000,000 for proper operation.

Use counters to count changes or edges in Boolean values. Each time the value changes from logical 0 to logical 1 (a rising edge), the counter Current Value increments. Counters are available in the protection freeform area and automation freeform area, as shown in *Table 13.13*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output, as listed in *Table 13.14*.

Table 13.13 Counter Quantities

Type	Typical Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 13.14 Counter Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay counts	Boolean SELOGIC control equation setting	PCN01IN CN09IN
Input	Preset Value	Number of counts before the output turns on	Constant or expression for the number of counts	PCN01PV ACN09PV
Input	Reset	Counter reset	Boolean SELOGIC control equation setting	PCN01R ACN09R
Output	Current Value	Current accumulated count	Value for math SELOGIC control equations	PCN01CV ACN09CV
Output	Output	Counter output	Value for Boolean SELOGIC control equations	PCN01Q ACN09Q

In freeform programming, the relay evaluates the counter at execution of the counter Input SELOGIC control equation (PCN*nn*IN or ACN*nn*IN). If you enter an expression for the counter Reset (PCN*nn*R) or the counter Preset (PCN*nn*PV), the values for Reset and Preset that the relay uses are the last values the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset in this manner, we recommend for most applications that you enter the Preset, Reset, and Input statements together in the order shown in *Example 13.9*. You can view the current value of the counter by assigning the protection counter current value, PCV*nn*CV, to a protection math variable or by assigning the automation counter current value, ACV*nn*CV, to an automation math variable. View the math variable values by issuing the appropriate **MET PMV** or **MET AMV** commands.

The current value count is stored in volatile memory. Elapsed time resets to zero for both protection and automation sequential timers when relay power cycles, you change settings or settings groups, or you perform any function that reboots the relay.

Example 13.9 Counter Programming

The freeform programming equations that follow demonstrate how to enter settings to control a protection counter in protection freeform SELOGIC control equation programming. Programming for an automation counter is similar.

Example 13.9 Counter Programming (Continued)

Protection Counter 1 counts close operations of the circuit breaker associated with the 52AA1 element. Initially, the current value, PCN01CV, is zero. The relay increments the current value each time the circuit breaker closes. The relay increases the count value, PCN01CV, each time the circuit breaker closes and the element 52AA1 value changes from 0 to 1 (a rising edge). When the count reaches 1000, the timer automatically resets and begins counting again.

```
# Example protection counter programming
#
# This example counts how many times a circuit breaker closes
# The counter automatically resets every 1,000 operations
PCN01PV := 1000
PCN01R := PCN01Q
PCN01IN := 52AA1
```

The SELOGIC control equations below provide multiple-change detection counting both close and open operations of the circuit breaker. The intermediate value PSV01 turns on for one processing interval each time the circuit breaker closes. The intermediate value PSV02 turns on for one processing interval each time the circuit breaker opens. The OR combination of PSV01 and PSV02 contains a rising edge for each circuit breaker operation, open or closed, that Protection Counter 1 counts.

```
# Example protection counter programming
#
# This example counts how many times a circuit breaker operates either open or closed
#
# Detect OPEN and CLOSE and combine
PSV01 := R_TRIG 52AA1 # Pulse for each close
PSV02 := F_TRIG 52AA1 # Pulse for each open
PSV03 := PSV01 OR PSV02 # Pulse for each open or close
#
# The counter automatically resets every 1,000 operations
PCN01PV := 1000
PCN01R := PCN01Q
PCN01IN := PSV03 # Count open and close operations
PSV04 := PCN01CV >900 # PSV04 signals impending reset
```

SELOGIC Control Equation Operators

There are two types of SELOGIC control equations. Boolean SELOGIC control equations comprise the first type. These equations are expressions that evaluate to a Boolean value of 0 or 1. Math SELOGIC control equations constitute the second type. The relay evaluates these equations to yield a result having a numerical value (for example, 6.25 or 1055).

Left value, LVALUE, determines the type of SELOGIC control equation you need for a setting or for writing freeform programming. If the LVALUE is a Boolean type (ER, ASV001, etc.) then the type of expression you need is a Boolean SELOGIC control equation. If the LVALUE is a numerical (non-Boolean) value (PMV12, PCT01PV, etc.), the type of expression you need is a math SELOGIC control equation.

Writing SELOGIC control equations requires that you use the appropriate operators and correct SELOGIC control equation syntax to combine relay elements including analog values, Relay Word bits, incoming control points, and SELOGIC control equation elements within the relay. The operators are grouped into two types, according to the type of SELOGIC control equation in which you can apply these operators.

Operator Precedence

When you combine several operators and operations within a single expression, the relay evaluates the operations from left to right, starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example PSV01 AND PSV02 AND PSV03, each AND will be evaluated from the left to the right. If you substitute NOT PSV04 for PSV03 to make PSV01 AND PSV02 AND NOT PSV04, the relay evaluates the NOT operation of PSV04 first and uses the result in subsequent evaluation of the expression. While you cannot use all operators in any single equation, the overall operator precedence follows that shown in *Table 13.15*.

Table 13.15 Operator Precedence From Highest to Lowest (Sheet 1 of 2)

Operator	Description
(Expression)	Parenthesis
Identifier (argument list)	Function evaluation
–	Negation
NOT	Complement
R_TRIG	
F_TRIG	Edge Trigger
SQRT, LN, EXP, LOG, COS, SIN, ACOS, ASIN, ABS, CEIL, FLOOR	Math Functions
*	Multiply
/	Divide
+	Add
–	Subtract
<, >, <=, >=	Comparison
=	Equality
<>	Inequality

Table 13.15 Operator Precedence From Highest to Lowest (Sheet 2 of 2)

Operator	Description
AND	Boolean AND
OR	Boolean OR

Boolean Operators

Use Boolean operators to combine values with a resulting Boolean value. The arguments of the operator may be either numbers or Boolean values, but the result of the operation must be a Boolean value. Combine the operators to form statements that evaluate complex Boolean logic. *Table 13.16* contains a summary of Boolean operators available in SEL-400 series relays.

Table 13.16 Boolean Operator Summary

Operator	Description
( )	Parentheses
NOT	Logical inverse
AND	Logical AND
OR	Logical OR
R_TRIG	Rising-edge trigger
F_TRIG	Falling-edge trigger
>, <, =, <=, >=, <>	Comparison of values

Parentheses

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The relay calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations. *Table 13.17* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 13.17 Parentheses Operation in Boolean Equation

A	B	C	A AND B OR C	A AND (B OR C)
0	0	0	0	0
0	0	1	1	0
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

NOT

Use NOT to calculate the inverse of a Boolean value according to the truth table shown in *Table 13.18*.

Table 13.18 NOT Operator Truth Table

Value A	NOT A
0	1
1	0

AND

Use AND to combine two Boolean values according to the truth table shown in *Table 13.19*.

Table 13.19 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

OR

Use OR to combine two Boolean values according to the truth table shown in *Table 13.20*.

Table 13.20 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

R_TRIG

R_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Figure 13.9* Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only once when the value changes. The R_TRIG output is a pulse of one protection processing interval duration (typically 1/8th cycle). This rising-edge pulse output asserts one processing interval after the monitored element asserts.

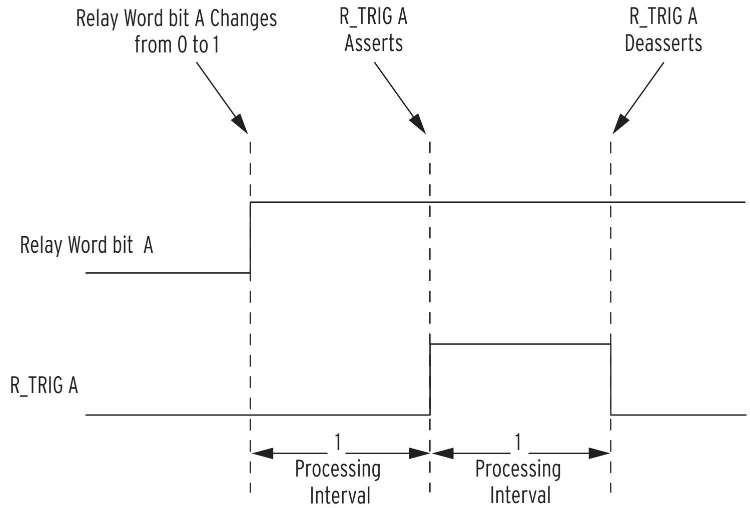

Figure 13.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the relay. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 13.10*.

Example 13.10 R_TRIG Operation

The SELOGIC control equation below is invalid.

PSV15 := **R_TRIG (PSV01 AND PSV23)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the R_TRIG operation on the result, as shown below.

PSV14 := **PSV01 AND PSV23** # Calculate quantity in an intermediate result variable

PSV15 := **R_TRIG PSV14** # Perform an R_TRIG on the quantity

F_TRIG

F_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Example 13.10*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state. The F_TRIG output is a pulse of one protection processing interval duration (typically 1/8th cycle). This pulse output asserts one processing interval after the monitored element deasserts.

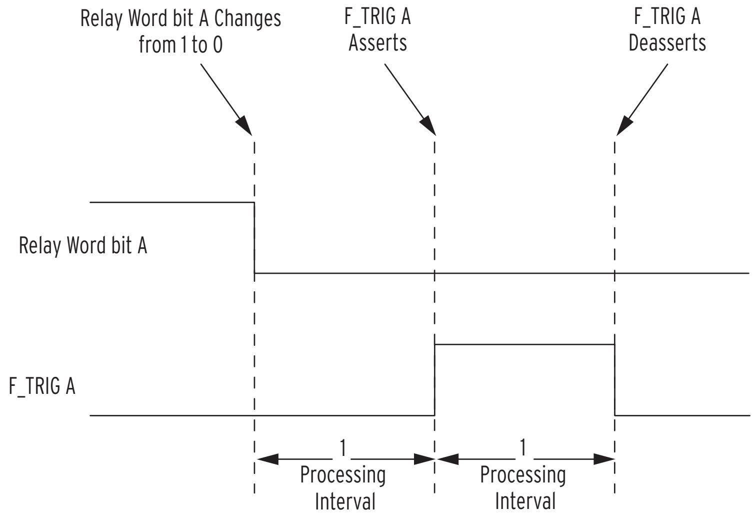

Figure 13.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the relay. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 13.11*.

Example 13.11 F_TRIG Operation

The SELOGIC control equation below shows an invalid use of the F_TRIG operation.

ASV015 := **F_TRIG (ASV001 AND ALT11)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the F_TRIG operation on the result, as shown below.

ASV014 := **ASV001 AND ALT11** # Calculate quantity in an intermediate result variable

ASV015 := **F_TRIG ASV14** # Perform an F_TRIG on the quantity

Comparison

Comparison is a mathematical operation that compares two numerical values with a result of logical 0 or logical 1. AND and OR operators compare Boolean values; comparison functions compare floating-point values such as currents and other quantities. Comparisons and truth tables for operation of comparison functions are shown in *Table 13.21*.

NOTE: Be careful how you use the equal (=) and the inequality (<>) operators. Because the relay uses a floating-point format to calculate analog values, only integer numbers will match exactly. Allow a small hysteresis of the following form: PSV01 := I01FM < 10.002 AND I01FM > 9.988.

Table 13.21 Comparison Operations

A	B	A > B	A ≥ B	A = B	A <> B	A ≤ B	A < B
6.35	7.00	0	0	0	1	1	1
5.10	5.10	0	1	1	0	1	0
4.25	4.00	1	1	0	1	0	0

Math Operators

Use math operators when writing math SELOGIC control equations. Math SELOGIC control equations manipulate numerical values and provide a numerical base 10 result. *Table 13.22* summarizes the operators available for math SELOGIC control equations.

Table 13.22 Math Operator Summary

Operator	Description
( )	Parentheses
+, –, *, /	Arithmetic
SQRT	Square root
LN, EXP, LOG	Natural logarithm, exponentiation of e, base 10 logarithm
COS, SIN, ACOS, ASIN	Cosine, sine, arc cosine, arc sine
ABS	Absolute value
CEIL	Rounds to the nearest integer toward infinity
FLOOR	Rounds to the nearest integer toward minus infinity
–	Negation

Parentheses

Use parentheses to control the order in which the relay evaluates math operations within a math SELOGIC control equation. Also use parentheses to group expressions that you use as arguments to function operators such as SIN and COS. Include as many as 14 levels of nested parentheses in your math SELOGIC control equation. *Example 13.12* shows how parentheses affect the operation and evaluation of math operations.

Example 13.12 Using Parentheses in Math Equations

The freeform math SELOGIC control equations below show examples of parentheses usage.

Examples of parenthesis usage

AMV001 := **AMV005 * (AMV004 + AMV003)** # Calculate sum first, then product

AMV002 := **AMV010 * (AMV009 + (AMV016 / AMV015)**) # Nest parentheses

AMV003 := **SIN (AMV037 + PMV42)** # Group terms for a function

Math Error Detection

If a math operation results in an error, the relay turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command resets this bit. For example, if you attempt to take the square root of a negative number (SQRT –5), the math error bit will be asserted until you clear the bit with a **STATUS SC** command or change settings.

Table 13.23 Math Error Examples

Example	Value in PMV01	Type	MATHERR
PMV01 := PMV02 / 0	0[a]	Divide by zero	Yes
PMV01 := LN (0)	0[a]	LN of 0	Yes
PMV01 := LN (-1)	0[a]	LN of negative number	Yes
PMV01 := SQRT (-1)	0[a]	Square root of a negative number	Yes

[a] Evaluation of expression results in an error and prevents storage of new result. In the example, PMV01 remains 0. If the argument were a variable, PMV01 would contain the result of the last evaluation when the argument is valid.

Arithmetic

Use arithmetic operators to perform basic mathematical operations on numerical values. Arguments of an arithmetic operation can be either Boolean or numerical values. In a numerical operation, the relay converts logical 0 or logical 1 to the numerical value of 0 or 1. For example, multiply numerical values by Boolean values to perform a selection operation. Use parentheses to group terms in math SELOGIC control equations and control the evaluation order and sequence of arithmetic operations.

NOTE: IEEE 32-bit floating point numbers have a precision of approximately 7 significant digits. This means that numbers bigger than 10,000,000 will lose precision in the least significant digit. Do not implement counters expecting them to get bigger than 10,000,000. Do not expect precise accuracy in analog quantities when they get bigger than 10,000,000.

The relay uses IEEE 32-bit floating-point numbers to perform SELOGIC control equation mathematical operations. If an operation results in a quantity that is not a numerical value, the SELOGIC control equation status bit that signals a math error, MATHERR, asserts. The value that the relay stored previously in the specified result location is not replaced. The relay clears the corresponding math error bits if you change SELOGIC control equation settings (protection or automation), or if you issue a **STATUS SC** command. *Example 13.13* contains examples of arithmetic operations in use.

Example 13.13 Using Arithmetic Operations

The freeform math SELOGIC control equations below show examples of arithmetic operator usage.

Arithmetic examples

AMV001 := **AMV005 + AMV034** # Calculate sum

AMV002 := **AMV005 – AMV034** # Calculate difference

AMV003 := **AMV005 * AMV034** # Calculate product

AMV004 := **AMV005 / AMV034** # Calculate quotient

The lines below demonstrate the use of Boolean values with the multiplication operation.

Use of multiplication to select numerical values based on active settings group

Use 7 if protection settings group 1 active

Use 5 if protection settings group 2 active

AMV005 := **7 * SG1 + 5 * SG2**

Example 13.13 Using Arithmetic Operations (Continued)

The lines below demonstrate math calculation error detection.

The line below results in a math error if AMV029 becomes 0

AMV006 := **732 / AMV029**

In the second line, if AMV029 is 6 on the first pass through the automation programming, the relay stores the result 122 in AMV006. If on the next pass AMV029 is 0, the MATHERR bit asserts and the value in AMV006 does not update.

SQRT

Use the SQRT operation to calculate the square root of the argument. Use parentheses to delimit the argument of a SQRT operation. A negative argument for the SQRT operation results in a math error and assertion of the corresponding math error bit described in Arithmetic. *Example 13.14* shows examples of the SQRT operator in use.

Example 13.14 Using the SQRT Operator

The freeform math SELOGIC control equations below show examples of SQRT operator usage.

SQRT examples

AMV001 := **SQRT (AMV005)** # Single argument version of SQRT

AMV002 := **SQRT (AMV005 + AMV034)** # Calculates the square root of the sum

AMV003 := **SQRT (AMV007)** # Produces a math error if AMV007 is negative

LN, EXP, and LOG

LN and EXP are complementary functions for operating with natural logarithms or logarithms calculated to the natural base e. LN calculates the natural logarithm of the argument. LOG calculates the base 10 logarithm of the argument. A negative or zero argument for the LN and LOG operation results in a math error and assertion of the corresponding math error bit described in Arithmetic. EXP calculates the value of e raised to the power of the argument. *Example 13.15* shows examples of expressions that use the LN, EXP, and LOG operators. Use parentheses to delimit the argument of a LN, EXP, or LOG operation.

Example 13.15 Using the LN, EXP, and LOG Operators

The freeform math SELOGIC control equations below are examples of LN, EXP, and LOG operator usage.

LN examples

AMV001 := **LN (AMV009)** # Natural logarithm of AMV009

AMV002 := **LN (AMV009 + AMV034)** # Natural logarithm of the sum

AMV003 := **LN (AMV010)** # Produces error if AMV010 is 0 or negative

Example 13.15 Using the LN, EXP, and LOG Operators (Continued)

EXP examples

AMV004 := **EXP (2)** # Calculates e squared

AMV005 := **EXP (AMV003)** # Calculates e to the power AMV003

AMV006 := **EXP (AMV046 + AMV047)** # e raised to the power of the sum

LOG examples

AMV007 := **LOG (AMV012)** # Base 10 logarithm of AMV012

AMV008 := **LOG (AMV012 + AMV022)** # Base 10 logarithm of the sum

AMV009 := **LOG (AMV100)** # Produces an error if AMV100 is 0 or negative

SIN and COS

Use the SIN or COS operators to calculate the sine or cosine of the argument. SIN and COS operate in degrees, the unit of angular measure the SEL-451 uses to express metering quantities. *Example 13.16* shows examples of SIN and COS. Use parentheses to delimit the argument of a SIN or COS operation.

Example 13.16 Using the SIN and COS Operators

The freeform math SELOGIC control equations below are examples of SIN and COS.

SIN examples

AMV001 := **SIN (AMV005)** # Sine of AMV005

AMV002 := **SIN (AMV005 + AMV034)** # Sine of the sum

COS examples

AMV003 := **COS (AMV005)** # Cosine of AMV005

AMV004 := **COS (AMV005 + AMV006)** # Cosine of the sum

ASIN and ACOS

Use the ASIN or ACOS operators to calculate the angle resulting from the trigonometric function equivalent to a given number (the argument), where the function is sine or cosine. ASIN and ACOS operate in degrees. An argument less than –1 or larger than 1 results in a math error and assertion of the corresponding math bit described in *Arithmetic on page 13.30*. *Example 13.17* shows examples of ASIN and ACOS. Use parentheses to delimit the argument of an ASIN or ACOS operation.

Example 13.17 Using the ASIN and ACOS Operators

The freeform math SELOGIC control equations below are examples of ASIN and ACOS.

ASIN examples

AMV001 := **ASIN (AMV010)** # Arc sine of AMV010

AMV002 := **ASIN (AMV010 + AMV011)** # Arc sine of the sum

AMV003 := **ASIN (AMV012)** # Produces an error if |AMV012| > 1

ACOS examples

AMV004 := **ACOS (AMV010)** # Arc cosine of AMV010

AMV005 := **ACOS (AMV010 + AMV011)** # Arc cosine of the sum

AMV006 := **ACOS (AMV012)** # Produces an error if |AMV012| > 1

ABS

Use the ABS operation to calculate absolute value of the argument. Use parentheses to group a math expression as the argument of an ABS operation. If the argument of the ABS operation is negative, the result is the value multiplied by –1. If the argument of the ABS operation is positive, the result is the same quantity as the argument. *Example 13.18* contains examples of the ABS operator in use.

Example 13.18 Using the ABS Operator

The freeform math SELOGIC control equations below show examples of the ABS operator usage.

ABS examples

AMV001 := **ABS (-6)** # Stores 6 in AMV001

AMV002 := **ABS (6)** # Stores 6 in AMV002

AMV003 := **ABS (AMV009)** # Absolute value of AM009

AMV004 := **ABS (AMV005 + AMV034)** # Absolute value of the sum

CEIL

Use the CEIL operator to round the argument to the nearest integer toward positive infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 13.19* contains examples of the CEIL operator.

Example 13.19 Using the CEIL Operator

The freeform math SELOGIC control equations below show examples of the CEIL operator usage.

CEIL examples

AMV001 := **CEIL (5.99)** # Stores 6 in AMV001

AMV002 := **CEIL (–4.01)** # Stores –4 in AMV002

FLOOR

Use the FLOOR operator to round the argument to the nearest integer toward minus infinity. Use parentheses to group a math expression as the argument of a FLOOR operation. *Example 13.20* contains examples of the FLOOR operator.

Example 13.20 Using the FLOOR Operator

The freeform math SELOGIC control equations below show examples of the FLOOR operator usage.

FLOOR examples

AMV001 := **FLOOR (5.99)** # Stores 5 in AMV001

AMV002 := **FLOOR (–4.01)** # Stores –5 in AMV002

Negation

Use the negation (–) operation to change the sign of the argument. The argument of the negation operation is multiplied by –1. Negation of a positive value results in a negative value, while negation of a negative value results in a positive value. *Example 13.21* contains examples of expressions that utilize the negation operator.

Example 13.21 Using the Negation Operator

The freeform math SELOGIC control equations below show examples of negation operator usage.

Negation examples

AMV001 := **-AMV009** # If AMV009 is 5, stores –5 in AMV001

AMV002 := **-AMV009** # If AMV009 is –5, stores 5 in AMV002

Effective Programming

This section contains several ideas useful for creating, maintaining, and troubleshooting programming in SEL-400 series relays protection and automation SELOGIC control equation programming environments.

Planning and Documentation

When you begin to configure the relay to perform a new automation task or customize protection operation, take time to design, document, and implement your project. Scale the planning effort to match the overall size of the project, but spend sufficient time planning to do the following:

- ➤ Document the inputs and outputs of your programming. This may include protection elements, physical inputs and outputs, metering quantities, user inputs, and other information within the relay.
- ➤ Document the processing or outcome of the programming. List the major tasks you want the relay to perform and provide detail about the algorithm you will use for each task. For example, if you need a timer or a counter, make a note of the requirements and how you will use these elements.

- Work in a top-down method, specifying and moving to more detailed levels, until you have sufficient information to create the settings. For simple tasks, one level may be sufficient. For complex tasks, such as automated station restoration, you may need several levels to move from idea to implementation.

Comments

SELOGIC control equation comments are very powerful tools for dividing, documenting, and clarifying your programming. Even if you completely understand your programming during installation and commissioning, comments will be very helpful if you need to modify operation a year later.

Create these comments in the fixed and freeform SELOGIC control equations, and store these comments in the relay. Obtain comments to assist you in using the ASCII interface or SEL configuration software, regardless of whether you have the original files downloaded to the relay.

Comments add structure to freeform programming environments such as Visual Basic, C, and freeform SELOGIC control equations. *Example 13.22* shows how to use comments to divide and structure freeform SELOGIC control equation programming.

Example 13.22 Comments in Freeform SELOGIC Control Equation Programming

Use comments to divide and direct your eye through freeform programming.

```
#
# This is a header comment that divides sections of freeform programming
#
AMV003 := 15 * AMV003 # Explain this line here
#
# This comment is a header for the next section.
# Inputs: provide more detail for more complex tasks
# Outputs: describe how the programming affects the relay operation
# Processing: discuss how the programming itself operates
#
ASV004 := ACN01Q AND RB03 # First line of next section
```

Many texts on programming in various computer programming languages suggest that you cannot include too many comments. The main reason to include comments is that something you find obvious may not be obvious to your coworker who will have to work with your programming in the future. Adding comments also gives you the opportunity to think about whether the program performs the function you intended.

Aliases

SEL-400 series relays provide the ability to alias relay word bit and analog quantity names. To make SELOGIC programming more understandable, alias the names of variables being used to something meaningful. For example, you could assign PMV01 an alias of THETA and PMV02 an alias of TAN and then write a SELOGIC equation of:

TAN := SIN(THETA)/COS(THETA)

See *Alias Settings on page 12.20* for more information on creating aliases.

Testing

After documentation and comments, the next essential element of an effective approach to programming is testing. Two types of testing are critical for determining if programming for complex tasks operates properly. First, test and observe whether the program performs the function you want under the conditions you anticipated. Second, look for opportunities to create conditions that are abnormal and determine how your program reacts to unusual conditions.

For example, test your system in unanticipated, but possible conditions such as loss of power, loss of critical field inputs, unexpected operator inputs, and conditions that result from likely failure scenarios of the equipment in your system. It is unlikely that you will find every possible weakness, but careful consideration and testing for abnormal conditions will help you avoid a failure and may reveal deficiencies in the normal operation of your system. Alternatively, you can substitute a remote bit or local bit that you can manually control to help exercise your logic.

Modify your SELOGIC control equations to simulate the process. While you may be unable to change the state of a discrete input easily, such as IN101, you can substitute a logical 1 or logical 0 in your logic to simulate the operation of IN101 and observe the results. Alternatively, you can substitute a remote bit or local bit that you can manually control to help exercise your logic.

Use the SER capabilities of the relay to monitor and record inputs, internal calculations, and outputs. For operations that occur very quickly, use the SER during testing to reconstruct the operation of your logic.

Use the **MET PMV** and **MET AMV** commands to display the contents of the protection or automation math variables.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 and SEL-351 series relays to logic for an SEL-400 series relay. In the SEL-351 series relays, SELOGIC control equation programming is restricted to equations where the left side value, LVALUE, is fixed. SEL-400 series relays use a combination of fixed and freeform programming. *Table 13.24* shows comparable features between the fixed logic settings of the SEL-351-5, -6, -7 series relays and the corresponding logic elements that can be programmed in an SEL-400 series relay using freeform logic programming.

Table 13.24 SEL-351 Series Relays and SEL-400 Series SELOGIC Control Equation Programming Equivalent Functions

Feature	SEL-351 Series	SEL-400 Series Protection Freeform Style
SELOGIC control equation variables	SV1–SV16	PSV01–PSV64
Timer Input	SV1–SV16	PCT01–PCT32
Timer Pickup settings	SV1PU–SV16PU	PCT01PU–PCT32PU
Timer Dropout settings	SV1DO–SV16DO	PCT01DO–PCT32DO
Timer Outputs	SV1T–SV16T	PCT01Q–PCT32Q
Latch Bit Set Control	SET1–SET16	PLT01S–PLT16S
Latch Bit Reset Control	RST1–RST16	PLT01R–PLT16R
Latch Bit	LT1–LT16	PLT01–PLT16

Table 13.25 is a summary that compares SELOGIC control equation programming in SEL-351 series relays and SEL-311 series relays with typical SEL-400 series relays.

Table 13.25 SEL-400 Series SELOGIC Control Equation Programming Summary

Element	SEL-351 Series/ SEL-311 Series	Typical SEL-400 Series	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64	256
SELOGIC math variables	0	64	256
Conditioning timers[a]	16	32	0
Sequencing timers	0	32	32
Counters	0	32	32
Latch bits	16	32	32

[a] Similar to SEL-300 series relay SELOGIC control equation programming.

Table 13.26 shows the SEL-400 series Boolean operators compared to the operators used in the SEL-351 series relays.

Table 13.26 SEL-351 Series Relays and SEL-400 Series SELOGIC Control Equation Boolean Operators

Feature	SEL-351 Series	SEL-400 Series
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling edge operators	/, \	R_TRIG, F_TRIG

In the SEL-351 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In SEL-400 series relays, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in SEL-400 series relays are different from those used in SEL-300 series relays. For example, if you wish to convert programming from an SEL-311 or SEL-351 series relay to an SEL-400 series relay, you must convert the operators. *Example 13.23* and *Example 13.24* demonstrate conversion of several settings to the SEL-451 setting.

Example 13.23 Converting SEL-351 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In an SEL-400 series relay, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04** # Freeform example

In the example above, first convert the + and * operators in the expression to the OR and AND operators. In the freeform example, use a protection SELOGIC control equation variable for the result. In the protection group settings example, use the input of a timer, as shown in *Table 13.21*.

Example 13.24 Converting SEL-351 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-351 series relay, convert it as shown below.

```
SV1 = IN101
SV1PU = 5.25
SV1DO = 3.50
OUT101 = SV1T
```

In an SEL-400 series relay, use the format shown below.

#

Freeform programming conversion of timer

#

PCT01PU := **5.25** # Pickup of 5.25 cycles

PCT01DO := **3.5** # Dropout of 3.5 cycles

PCT01IN := **IN101** # Use the timer to monitor IN101

In the output settings, set OUT101 as shown below:

OUT101 := **PCT01Q**

Example 13.25 Converting SEL-351 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-351 series relay, convert it as shown below.

```
SET1 = RB4
RST1 = RB5
OUT101 = LT1
```

Example 13.25 Converting SEL-351 Series Relay Latch Bits (Continued)

In an SEL-400 series relay, use the format shown below.

Protection freeform style settings:

```
#
# Freeform programming conversion of latch bit
#
PLT01S := RB04 # Set if RB04
PLT01R := RB05 # Reset if RB05
```

In the output settings, set OUT101 as shown below:

```
OUT101 := PLT01
```

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SECTION 14

ASCII Command Reference

You can use a communications terminal or terminal emulation program to set and operate the relay. This section explains common SEL-400 series relay commands that you send to the relay using SEL ASCII communications protocol. The relay responds to commands such as settings, metering, and control operations.

Not every command listed in this section is supported by every SEL-400 series relay. Additionally, some SEL-400 series relays support additional commands. See the product-specific instruction manual to see what specific commands are supported in that relay.

This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lowercase italic letters and words in a command represent command variables that you determine based on the application (for example, circuit breaker number *n* = 1 or 2, remote bit number *nn* = 01–32, and level).

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return <CR> character, or a carriage return character followed by a line feed character <CR><LF> to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a <CR>. For example, to send the **ACCESS** command, type **ACC <Enter>**. For more information on SEL ASCII protocol, including handshaking, see *Section 15: Communications Interfaces*.

Tables in this section show the access level(s) where the command or command option is active. Access levels in the relay are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), and Access Level 2. For information on access levels see *Changing the Default Passwords in the Terminal on page 3.10*.

Command Description

2ACCESS

Use the **2AC** command to gain access to Access Level 2 (full relay control). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.1 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

89CLOSE *n*

Use the **89CLOSE *n*** command to close disconnect switches. (The number of disconnects supported, *n*, depends on the relay.) The main board circuit breaker jumper (on jumper BREAKER) must be in place.

NOTE: The SEL-487B does not support disconnect control operations.

If the disconnect switch is open and Relay Word bit LOCAL is deasserted, the **89CLOSE *n*** command asserts Relay Word bit 89CLS*n* for the 89CSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page 5.1*. If the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to close, the relay displays `Operation in Progress...` With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89CLOSE** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89CLOSE** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). Use the 89CLS*n* Relay Word bit as part of a SELOGIC Output control equation to close the appropriate disconnect switch.

Table 14.2 89CLOSE *n* Command

Command	Description	Access Level
89CLOSE *n*	Set Relay Word bit 89CLS*n*	B, P, A, O, 2

If the relay is disabled and you attempt an **89CLOSE *n*** command, the relay responds with `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper J18C (BREAKER) is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

When the **89CLOSE *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds, `CLOSE DISNAMn (Y/N)?`. If you answer **Y <Enter>**, the relay responds with `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

89OPEN *n*

Use the **89OPEN *n*** command to open disconnect switches. (The number of disconnects supported, *n*, depends on the relay.) The main board circuit breaker jumper (on jumper BREAKER) must be in place.

NOTE: The SEL-487B does not support disconnect control operations.

If the disconnect switch is closed and Relay Word bit LOCAL is deasserted, the **89OPEN n** command asserts Relay Word bit 89OPEN*n* for the 89OSIT*n* time. See *Disconnect Switch Close and Open Control Logic on page 5.1*. If the Relay Word bit 89OIP*n* asserts, indicating that the disconnect has started to open, the relay displays `Operation in Progress...` With Relay Word bit 89OIP*n* asserted and Relay Word bit 89ALP*n* deasserted, a dot (.) is appended to the above message every half second to show progress. While the operation is in progress, communications are unavailable on the port where the **89OPEN** command was executed. Assertion of Relay Word bit 89OIP*n* starts the 89ALP*n* alarm timer. The relay waits for the 89ALP*n* timer to expire and then checks the status of the 89AM*n* and 89BM*n* disconnect inputs. If the 89ALP*n* timer does not expire within 30 seconds, the relay exits the **89OPEN** command and reads the status of the disconnect inputs. The state of Relay Word bits 89AM*n* and 89BM*n* determine which disconnect status message the relay displays (`Disconnect OPEN`, `Disconnect CLOSED`, or `Status Undetermined - check wiring`). Use Relay Word bit 89OPEN*n* as part of a SELOGIC Output control equation to open the appropriate disconnect switch.

Table 14.3 89OPEN *n* Command

Command	Description	Access Level
89OPEN *n*	Set Relay Word bit 89OPEN*n*	B, P, A, O, 2

If the relay is disabled and you attempt an **89OPEN *n*** command, the relay responds with `Command Aborted` because the relay is disabled. If the circuit breaker control enable jumper J18C (BREAKER) is not in place, the relay aborts the command and responds `Aborted: the breaker jumper is not installed`.

When the **89OPEN *n*** command is issued and the circuit breaker control enable jumper is in place, the relay responds with `Open DISNAMn (Y/N)?`. If you answer **Y <Enter>**, the relay responds `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the command is executed. If the response to either prompt is not y or Y, the relay responds with `Command Aborted`.

AACCESS

Use the **AAC** command to gain access to Access Level A (automation). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.4 AAC Command

Command	Description	Access Level
AAC	Go to Access Level A (automation).	1, B, P, A, O, 2

ACCESS

Use the **ACC** command to gain access to Access Level 1 (monitor). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.5 ACC Command

Command	Description	Access Level
ACC	Go to Access Level 1 (monitoring).	0, 1, B, P, A, O, 2

BACCESS

Use the **BAC** command to gain access to Access Level B (breaker). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.6 BAC Command

Command	Description	Access Level
BAC	Go to Access Level B (breaker).	1, B, P, A, O, 2

BNAME

The **BNA** command produces ASCII names of all relay Fast Meter status bits in a Compressed ASCII format. See *SEL Protocol on page 15.23* for more information on Fast Meter and the Compressed ASCII command set.

Table 14.7 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits.	0, 1, B, P, A, O, 2

BREAKER

NOTE: Not all SEL-400 series relays support breaker monitoring.

Use the **BREAKER** command to display circuit breaker reports and the circuit breaker history reports. You can also preload accumulated breaker monitor data. The **BRE** command also resets the circuit breaker monitor data. To use the **BRE** command, you must enable the circuit breaker monitors for the circuit breakers of interest. See *Circuit Breaker Monitor on page 8.1* for more information.

BRE *n*

The **BRE *n*** command displays the comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times, among many parameters. The relay displays a listing of breaker monitor alarms with the breaker report.

Table 14.8 BRE n Command

Command	Description	Access Level
BRE *n*[a]	Display the breaker report for the most recent Circuit Breaker n operation.	1, B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

BRE *n* C and BRE *n* R

The **BRE *n* C** and **BRE *n* R** commands clear/reset the circuit breaker monitor data. Options **C** and **R** are identical.

Table 14.9 BRE *n* C and BRE *n* R Commands

Command	Description	Access Level
BRE *n*[a] **C**	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n* R	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

BRE C A and BRE R A

The **BRE C A** and **BRE R A** commands clear all circuit breaker monitor data for all circuit breakers from memory. Options **C A** and **R A** are identical.

Table 14.10 BRE C A and BRE R A Commands

Command	Description	Access Level
BRE C A	Clear all circuit breaker data.	B, P, A, O, 2
BRE R A	Clear all circuit breaker data.	B, P, A, O, 2

BRE *n* H

Display the circuit breaker monitor history report with the **BRE *n* H** command. The breaker history report is a summary of recent circuit breaker operations.

Table 14.11 BRE *n* H Command

Command	Description	Access Level
BRE *n*[a] H	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

BRE *n* P

Use the **BRE *n* P** command to preload existing circuit breaker contact wear, operation counts, and accumulated currents to the circuit breaker monitor.

Table 14.12 BRE *n* P Command

Command	Description	Access Level
BRE *n*[a] P	Preload previously accumulated Breaker *n* data.	B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

CAL

Use the **CAL** command to gain access to Access Level C. See *Access Levels and Passwords on page 3.7* for more information. Only go to Level C to modify the default password or under the direction of an SEL employee. The additional commands available at Level C are not intended for normal operational purposes.

Table 14.13 CAL Command

Command	Description	Access Level
CAL	Go to Access Level C.	2, C

CASCII

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands. See *SEL Compressed ASCII Commands on page 15.24* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 14.14 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CBREAKER

NOTE: Not all SEL-400 series relays support breaker monitoring

The **CBREAKER** command provides a Compressed ASCII response circuit breaker report that is similar to the **BREAKER** command. You must enable the Breaker Monitor function for at least one breaker to generate the Compressed ASCII report. You can specify a specific circuit breaker to retrieve a report for one circuit breaker only. See *SEL Compressed ASCII Commands on page 15.24* for information on the Compressed ASCII command set.

CBR

Use the **CBR** command to gather the comprehensive circuit breaker report in Compressed ASCII format.

Table 14.15 CBR Command

Command	Description	Access Level
CBR	Return the most recent circuit breaker reports for all circuit breakers in Compressed ASCII format.	1, B, P, A, O, 2
CBR *n*[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

CBR TERSE

The **CBR TERSE** command omits the breaker report labels.

Table 14.16 CBR TERSE Command

Command	Description	Access Level
CBR TERSE	Return the most recent circuit breaker report for all circuit breakers in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2
CBR *n*[a] **TERSE**	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2

[a] Parameter *n* = breaker identification character.

CEVENT

The **CEVENT** command provides a Compressed ASCII response similar to the **EVENT** command. See *SEL Compressed ASCII Commands on page 15.24* for information on the Compressed ASCII command set.

CEV

Use the **CEV** command to gather relay event reports. When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter n is 10000–42767, *n* indicates the absolute serial number of the event report.

Table 14.17 CEV Command

Command	Description	Access Level
CEV	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a]	Return particular *n* event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

CEV ACK

Use **CEV ACK** to acknowledge viewing the oldest unacknowledged event on the present communications port. View this event with the **CEV NEXT** or **EVE NEXT** commands.

Table 14.18 CEV ACK Command

Command	Description	Access Level
CEV ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

CEV C

Use **CEV C** to return a 15-cycle length event report with analog and digital information in Compressed ASCII format. The L*yyy* option overrides the **C** option (see **CEV L*yyy***).

Table 14.19 CEV C Command

Command	Description	Access Level
CEV C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV C *n*	Return particular n event report at a 15-cycle length with 8-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

CEV L

Use **CEV L** to return a large resolution event report in Compressed ASCII format. The **S*x*** option overrides the **L** option (see **CEV S*x***).

NOTE: Not all SEL-400 series relays support the CEV L option.

Table 14.20 CEV L Command

Command[a]	Description	Access Level
CEV L	Return the most recent event report at full length with large resolution data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* L	Return particular n event report at full length with large resolution data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *CEV on page 14.6*.

CEV L*yyy*

Command **CEV L*yyy*** returns a specified length event report in Compressed ASCII format, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle to a value including and beyond the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full event report. The **L*yyy*** option overrides the **C** option.

Table 14.21 CEV L*yyy* Command

Command	Description	Access Level
CEV L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] L*yyy*	Return *yyy* cycles of a particular n event report with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *CEV on page 14.6*.

CEV NEXT

CEV NEXT returns the oldest unacknowledged event report on the present communications port in Compressed ASCII format.

Table 14.22 CEV N Command

Command	Description	Access Level
CEV N	Return the oldest unacknowledged event report with 4-samples/cycle sampling in Compressed ASCII format.	1, B, P, A, O, 2

CEV NSET

The **CEV NSET** command returns the Compressed ASCII event report with no relay settings.

Table 14.23 CEV NSET Command

Command	Description	Access Level
CEV NSET	Return the most recent event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] NSET	Return a particular n event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

CEV NSUM

The **CEV NSUM** returns the Compressed ASCII event report with no event summary.

Table 14.24 CEV NSUM Command

Command	Description	Access Level
CEV NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] **NSUM**	Return a particular n event report without the event summary at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

a Parameter *n* indicates event order or serial number; see *CEV on page 14.6*.

CEV S*x*

Use the **CEV S*x*** command to specify the sample data resolution of the Compressed ASCII event report. The sample data resolution *x* can be 4, 8, or 12, depending on the relay; the default value is 4-samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 14.25 CEV S*x* Command

Command	Description	Access Level
CEV S*x*	Return the most recent event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] S*x*	Return a particular n event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

a Parameter *n* indicates event order or serial number: see *CEV on page 14.6*.

CEV TERSE

The **CEV TERSE** command returns a Compressed ASCII event report without the event report labels.

Table 14.26 CEV TERSE Command

Command	Description	Access Level
CEV TERSE	Return the most recent event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a] TERSE	Return a particular n event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

a Parameter *n* indicates event order or serial number.

Use the **TERSE** option with any of the **CEV** commands except **CEV ACK**.

CEV Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, **S*x***, and **TERSE** in one command. Enter the options according to the following guidelines:

- The **L*yyy*** option overrides the **C** option
- The **S*x*** option overrides the **L** option
- Enter the options in any order

Table 14.27 lists the choices you can make in the **CEV** command. Combine options on each row, selecting one option from each column, to create a **CEV** command.

Table 14.27 CEV Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK	***n*, NEXT**	**S*x*, L**	**C**	**L*yyy*, C**	**NSET, NSUM, TERSE**

The following examples illustrate some possible option combinations.

Example	Description
CEV L10 S8	Return 10 cycles of an 8-samples/cycle Compressed ASCII event report for the most recent event.
CEV L10 L	Return 10 cycles of an large resolution Compressed ASCII event report for the most recent event (same as above).
CEV 2 C NSUM TERSE	For the second most recent event, return 15 cycles of the event in Compressed ASCII format with no event summary and no report label lines with large resolution data.

CFG

In TiDL and IEC Sampled Values (SV) subscriber relays, certain aspects of the relay must be configured before the relay can be set. This command is used to perform this configuration.

CFG CTNOM

In TiDL and IEC SV subscriber relays, use the **CFG CTNOM** command to inform the relay which CT inputs are 1 A nominal and which are 5 A nominal. (By default, the relay assumes all CT inputs are 5 A nominal.) This is necessary so the relay scales the information correctly. See *Section 2: Installation* of the product-specific instruction manual for more information on using this command as part of configuring the relay. This will restart the relay and force all settings to default, so this command must be made before making any other settings in the relay.

Table 14.28 CFG CTNOM Command

Command	Description	Access Level
CFG CTNOM *n*[a]	Change nominal CT configuration to selected value	2

[a] The parameter *n* (or parameters) is relay-specific.

CFG NFREQ

In TiDL relays, use the **CFG NFREQ** command to set the nominal frequency of the relay (which is 60 Hz by default). In relays that do not support TiDL, the nominal frequency is controlled by the NFREQ Global setting. This should be configured after the nominal currents are configured (through the use of the **CFG CTNOM** command) and before settings are loaded into the relay. This will restart the relay.

Table 14.29 CFG NFREQ Command

Command	Description	Access Level
CFG NFREQ *f*	Change nominal frequency to *f* (50 or 60)	2

CHISTORY

The **CHISTORY** command provides a **HISTORY** report in the Compressed ASCII format.

CHI

Use the **CHI** command to gather one-line descriptions of event reports.

Table 14.30 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report (short form descriptions) for the most recent 100 event reports in Compressed ASCII format (for SEL-2030 compatibility).	1, B, P, A, O, 2
CHI A	Return one-line descriptions of the most recent 100 event reports in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k*	Return one-line descriptions of the most recent *k* number of event reports in Compressed ASCII format.	1, B, P, A, O, 2

CHI TERSE

The **CHI TERSE** command returns a Compressed ASCII event report without the event report label lines.

Table 14.31 CHI TERSE Command

Command	Description	Access Level
CHI TERSE	Return one-line descriptions for the most recent 100 event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k* TERSE	Return one-line descriptions for the most recent k number of event reports without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

CLOSE *n*

Use the **CLOSE *n*** command to close a circuit breaker. The main board circuit breaker jumper (on jumper BREAKER) must be in place. Further, you must enable breaker control for any breakers you want to control.

NOTE: The SEL-487B does not support the **CLOSE** command.

The **CLOSE *n*** command asserts Relay Word bit CC*n*. The CC*n* bit must be included in the close SELOGIC equation for breaker *n* (BK*n*MCL) for this command to effect a close operation. The relay uses these equations and additional relay logic to assert a control output (for example, OUT103 := BK1CL) to close a circuit breaker.

Table 14.32 CLOSE *n* Command

Command	Description	Access Level
CLOSE *n*	Command the relay to close Circuit Breaker *n*.	B, P, A, O, 2

If the circuit breaker control enable jumper BREAKER is in place, the relay responds with `Close breaker (Y/N)?`. When you answer **Y <Enter>** (for yes), the relay prompts, `Are you sure (Y/N)?`. If you again answer **Y <Enter>**, the relay asserts the Relay Word bit for one processing interval.

If you have assigned a circuit breaker auxiliary contact (52A) to a relay control input (based on the 52AA*n*, 52ABn, 52AC*n* settings), the relay waits 0.5 second, checks the state of the circuit breaker, and issues either a `Breaker OPEN` or `Breaker CLOSED` message.

If circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. If the relay is disabled, the relay responds with `Command aborted because relay is disabled`. If Breaker *n* is not enabled and you issue the **CLOSE *n*** command, the relay responds with `Breaker n is not available`.

COMMUNICATIONS

The **COMMUNICATIONS** command displays communications statistics for the MIRRORED BITS communications channels and for synchrophasor client channels. Some relays support additional options to the **COM** command besides those described here.

COM c

Use the **COM *c*** command to view records of the MIRRORED BITS communications buffers for specific relay communications channels.

Table 14.33 COM *c* Command[a]

Command	Description	Access Level
COM A	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1, B, P, A, O, 2
COM B	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1, B, P, A, O, 2
COM M	Return a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1, B, P, A, O, 2

[a] Parameter *c* is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

The *c* option in the **COM** command is **A** for MIRRORED BITS communications Channel A, B for MIRRORED BITS communications Channel B, and Channel M for the MIRRORED BITS communications channels in general. If both MIRRORED BITS communications channels are in use, then the **M** option does not function and you must specify **A** or **B**.

COM *c* C and COM *c* R

The **COM *c* C** and **COM *c* R** commands clear/reset the communications buffer data for the specified Channel *c*. Options **C** and **R** are identical.

Table 14.34 COM *c* C and COM *c* R Command

Command	Description	Access Level
COM A C	Clear/reset communications buffer data for MIRRORED BITS communications Channel A.	P, A, O, 2
COM B R	Clear/reset communications buffer data for MIRRORED BITS communications Channel B.	P, A, O, 2
COM M C	Clear/reset communications buffer data for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	P, A, O, 2

COM *c* L *m n* and COM *c* L date1 date2

Use **COM *c* L** to list the records in the communications buffer in a specified manner. The relay returns the list of records in rows. You can specify a range of buffer records in forward or reverse chronological order or in forward or reverse date order. Date parameter entries depend on the setting DATE_F format you chose in the relay Global settings.

The relay organizes the records in rows in a 256-entry buffer in newest to oldest time order. The relay puts the newest record in the buffer and discards the oldest record if the buffer is full.

Table 14.35 is a representative list of options for listing records in the communications buffer.

Table 14.35 COM *c* L Command

Command	Description	Access Level
COM A L	Display all available records from MIRRORED BITS communications Channel A; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM B L *k*[a]	Display the first *k* records for MIRRORED BITS communications Channel B; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM M L *m n*[b]	Display the records for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled; show the records with Record *m* at the top of the report through Record *n* at the bottom of the report.	1, B, P, A, O, 2
COM A L *date1*[c]	Display the records from MIRRORED BITS communications Channel A on the date *date1*.	1, B, P, A, O, 2
COM B L *date1 date2*[c]	Display the records from MIRRORED BITS communications Channel B between the dates *date1* and *date2*. The date listed first, *date1*, is at the top of the report; the date listed second, *date2*, is at the bottom of the report.	1, B, P, A, O, 2

[a] Parameter *k* indicates a specific number of communications buffer records.
[b] Parameters *m* and *n* are communications buffer row numbers.
[c] Enter *date1* and *date2* in the same format as Global setting DATE_F.

COM PTP

The **COM PTP** command provides a report of the PTP data sets maintained by the device as well as statistics for the measured time offsets with the parent (master) clock. The PTP data sets contain information about the state, identity, and configuration of the local, parent, and grandmaster clocks in addition to properties of the time being distributed by the grandmaster clock.

Table 14.36 COM PTP Command

Command	Description	Access Level
COM PTP	Display PTP data sets and offset statistics	2
COM PTP C	Clears PTP offset statistics	2

If EPTP = N or the relay hardware does not support PTP, then the **COM PTP** command will respond with `PTP Not Enabled`. If a settings change is in progress or if the hardware is not yet initialized, then the **COM PTP** command will respond with `Data unavailable, please try again later`.

```
=>>COM PTP <Enter>

Relay 1                                    Date: 02/24/2016  Time: 15:08:43.516
Station A                                  Serial Number: 0000000000

PTP offset statistics previously cleared on 02/24/2016 14:08:36.303 (UTC)


Settings Data Set
  PTP Profile : Default
  Transport Mechanism : Layer2
  Path Delay : P2P


Default Data Set
  Two Step : true
  Clock Identity : 00 30 A7 FF FE 44 55 66
  Number of Ports : 1
  Clock Quality
    Clock Class : 255
    Clock Accuracy : 254
    Offset Log Variance : 0
  Priority1 : 255
  Priority2 : 255
  Domain Number : 1
  Slave Only : true


Current Data Set
  Steps Removed : 1
  Offset from Master : -5 ns
  Mean Path Delay : 0 ns


Parent Data Set
  Parent Port Identity
    Clock Identity : 00 30 A7 FF FE 04 7C 22
    Port Number : 1
  Grandmaster Clock Identity : 00 30 A7 FF FE 04 7C 22
  Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0
  Grandmaster Priority1 : 0
  Grandmaster Priority2 : 0
```

Figure 14.1 Sample COM PTP Command Response

```
Time Properties Data Set
  Current UTC Offset : 0
  Current UTC Offset Valid : true
  Leap59 : false
  Leap61 : false
  Time Traceable : true
  Frequency Traceable : true
  PTP Timescale : true
  Time Source : PTP
  Local Time Offset
    Offset Valid : true
    Name : PST
    Current Offset : 3600
    Jump Seconds : 3600
    Time of Next Jump : 1456797635


Port Data Set
  Port Identity
    Clock Identity : 00 30 A7 FF FE 44 55 66
    Port Number: 1
  Port State : SLAVE
  Log Pdelay Request Interval : 0
  Peer Mean Path Delay : 0 ns
  Announce Receipt Timeout : 2 intervals
  Path Delay Mechanism : Peer-to-Peer
  Failed to Receive Response : true
  Received Multiple Pdelay Responses : false
  Reason for Non-synchronization :


Time Offset Statistics
  Mean : -0.013393 ns
  Standard Deviation : 5.291062 ns
  Latest Time Offsets with respect to Reference Time (in ns)
    #1 :                     -5
    #2 :                     -1
    #3 :                      0
    #4 :                      1
    #5 :                     -1
    #6 :                      2
    #7 :                      8
    #8 :                      3
    #9 :                      1

    #10 :                     -9
    #11 :                      2
    #12 :                      0
    #13 :                      3
    #14 :                     -4
    #15 :                     -9
    #16 :                      5
    #17 :                     -1
    #18 :                     -4
    #19 :                     -4
    #20 :                      1
    #21 :                      5
    #22 :                      7
    #23 :                     -7
    #24 :                     -1
    #25 :                      6
    #26 :                     -2
    #27 :                     -2
    #28 :                      8
    #29 :                     -5
    #30 :                      2
    #31 :                      0
    #32 :                     -2

=>>
```

Figure 14.1 Sample COM PTP Command Response (Continued)

COM RTC

Use the **COM RTC** to get a report on the status of the configured synchrophasor client channels.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.37 COM RTC Command

Command[a]	Description	Access Level
COM RTC	Return a report describing the communications on all enabled synchrophasor client channels.	1, B, P, A, O, 2
COM RTC A	Return a report describing the communications on synchrophasor client Channel A.	1, B, P, A, O, 2
COM RTC B	Return a report describing the communications on synchrophasor client Channel B.	1, B, P, A, O, 2

[a] Parameter *c* is A, B, or absent for Channel A, Channel B, or all enabled channels, respectively.

COM RTC *c* C and COM RTC *c* R

The **COM RTC C** and **COM RTC R** commands clear/reset the maximum packet delay. The **C** and **R** options are identical.

Table 14.38 COM RTC *c* C and COM RTC *c* R Command

Command	Description	Access Level
COM RTC C	Clear/reset the maximum packet delay on all enabled synchrophasor client channels.	P, A, O, 2
COM RTC A R	Clear/reset the maximum packet delay on synchrophasor client Channel A.	P, A, O, 2
COM RTC B C	Clear/reset the maximum packet delay on synchrophasor client Channel B.	P, A, O, 2

CONTROL *nn*

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits. Remote bits in SELOGIC control equations are similar to hardwired control inputs, in that you use these bits to affect relay operation from outside sources. For control inputs, external input to the relay comes through the rear panel; in the case of the **CON *nn*** command, external control signals come through the communications ports. See *Remote Bits on page 5.11* for information on remote bits.

Table 14.39 CON *nn* Command

Command	Description	Access Level
CON *nn*[a] C	Clear Remote Bit *nn*.	P, A, O, 2
CON *nn* P	Pulse Remote Bit *nn* for one processing cycle.	P, A, O, 2
CON *nn* S	Set Remote Bit *nn*.	P, A, O, 2

[a] Parameter *nn* is the remote bit reference for RB*nn*.

If you enter **CON *nn*** with no set, clear, or pulse option specified, the relay responds, `Control RBnn:`. You must then provide the control action (set, clear, or pulse) that you want to perform. (The relay checks only the first character; you can type **Set** and **Clear**.) When you issue a valid **CON** command, the relay performs the control action immediately and displays `Remote Bit Operated`.

COPY

The **COPY** command copies the settings from one class instance to another instance in the same class. For example, you can copy Group settings from one group to another. You cannot copy Group settings to Port settings.

This command is limited to the same access level as the **SET** command for the class of settings you are copying.

Table 14.40 COPY Command

Command	Description	Access Level
COPY *m n*[a]	Copy settings from instance m of the Group settings to instance n of the Group settings.	P, A, O, 2
COPY *class m n*[b]	Copy settings from instance *m* of Class *class* to instance *n* of Class *class*.	P, A, O, 2

[a] Parameters *m* and *n* are 1 to 6 for the Group class and 1, 2, 3, and F for the Port class.
[b] Parameter class is S, P, and L for group settings, port settings, and protection SELOGIC control equations, respectively.

The parameters *m* and *n* must be valid and distinct (not the same) instance numbers. You can typically choose from classes of group (S), port (P), and protection SELOGIC control equations (L). Some SEL-400 series relays support copying additional classes. The **COPY** command is not available within the Automation class and is not available for the Breaker Monitor settings.

In addition, port settings instances must be compatible; you cannot copy from/to Port 5 and the other communications ports settings. You cannot copy to a port that is presently in transparent communication. If you attempt such a copy, the relay responds with `Cannot copy to a port involved in transparent communication`. In addition, you cannot copy to the present port (the port you are using to communicate with the relay). If you attempt such a copy, the relay responds with `Cannot copy port settings to present port`.

When you enter the **COPY** command with valid parameters, the relay responds with `Are you sure (Y/N)?`. Answer **Y <Enter>** (for yes) to complete copying.

If the destination instance is the active group, the relay changes to the new settings and pulses the SALARM Relay Word bit.

CPR

Use the **CPR** command to access the Signal Profile data for as many as 20 user selectable analog values in Compressed ASCII format. Notice that the CPR records are in reverse chronological progression as compared to the PRO reports.

Table 14.41 CPR Command (Sheet 1 of 2)

Command	Description	Access Level
CPR	Displays the first 20 rows of the profile report, with the oldest row at the bottom and the latest row at the top.	1, B, P, A, O, 2
CPR *m*	Displays the first *m* rows of the profile report, with the oldest row at the bottom and the latest row at the top.	1, B, P, A, O, 2
CPR *m n (m > n)*	Displays the row between *m* and *n*, (including *m* and *n*).	1, B, P, A, O, 2
CPR *date1*	Displays all the rows that were recorded on that date, with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2

Table 14.41 CPR Command (Sheet 2 of 2)

Command	Description	Access Level
CPR *date1 date2*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date1* chronologically precedes *date2*), with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2
CPR *date2 date1*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date2* chronologically precedes *date1*), with the latest row at the bottom and the oldest row at the top.	1, B, P, A, O, 2
CPR TERSE	The **CPR TERSE** command omits the report labels.	1, B, P, A, O, 2

CSER

The **CSER** command provides an **SER** report in Compressed ASCII format. The default order of the **CSER** command (chronologically newest to oldest from list top to list bottom) is the reverse of the **SER** command (oldest to newest from list top to list bottom).

CSE

Use the **CSE** command to gather Sequential Events Recorder (SER) records. You can sort these records in numerical or date order.

Table 14.42 CSE Command

Command	Description	Access Level
CSE	Return all records from the SER in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *k*[a]	Return the *k* most recent records from the SER in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *m n*[b]	Return the SER records in Compressed ASCII format from *m* to *n*. If m is greater than n, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If m is less than n, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1*[c]	Return the SER records in Compressed ASCII format on date *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the SER records in Compressed ASCII format from date *date1* to date *date2*.	1, B, P, A, O, 2

[a] Parameter *k* indicates a specific number of SER records.
[b] Parameters *m* and *n* indicate an SER record number.
[c] Enter *date1* and *date2* in the same format as Global setting DATE_F.

CSE TERSE

The **CSE TERSE** command returns a SER report in Compressed ASCII format without labels; the relay sends only the data (including header data). You can apply the **TERSE** option with any of the **CSE** commands.

Table 14.43 CSE TERSE Command

Command	Description	Access Level
CSE TERSE	Return all SER records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *k* TERSE[a]	Return the *k* most recent SER records without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *m n* TERSE[b]	Return the SER records in Compressed ASCII format from *m* to *n* without the label lines in Compressed ASCII format. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1* TERSE[c]	Return the SER records in Compressed ASCII format on date date1 without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *date1 date2* TERSE[c]	Return the SER records in Compressed ASCII format from date *date1* to date *date2* without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *k* indicates a specific number of SER records.
[b] Parameters *m* and *n* indicate an SER record number.
[c] Enter *date1* and *date2* in the same format as Global setting DATE_F.

CSTATUS

The **CSTATUS** command provides a **STATUS** report in the Compressed ASCII format. The **TERSE** option eliminates the report label lines.

Table 14.44 CST Command

Command	Description	Access Level
CST	Return the relay status in Compressed ASCII.	1, B, P, A, O, 2
CST TERSE	Return the relay status in Compressed ASCII; suppress the label lines and transmit only the data lines.	1, B, P, A, O, 2

CSUMMARY

The **CSUMMARY** provides the same information as the **SUMMARY** command but in Compressed ASCII format. You can combine the *n*, **ACK**, **MB**, and **TERSE** options.

CSU

Use the **CSU** command to gather event report summaries.

Table 14.45 CSU Command

Command	Description	Access Level
CSU	Return the most recent event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a]	Return a particular *n* event summary (with label lines) in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

CSU ACK

Use the **CSU ACK** command to acknowledge an event summary that you recently retrieved with the **CSU NEXT** command on the present communications port.

Table 14.46 CEV ACK Command

Command	Description	Access Level
CSU ACK	Acknowledge the oldest unacknowledged event summary at the present communications port for Compressed ASCII format.	1, B, P, A, O, 2

CSU MB

The **CSU MB** command causes the relay to output the labels for the MIRRORED BITS communications channel data in Compressed ASCII format.

Table 14.47 CSU MB Command

Command	Description	Access Level
CSU MB	Return the MIRRORED BITS communications channel labels.	1, B, P, A, O, 2

CSU NEXT

Use the **CSU NEXT** command to view the oldest unacknowledged event summary in Compressed ASCII format.

Table 14.48 CSU N Command

Command	Description	Access Level
CSU N	View the oldest unacknowledged event summary.	1, B, P, A, O, 2

CSU TERSE

The **TERSE** command option returns an event summary report in Compressed ASCII format without labels; the relay sends only the data (including header data).

Table 14.49 CSU TERSE Command

Command	Description	Access Level
CSU TERSE	Return the event summary report without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a] **TERSE**	Return a particular *n* event summary report without the label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU N TERSE	View the oldest unacknowledged event summary without the label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter *n* indicates event number or serial order.

You can apply the **TERSE** option with any of the **CSU** commands except **CSU ACK** and **CSU MB**.

DATE

Use the **DATE** command to view and set the relay date. The relay can overwrite the date that you enter by using other time sources, such as IRIG and DNP3. Enter the **DATE** command with a date to set the internal clock date. You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

Set the year in two-digit form (for dates 2000–2099) or four-digit form. If you enter the year as **12**, the relay date is 2012. You must enter the data in the format specified in the Global setting DATE_F.

If an IRIG-B time synchronization signal is connected to the relay, the DAT command cannot alter the month or day portion of the date. If the IRIG-B time source is IEEE C37.118 compliant and Global setting IRIGC = C37.118, or if an Simple Network Time Protocol (SNTP) time source is connected, the **DAT** command cannot alter any time setting.

Table 14.50 DATE Command

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE ***date***[a]	Set the internal clock date.	1, B, P, A, O, 2

[a] Enter date parameters in the same order as Global setting DATE_F.

DNAME X

The **DNA X** command produces the ASCII names of all relay digital I/O (input/output) quantities reported in a Fast Meter message in Compressed ASCII format.

Table 14.51 DNA Command

Command	Description	Access Level
DNA X	Display ASCII names of all relay digital I/O.	0, 1, B, P, A, O, 2

DNP

The **DNP** command accesses the serial port DNP3 settings and is similar to the **SHOW D** command. Use the **DNP** or **DNP VIEW** command to show the relay serial port DNP3 settings beginning at the first setting label just like **SHOW D**. Issue the **DNP** command with any parameter *param* to set the serial port DNP3 settings; the relay begins at the first DNP3 setting just like **SET D**.

Table 14.52 DNP Command

Command	Description	Access Level
DNP	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP VIEW	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP *param*	Set the serial port DNP3 settings (same as **SET D**); begin at the first DNP3 setting.	P, A, O, 2

ETHERNET

The **ETH** command displays the current Ethernet port (Port 5) configuration and status. Communications statistics, such as the number of packets, bytes, and errors received and sent, are displayed for the ports that carry standard Ethernet, DNP3 or optional IEC 61850 communications. Other commands are available to display similar statistics for ports that exclusively carry other types of traffic, for example, **COM 87L** for 87L traffic.

ETH

Use the **ETH** command when troubleshooting Ethernet connections.

Table 14.53 ETH Command

Command	Description	Access Level
ETH	Displays information about Ethernet port(s)	1, B, P, A, O, 2

Figure 14.2 shows a sample **ETH** command response for a relay with four copper Ethernet ports and Port 5 setting NETMODE = SWITCHED. Different Ethernet configurations and different NETMODE settings result in slightly different information being displayed. See *Ethernet Communications on page 15.6* for a description of the settings and operating modes related to the Ethernet port.

```
==>>ETH <Enter>

Relay 1                                     Date: 11/04/2010  Time: 10:22:19.984
Station A                                   Serial Number: 0000000000


MAC 1: 00-30-A7-01-E3-0A
MAC 2: 00-30-A7-01-E3-0B
IP ADDRESS: 10.201.5.27/16
DEFAULT GATEWAY: 10.201.0.1

NETMODE: SWITCHED

PRIMARY 87L PORT:  5A
ACTIVE 87L PORT:   5A


LINK   SPEED  DUPLEX  MEDIA
PORT 5A      Down   ---    ---     TX
PORT 5B      Down   ---    ---     TX
PORT 5C      Up     100M   Full    TX
PORT 5D      Down   ---    ---     TX


PACKETS          BYTES          ERRORS
   SENT  RCVD      SENT    RCVD    SENT  RCVD
      0     8         0     512       0     4
```

Figure 14.2 Sample ETH Command Response

ETH C and ETH R

The **ETH C** and **ETH R** commands clear the Ethernet connection statistics. Option **C** and **R** are identical.

Table 14.54 ETH C and ETH R Command

Command	Description	Access Level
ETH C	Clears the statistics on Port 5 Ethernet connection	1, B, P, A, O, 2
ETH R	Clears the statistics on Port 5 Ethernet connection	1, B, P, A, O, 2

When you issue the **ETH C** and **ETH R** command, the relay sends the following prompt: `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears the Ethernet statistics and response: `Ethernet Statistics Cleared`.

EVENT

Use the **EVENT** command to view the relay filtered event reports (see *Event Report on page 9.14* for information on event reports).

EVE

The **EVE** command displays the full-length event reports stored in relay memory. When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

Table 14.55 EVE Command

Command	Description	Access Level
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a]	Return a particular n event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

EVE A

The **EVE A** command returns only the analog information in the event report.

Table 14.56 EVE A Command

Command	Description	Access Level
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE A *n*[a]	Return only the analog information for a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *EVE on page 14.23*.

EVE ACK

Use **EVE ACK** to acknowledge the oldest unacknowledged event that you recently viewed with the **EVE NEXT** or the **CEV NEXT** commands on the present communications port.

Table 14.57 EVE ACK Command

Command	Description	Access Level
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **EVE NEXT** command, the relay responds with `Event summary number n has not been viewed with the NEXT option`.

EVE C

Use **EVE C** to return a 15-cycle length event report with both analog and digital data. You cannot mix the A and D options with the **EVE C** command. The L*yyy* option overrides the C option (see *EVE Lyyy on page 14.25*).

Table 14.58 EVE C Command

Command	Description	Access Level
EVE C	Return the most recent event report at a 15-cycle length with large resolution data.	1, B, P, A, O, 2
EVE C *n*[a]	Return a particular *n* event report at a 15-cycle length with large resolution data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *EVE on page 14.23*.

EVE D

Use **EVE D** to return only the digital information in the event report.

Table 14.59 EVE D Command

Command	Description	Access Level
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE D *n*[a]	Return only the digital information for a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number (see *EVE on page 14.23*).

EVE L

Use **EVE L** to return a large resolution event report. The **S*x*** option overrides the **L** option (see *EVE Sx on page 14.26*).

Table 14.60 EVE L Command

Command	Description	Access Level
EVE L	Return the most recent event report at full length with large resolution data.	1, B, P, A, O, 2
EVE *n*[a] L	Return a particular *n* event report at full length with large resolution data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

EVE L*yyy*

Command **EVE L*yyy*** returns a specified length event report, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle up to a value including and exceeding the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full duration event report. The **L*yyy*** option overrides the **C** option.

Table 14.61 EVE L*yyy* Command

Command[a]	Description	Access Level
EVE L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L*yyy*	Return *yyy* cycles of a particular n event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *EVE on page 14.23*.

EVE NEXT

EVE NEXT returns the oldest unacknowledged event report on the present communications port.

Table 14.62 EVE N Command

Command	Description	Access Level
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data.	1, B, P, A, O, 2

EVE NSET

The **EVE NSET** command returns the event report with no relay settings.

Table 14.63 EVE NSET Command

Command	Description	Access Level
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] NSET	Return a particular n event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see *EVE on page 14.23*.

EVE NSUM

The **EVE NSUM** returns the event report with no event summary.

Table 14.64 EVE NSUM Command

Command	Description	Access Level
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] NSUM	Return a particular n event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number.

EVE S*x*

Use the **EVE S*x*** command to specify the sample data resolution of the event report. The sample data resolution x is either 4-samples/cycle or large resolution; the default value is 4-samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 14.65 EVE S*x* Command

Command	Description	Access Level
EVE S*x*	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2
EVE *n*[a] S*x*	Return a particular n event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; *x* is 4, 8, or 12 to represent data at 4 samples/cycle, 8 samples/cycle, or 12 samples/cycle respectively. See the product-specific instruction manual to see whether 8 or 12 samples/cycle are supported for larger resolution reports.

EVE Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, and **S*x***, in one command. Enter the options according to the following guidelines:

- ➤ The **L*yyy*** option overrides the **C** option.
- ➤ The **S*x*** option overrides the **L** option.
- ➤ When choosing option **A** or option **D** as a report type, you cannot use option **C** to specify the report length at 15 cycles. Use option **L*yyy*** at L015 to specify a 15-cycle report.
- ➤ Enter the options in any order.

Table 14.66 lists the choices you can make in the **EVE** command. Combine options on each row, selecting one option from each column, to create an **EVE** command.

Table 14.66 EVE Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK	***n*, NEXT**	**S*x*, L**	**C, A, D**	**L*yyy*, C**	**NSET, NSUM**

The following examples illustrate some possible option combinations.

Table 14.67 EVE Command Examples

Example	Description
EVE L010 S8	Return 10 cycles of an 8-samples/cycle event report for the most recent event.
EVE L10 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 C NSUM	For the second most recent event, return the event with 8-samples/cycle data, and omit the event summary.

EXIT

Use the **EXIT** command to terminate a Telnet session and revert to Access Level 0 (exit relay control).

Table 14.68 EXIT Command

Command	Description	Access Level
EXIT	Terminate the Ethernet port Telnet sessions and go to Access Level 0 (exit relay control)	0, 1, B, P, A, O, 2

FILE

The **FILE** command provides a safe and efficient means of transferring files between IEDs and external support software (ESS) by providing Ymodem file transfer. The **FILE** commands are especially useful for retrieving high-resolution sampled data in binary COMTRADE format from the relay.

Table 14.69 FILE Command

Command	Description	Access Level
FILE DIR *directory*	Returns a list of filenames in specified directory *(directory)*. If not specified, then the list of files and directories in the root directory is returned.	1, B, P, A, O, 2
FILE READ *directory filename*	Initiates a file transfer of the file *filename* (in the folder *directory*) from the relay to external support software. The *filename* parameter is required.	1, B, P, A, O, 2
FILE WRITE SETTINGS *filename*	Initiates a file transfer of the file *filename* from external support software to the relay. If the *filename* parameter is not specified, the file name must be given in the Ymodem header.	P, A, O, 2

All text enclosed in [brackets] indicates optional command line parameters. The specific directories available in the relay depends on the relay model, but typically includes EVENTS, REPORTS, SETTINGS, and SYNCHROPHASOR directories. For **FILE READ** operations, specify the directory parameters as needed. The **FILE WRITE** command is available only for the SETTINGS directory.

GOOSE

Use the **GOOSE** command to display transmit and receive GOOSE messaging information, which can be used for troubleshooting.

Table 14.70 GOOSE Command

Command	Description	Access Level
GOOSE	Displays GOOSE information	1, B, P, A, O, 2
GOOSE *k*	Displays GOOSE information successively for *k* times	1, B, P, A, O, 2

The information displayed for each GOOSE IED is described in *Table 14.71*.

Table 14.71 Accessible GOOSE IED Information (Sheet 1 of 2)

<table>
<tr><th>IED</th><th colspan="2">Description</th></tr>
<tr><td>Transmit GOOSE Control Reference</td><td colspan="2">This field represents the GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name) (e.g., SEL_411L_OtterCFG/LLN0$DSet13).</td></tr>
<tr><td>Receive GOOSE Control Reference</td><td colspan="2">This field shall contain the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and cbName (GSE Control Block Name) (e.g., SEL_411L_1CFG/LLN0$DSet13)</td></tr>
<tr><td>Multicast Address (MultiCastAddr)</td><td colspan="2">This hexadecimal field represents the GOOSE multicast address.</td></tr>
<tr><td>Priority Tag (Ptag)</td><td colspan="2">This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown.</td></tr>
<tr><td>VLAN (Vlan)</td><td colspan="2">This 12-bit decimal field represents the virtual LAN (Local Area Network) setting, where spaces are used if the virtual LAN is unknown.</td></tr>
<tr><td>State Number (StNum)</td><td colspan="2">This hexadecimal field represents the state number that increments with each state change.</td></tr>
<tr><td>Sequence Number (SqNum)</td><td colspan="2">This hexadecimal field represents the sequence number that increments with each GOOSE message sent.</td></tr>
<tr><td>Time to Live (TTL)</td><td colspan="2">This field contains the time (in ms) before the next message is expected.</td></tr>
<tr><td rowspan="10">Code</td><td colspan="2">This text field indicates warning or error conditions that are abbreviated as follows:</td></tr>
<tr><td>Code Abbreviation</td><td>Explanation</td></tr>
<tr><td>OUT OF SEQUENC</td><td>Out of sequence error</td></tr>
<tr><td>CONF REV MISMA</td><td>Configuration Revision mismatch</td></tr>
<tr><td>NEED COMMISSIO</td><td>Needs Commissioning</td></tr>
<tr><td>TEST MODE</td><td>Test Mode</td></tr>
<tr><td>MSG CORRUPTED</td><td>Message Corrupted</td></tr>
<tr><td>TTL EXPIRED</td><td>Time to live expired</td></tr>
<tr><td>HOST DISABLED</td><td>Optional code for when the host is disabled or becomes unresponsive after the GOOSE command has been issued</td></tr>
</table>

Table 14.71 Accessible GOOSE IED Information (Sheet 2 of 2)

IED	Description
Transmit Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the IED name, LN0 lnClass (Logical Node Class), and GSEControl datSet (Data Set Name) (e.g., SEL_411L_1CFG/LLN0$DSet13).
Receive Data Set Reference	This field represents the datSetRef (Data Set Reference) that includes the iedName (IED name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class) and datSet (Data Set Name) (e.g., SEL_411L_1CFG/LLN0$DSet13).

An example response to the GOOSE commands is shown in *Figure 14.3*.

```
=>>GOOSE <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------

SEL_411L_OtterCFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-10  4:1     1          166        457
   Data Set: SEL_411L_OtterCFG/LLN0$DSet13

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
----------------------------------------------------------------------------

SEL_411L_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-04   :      0          0          0      TTL EXPIRED
   Data Set: SEL_487B_1CFG/LLN0$DSet13


SEL_2440_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-0A   :      0          0          0      TTL EXPIRED
   Data Set: SEL_2440_1CFG/LLN0$DSet13


SEL_487E_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-10   :      0          0          0      TTL EXPIRED
   Data Set: SEL_487E_1CFG/LLN0$DSet13

SEL_710_1CFG/LLN0$GO$GooseDSet13
   01-0C-CD-01-00-08   :      0          0          0      TTL EXPIRED
   Data Set: SEL_710_1CFG/LLN0$DSet13
```

Figure 14.3 GOOSE Command Response

If the **GOOSE** command is issued during CID file processing, the relay responds with `CID file is currently being processed. No GOOSE statistics available`. When **GOOSE** is disabled by settings (EGSE = N), the relay sends `Command is not available` in responding to a **GOOSE** command. If an error is detected during the processing of the IEC 61850 file, the relay responds with `Error detected in parsing the CID file. All GOOSE processing disabled` to a **GOOSE** command.

GOO S

The **GOO S** command provides statistics for GOOSE subscriptions.

Table 14.72 GOO S Command (Sheet 1 of 2)

Command	Description	Access Level
GOO S	Display a list of GOOSE subscriptions with their ID.	1,B,P,A,O,2
GOO S *n*	Display GOOSE statistics for subscription ID *n*.	1,B,P,A,O,2
GOO S ALL	Display GOOSE statistics for all subscriptions.	1,B,P,A,O,2
GOO S *n* L	Display GOOSE statistics for subscription ID *n* including error history.	1,B,P,A,O,2

Table 14.72 GOO S Command (Sheet 2 of 2)

Command	Description	Access Level
GOO S ALL L	Display GOOSE statistics for all subscriptions including error history.	1,B,P,A,O,2
GOO S *n* C	Clear GOOSE statistics for subscription ID *n*.	1,B,P,A,O,2
GOO S ALL C	Clear GOOSE statistics for all subscriptions.	1,B,P,A,O,2

When reporting a list of subscriptions with the **GOO S** command, the response includes the subscription ID, the application identifier, and the GOOSE control block reference. The other variants of **GOO S** provide statistics on the selected subscriptions. *Figure 14.4* and *Figure 14.5* illustrates this.

```
==>goo s 2 <Enter>

 SubsID 2
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet02
 AppID   : 4114
 From    : 06/30/2014 10:59:29.760  To: 06/30/2014 11:10:32.817

 Accumulated downtime duration                      : 0000:10:59.325
 Maximum downtime duration                          : 0000:10:59.325
 Date & time maximum downtime began                 : 06/30/2014 10:59:33.492
 Number of messages received out-of-sequence(OOS)   : 0
 Number of time-to-live(TTL) violations detected    : 1
 Number of messages incorrectly encoded or corrupted: 654
 Number of messages lost due to receive overflow    : 0
 Calculated max. sequential messages lost due to OOS: 0
 Calculated number of messages lost due to OOS      : 0
```

Figure 14.4 Example GOO S Command Response

```
=>>GOO S ALL L <Enter>

 SubsID 1
-----------------------------------------------------------------------------
 Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet01
 AppID   : 4113
 From    : 07/01/2014 11:23:13.851  To: 07/01/2014 11:37:54.790
```

Figure 14.5 Example GOO S ALL L Command Response (Sheet 1 of 2)

```
Accumulated downtime duration                      : 0000:00:34.002
Maximum downtime duration                          : 0000:00:13.000
Date & time maximum downtime began                 : 07/01/2014 11:35:36.048
Number of messages received out-of-sequence(OOS)   : 4
Number of time-to-live(TTL) violations detected    : 0
Number of messages incorrectly encoded or corrupted: 0
Number of messages lost due to receive overflow    : 0
Calculated max. sequential messages lost due to OOS: 12
Calculated number of messages lost due to OOS      : 30

#    Date        Time          Duration        Failure
1    07/01/2014  11:37:02.051  0000:00:01.000  OUT OF SEQUENCE
2    07/01/2014  11:36:59.051  0000:00:03.000  CONF. REV. MISMATCH
3    07/01/2014  11:36:38.050  0000:00:00.999  OUT OF SEQUENCE
4    07/01/2014  11:36:29.049  0000:00:09.000  NEEDS COMMISSIONING
5    07/01/2014  11:36:09.049  0000:00:00.999  OUT OF SEQUENCE
6    07/01/2014  11:36:03.049  0000:00:06.000  CONF. REV. MISMATCH
7    07/01/2014  11:35:48.048  0000:00:00.999  OUT OF SEQUENCE
8    07/01/2014  11:35:36.048  0000:00:12.000  TEST MODE

SubsID 2
-----------------------------------------------------------------------------
Ctrl Ref: GOOSE_SIM_CFG/LLN0$GO$GooseDSet02
AppID   : 4114
From    : 07/01/2014 11:37:45.158  To: 07/01/2014 11:37:54.796

Accumulated downtime duration                      : 0000:00:09.638
Maximum downtime duration                          : 0000:00:09.638
Date & time maximum downtime began                 : 07/01/2014 11:37:45.158
Number of messages received out-of-sequence(OOS)   : 0
Number of time-to-live(TTL) violations detected    : 0
Number of messages incorrectly encoded or corrupted: 0
Number of messages lost due to receive overflow    : 0
Calculated max. sequential messages lost due to OOS: 0
Calculated number of messages lost due to OOS      : 0

#    Date        Time          Duration        Failure
```

Figure 14.5 Example GOO S ALL L Command Response (Sheet 2 of 2)

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 14.73 GROUP Command

Command	Description	Access Level
GROUP	Display the presently active group.	1, B, P, A, O, 2
GROUP *n*[a]	Change the active group to Group n.	B, P, A, O, 2

[a] Parameter *n* indicates group numbers 1–6.

When you change the active group, the relay responds with a confirmation prompt: `Are you sure (Y/N)?`. Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for one second when you change the active group.

If any of the SELOGIC control equations SS1–SS6 are set when you issue the **GROUP *n*** command, the group change will fail. The relay responds with `No group change: SELogic equations SS1-SS6 have priority over GROUP command.`

HELP

The **HELP** command gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Table 14.74 HELP Command

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1, B, P, A, O, 2
HELP *command*	Display information on the command *command*.	1, B, P, A, O, 2

HISTORY

The **HISTORY** command displays a quick synopsis of the last 100 events that the relay has captured. The rows in the **HISTORY** report typically contains the event serial number, date, time, location, maximum current, active group, and targets. (The specific content depends on the relay.) See *Section 9: Reporting* and *Section 7: Metering, Monitoring and Reporting* in the product-specific instruction manual for more information on history reports.

HIS

Use the **HIS** command to list one-line descriptions of relay events. You can list event histories by number or by date.

Table 14.75 HIS Command

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *k*[a]	Return the *k* most recent event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *date1*[b]	Return the event histories on date *date1*.	1, B, P, A, O, 2
HIS *date1 date2*[b]	Return the event histories from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.	1, B, P, A, O, 2

[a] Parameter *k* indicates an event number.
[b] Enter *date1* and *date2* in the order selected by the Global setting DATE_F.

HIS C and HIS R

The **HIS C** and **HIS R** commands clear/reset the history data and corresponding high-resolution/event report data on the present port. Options **C** and **R** are identical.

Table 14.76 HIS C and HIS R Commands

Command	Description	Access Level
HIS C	Clear/reset event data on the present port only.	1, B, P, A, O, 2
HIS R	Clear/reset event data on the present port only.	1, B, P, A, O, 2

The relay prompts you with `Are you sure (Y/N)?` when you issue the **HIS C** and **HIS R** commands. If you answer **Y <Enter>**, the relay clears the present port history data.

HIS CA and HIS RA

The **HIS CA** and **HIS RA** commands clear all history data and event reports from memory. Use these commands to completely delete high-resolution/event report data captures.

Table 14.77 HIS CA and HIS RA Commands

Command	Description	Access Level
HIS CA	Clear all event data for all ports.	P, A, O, 2
HIS RA	Clear all event data for all ports.	P, A, O, 2

If you issue the **HIS CA** and **HIS RA** commands, the relay prompts you with `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears all history data and event reports. The relay resets the event report number to 10000.

ID

Use the **ID** command to extract relay identification codes.

Table 14.78 ID Command

Command	Description	Access Level
ID	Return a list of relay identification codes.	0, 1, B, P, A, O, 2

Each line of the **ID** command report contains an identification code and a line checksum. The relay presents these codes in the following order:

FID: the Firmware Identification string

BFID: the Boot Firmware Identification string

CID: the checksum of the firmware

DEVID: the RID string as stored in the relay settings of the IED

DEVCODE: a unique Device Code (for Modbus identification purposes)

PARTNO: the Part Number

SERIALNO: the serial number of the relay

CONFIG: abcdef

The designator positions indicate a specific relay configuration:

"a" represents the nominal frequency, where 0 = N/A, 1 = 60 Hz, and 2 = 50 Hz.

"b" represents the phase rotation, where 0 = N/A, 1 = ABC, and 2 = ACB.

"c" represents the phase input current scaling, where 0 = N/A, 1 = 5 A, and 2 = 1 A.

"d" represents the neutral input current scaling, where 0 = N/A, 1 = 5 A, 2 = 1 A.

"e" represents the voltage input connection, where 0 = N/A, 1 = Delta, and 2 = Wye.

"f" represents the current input connection, where 0 = N/A, 1 = Delta, and 2 = Wye.

SPECIAL: the Special Configuration Designators—a mechanism for anticipating future product enhancements

If the device supports IEC 61850 and the IEC 61850 protocol is enabled, the **ID** command will display the following additional information.

- ➤ iedName: the IED name (e.g., SEL-411L_OtterTail)
- ➤ type: the IED type (e.g., SEL-411L)
- ➤ configVersion: the CID file configuration version (e.g., ICD-411L-R100-V0-Z001001-20060512)
- ➤ LIB61850ID: an eight-character code indicating the IEC 61850 library version within the product

A sample **ID** command response from the relay (with IEC 61850 enabled) is shown in *Figure 14.6*.

```
=ID <ENTER>
"FID=SEL-451-5-R319-V0-Z024013-D20170608","0916"
"BFID=SLBT-4XX-R209-V0-Z001002-D20150130","097C"
"CID=85F4","0264"
"DEVID=Relay 1","0467"
"DEVCODE=40","030B"
"PARTNO=04515415XC4X4H60X0XXX","07B3"
"SERIALNO=1234567890","0517"
"CONFIG=11102200","03EA"
"SPECIAL=000000","03CE"
"iedName=SEL_451_1","05CD"
"type=SEL_451","044C"
"configVersion=ICD-451-R301-V0-Z316006-D20170130","0D1C"
"LIB61850ID=9048BE8A","04EA"

=
```

Figure 14.6 Sample ID Command Response From Ethernet Card

IRIG

The **IRIG** command directs the relay to use the next available demodulated IRIG-B time code to update the relay internal clock. For information on the IRIG time mode, see *IRIG-B Timekeeping on page 11.1*.

Table 14.79 IRIG Command

Command	Description	Access Level
IRIG	Lock the relay internal clock to the IRIG-B time code input.	1, B, P, A, O, 2

NOTE: Not all SEL-400 series relays support the **IRIG** command.

The **IRIG** command was originally provided in the relay as a testing aid. The **IRIG** command was used to update the relay internal clock with the IRIG-B time value without waiting for the 30-second confirmation time delay.

There is no longer a 30-second confirmation time delay—the relay uses the IRIG time source as soon as it determines that the signal is valid, a process that may take several seconds. Once the IRIG signal is verified, the relay clock is updated once per second. The **IRIG** command is still available, but is no longer necessary. To check IRIG status, use the **TIME Q** command instead—see *TIME Q Command on page 11.8*.

If the relay has no valid IRIG-B time code at the rear panel, or if the **TIME Q** command reports a relay time source other than IRIG or HIRIG, the relay responds to the **IRIG** command with the following error message, `IRIG-B DATA ERROR`. See the **TIME** command for more information.

LOOPBACK

Use the **LOOPBACK** command to instruct the relay to receive the transmitted MIRRORED BITS communications data on the same serial port. See *SEL MIRRORED BITS Communication on page 15.31* for more information on MIRRORED BITS communications.

LOOP

The **LOOP** command puts the relay serial port in loopback if you have previously configured the port for MIRRORED BITS communications. If you have enabled both of the MIRRORED BITS communications channels (A and B), then you must specify the channel parameter. If you have only one of the channels enabled, then the relay assumes that channel if you do not specify that channel in the command. If you do not specify a time-out period, the relay provides a 5-minute time-out.

Table 14.80 LOOP Command

Command	Description	Access Level
LOOP	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *c*[a]	Begin loopback of MIRRORED BITS communications Channel *c* for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *t*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after time-out *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2
LOOP *t c*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after time-out t minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2

[a] Parameter *c* is A or B, representing Channel A or Channel B.

You can enter the options in any order. If you operate the relay using both MIRRORED BITS communications channels (A and B), then you must specify the channel parameter by using the **LOOP A** command and the **LOOP B** command.

When you issue the **LOOP** command, the relay responds with statements about the loopback time, status of the RMB (Receive MIRRORED BITS), and `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay responds with `Loopback Mode Started`.

In the loopback mode, ROK drops out and the relay uses LBOK to indicate whether the data transmissions are satisfactory. The relay collects COM data as usual. Time synchronization and virtual terminal modes are not available during loopback. The relay continues passing analog quantities.

LOOP DATA

The **LOOP DATA** command tells the relay to pass input MIRRORED BITS communications data through to the receive (RMB) bits, as in the nonloopback mode.

Table 14.81 LOOP DATA Command

Command	Description	Access Level
LOOP DATA	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA	Begin loopback of MIRRORED BITS communications Channel *c* only for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA *t*	Begin loopback of MIRRORED BITS communications Channel *c* only for *t* minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2

The relay ignores received values if you do not specify the **DATA** option. You can enter the options in any order.

LOOP R

The **LOOP R** command terminates the loopback condition on MIRRORED BITS communications channels in loopback. If you do not specify a Channel *c*, then the relay disables loopback on both channels. If you specify a channel, you can enter the options in any order.

Table 14.82 LOOP R Command

Command	Description	Access Level
LOOP R	Cease loopback on all MIRRORED BITS communications channels. (Reset the channels to normal use.)	P, A, O, 2
LOOP *c* R	Cease loopback on MIRRORED BITS communications Channel *c*. (Reset Channel *c* to normal use.)	P, A, O, 2

MAC

The **MAC** command returns the Media Access Control (MAC) addresses of the Ethernet ports.

Table 14.83 MAC Command

Command	Description	Access Level
MAC	Display all Ethernet ports MAC addresses	1, B, P, A, O, 2

A sample **MAC** command response for a relay with dual copper Ethernet ports is shown in *Figure 14.7*.

```
=>>MAC <Enter>
Port 5-1 MAC Address:  01-30-A7-00-F2-SA
Port 5-2 MAC Address:  01-30-A7-00-F2-9B
```

Figure 14.7 Sample MAC Command Response

MAP

Use the **MAP** command to view the organization of the relay database. The **MAP** command in the relay is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors.

MAP 1

The **MAP 1** command lists the relay database regions. Typical database region names are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS.

Table 14.84 MAP 1 Command

Command	Description	Access Level
MAP 1	List the database regions in the relay.	1, B, P, A, O, 2

MAP 1 *region* and MAP 1 *region* BL

Use the **MAP 1** command with the region option to view the layout of a specific region.

Table 14.85 MAP 1 *region* Command

Command	Description	Access Level
MAP 1 ***region***	List the data labels, database address, and data type.	1, B, P, A, O, 2
MAP 1 ***region*** **BL**	List the data labels, database address, and data type; list the bit labels, if assigned.	1, B, P, A, O, 2

The *region* option is the database region name shown in the simple **MAP 1** command response. The region map consists of columns for data item labels, database address, and data type.

If you specify the **BL** option and the region contains items with bit labels, the relay lists these bit labels in MSB (most significant bit) to LSB (least significant bit) order. The TARGET region is usually the only region containing bit labels.

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, and so on) and internal relay operating quantities (math variables and synchronism-check values).

All SEL-400 series relays support a **METER** command, but the options and responses are device specific. See the product-specific instruction manual for details of the **METER** command. Included below are the variants of the **METER** command that are common.

MET AMV

The **MET AMV** command lists automation math variables.

Table 14.86 MET AMV Command

Command	Description	Access Level
MET AMV	Display all automation math variables.	1, B, P, A, O, 2
MET AMV *k*	Display all automation math variables successively for *k* times.	1, B, P, A, O, 2

The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET ANA

Use the **MET ANA** command to view the analog quantities from the MIRRORED BITS communications channels.

Table 14.87 MET ANA Command

Command	Description	Access Level
MET ANA	Display the MIRRORED BITS communications analog quantities.	1, B, P, A, O, 2
MET ANA *k*	Display the MIRRORED BITS communications analog quantities successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the MIRRORED BITS communications channels and the remote analog data, the relay response to this command will not include any values. If MIRRORED BITS communications is enabled but not communicating, the relay will display `ERROR` under the `RMBA` or `RMBB` entries, depending on settings.

MET BAT

Use the **MET BAT** command to view the station dc monitor quantities for the battery voltages.

NOTE: Some relays provide one battery monitor channel and some support two.

Table 14.88 MET BAT Command

Command	Description	Access Level
MET BAT	Display station battery measurements.	1, B, P, A, O, 2
MET BAT *k*	Display station battery measurements successively for *k* times.	1, B, P, A, O, 2
MET RBM	Reset station battery measurements.	P, A, O, 2

If you have not enabled the Station DC Battery Monitor, the relay responds with `DC Monitor Is Not Enabled`. (Enable the dc monitor with the Global setting EDCMON.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds with `Reset Max/Min Battery Metering (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Max/Min Battery Reset`.

MET D

Use the **MET D** command to view the demand and peak demand quantities.

NOTE: Not all SEL-400 series relays support demand metering.

Table 14.89 MET D Command

Command	Description	Access Level
MET D	Display demand metering data.	1, B, P, A, O, 2
MET D *k*	Display demand metering data successively for *k* times	1, B, P, A, O, 2
MET RD	Reset demand metering data.	P, A, O, 2
MET RP	Reset peak demand metering data.	P, A, O, 2

The reset command (**MET RD**) resets the demand metering quantities. When you issue the **MET RD** command, the relay responds, `Reset Demands (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Demands Reset`.

The reset command, **MET RP**, resets the peak demand metering quantities. When you issue the **MET RP** command, the relay responds, `Reset Peak Demands (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Peak Demands Reset`.

MET M

Use the **MET M** command to view power system maximum and minimum quantities.

NOTE: Not all SEL-400 series relays support maximum/minimum metering.

Table 14.90 MET M Command

Command	Description	Access Level
MET M	Display maximum/minimum metering data.	1, B, P, A, O, 2
MET M *k*	Display maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET BK*n*[a] M	Display Breaker *n* maximum/minimum metering data.	1, B, P, A, O, 2
MET BK*n* M *k*	Display Breaker *n* maximum/minimum metering data successively for *k* times.	1, B, P, A, O, 2
MET RM	Reset maximum/minimum metering data.	P, A, O, 2

[a] Parameter *n* is the breaker indication.

The reset command, **MET RM**, resets the maximum/minimum metering quantities. When you issue the **MET RM** command, the relay responds, `Reset Max/Min Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Reset`.

MET PM

Use the **MET PM** command to view the time-synchronized quantities. The relay must be in the high-accuracy timekeeping HIRIG or HPTP mode. For more information on high-accuracy timekeeping, see *Section 11: Time and Date Management*.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.91 MET PM Command (Sheet 1 of 2)

Command	Description	Access Level
MET PM	Display time-synchronized values.	1, B, P, A, O, 2
MET PM *k*	Display time-synchronized values successively for *k* times.	1, B, P, A, O, 2

Table 14.91 MET PM Command (Sheet 2 of 2)

Command	Description	Access Level
MET PM *time*	Display time-synchronized values captured at trigger *time*.	1, B, P, A, O, 2
MET PM HIS	Display time-synchronized values captured for the previous **MET PM** command.	1, B, P, A, O, 2

If the relay is not in the high-accuracy IRIG (HIRIG) timekeeping mode, it will respond to the **MET PM** command with the following message:

```
Aborted: A High Accuracy Time Source is Required
```

If Global enable setting EPMU := N, the relay will respond to the **MET PM** command with:

```
Synchronized phasor measurement is not enabled
```

To request a report of the synchrophasor data at a specific time, enter the optional *time* parameter as a time of day. For example, the relay will respond to the **MET PM 16:40:10** command with:

```
Synchronized Phasor Measurement Data Will Be Displayed at
16:40:10.000
```

In this example, when the internal clock reaches 16:40:10.000, the relay will display the synchrophasor data from that exact time. If the relay is not in HIRIG mode at that time, it will display the following message:

```
Aborted: A High Accuracy Time Source is Required
```

After the **MET PM *time*** command is issued, other **MET PM** commands may be entered without affecting the timed request, even if the stated time has not arrived. However, issuing a second **MET PM *time*** command while the first command is still pending will cancel the first command request in favor of the newer request.

If you are not connected to the relay when the **MET PM *time*** command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue **MET PM *time*** to multiple relays using a common time and then go back later to see the results from all the relays at this common instant in time.

See *Section 18: Synchrophasors* for more information on phasor measurement functions, and *View Synchrophasors by Using the MET PM Command on page 18.21* for sample **MET PM** responses.

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 14.92 MET PMV Command

Command	Description	Access Level
MET PMV	Display all protection math variables.	1, B, P, A, O, 2
MET PMV *k*	Display all protection math variables.	1, B, P, A, O, 2

The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET RTC

Use the **MET RTC** command to view the data received on all active synchrophasor client channels.

Table 14.93 MET RTC Command

Command	Description	Access Level
MET RTC	Display received synchrophasor client data	1, B, P, A, O, 2
MET RTC *k*	Display received synchrophasor client data *k* times	1, B, P, A, O, 2

MET T

Use the **MET T** command to view the temperature data from the SEL-2600A RTD Module. This command requires setting PROTO = RTD for the serial port connected to the SEL-2600A RTD Module.

NOTE: Some SEL-400 series relays use the option MET RTD to get this same information.

Table 14.94 MET T Command

Command	Description	Access Level
MET T	Display as many as 12 temperature analog values from the SEL-2600A RTD Module.	1, B, P, A, O, 2
MET T *k*	Display as many as 12 temperature analog values from the SEL-2600A RTD Module successively for *k* times.	1, B, P, A, O, 2

NOTE: The SEL-487B does not support RTD inputs.

The relay displays the number of RTD channels specified by the RTDNUM Port Setting. If the RTD protocol is not enabled on any of the relay ports, the relay displays the following:

```
No data available
```

If there is a communications failure between the relay and the SEL-2600A, as indicated by the RTDCOMF Relay Word bit, the relay displays the following:

```
Communication Failure
```

If the RTDFL Relay Word bit is set to indicate a SEL-2600A failure, the relay displays the following:

```
SEL-2600 Failure
```

If any of the RTD*x*TY Port Settings are set to NA, the relay displays the following for that channel:

```
Channel Not Used
```

If the RTD*xx*ST Relay Word bit is set for any of the RTDNUM channels being reported, the relay displays the following:

```
Channel Failure
```

OACCESS

Use the **OACCESS** command to gain access to Access Level O (output). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.95 OAC Command

Command	Description	Access Level
OAC	Go to Access Level O (output).	1, B, P, A, O, 2

OPEN *n*

Use the **OPEN *n*** command to open a circuit breaker(s). The **OPEN *n*** command pulses Relay Word bit OC*n*. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker. See *Trip Logic* in *Section 5: Protection* of the product-specific instruction manual for information on trip SELOGIC control equations.

Table 14.96 OPEN *n* Command

Command	Description	Access Level
OPEN *n*	Pulse Relay Word bit OC*n*.	B, P, A, O, 2

If you have disabled the relay and attempt an **OPEN *n*** command, the relay responds, `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

When you issue the **OPEN *n*** command, and the circuit breaker control enable jumper is in place, the relay responds, `Open breaker (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay asserts OC*n* for one processing interval.

If you have assigned auxiliary contact 52A inputs for this circuit breaker, the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and responds `Breaker OPEN` or `Breaker CLOSED`, as appropriate.

If Breaker *n* is not enabled, the relay responds, `Breaker n is not available`.

PACCESS

Use the **PACCESS** command to gain access to Access Level P (protection). See *Access Levels and Passwords on page 3.7* for more information.

Table 14.97 PAC Command

Command	Description	Access Level
PAC	Go to Access Level P (protection).	1, B, P, A, O, 2

PASSWORD

Use the **PASSWORD** command to control password protection for relay access levels.

PAS *level*

The relay changes the existing password for the specified access level that you specify when you issue the **PAS *level*** command.

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private pass word may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Table 14.98 PAS *level* New_Password Command

Command	Description	Access Levels
PAS *n*	Set a new password for Access Level *n*.	2

Relay access levels that have passwords are 1, B, P, A, O, 2, and C. Valid passwords are character sequences of as many as 12 characters. Valid characters are any printable ASCII character. HMI password entry is limited to upper- and lowercase letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel.

All passwords are case sensitive. When you successfully enter a new password, the relay pulses the Relay Word bit SALARM for one second, and responds, `Set`.

PAS *level* DISABLE

Issuing the **PAS *level* DISABLE** command disables password checking for the specified access level. You must type **DISABLE** in upper case.

Table 14.99 PAS *level* DISABLE Command

Command[a]	Description	Access Levels
PAS *n* DISABLE	Disable password protection for the Access Level *n*.	2

[a] Parameter *n* represents the relay Access Levels 1, B, P, A, O, or 2.

When you successfully disable password checking, the relay pulses the SALARM Relay Word bit for one second, and responds, `Password Disabled`. SEL does not recommend disabling passwords.

PING

Use the **PING** command to determine whether the network is connected properly and other network devices are reachable.

Table 14.100 PING Command

Command	Description	Access Level
PING *addr*[a]	Send ICMP echo request messages to remote device at *addr*.	1, B, P, A, O, 2

[a] IP address of device to ping in the format of four decimal numbers (0–255) separated by periods.

When the IP address parameter is not of a valid format, the relay responds with `Invalid IP address`. After a valid **PING** command is issued, the relay sends out an ICMP echo request messages at one second intervals until receiving a carriage return **<CR>** or five minutes elapses. A sample **PING** command response is shown in *Figure 14.8*.

```
=>>PING 192.9.201.1 <Enter>

Pinging 192.9.201.1
Press <Enter> to Terminate Ping Test.

Ping Echo Message Received.
Ping Echo Message Received.
Ping Echo Message Received.
Ping Echo Message Received.


Ping Results:

   Number of Ping Messages:
      Transmitted:   4
      Received:      4

   Elapsed Time:    11 seconds

=>>
```

Figure 14.8 Sample PING Command Response

PORT

The **PORT** command can be used to connect to a remote relay.

PORT *p*

The **PORT *p*** command connects a relay serial port to another device through a virtual terminal session.

NOTE: The BAY1 and BAY2 options only apply to relays that support 87L communications and have the corresponding bay card installed.

In the relay, serial port virtual terminal capability is available in MIRRORED BITS communications. You must have previously configured the serial port for MIRRORED BITS communications operation, set port setting MBNUM less than 8, and have at least one virtual terminal session available (set MBNUMVT to 0 or greater). Choosing MBNUMVT to 0 uses virtual terminal within the synchronization channel only. See *SEL MIRRORED BITS Communication on page 15.31* for information on the MIRRORED BITS communications protocol.

Table 14.101 PORT *p* Command

Command	Description	Access Level
PORT *p*[a]	Connect to a remote device through Port *p* (over MIRRORED BITS communications virtual terminal mode).	1, B, P, A, O, 2

[a] Parameter *p* is 1, 2, 3, and F to indicate Communications PORT 1 – PORT 3 and PORT F, or BAY1 or BAY2 for 87L ports.

When the relay establishes a connection, the relay responds, `Transparent session to Port p established`. To quit the transparent connection, type the control string that you specify in port setting TERSTRN; the default is **<Ctrl+E>**. Only one transparent port connection to each MIRRORED BITS communications port is possible at one time. If you issue a **PORT *p*** command when the selected session is already active, the relay responds, `Transparent session already in use`.

If you issue the **PORT *p*** command to ports 1, 2, 3, or F or BAY1 or BAY2 (87L ports) and you have not properly configured the MIRRORED BITS communications port, the MBNUMVT is not set to 1 or larger, `Invalid destination port`.

PORT KILL *n*

It is possible to forcefully disconnect a transparent session from another port (a port not involved in the present transparent connection) by using the **PORT KILL *n*** command (shown in *Table 14.102*).

Table 14.102 PORT KILL *n* Command

Command	Description	Access Level
PORT KILL *n*[a]	Terminate the virtual terminal connection with a remote device through port *n* by using a port not involved in the connection.	P, A, O, 2

[a] Parameter *n* is 1, 2, 3, or F or BAY1 or BAY2 (for 87L ports) to indicate communications PORT 1–3 or PORT F; *n* is not the present port.

The port parameter *n* can refer to either of the ports involved in the session you want to kill. When you issue the **PORT KILL *n*** command, the relay responds, `Kill connection between ports m and n (Y/N)?` Answer **Y <Enter>** to terminate the connection. The relay sends a character sequence to the remote relay (to make sure the remote device is left in a known state) and responds, `Connection between ports m and n disconnected`.

PROFILE

Use the **PROFILE** command (**PRO**) to access the Signal Profile data for as many as 20 user selectable analog values.

Table 14.103 PRO Command

Command	Description	Access Level
PRO	Displays the first 20 rows of the profile report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m*	Displays the first *m* rows of the report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m n (m > n)*	Displays the row between *m* and *n*, (including *m* and *n*) with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date1*	Displays all the rows that were recorded on that date, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date1 date2*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date1* chronologically precedes *date2*, with the oldest row (*date1*) at the top and the latest row (*date2*) at the bottom.	1, B, P, A, O, 2
PRO *date2 date1*	Displays all the rows that were recorded on and between (including) *date1* and *date2* (*date2* chronologically precedes *date1*, with the oldest row (*date2*) at the top and the latest row (*date1*) at the bottom.	1, B, P, A, O, 2
PRO D	Displays, for each port, the maximum number of days data may be acquired with the present settings before data overwrite occurs.	1, B, P, A, O, 2
PRO C or R	Clears the signal profile data from nonvolatile memory on a per-port basis. The data are still visible to other ports and to file transfer accesses and is cleared independently for those points-of-view.	B, P, A, O, 2
PRO CA or RA	Completely clears all signal profile data from nonvolatile memory.	P, A, O, 2

PULSE

Use the **PULSE OUT*nnn*** command to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. If the output is open, the **PUL** command momentarily closes the output; if the output is closed, the **PUL** command momentarily opens the output. The control outputs are **OUT*nnn***, where *nnn* represents the 100-series, 200-series, 300-series, 400-series, and 500-series addresses.

Table 14.104 PUL OUT*nnn* Command

Command	Description	Access Level
PUL OUT*nnn*[a]	Pulse output OUT*nnn* for 1 second.	B, P, A, O, 2
PUL OUT*nnn s*[b]	Pulse output OUT*nnn* for *s* seconds.	B, P, A, O, 2

[a] Parameter *nnn* is a control output number.
[b] Parameter *s* is time in seconds, with a range of 1–30.

If the circuit breaker control enable jumper BREAKER is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

When you issue the **PUL** command and the breaker jumper is in place, the relay responds, `Pulse contact OUTnnn for s seconds (Y/N)?`. If you answer **Y <Enter>**, the relay asserts OUT*nnn* for the time you specify.

During the **PUL** operation, the Relay Word bit corresponding to the control output you specified (OUT*nnn*) asserts; Relay Word bit TESTPUL also asserts during any **PUL** command, so you can monitor pulse operation by programming TESTPUL into event triggers and alarm outputs.

QUIT

Use the **QUIT** command to revert to Access Level 0 (exit relay control).

Table 14.105 QUIT Command

Command	Description	Access Level
QUIT	Go to Access Level 0 (exit relay control).	0, 1, B, P, A, O, 2

Access Level 0 is the lowest access level; the relay performs no password check to descend to this level (or remain at this level).

In a Telnet session, **QUIT** terminates the connection.

RTC

Use the **RTC** command to display a description of all data being received on synchrophasor client channels. This report will list the analog quantity and Relay Word bits the data gets stored in locally, matched up with a label provided by the sending PMU. Use this information as aid to understanding the local values.

NOTE: Not all SEL-400 series relays support synchrophasors.

Table 14.106 RTC Command

Command	Description	Access Level
RTC	Display report of all configured synchrophasor client data labels.	1, B, P, A, O, 2

SER

The **SER** command retrieves SER records. The relay SER captures state changes of Relay Word bit elements and relay conditions. Relay conditions include startup, relay enable/disable, group changes, settings changes, memory queue overflow, and SER autoremoval/reinsertion. For more information on the SER, see *Sequential Events Recorder (SER) on page 9.28*.

SER

The default order of the **SER** command is oldest to newest from list top to list bottom. You can view the SER records in numerical or date order.

Table 14.107 SER Command

Command	Description	Access Level
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.	1, B, P, A, O, 2
SER *date1*[b]	Return the SER records on date *date1*.	1, B, P, A, O, 2
SER *date1 date2*[b]	Return the SER records from *date1* at the top of the list, to *date2* at the bottom of the list.	1, B, P, A, O, 2

[a] Parameters *m* and *n* indicate an SER number, which the relay assigns at each SER trigger.
[b] Enter *date1* and *date2* in the same format as Global setting DATE_F.

SER C and SER R

The **SER C** and **SER R** commands clear/reset the SER records for the present port. Options **C** and **R** are identical.

Table 14.108 SER C and SER R Commands

Command	Description	Access Level
SER C	Clear/reset SER records on the present port.	1, B, P, A, O, 2
SER R	Clear/reset SER records on the present port.	1, B, P, A, O, 2

The relay prompts you with `Clear the sequential events recorder for this port. Are you sure (Y/N)?` when you issue the **SER C** or **SER R** command. If you answer **Y <Enter>**, the relay clears the particular port SER records.

SER CA and SER RA

The **SER CA** and **SER RA** commands clear all SER records from memory.

Table 14.109 SER CA and SER RA Commands

Command	Description	Access Level
SER CA	Clear SER data for all ports.	P, A, O, 2
SER RA	Clear SER data for all ports.	P, A, O, 2

If you issue the **SER CA** or **SER RA** command, the relay prompts you with `Clear the sequential events recorder for all ports. Are you sure (Y/N)?` commands. If you answer **Y <Enter>**, the relay clears all SER records in nonvolatile memory.

SER CV and SER RV

The **SER CV** and **SER RV** commands clear any SER data records that have been viewed from the present port. The two commands are equivalent.

Table 14.110 SER CV or SER RV Commands

Command	Description	Access Level
SER CV	Clear viewed SER data for this port.	1, B, P, A, O, 2
SER RV	Clear viewed SER data for this port.	1, B, P, A, O, 2

If you issue the **SER CV** or **SER R**V command, the relay prompts you with `Clear viewed SER records for this port. Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears all SER records viewed from this port. The data are still visible to other ports and to file transfer accesses, and they must be cleared independently for those ports. Data not yet viewed remain available.

SER D

The **SER D** command shows a list of SER items that the relay has automatically removed. These are "chattering" elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL.

Table 14.111 SER D Command

Command	Description	Access Level
SER D	List chattering SER elements that the relay is removing from the SER records.	1, B, P, A, O, 2

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds, `Automatic removal of chattering SER elements not enabled`.

SET

Use the **SET** command to change relay settings. The relay settings structure is ordered and contains these items (in structure order): classes, instances, categories, and settings. An outline of the relay settings structure is as follows:

Classes (Global, Group, Breaker Monitor, Protection, Automation, Outputs, Front Panel, Report, DNP3, and Ports)

Instances (some classes have instances: Group = 1–6; Protection = 1–6; Automation = 1–10; PORTs = 1–3, F, 5)

Categories (collections of similar settings)

Settings (specific relay settings with values)

The **SET** and **SHOW** commands contain these settings structure items, which you must specify in order from class to instance (if applicable) to setting. The order that specific settings appear in the relay settings structure is factory programmed.

SET

The **SET** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To set a different instance, specify the instance number (1–6).

Table 14.112 SET Command Overview

Command[a]	Description	Access Level
SET	Set the Group relay settings, beginning at the first setting in the active group.	P, 2
SET *n*	Set the Group *n* relay settings, beginning at the first setting *n* each instance.	P, 2
SET *label*	Set the Group relay settings, beginning at the active group setting label *label*.	P, 2
SET *n label*	Set the Group n relay settings, beginning at setting label *label*.	P, 2
SET *c*	Set class *c,* using the default instance beginning at the first setting.	P,A,O,2
SET *c i*	Set class *c*, instance *i*, beginning at the first setting.	P,A,O,2
SET *c i label*	Set class *c*, instance *i*, beginning at setting *label.*	P,A,O,2

[a] Parameter *n* = 1–6, representing Group 1–6.
c = settings class (relay specific).
i = class instance (choices depends on the class).

The specific classes and instances available depends on the relay. See the relay-specific instruction manual for the specific options that are available. The relay validates your settings entries as you enter each setting. At the end of a settings instance session, the relay responds with a readback of all the settings in the settings instance, then prompts you with `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait..........` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SET TERSE

Use the **TERSE** option to inhibit the relay from sending the settings class or instance readback when you end a settings session. SEL recommends that you use the **TERSE** option sparingly; you should review the readback information to confirm that you have entered the settings that you intended.

Table 14.113 SET TERSE Command Examples

Command	Description	Access Level
SET TERSE	SET Group relay settings for the active group, beginning at the first setting in this instance; omit settings readback.	P, 2
SET 3 TE[a] *label*	SET Group 3 settings, beginning at the settings label *label*; omit settings readback.	P, 2
SET P *p label* TERSE	Set the communications Port relay settings for Port *p*, beginning at the settings label *label*; omit readback.	P, A, O, 2

[a] TERSE may be entered as TE, as shown in this example.

You can use the **TERSE** option in any **SET** command at any position after typing **SET**. When you end the settings edit session, the relay responds, `Save settings (Y,N)?`. If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait...........` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SHOW

The **SHOW** command shows the relay settings. When showing settings, the relay displays the settings label and the present value from nonvolatile memory.

The relay organizes settings in classes, instances, categories, and specific settings; see *SET on page 14.48* for information on settings organization. The relay displays each setting in the order specified in the settings tables. When you are using a terminal and you specify a setting in the middle of a settings category, the relay displays the category title, then proceeds with the class or instance settings from the setting that you specified.

Table 14.114 SHO Command Overview

Command[a]	Description	Access Level
SHO	Show the Group relay settings, beginning at the first setting in the active group.	1, B, P, A, O, 2
SHO *n*	Show the Group *n* relay settings, beginning at the first setting in each instance.	1, B, P, A, O, 2
SHO *label*	Show the Group relay settings, beginning at the active group settings label *label*.	1, B, P, A, O, 2
SHO *n label*	Show the Group *n* relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2
SHO *c*	Show class *c* using the default instance beginning at the first setting.	P, A, O, 2
SHO *c i*	Show class *c*, instance *i* beginning at the first setting.	P, A, O, 2
SHO *c i label*	Show class *c*, instance *i*, beginning at setting *label*.	P, A, O, 2

[a] Parameter *n* = 1–6, representing Group 1–6.
c = settings class (relay specific).
i = class instance (choices depends on the class).

SNS

In response to the **SNS** command, the relay sends the names of the SER elements. This is a comma-delimited string used to support the SEL Fast SER report.

Table 14.115 SNS Command

Command	Description	Access Level
SNS	Send the names of SER elements.	0, 1, B, P, A, O, 2

STATUS

The **STATUS** command reports relay status information that the relay derives from internal diagnostic routines and self-tests. See *Relay Self-Tests on page 10.15* for information on relay diagnostics.

STA

The **STA** command with no options displays a short-form relay status report. Items in the STA report are the header, failures, warnings, SELOGIC control equation programming environment errors, and relay operational status. See *Checking Relay Status on page 3.11* for information on relay status reports.

Table 14.116 STA Command

Command	Description	Access Level
STA	Return the relay status.	1, B, P, A, O
STA	Return the relay status and show a new hardware configuration prompt.	2

If you change an I/O interface board, the relay detects the new configuration and initiates a status warning. When you issue the **STA** command at Access Level 2, the relay responds to this situation with `Accept new hardware configuration (Y/N)?`. If you answer **Y <Enter>**, the relay responds, `New configuration accepted`. If you answer **N <Enter>**, the relay responds, `Command aborted`.

STA A

Use the **STA A** command to view the entire relay status report. Items in the full status report include the short-form status report items plus data on A/D (analog/digital) channel offsets, power supply voltages, temperature, communications interfaces, and time-source synchronization.

Table 14.117 STA A Command

Command	Description	Access Level
STA A	Display all items of the status report.	1, B, P, A, O, 2

STA C and STA R

The **STA C** and **STA R** commands reboot the relay. Thus, these commands clear a transient failure should this unlikely event occur. Options **C** and **R** are identical. Contact your Technical Service Center or the SEL Factory before using this command.

Table 14.118 STA C and STA R Command

Command	Description	Access Level
STA C	Reset the relay.	2
STA R	Reset the relay.	2

STA S

Use the **STA S** command to view all SELOGIC control equation storage and execution capacity and operating errors.

Table 14.119 STA S Command

Command	Description	Access Level
STA S	Display detailed SELOGIC control equation error information.	1, B, P, A, O, 2

STA SC and STA SR

The **STA SC** and **STA SR** commands clear/reset the SELOGIC control equation operating errors from the status report if the errors are no longer present. In addition, these commands reset the Automation SELOGIC Peak and Average Execution Cycle Time statistics.

Table 14.120 STA SC and STA SR Command

Command	Description	Access Level
STA SC	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2
STA SR	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2

SUMMARY

The **SUMMARY** command displays a summary event report. See *Event Summary on page 9.26* for information on summary event reports.

SUM

Use the **SUM** command to view the event summary reports in the relay memory.

Table 14.121 SUM Command

Command	Description	Access Level
SUM	Return the most recent event summary.	1, B, P, A, O, 2
SUM *n*[a]	Return an event summary for event *n*.	1, B, P, A, O, 2

[a] Parameter *n* indicates event order or serial number; see the event history report (*HIS on page 14.32* command).

When parameter *n* is 1–9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000–42767, *n* indicates the absolute serial number of the event report.

SUM ACK

Use **SUM ACK** to acknowledge an event summary that you recently viewed with the **SUM NEXT** command on the present communications port. Acknowledge the oldest summary (specify no event number).

Table 14.122 SUM ACK Command

Command	Description	Access Level
SUM ACK	Acknowledge the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **SUM NEXT** command, the relay responds, `Event summary number n has not been viewed with the NEXT option`.

SUM NEXT

Use the **SUM N** command to view the oldest (next) unacknowledged event summary.

Table 14.123 SUM N Command

Command	Description	Access Level
SUM N	View the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

TARGET

The **TARGET** command displays the elements for a selected row in the Relay Word bit table.

TAR

Use the **TAR** command to view a row of Relay Word bit elements or aliases. When using the **TAR** command, you can specify the row number or element name.

Table 14.124 TAR Command

Command	Description	Access Level
TAR	Display target Row 0 or display the most recently viewed target row.	1, B, P, A, O, 2
TAR *n*	Display target Row *n*.	1, B, P, A, O, 2
TAR *n k*[a]	Display target Row *n* and repeat for *k* times; the repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name*	Display the target row with the element name *name*.	1, B, P, A, O, 2
TAR *name k*	Display the target row with the element name *name* and repeat for *k* times; the repeat count *k* can be before or after the name option.	1, B, P, A, O, 2

[a] Parameter *k* is the repeat count from 1–32767.

The relay memorizes the latest target row input conditioned by your present access level. The relay displays Row 0 if you have not specified a row since the relay was turned on, the access level has timed out, or you have issued the **QUIT** command.

If you specify the repeat count k at a number greater than 8, the relay displays the repeated target rows on the terminal screen in groups of eight, with the target row elements listed above each grouping.

TAR ALL

Use the **TAR ALL** command to display all of the relay targets.

Table 14.125 TAR ALL Command

Command	Description	Access Level
TAR ALL	Display all target rows.	1, B, P, A, O, 2

TAR R

The **TAR R** command has two functions. Use this command to reset any latched relay targets resulting from a tripping event. Also employ the **TAR R** command to reset to Row 0 the memorized target row that the relay reports when you issue a simple **TAR** command.

Table 14.126 TAR R Command

Command	Description	Access Level
TAR R	Reset latched targets and return memorized row to Row 0.	1, B, P, A, O, 2

TAR X

Use the **TAR X** command to view a different target row in the Relay Word bit table than the target row in the target row repeat memory. This function is useful for relay testing. See *Testing With Relay Word Bits on page 10.7* for more information.

Table 14.127 TAR X Command

Command[a]	Description	Access Level
TAR *n* X	Display target Row *n*, but do not memorize Row *n*.	1, B, P, A, O, 2
TAR X *n k*	Display target Row *n* and repeat for *k* times, but do not memorize Row *n*. The repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name* X	Display the target row with the element name *name*, but do not memorize the row *n*umber.	1, B, P, A, O, 2
TAR *name* X *k*	Display the target row with the element name *name* and repeat for *k* times, but do not memorize the row number. The repeat count *k* can be at any position in the command after **TAR**.	1, B, P, A, O, 2

[a] Parameter *k* is the repeat count from 1–32767.

You can place the **X** option at any position in the **TAR** command.

TEC

Enter the **TEC** (time-error calculation) command to display the present time-error estimate and the status of the time-error control equations, and to modify the time-error correction value.

NOTE: Not all SEL-400 series relays support the **TEC** command.

Table 14.128 TEC Command

Command	Description	Access Level
TEC	Display time-error data.	1, B, P, A, O, 2
TEC *n*	Preload time-error correction value *n*, where –30.000 <= *n* <= 30.000.	B, P, A, O, 2

Use the **TEC *n*** command to preload the time-error correction value, TECORR. If the value *n* is within range, the relay will prompt you with `Are you sure (Y/N)?`. If the prompt is acknowledged, the relay sets analog quantity TECORR = *n*, and asserts Relay Word bit PLDTE for approximately 1.5 cycles. The relay then displays the new TECORR value, along with the remaining **TEC** command data.

The TECORR value does not affect the TE (time-error) estimate until the LOADTE SELOGIC equation asserts.

TEST DB

The **TEST DB** command is used for testing access of the virtual device database used for Fast Message Data Access.

TEST DB

Use the **TEST DB** command to write temporary values to the virtual device database to verify the database values. The relay contains a database that describes the relay to external devices. When other devices access the relay via the Fast Message protocol, the relay appears as a virtual device described by the database. The relay is Virtual Device 1.

The virtual database is accessible to master stations of supported Fast Message protocol connected to the relay through serial communication or Ethernet network. You can therefore test the read functionality of the Fast Message protocol in the serial port or Ethernet interface with this command.

Use the **TEST DB 1** command to override any value in the relay database. You must understand the relay database structure to effectively use the **TEST DB** command. Use the **MAP** and **VIEW** commands to see the organization and contents of the database.

Values you enter in the relay database are override values. Use the **TEST DB** command to write override values in the database accessed through the Fast Message Data Access operations.

Table 14.129 TEST DB Command

Command	Description	Access Level
TEST DB	Display present override values by virtual device number and address.	1, B, P, A, O, 2
TEST DB 1 *addr value1*	Write new data *value1* to the database at an address *addr*.	B, P, A, O, 2
TEST DB 1 *addr value1 M D Y h m s*	Write new data value1 to the database at an address *addr* and include the provided date/time stamp *M D Y h m s*.	B, P, A, O, 2

The database address *addr* can be any legitimate decimal or hexadecimal address. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.)

You can enter the override value *value1* as an integer, a floating-point number (which overrides two registers), a character (which must be in single quotes), or a string (which must be in double quotes and overrides the number of registers corresponding to the length of the string).

If a date/time stamp is also provided (*M D Y h m s*), the relay will change the static state given and, for any bits being changed by this operation, queued entries will be pushed with the provided date/time stamp. If no queue is associated with the database region (determined by *addr*), the date/time stamp will be ignored.

The order that the date should be entered on the command line depends upon the DATE_F (Global) setting. For example, if DATE_F := DMY, you would enter **TEST DB 1 *addr value D M Y h m s***.

While there are active test data, the relay asserts Relay Word bit TESTDB.

TEST DB OFF

Use the **TEST DB OFF** command to end the testing session and remove the override values. The relay returns the database registers to the pretest values.

Table 14.130 TEST DB OFF Command

Command	Description	Access Level
TEST DB OFF	Clear all override testing values from all virtual devices.	B, P, A, O, 2
TEST DB OFF 1	Clear all override testing values from Virtual Device 1 (the relay).	B, P, A, O, 2
TEST DB OFF 1 *region*	Clear all override testing values from the region *region* in Virtual Device 1 (the relay).	B, P, A, O, 2

TEST DB2

The **TEST DB2** command is used to test DNP3 and IEC 61850 MMS communication protocols.

TEST DB2

Other than Fast Message Protocol, all the communication protocols supported by the relay (DNP3, IEC 61850, GOOSE) retrieve data from a storage area called the CADI2 database. These data include both digital quantities and analog quantities. All Relay Word bits along with additional binary input points in DNP3 map are available in CADI2 database as digital quantities.

Use the **TEST DB2** command to override any value in the CADI2 database. Values you enter in the CADI2 database are override values read by the master stations.

Table 14.131 TEST DB2 Command

Command	Description	Access Level
TEST DB2	Display present analog and digital override names and values.	1, B, P, A, O, 2
TEST DB2 D *name1*[a] *value1*	Write the specified override value *value1* into the digital quantity *name1*.	B, P, A, O, 2
TEST DB2 A *name2*[b] *value2*	Write the specified override value *value2* into the analog quantity *name2*.	B, P, A, O, 2

[a] Digital *name1* can be any Relay Word bits or additional binary input points in DNP3 map.
[b] The analog *name2* is any analog available in the DNP3 reference map and any analog listed as a data source for IEC 61850 logical devices.

The override value *value1* can be logical 0 or logical 1 for digital and status elements. The analog *value2* can be an integer or a floating-point number.

The Relay Word bit TESTDB2 will be asserted while there are points in this test mode.

TEST DB2 OFF

Use the **TEST DB2 OFF** command to end the CADI2 database testing session and remove the override values. The relay returns the CADI2 database registers to the pretest values.

Table 14.132 TEST DB2 OFF Command

Command	Description	Access Level
TEST DB2 D OFF	Clear all digital override testing values from the CADI2 database.	B, P, A, O, 2
TEST DB2 D *name1*[a] OFF	Clear digital override testing value specified by name *name1* from the CADI2 database.	B, P, A, O, 2
TEST DB2 A OFF	Clear all analog override testing values from the CADI2 database.	B, P, A, O, 2
TEST DB2 A *name2*[b] OFF	Clear analog override testing value specified by name *name2* from the CADI2 database.	B, P, A, O, 2

[a] Digital *name1* can be any Relay Word bits or additional binary input points in DNP3 map.
[b] See Section 12: Analog Quantities in the product-specific instruction manual for available analog *name2*.

When removing all existing digital override values, the relay responds, `Digital Overrides Removed`. If no digital override is ever configured, the `Overrides Not Found` message will be displayed. The analog override removal acknowledgment messages are similar.

TEST FM

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can override only "reported" Fast Meter values. For more information on Fast Meter and the relay, see *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.

TEST FM

Values you enter in Fast Meter storage are "override values." Use the **TEST FM** command to display override values and write override values in the Fast Meter report.

Table 14.133 TEST FM Command

Command	Description	Access Level
TEST FM	Display present override values.	1, B, P, A, O, 2
TEST FM *label value1 value2*	Write new data *value1* and *value2* to the Fast Meter report at the item label *label*. Parameter *value2* is optional.	B, P, A, O, 2

When you display Fast Meter data overrides with the **TEST FM** command, the relay shows the item label, and override values.

To force a value, use the **TEST FM *label value1 value2*** command. The item label *label* is any analog channel label in the Fast Meter configuration (if available), any digital element label (from the **DNA** command), and any status element label (from the **BNA** command) except the TEST and FMTEST items.

The value *value1* can be logical 0 or logical 1 for digital and status elements, or a floating-point value for all meter quantities. For meter items that report a pair of values in the Fast Meter message, *value1* is the magnitude and *value2*, if provided, is the angle. If you do not specify *value2*, the relay uses an angle of 0.

When you have successfully added a new Fast Meter test value (for example, **TEST FM IA1 3.7 0.0**), the relay responds, `Override Added`.

The relay asserts Relay Word bit TESTFM while any Fast Meter override data are present in the relay.

Fast Meter Status Byte

Bits labeled TEST and FMTEST reside in the Fast Meter status byte. If any item within the Fast Meter message is in test mode, the relay sets the TEST bit. Similarly, if any item in any Fast Meter message is in test mode, the FMTEST is set in all three Fast Meter responses.

TEST FM DEM

Use the **TEST FM DEM** command to insert override values in Fast Meter demand metering.

NOTE: Not all SEL-400 series relays support demand metering. These relays will not support the **TEST FM DEM** command.

Table 14.134 TEST FM DEM Command

Command	Description	Access Level
TEST FM DEM *label value1*	Write new data value1 to the Fast Meter demand meter report at the item label *label*.	B, P, A, O, 2

TEST FM OFF

Use the **TEST FM OFF** command to remove override values. The relay returns the Fast Meter registers to the pretest values.

Table 14.135 TEST FM OFF Command

Command	Description	Access Level
TEST FM *label* OFF	Clear the override values for the Fast Meter item *label*.	B, P, A, O, 2
TEST FM OFF	Clear all override testing values from Fast Meter.	B, P, A, O, 2

When you have successfully removed a Fast Meter test value (for example, **TEST FM IA1 OFF**), the relay responds, `Override Removed`. When an attempt to remove an FM test value fails, the relay responds, `Override Not Found`. When removing all FM test values (for example, **TEST FM OFF**), the relay responds, `All Overrides Removed`.

TEST FM PEAK

Use the **TEST FM PEAK** command to insert override values in Fast Meter peak demand metering.

NOTE: Not all SEL-400 series relays support demand metering. These relays will not support the **TEST FM PEAK** command.

Table 14.136 TEST FM PEAK Command

Command	Description	Access Level
TEST FM PEAK *label value1*	Write new data *value1* to the Fast Meter peak demand meter report at the item label *label*.	B, P, A, O, 2

TIME

Use the **TIME** command to view and set the relay time clock. The ASCII interface is just one source by which you can set the internal clock. Other sources can override the ASCII **TIME** command; overriding occurs in HIRIG time mode, IRIG time mode, and when using DNP3. See *Section 11: Time and Date Management* for more information on configuring time functions.

TIME

The **TIME** command returns information about the internal relay clock. You can also set the clock to local time if you specify hours and minutes (seconds data are optional). Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

```
=>>TIME <Enter>
local: 16:48:33     UTC: 23:48:33     UTC Offset: -07.0 hrs
```

If a valid IRIG-B or SNTP signal is connected to the relay, the **TIM** command cannot be used to set the relay time.

Table 14.137 TIME Command

Command	Description	Access Level
TIME	Display the present relay internal clock time, in three formats: local, UTC, and UTC offset.	1, B, P, A, O, 2
TIME *hh:mm*	Set the relay internal clock to *hh:mm*.	1, B, P, A, O, 2
TIME *hh:mm:ss*	Set the relay internal clock to *hh:mm:ss*.	1, B, P, A, O, 2

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the relay internal clock time. The value *hh* is for hours from 0–23, the value *mm* is for minutes from 0–59, and the value *ss* is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the relay responds, `Invalid Time`.

TIME Q

The **TIME Q** command returns detailed information on the relay internal clock. Use this command to query the status of high-accuracy time source inputs and the present clock time mode.

Table 14.138 TIME Q Command

Command	Description	Access Level
TIME Q	Display detailed information about the internal relay clock; query relay time.	1, B, P, A, O, 2

When you issue the **TIME Q** command, the relay reports statistics on the relay time sources. These statistics include the present time source and the last time value update source (see *TIME Q Command on page 11.8*).

```
=>TIME Q <Enter>

Station A                                  Date: 2016/02/24  Time: 23:04:16.336
Relay 1                                    Serial Number: 0000000000


Time Source: HIRIG
Last Update Source: HIRIG

IRIG Time Quality:   0.000 ms

Time Mark Period:   999.990539 ms

Internal Clock Period:  20.000006 ns
```

Figure 14.9 Sample TIME Q Command Response With IRIG

```
=>>TIME Q <Enter>

Relay 1                                    Date: 02/24/2016  Time: 15:08:41.468
Station A                                  Serial Number: 0000000000


Time Source: HPTP
Last Update Source: HPTP

Grandmaster Clock Quality
    Clock Class : Synchronized with PTP timescale (6)
    Time Traceable : TRUE
    Clock Accuracy : Within 25 ns
    Offset Log Variance : 0

Time Mark Period:  1000.000061 ms

Internal Clock Period:  19.999935 ns
```

Figure 14.10 Sample Time Q Command Response With PTP

TIME DST

In response to the **TIME DST** command, the relay displays local time, UTC time and UTC Offset, followed by daylight-savings time rules and information.

```
=>>TIME DST <Enter>
local: 11:28:19     UTC: 18:28:19     UTC Offset: -07.0 hrs


Daylight Savings Time Begin Rule: 2nd Sunday of March at 02:00
Daylight Savings Time End Rule: 1st Sunday of November at 02:00


Daylight Savings Time Presently Active

Next Daylight Savings Time Beginning: 03/11/2012 02:00
Next Daylight Savings Time Ending: 11/06/2011 02:00
=>>
```

Table 14.139 TIME DST Command

Command	Description	Access Level
TIME DST	Daylight-saving time rules and information	1, B, P, A, O

TRIGGER

The **TRIGGER** command initiates data captures for high-resolution oscillography and event reports. For information on high-resolution oscillography and event reports see *Triggering Data Captures and Event Reports on page 9.6*.

Use the **TRI** command to trigger the relay to record data for high-resolution oscillography and event reports.

Table 14.140 TRI Command

Command	Description	Access Level
TRI	Trigger relay data capture.	1, B, P, A, O, 2

When you issue the **TRI** command, the relay responds, `Triggered`. If the event did not trigger within 1 second, the relay responds, `Did not trigger`.

VECTOR

The **VECTOR** command displays information useful to the factory for troubleshooting purposes.

Use the **VEC** command to view the exception and diagnostics records in the relay.

Table 14.141 VEC Command

Command	Description	Access Level
VEC	Report relay internal diagnostics information.	2

VERSION

The **VERSION** command displays the relay hardware and software configuration.

Use the **VER** command to list the part numbers, serial numbers, checksums, software release numbers, and other important relay configuration information.

Table 14.142 VER Command

Command	Description	Access Level
VER	Display the hardware and software configurations.	1, B, P, A, O, 2

When you issue the **VER** command, the relay displays the latest release numbers for various items, typically including:

- FID
- CID
- Part number
- Serial number
- SELBOOT BFID
- Mainboard memory types and sizes
- Front-panel hardware
- Analog inputs ratings
- Interface board inputs and outputs
- Extended relay features list

A sample **VER** command response is shown in *Figure 14.11*.

```
=>VER <Enter>
FID=SEL-411L-R101-V0-Z013012-D20101111
CID=B66B
Part Number:  0411L5415XC0X4H343XX22
Serial Number:  2010123234
SELboot:
    BFID= SLBT-4XX-R205-V0-Z001002-D20100128
    Checksum:  A92C

Mainboard:
    Code FLASH Size:   12 MB
    Data FLASH Size:   52 MB
    RAM Size:          32 MB
    EEPROM Size:      128 kB

Front Panel: installed
Analog Inputs:
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y:  Voltage:   67 Volts
    Z:  Voltage:   67 Volts

Interface Boards:
    Board 1:  24 inputs   8 outputs
    Board 2:  not installed
E4 Configuration: 0

Extended Relay Features:
    IEC 61850

If the above information is not as expected, contact SEL for assistance.

=>
```

Figure 14.11 Sample VER Command Response

If an item is not installed, the **VER** report indicates `Not installed` at the appropriate line. If a detected hardware configuration does not match the component part number, the relay adds the statement `Warning - hardware does not match part number` on the corresponding line.

VIEW

Use the **VIEW** command to examine data within the relay database. You can view these data in three ways:

- ➤ Region
- ➤ Register item
- ➤ Bit

The **VIEW** command in the relay is very similar to the **VIEW** command in SEL Communications Processors. See *Section 10: Communications Interfaces* in the product-specific instruction manual for more information on the relay database regions and data types.

Typical relay regions are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS; view this list with the **MAP 1** command.

The relay is Virtual Device 1; all commands begin with VIEW 1. In all database views, if a data item is in test mode (controlled by **TEST DB** command), the relay displays an asterisk (*) mark following the data value.

VIEW 1 Commands—Region

Use the commands in *Table 14.143* to view the contents of the database regions.

Table 14.143 VIEW 1 Commands—Region

Command	Description	Access Level
VIEW 1 *region*	Display the data in the relay database in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region* BL	Display the data in the region *region* and include bit labels.	1, B, P, A, O, 2

VIEW 1 Commands—Register Item

Use the commands in *Table 14.144* to view register items in the relay database. Typical examples of register items in the METER region are IA1, I0_1, VB, and PF. Examples of register items in the LOCAL region are FID, SER_NUM, and PART_NUM.

Table 14.144 VIEW 1 Commands—Register Item

Command	Description	Access Level
VIEW 1 *addr*	Display the data in the relay database at register address *addr*.	1, B, P, A, O, 2
VIEW 1 *addr* NR *m*[a]	Display the data beginning at register address *addr* and continue for *m* registers.	1, B, P, A, O, 2
VIEW 1 *region item_label*	Display the data for the addresses in the *region item_label* area of the database.	1, B, P, A, O, 2
VIEW 1 *region item_label* NR *m*	Display the data for addresses in the *region item_label* area of the database; begin at the start of *item_label* and proceed for *m* registers.	1, B, P, A, O, 2
VIEW 1 *region offset*	Display the data for the address in the database region *region* at the offset *offset* from the beginning of the region.	1, B, P, A, O, 2
VIEW 1 *region offset* NR *m*	Display the data for the addresses in the database region *region*; begin at the offset *offset* from the beginning of the region and proceed for *m* registers.	1, B, P, A, O, 2

[a] Parameter *m* is an integer value representing the number of registers.

In the **VIEW 1 *addr*** commands, option *addr* is the register address. Use the **MAP 1 *region*** command to find the register address. You can specify register addresses as a decimal or hexadecimal number. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.) If you specify the data by address or by offset with the *addr* and *offset* options, the relay returns the data in hexadecimal number format. The **NR** option specifies the number of registers *m* that the relay includes in the data listing.

VIEW 1 Commands—Bit

Use commands in *Table 14.145* to inspect a specific bit in the relay database. The relay displays bit data as the bit label or number and the value logical 1 or logical 0. An example of a relay response for bit commands is `1:TARGET:ALTI = 0`, where `ALTI` is the bit label and `0` is the bit value.

Table 14.145 VIEW 1 Commands—Bit[a]

Command	Description	Access Level
VIEW 1 *addr bit*	Display the value at register address *addr* for the bit number *bit*.	1, B, P, A, O, 2
VIEW 1 *bit_label*	Display the value for the bit with the bit label *bit_label*.	1, B, P, A, O, 2
VIEW 1 *region bit_label*	Display the value for the particular bit with the bit label *bit_label* in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region offset bit*[b]	Display the value for the bit *bit* in the region *region* that is offset from the beginning of the region by offset *offset*.	1, B, P, A, O, 2

[a] Parameter *bit* is a number from 0–15, with 0 as the LSB (least significant bit).
[b] Parameter *offset* is a decimal or hexadecimal number to indicate the offset.

The command option *bit* is the bit number. If you access bit data, the relay displays the bit label or number and the value (logical 0 or logical 1). If you reference the data by label with the **BL** and *bit_label* options, the relay returns the data according to the data type.

Use the **VIEW 1 *bit_label*** command as a shorthand method to inspect a specific data bit in the relay database. The relay searches the entire relay database structure for the bit label you specified; this process takes more time and processing than narrowing the search by using the **VIEW 1 *region*** command and the **VIEW 1 *addr*** command with the bit label option *bit_label*.

SECTION 15

Communications Interfaces

This section provides information on communications interface options for SEL-400 series relays. The following topics are discussed:

- *Serial Communication on page 15.2*
- *Serial Port Hardware Protocol on page 15.5*
- *Ethernet Communications on page 15.6*
- *Virtual File Interface on page 15.18*
- *Software Protocol Selections on page 15.22*
- *SEL Protocol on page 15.23*
- *SEL MIRRORED BITS Communication on page 15.31*
- *SEL Distributed Port Switch Protocol (LMD) on page 15.37*
- *SEL-2600A RTD Module Operation on page 15.39*
- *Direct Networking Example on page 15.40*

The relay collects, stores, and calculates a variety of data. These include electrical power system measurements, calculated quantities, diagnostic data, equipment monitoring data, fault oscillography, and sequential event reports. You must enter settings to configure the relay to protect and monitor your power system properly. A communications interface is the physical connection on the relay that you can use to collect data from the relay, set the relay, and perform relay test and diagnostic functions.

The relay has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA-232 standard (often called RS-232). Several optional SEL devices are available to provide alternative physical interfaces, including EIA-485 and fiber-optic cable. The relay also has a Ethernet card slot for the optional Ethernet card.

Once you have established a physical connection, you must use a communications protocol to interact with the relay. A communications protocol is a language that you can use to perform relay operations and collect data. For information on protocols that you can use with the relay, see the instruction manual sections listed in *Table 15.1*.

Table 15.1 Relay Communications Protocols (Sheet 1 of 2)

Communications Protocol	Communications Interface	For More Information See
ASCII Commands	EIA-232[a] or Telnet using Ethernet	*Section 14: ASCII Command Reference*
Distributed Port Switch (LMD)	SEL-2885 EIA-232 to EIA-485 transceiver on an EIA-232 port	*SEL Distributed Port Switch Protocol (LMD) on page 15.37*
DNP3	EIA-232[a] or Ethernet	*Section 16: DNP3 Communication*
FTP	Ethernet	*FTP on page 15.12*
HTTP	Ethernet	*HTTP (Hypertext Transfer Protocol) Server on page 15.17*

Table 15.1 Relay Communications Protocols (Sheet 2 of 2)

Communications Protocol	Communications Interface	For More Information See
IEC 61850	Ethernet	*Section 17: IEC 61850 Communication*
MIRRORED BITS Communications	EIA-232[a]	*SEL MIRRORED BITS Communication on page 15.31*
Phasor Measurement Protocols (C37.118 and SEL Fast Message)	EIA-232[a] Ethernet[b]	*Section 18: Synchrophasors*
PTP	Ethernet	*Precision Time Protocol (PTP) on page 15.15*
SEL Binary Protocols (Fast Meter, Fast Operate, Fast SER)	EIA-232[a] or Telnet using Ethernet	*SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*
SEL Fast Message RTD Protocol	EIA-232[a]	*SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*
SNTP	Ethernet	*Simple Network Time Protocol (SNTP) on page 15.13*
Telnet	Ethernet	*Telnet on page 15.13*

[a] You can add converters to transform EIA-232 to other physical interfaces.
[b] Phasor Measurement over the Ethernet card is only C37.118 protocol.

Serial Communication

Each relay has four serial ports that you can use for serial communication with other devices. While these ports are all EIA-232, you can add transceivers or converters to operate on different physical media including EIA-485 and fiber-optic cable.

EIA-232 Interfaces

The relay has four EIA-232 communications interfaces. The serial port locations for the 4U chassis are shown in *Figure 15.1*, *Figure 15.2*, and *Figure 15.3*; other chassis sizes are similar. The port on the front panel is PORT F and the three rear-panel ports are PORT 1, PORT 2, and PORT 3.

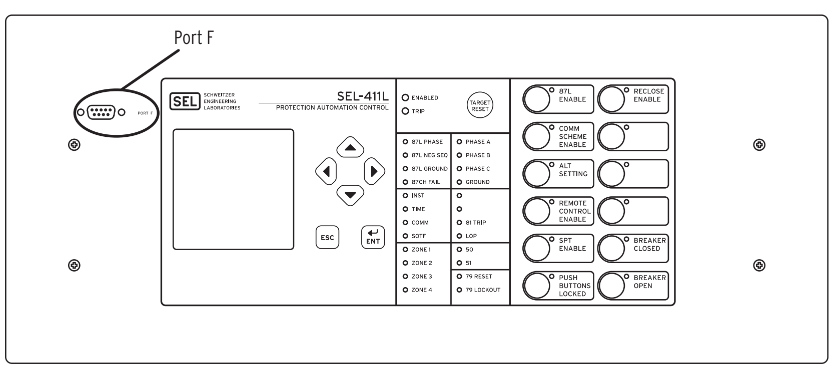

Figure 15.1 Relay 4U Chassis Front-Panel Layout

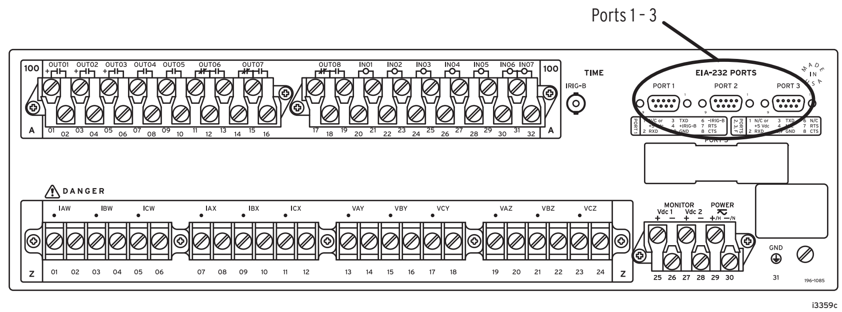

Figure 15.2 Example 3U Rear-Panel Layout

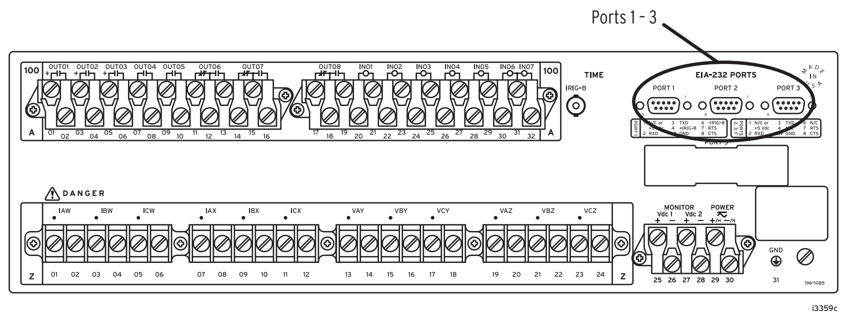

Figure 15.3 Example 4U Rear-Panel Layout in Relay With Bay Cards

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 15.4*. The pin functions are listed in *Table 15.2*. Pin 1 can provide power to an external device.

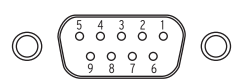

Figure 15.4 EIA-232 Connector Pin Numbers

NOTE: Pins 5 and 9 are not intended to provide a chassis ground connection.

Table 15.2 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem power	Jumper selectable on PORT 1–PORT 3. No connection on PORT F.
2	RXD	Receive data	
3	TXD	Transmit data	
4	+IRIG-B	Time code signal positive	PORT 1 only. No connection on PORT F, PORT 2, and PORT 3.
5	GND	Signal ground	Also connected to chassis ground.
6	–IRIG-B	Time code signal negative	PORT 1 only. No connection on PORT F, PORT 2, and PORT 3.
7	RTS	Request to send	
8	CTS	Clear to send (input)	
8	TX/RX CLK (for SPEED := SYNC, only available when PROTO := MBA or MBB)	Transmit and receive clock (input)	Rear-panel serial ports only
9	GND	Chassis ground	

The +5 V serial port supply that is common to all three rear serial ports is monitored by the relay. If the +5 V supply is overloaded, the relay issues an HALARM warning (pulses HALARM bit for 5 seconds) and displays a port overload message in the relay status report. The serial port keeps working, regardless of this condition.

EIA-232 Communications Cables

For most installations, you can obtain information on the proper EIA-232 cable configuration from the SEL-5801 Cable Selector Program. Using the SEL-5801 software, you can choose a cable by application. The software provides the SEL cable number with wiring and construction information, so you can order the appropriate cable from SEL or construct one. If you do not see information for your application, please contact SEL and we will assist you. You can obtain a copy of the SEL-5801 software by contacting SEL or from selinc.com.

Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

You can connect to a standard 9-pin computer port with an SEL-C234A cable for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet SEL-5030 software.

Fiber-Optic Interface

You can add transceivers to the EIA-232 ports to use fiber-optic cables to connect devices. We strongly recommend that you use fiber-optic cables to connect devices within a substation. Power equipment and control circuit switching can cause substantial interference with communications circuits. You can also experience significant ground potential differences during fault conditions that can interfere with communications and damage equipment. Fiber-optic cables provide electrical isolation that increases safety and equipment protection.

Use the SEL-2800 product family transceivers for multimode or single-mode fiber-optic communications. All of these transceivers are port powered, require no settings, and operate automatically over a broad range of data rates. SEL-2800 series transceivers operate over the same wide temperature ranges as SEL relays, providing reliable operations in extreme conditions.

EIA-485

There is no EIA-485 port integral to the relay. You can install an SEL-2885 or SEL-2886 transceiver to convert one of the rear-panel EIA-232 ports (**PORT 1**–**PORT 3**) on the relay to an EIA-485 port. The SEL-2885 and SEL-2886 are powered by the +5 Vdc output on Pin 1. These transceivers offer transformer isolation not found on most EIA-232-to-EIA-485 transceivers. See the transceiver product fliers for more information.

The SEL-2885 offers the SEL Distributed Port Switch Protocol (LMD). With this protocol you can selectively communicate with multiple devices on an EIA-485 network. You can communicate with other network nodes including EIA-232 devices with an SEL-2885 and SEL devices having integral EIA-485 ports. You can find more information about using SEL LMD in *SEL Distributed Port Switch Protocol (LMD) on page 15.37*.

Serial Port Hardware Protocol

The serial ports comply with the EIA-232 Standard (formerly known as RS-232). The serial ports support RTS/CTS hardware flow control. See also *Software Flow Control on page 15.27*.

Hardware Flow Control

Hardware handshaking is one form of flow control that two serial devices use to prevent input buffer information overflow and loss of characters. To support hardware handshaking, connect the RTS output pin of each device to the CTS input pin of the other device. To enable hardware handshaking, use the **SET P** command (or front-panel SET pushbutton sequence) to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N. *Table 15.3* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 15.3 Hardware Handshaking

Setting RTSCTS Value	Condition	Relay Action
N	All	Assert RTS output pin and ignore CTS input pin.
Y	Normal input reception	Assert RTS output pin.
Y	Local input buffer is close to full	Deassert RTS pin to signal remote device to stop transmitting.
Y	Normal transmission	Sense CTS input is asserted, transmit normally.
Y	Remote device buffer is close to full, so remote device deasserts RTS	Sense CTS input is deasserted, stop transmitting.

Note that the relay must assert the RTS pin to provide power for some modems, fiber-optic transceivers, and hardware protocol converters that are port powered. Check the documentation for any port-powered device to determine if the device supports hardware handshaking or if you must always assert RTS (RTSCTS := N) for proper operation.

Data Frame

The relay ports use asynchronous data frames to represent each character of data. Four port settings influence the framing: SPEED, DATABIT, PARITY, and STOPBIT. The time allocated for one bit is the reciprocal of the SPEED. For example, at 9600 bits per second, one bit-time is 0.104 milliseconds (ms).

The default port framing uses one start bit, eight data bits, no parity bit, and one stop bit. The transmitter asserts the TXD line for one data frame, as described in the following steps:

The TXD pin is normally in a deasserted state.

- To send a character, the transmitter first asserts the TXD pin for one bit time (start bit).
- For each data bit, if the bit is set, the transmitter asserts TXD for one bit time. If the bit is not set, it deasserts the pin for one bit time (data bits).

- If the PARITY setting is E, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an even number. If the PARITY setting is O, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an odd number. If the PARITY setting is N, the data frame does not include a parity bit.
- At the completion of the data bits and parity bit (if any), the transmitter deasserts the line for one bit time (stop bit). If STOPBIT is set to 2, the transmitter deasserts the line for one more bit time (stop bit).
- Until the relay transmits another character, the TXD pin will remain in the unasserted state.

Ethernet Communications

Ethernet Card

SEL-400 series relays support an optional Ethernet Card. In some SEL-400 series devices, this is a daughter card to the mainboard. In others, it goes into Bay 3. You can either field install the optional communications card or order the relay with the card installed at the factory. As with other SEL products, SEL has designed and tested SEL Ethernet cards for operation in harsh environments.

The optional Ethernet card provides Ethernet communications for the relay. The Ethernet card is available with standard twisted-pair and fiber-optic physical interfaces. The Ethernet card includes redundant physical interfaces with the capability to automatically transfer communications to the backup interface in the event that the primary network fails. For information on substation integration architectures, see *Section 16: DNP3 Communication* and *Section 17: IEC 61850 Communication*.

Once installed in a relay, the settings needed for network operation and data exchange protocols, including DNP3 and IEC 61850, are available in the **PORT 5** settings.

Ethernet Network Operation

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. SEL recommends that you work with a networking professional to design your substation Ethernet network.

Several settings control how the relay with the optional Ethernet card operates on an Ethernet network. These settings include IP addressing information, network port failover options, and network speed.

NOTE: Only some SEL-400 series relays are available with four Ethernet ports.

Use the network configuration settings shown in *Table 15.4* to configure the relay for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation. The relay is equipped with either two or four Ethernet ports: A, B, C, and D. Ports A and B support PTP protocol, ports C and D do not. If the relay has two ports without the PTP option, they will support standard Ethernet, DNP3, and optional IEC 61850 communications. If the relay has four ports, the additional two ports can be used for relay-specific functions.

Table 15.4 Ethernet Card Network Configuration Settings

Label	Description	Range	Default
EPORT	Enable Ethernet port communication	Y, N	N
IPADDR	IP network address/CIDR network prefix	IP address *w.x.y.z/t* where: *w* = 0–126, 128–223 *x* = 0–255 *y* = 0–255 *z* = 0–255 *t* = 1–30	192.168.1.2/24
DEFRTR	Default router	*w* = 0–126, 128–223 *x* = 0–255 *y* = 0–255 *z* = 0–255	192.168.1.1
ETCPKA	Enable TCP keep-alive functionality in all TCP communication supported by the relay	Y, N	Y
KAIDLE	Length of time to wait with no detected activity before sending a keep alive packet	1–20 s	10
KAINTV	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet	1–20 s (must be less than or equal to KAIDLE)	1
KACNT	Maximum number of keep-alive packets to send	1–20	6
NETMODE	Network operating mode	FIXED, FAILOVER, SWITCHED, PRP, ISOLATEIP	FAILOVER
NETPORT	Primary network port	A, B, C, D	C
FTIME	Failover time out	0–65535 ms	1
NETASPD	Network speed or autodetect on Port A	AUTO, 10 Mbps, 100 Mbps	AUTO
NETBSPD	Network speed or autodetect on Port B	AUTO, 10 Mbps, 100 Mbps	AUTO
NETCSPD	Network speed or autodetect on Port C	AUTO, 10 Mbps, 100 Mbps	AUTO
NETDSPD	Network speed or autodetect on Port D	AUTO, 10 Mbps, 100 Mbps	AUTO

The relay IPADDR setting uses Classless Inter-Domain Routing (CIDR) notation and a variable-length subnet mask (VLSM) to define its local network and host address.

An IP address consists of two parts: a prefix that identifies the network followed by a host address within that network. Early network devices used a subnet mask to define the network prefix of an associated host address. Within the mask, subnet boundaries were defined by the 8-bit segments of the 32-bit IP address. These boundaries constrained network prefixes to 8, 16, or 24 bits, defining Class A, B, and C networks, respectively.

This classful networking often created subnetworks that were not sized efficiently for actual requirements. CIDR allows more effective usage of a given range of IP addresses. In CIDR notation, you enter the IPADDR setting in the form a.b.c.d/p, where a.b.c.d is the host address in standard dotted decimal form and p is the network prefix expressed as the number of “1” bits in the mask. For example, if IPADDR := 192.168.1.2/24, the host address is 192.168.1.2 and the network prefix is the first 24 bits of the address, or 192.168.1. The network address is derived by applying the network prefix to IPADDR and filling the remaining bits with zeros (in our example, it is 192.168.1.0). The broadcast address is derived similarly, but the remaining bits are filled with ones (192.168.1.255 for the example above). Neither the network (base) address nor the broadcast address can be used for any host or router addresses on the network.

Table 15.5 CIDR Notation

CIDR Value	Subnet Mask
/32	255.255.255.255
/31	255.255.255.254
/30	255.255.255.252
/29	255.255.255.248
/28	255.255.255.240
/27	255.255.255.224
/26	255.255.255.192
/25	255.255.255.128
/24	255.255.255.000
/23	255.255.254.000
/22	255.255.252.000
/21	255.255.248.000
/20	255.255.240.000
/19	255.255.224.000
/18	255.255.192.000
/17	255.255.128.000
/16	255.255.000.000
/15	255.254.000.000
/14	255.252.000.000
/13	255.248.000.000
/12	255.240.000.000
/11	255.224.000.000
/10	255.192.000.000
/9	255.128.000.000
/8	255.000.000.000
/7	254.000.000.000
/6	252.000.000.000
/5	248.000.000.000
/4	240.000.000.000
/3	224.000.000.000
/2	192.000.000.000
/1	128.000.000.000
/0	000.000.000.000

The relay uses the DEFRTR address setting to determine how to communicate with nodes on other local networks. The relay communicates with the default router to send data to nodes on other local networks. The default router must be on the same local network as the relay or the relay will reject the DEFRTR setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table 15.6* for examples of how IPADDR and SUBNETM define the network and node and how these settings affect the DEFRTR setting.

If there is no router on the network, enter a null string (“”).

Table 15.6 DEFRTR Address Setting Examples

IPADDR (CIDR)	SUBNET Mask (Non-CIDR)	Network Address	Broadcast Address	DEFRTR Range[a]
192.168.1.2/28	255.255.255.240	192.168.1.0	192.168.1.15	192.168.1.0–192.168.1.15
192.168.1.2/24	255.255.255.0	192.168.1.0	192.168.1.255	192.168.1.a[b]
192.168.1.2/20	255.255.240.0	192.168.0.0	192.168.15.255	192.168.0.a[b]–192.168.15.a[b]
192.168.1.2/16	255.255.0.0	192.168.0.0	192.168.255.255	192.168.a[b].b[b]
192.168.1.2/12	255.240.0.0	192.160.0.0	192.175.255.255	192.160.a[b].b[b]–192.175.a[b].b[b]
192.168.1.2/8	255.0.0.0	192.0.0.0	192.255.255.255	192.a[b].b[b].c[b]
192.168.1.2/4	240.0.0.0	192.0.0.0	207.255.255.255	192.a[b].b[b].c[b]–207.a[b].b[b].c[b]

[a] DEFRTR cannot be the same as IPADDR, Network Address, or Broadcast Address.
[b] Value in the range 0–255.

NOTE: The ETCPKA setting applies to all TCP traffic on Ethernet ports, including TELNET, FTP, DNP3, IEC 61850 MMS, and C37.118.

The ETCPKA setting, along with the KAIDLE, KAINTV, and KACNT settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If ETCPKA is enabled and the relay does not transmit any TCP data within the interval specified by the KAIDLE setting, the relay sends a keep-alive packet to the remote computer. If the relay does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is re-transmitted as many as KACNT times. After this count is reached, the relay considers the remote device no longer available, so the relay can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The relay monitors MMS inactivity to identify and disconnect MMS clients that have stopped communicating with it. You can set it from 0 to 42000000 seconds via the IED Properties MMS Settings in ACSELERATOR Architect SEL-5032 Software. The MMS Inactivity default value is either 120 seconds or 900 seconds, depending on the relay. Setting this value to 0 disables the MMS Inactivity timer. If enabled, the relay starts a timer for an MMS session after it receives an MMS request from the client on that session. It resets the timer whenever it receives a new MMS request from that client. When the timer runs out, the relay disconnects the MMS session, making it available for other MMS clients.

This feature was implemented in addition to the TCP keep-alive timer to specifically handle MMS clients that do not disconnect properly. As there are a limited number of MMS sessions available, this ensures that misbehaving MMS clients do not take up multiple MMS sessions. Note that the MMS inactivity time-out can still disconnect an MMS session even if the relay receives TCP keep-alive messages from that MMS client.

The relay Ethernet card operates over either twisted-pair or fiber-optic media. Each Ethernet card is equipped with two or four network ports. With an initial ordering option, you can select the medium for each port (10/100 Mbps twisted-pair or 100 Mbps fiber-optic). Speeds for the physical media are fixed for fiber-optic connections. For twisted-pair connections, the Ethernet card can autodetect the network speed or you can set a fixed speed.

Using Redundant Ethernet Ports

Relays may have as many as four Ethernet ports, which work together in pairs: A and B, C and D. One pair of ports are for TDP/I/P or UDP/IP Ethernet communications, including FTP, TELNET, DNP3 LAN/WAN, etc., and IEC 61850 GOOSE. You can configure these ports for redundant network architectures, or force the relay to use a single Ethernet port for these protocols. If the relay has four ports, the second pair of ports can be used for relay specific functionality. PTP is only available on ports A and B.

Redundant Ethernet Network Using FAILOVER Mode

Make the following settings in Port 5 to configure the relay for FAILOVER mode.

- NETMODE := FAILOVER
- FTIME := desired time-out for the active port before failover to the backup port
- NETPORT := the preferred primary network interface (C for Port 5C, D for Port 5D)

Use the internal failover switch to connect the relay to redundant networks as shown in *Figure 15.5*.

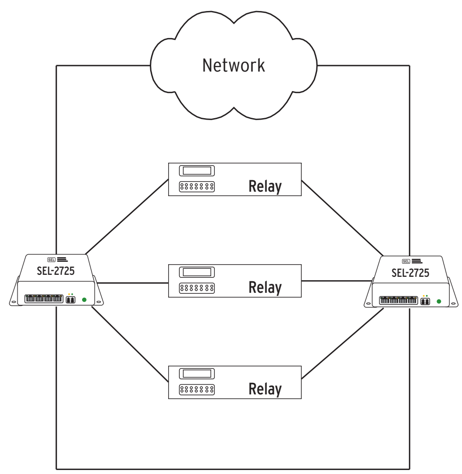

Figure 15.5 Failover Network Topology

On startup, the relay communicates using the primary network interface selected by the NETPORT setting. If the relay detects a link failure on the primary interface, it asserts the LNKFAIL Relay Word bit. If the link status on the standby interface is healthy, the relay activates the standby network interface after time FTIME. If the link status on the primary interface returns to normal before time FTIME, the failover timer resets and operation continues on the primary network interface.

After failover, while communicating via the standby interface, if the relay detects a link failure on the standby interface and the link status on the primary interface is healthy, the relay activates the primary network interface after time FTIME. The choice of active port is reevaluated after settings change, and after relay restart.

In either case, if the relay detects a link failure on the interface on which it is currently communicating, it asserts the LNKFAIL Relay Word bit. In relays that support process bus functionality, FAILOVER is the only supported mode. If the relay detects a failure on its current process bus interface, it will assert the LNK-

FL2 Relay Word bit. Note that for very small values of FTIME, or for a failover event on the process bus, the assertion or deassertion of LNKFAIL and LNKFL2 can be too short for a state change to register in the SER.

Network Connection Using Isolated IP Connection Mode

The Isolated IP mode (NETMODE = ISOLATEIP) permits IEC 61850 GOOSE messages on two ports, but restricts IP traffic to just one port. This mode is useful for cases where it is desired to connect one port to a secured network (the IP port) but have the other port leave the security perimeter.

NOTE: If NETMODE = ISOLATEIP, Precision Time Protocol (PTP) is only supported on the port designated as the IP port.

The NETPORT setting selects which port will be the IP port. The other port will only support GOOSE traffic. IP transmissions will only go out the IP port. IP receptions will only be processed from the IP port. GOOSE publications will go out both ports. GOOSE subscriptions will be accepted from either port. Any non-GOOSE traffic received on the non-IP port will be ignored. No traffic will go from one external port to the other.

Redundant Ethernet Network Using SWITCHED Mode

Make **Port 5** setting NETMODE = SWITCHED to activate the internal Ethernet switch. The internal switch connects a single Ethernet stack inside the relay to two external Ethernet ports. The combination of relay and internal switch operate the same as if a single Ethernet port on a relay were connected to an external unmanaged Ethernet switch. Use the internal switch to add devices to a network, as shown in *Figure 15.6*.

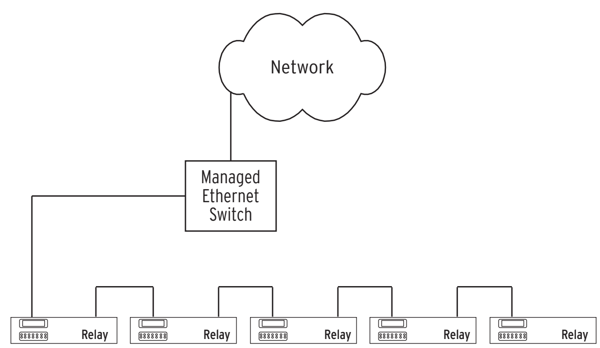

Figure 15.6 Using Internal Ethernet Switch to Add Networked Devices

Using this topology, the internal network switch of the relay supports connecting Ethernet devices in series. This configuration is only recommended for temporary use.

When using this switched mode, take care not to connect the last device back to the Managed Ethernet Switch, thereby creating a loop or ring.

In switched mode, the internal Ethernet switch of the relay is an unmanaged Ethernet switch and does not provide RSTP functionality. You will experience very large RSTP healing times in such a network.

Network Connection Using Fixed Connection Mode

Force the relay to use a single Ethernet port even when it is equipped with two or more Ethernet ports by making setting NETMODE := FIXED. When NETMODE := FIXED, only the interface selected by NETPORT is active. The other interfaces are disabled.

Network Connection Using PRP Connection Mode

Parallel Redundancy Protocol (PRP) is part of an IEC standard for high availability automation networks (IEC 62439-3). The purpose of the protocol is to provide seamless recovery from any single Ethernet network failure.

The basic concept is that the Ethernet network and all traffic are fully duplicated with the two copies operating in parallel.

NOTE: PTP cannot be used in combination with PRP.

Make the following settings in Port 5 to configure the relay for PRP mode.

- NETMODE := PRP
- PRPTOUT := desired time-out for PRP frame entry
- PRPADDR := PRP destination MAC address LSB 01-15-4E-00-01-XX
- PRPINTV := desired supervision frame transmit interval

When NETMODE is not set to PRP, the PRP settings are hidden.

When PRP is enabled, SEL recommends reducing the maximum number of incoming GOOSE subscriptions to 64. Incoming GOOSE buffers are sized to accommodate a maximum of 128 GOOSE messages. The number of messages doubles when PRP is enabled.

Ethernet Protocols

NOTE: The relay prioritizes processing IEC 61850 GOOSE data over the data access protocols listed above. With GOOSE enabled, high GOOSE traffic to and from the relay sustained over long periods may cause slowed responsiveness to data transfer requests via TCP/IP protocols.

Access data using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the (Web) HTTP Server, DNP3 LAN/WAN or IEC 61850 interface. You cannot access all data through all interfaces. See the appropriate interface section below for details on data access.

FTP

FTP is a standard application-level protocol for exchanging files between computers over a TCP/IP network. The relay Ethernet card operates as an FTP server, presenting files to FTP clients. The relay Ethernet card supports one FTP connection at a time. Subsequent requests to establish FTP sessions will be denied. If your FTP client does not work properly, be sure to set your client to use a single session.

Table 15.7 lists the settings that affect FTP server operation.

NOTE: SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP user name "anonymous". If you enable anonymous FTP logins, you are allowing unrestricted access to the relay and host files.

Table 15.7 FTP Settings

Label	Description	Range	Default
FTPSERV[a]	FTP session enable	Y, N	N
FTPCBAN	FTP connect banner	254 characters	FTP SERVER:
FTPIDLE[a]	FTP connection time-out	5–255 minutes	5
FTPANMS[a]	Anonymous login enable	Y, N	N
FTPAUSR	User level from which anonymous FTP client inherits access rights	0, 1, B, P, A, O, 2	0

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

File Structure

The basic file structure is organized as a directory and subdirectory tree similar to that used by Unix, DOS, Windows, and other common operating systems. See *Virtual File Interface on page 15.18* for information on the basic file structure.

Access Control

The standard FTP logins consist of the three-character access level command (e.g., ACC, BAC) with their respective passwords. For example, with default passwords, if you use the user name of 2AC and password of TAIL, you will connect with Access Level 2 privileges.

FTP settings control anonymous file access features. The special FTP user name "anonymous" does not require a password. It has the access rights of the access level selected by the FTPAUSR setting. For example, if FTPAUSR is set to 1 (for Access Level 1), the FTP anonymous user has Access Level 1 rights.

SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP user name "anonymous". If you enable anonymous FTP logins, you are allowing unrestricted access to the relay and host files.

Telnet

Telnet is part of the TCP/IP protocol suite. A Telnet connection provides access to the relay user interface. When you connect with Telnet and log into the relay, you can use all of the ASCII and Compressed ASCII commands described in *Section 14: ASCII Command Reference* to configure and interact with the relay. You can also use the SEL binary Fast Meter and Fast Operate commands described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.

Use a Telnet client or QuickSet on the host PC to communicate with the relay. To terminate a Telnet session, use the **EXI** command from any access level.

Telnet settings available when ETELNET := Y are listed in *Table 15.8*.

Table 15.8 Telnet Settings

Label	Description	Range	Default
TCBAN	Telnet connect banner	254 characters	TERMINAL SERVER:
TPORT	Telnet TCP/IP port	23, 1025–65534	23
TIDLE	Telnet Port connection time-out	1–30 minutes	15

Simple Network Time Protocol (SNTP)

When SNTP is enabled (Port 5 setting ESNTP is not OFF), the relay internal clock conditionally synchronizes to the time of day served by a Network Time Protocol (NTP) server. The relay uses a simplified version of NTP called the Simple Network Time Protocol (SNTP). SNTP is not as accurate as IRIG-B or PTP. The relay can use SNTP as a less accurate primary time source, or as a backup to the higher accuracy IRIG-B or PTP time sources.

If an IRIG-B time source is connected and either Relay Word bits TSOK or TIRIG assert, then the relay synchronizes the internal time-of-day clock to the incoming IRIG-B time code signal, even if SNTP is configured in the relay and an NTP server is available. If the IRIG-B source is disconnected (TIRIG deassert) then the relay synchronizes the internal time-of-day clock to the NTP server if available. In this way an NTP server acts as either the primary time source, or as a backup time source to the more accurate IRIG-B time source. The above is also true if the relay is connected to an accurate PTP time source, but TPTP (not TIRIG) will deassert when the PTP time source is disconnected.

Three SEL application notes available from the SEL web site describe how to create an NTP server.

- AN2009-10: Using an SEL-2401, SEL-2404, or SEL-2407 to Serve NTP Via the SEL-3530 RTAC
- AN2009-38: Using SEL Satellite-Synchronized Clocks With the SEL-3332 or SEL-3354 to Output NTP
- AN2010-03: Using an SEL-2401, SEL-2404, or SEL-2407 to Create a Stratum 1 Linux NTP Server

Configuring SNTP Client in the Relay

To enable SNTP in the relay make Port 5 setting ESNTP = UNICAST, MANYCAST, or BROADCAST. *Table 15.9* shows each setting associated with SNTP.

Table 15.9 Settings Associated With SNTP

Setting	Prompt	Range	Default	Description
ESNTP	SNTP Enable (OFF, UNICAST, MANYCAST, BROADCAST)	UNICAST, MANYCAST, BROADCAST	OFF	Selects the mode of operation of SNTP. See descriptions in *SNTP Operation Modes on page 15.14*.
SNTPRAT[a]	SNTP Request Update Rate (15–3600 s)	15–3600 s	60	Determines the rate at which the relay asks for updated time from the NTP server when ESNTP = UNICAST or MANYCAST. Determines the time the relay will wait for an NTP broadcast when ENSTP = BROADCAST.
SNTPTO	SNTP Timeout (5–20 s)	5–20 s	5	Determines the time the relay will wait for the NTP master to respond when ENSTP = UNICAST or MANYCAST.
SNTPPIP	SNTP Primary Server IP Address (w.x.y.z)[b]	Valid IP Address	192.168.1.110	Selects primary NTP server when ENSTP = UNICAST, or broadcast address when ESNTP = MANYCAST or BROADCAST.
SNTPBIP	SNTP Backup Server IP Address (w.x.y.z)[c]	Valid IP Address	192.168.1.111	Selects backup NTP server when ESNTP = UNICAST.
SNTPPOR[d]	SNTP IP Local Port Number (1–65534)	1–65534	123	Ethernet port used by SNTP. Leave at default value unless otherwise required.

[a] This setting is hidden if ESNTP = OFF and hidden and forced to 5 if ESNTP = BROADCAST.
[b] Where w: 0–126, 128–239, x: 0–255, y: 0–255, z: 0–255.
[c] Where w: 0–126, 128–223, x: 0–255, y: 0–255, z: 0–255.
[d] This setting is hidden if ESNTP ≠ UNICAST.

SNTP Operation Modes

The following sections explain the setting associated with each SNTP operation mode (UNICAST, MANYCAST, and BROADCAST).

ESNTP = UNICAST

In unicast mode of operation the SNTP client in the relay requests time updates from the primary (IP address setting SNTPPIP) or backup (IP address setting SNTPBIP) NTP server at a rate defined by setting SNTPRAT. If the NTP server does not respond with the period defined by the sum of setting SNTPTO and SNTPRAT then the relay tries the other SNTP server. When the relay successfully synchronizes to the primary NTP time server, Relay Word bit TSNTPP asserts. When the relay successfully synchronizes to the backup NTP time server, Relay Word bit TSNTPB asserts.

ESNTP = MANYCAST

In manycast mode of operation the relay initially sends an NTP request to the broadcast address contained in setting SNTPPIP. The relay continues to broadcast requests at a rate defined by setting SNTPRAT. When a server replies, the relay considers that server to be the primary NTP server, and switches to UNICAST mode, asserts Relay Word bit TSNTPP, and thereafter requests updates from the primary server. If the NTP server stops responding for time SNTPTO, the relay deasserts TSNTPP and begins to request time from the broadcast address again until a server responds.

ESNTP = BROADCAST

Setting SNTPPIP = 0.0.0.0 while ESNTP = BROADCAST, the relay will listen for and synchronize to any broadcasting NTP server. If setting SNTPPIP is set to a specific IP address while setting ESNTP = BROADCAST, then the relay will listen for and synchronize to only NTP server broadcasts from that address. When synchronized the relay asserts Relay Word bit TSNTPP. Relay Word bit TNSTPP deasserts if the relay does not receive a valid broadcast within the SNTPT0 setting value after the period defined by setting SNTPRAT.

SNTP Accuracy Considerations

SNTP time synchronization accuracy is limited by the accuracy of the SNTP Server and by the networking environment. The highest degree of SNTP time synchronization can be achieved by minimizing the number of switches and routers between the SNTP Server and the relay.

When installed on a network with low burden configured with one Ethernet switch between the relay and the SNTP Server, and when using ESNTP = UNICAST or MANYCAST, the relay time synchronization error to the SNTP server is typically less than ±1 millisecond.

Precision Time Protocol (PTP)

If the optional Ethernet card is installed and it includes ports A and B, then the relay supports Precision Time Protocol version 2 (PTPv2) as a slave-only clock as defined by IEEE-1588-2008 on ports A and B. PTP provides high accuracy timing over an Ethernet network, eliminating the need for a separate IRIG-B cable and connection. To achieve the best accuracy (<1 µs), it is necessary to have one or more PTP master clocks and that all intervening equipment (e.g., Ethernet switches) need to be 1588-aware (i.e. all intervening network devices need to be transparent or boundary clocks).

NOTE: The SEL-2488 with the PTP option is a PTP grandmaster clock capable GPS receiver.

In PTP, a clock that provides time to other devices, typically based on GPS input, is a master clock. The intervening switches are transparent clocks. It is also possible to connect networks together and pass time from one network to another using boundary clocks. Transparent and boundary clocks are important because they provide time correction in the PTP messages that pass through them, whereas devices that are not 1588 aware would not provide this correction. Because it is possible for a network to have multiple master clocks, PTP clocks implement algorithms to select the best available clock. The one selected for use by an end device is the grandmaster clock. A complete description of possible PTP networking configurations is beyond the scope of this manual. You can learn more about configuring a PTP network in these application guides:

> "Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality in a Redundant Network Topology" (AN2015-07)

> "Using the SEL-2488 to Provide IEEE 1588 Version 2 Grandmaster Functionality to Isolated Ethernet Networks" (AN2015-06)

NOTE: PTP is not available when Parallel Redundancy Protocol (PRP) is enabled.

To configure PTP, update the Port 5 PTP settings as described in *Table 12.23*. By default, PTP is disabled in the relay. Set EPTP to Y to enable PTP and make the other PTP settings available.

Within PTP, there are multiple clock profiles available. A profile defines the set of PTP features available in a specific application domain. SEL-400 series relays support two profiles: Default and Power System profile (C37.238-2011).

The Default profile has many optional features. It was intended to address common applications, so has been implemented by most PTP capable devices. The Default profile supports both UDP or layer 2 (802.3) Ethernet transport, and can use either end-to-end (E2E) or peer-to-peer (P2P) Delay Mechanism. Grandmaster clocks can send Announce, Sync, and Delay request messages over a wide range of intervals. A Default profile network can consist of boundary clocks or transparent clocks anywhere between the grandmaster and the end devices. The only performance requirement for the Default profile is that a master clock must maintain frequency accurate to within 0.01%. A well designed Default profile network with an accurate grandmaster can come close to the 1 µs accuracy available to Power profile networks.

The Power profile was created to minimize the number of optional features to facilitate interoperability and predictable performance in order to provide the required time accuracy for Synchrophasors and for SCADA. The Power profile is only supported on layer 2 networks and exclusively uses the peer-to-peer Delay Mechanism. All messages must be sent at 1-second intervals, must have 802.1Q VLAN tags, and announce messages must include grandmaster ID and (maximum) inaccuracy fields. Transparent clocks are mandatory in a power profile network; boundary clocks are not allowed. For a network with less than 16 hops between Grandmaster and IED, the Power profile can deliver time with better accuracy than 1 µs. Select the profile using the PTPPRO setting.

PTP defines a logical grouping of clocks in a network as a clock domain. This allows a logical separation between clocks that participate in different application domains to coexist on the same network. Domains are identified by domain numbers. The domain number for the relay is selected by the DOMNUM setting. Set DOMNUM to match the domain number configured in the master clocks the relay should synchronize with.

The relay supports transport of PTP messages over UDP or layer 2 (Ethernet). Use the PTPTR setting to select the PTP transport mechanism. This needs to match the transport mechanism used in the master clocks. Only layer 2 is available with the Power System profile. If operating in a UDP network, PTP will operate on port 320. Except for peer delay messages, the relay sets the time allowed to live (TTL) value in the UDP/IP header of PTP messages to 64. This allows the possibility of synchronizing relay time through routers across a WAN to a PTP master. High-accuracy synchronization may not be achievable across the WAN, so it is left to the user to determine if the accuracy meets the needs of their application.

When using the Power System profile, use the VLAN number and priority settings PVLAN and PVLANPR to set the VLAN ID and priority, respectively, of the Ethernet frames. Be sure to set PVLAN unique from other VLANs used within the relay.

PTP defines two methods for calculating and correcting for the communications path delay between the relay and the master clock: end-to-end (Delay Request-Response) and peer-to-peer (Peer Delay Request-Response). The end-to-end mechanism calculates the total path delay between the relay and the master clock. The peer-to-peer mechanism calculates the total path delay in a piecemeal fashion between each device in the path. Peer-to-peer is the more accurate method and is recommended for use in SEL relays. The relay periodically initiates path delay calculations. Use the PTHDLY and PDINT settings to configure the path delay method and the path delay request rate. If PTHDLY is set to OFF, then the relay will not calculate and correct for path delay. Only the peer-to-peer mechanism is available for Power System profile.

By default, the relay will synchronize to any clock on the network that it evaluates to be the best clock based on the Best Master Clock Algorithm. Use the Acceptable Master Table settings to specify a list of master (grandmaster or boundary) clocks to which the relay may synchronize. The relay will not synchronize to any master clock that is not in the list. It is recommended to use this feature for additional security. The AMNUM setting selects the number of master clocks you will list in this table. The default value is OFF, which means the relay will synchronize to any master clock on the network. If AMNUM is set to a value other than OFF, that number of allowable masters must be identified in accordance with the PTP transport chosen, i.e., MAC address for 802.3 or IP address for UDP transport.

If the PTP transport (PTPTR) is set to UDP, use the AMIP*n* settings to specify the IP addresses of the clocks the relay is permitted to synchronize to. If PTP transport is set to layer 2, use the AMMAC*n* settings to specify the MAC addresses of the clocks the relay is permitted to synchronize to.

NOTE: The Acceptable Master Table feature may not work for transport over layer 2 if the intervening Ethernet switch(es) modify the source MAC address of Announce messages passing through them. With transport over layer 2, the relay uses the source MAC address to identify if an Announce message is coming from a master clock in the table.

If the ALTPRI*n* (alternate priority1 for master n) setting is set to a positive value, the priority1 value in received Announce messages from the corresponding master clock will be replaced by the ALTPRI*n* value before applying the Best Master Clock Algorithm. The ALTPRI*n* values reprioritize the master clocks locally. A discussion of reasons to apply alternate priorities is beyond the scope of this manual. If you are not familiar with the Best Master Clock Algorithm, leave the setting set to 0.

HTTP (Hypertext Transfer Protocol) Server

The relay provides an HTTP (Web) server to provide read-only access to selected settings, metering, and reports. The HTTP server is disabled by default. To enable the HTTP server, make the following settings using the **SET P 5** command.

Table 15.10 Web Server Settings

Label	Description	Range	Default
EHTTP	Enable or disable Web Server	Y, N	N
HTTPPOR	Web Server TCP/IP Port Number	1–65535	80
HIDLE	Web server inactivity time-out (minutes)	1–30	5

When enabled, the HTTP server opens TCP/IP Port 80 by default. Set HTTPPOR to configure any other port as needed.

Virtual File Interface

You can retrieve and send data as files through the virtual file interface of the relay. Devices with embedded computers can also use the virtual file interface. When using serial ports or virtual terminal links, use the FILE DIR command. When you use an Ethernet card, the FTP protocol supported by Ethernet presents the file structure and sends and receives files.

The relay has a two-level file structure. There are a few files at the root level and three or more subdirectories or folders. Some SEL-400 series relays support directories in addition to those listed here. *Table 15.11* shows the directories and the contents of each directory.

Table 15.11 Virtual File Structure

Directory	Usage	Access Level
Root	CFG.TXT file, CFG.XML[a] file, SWCFG.ZIP file and the following directories	1
SETTINGS	Relay Settings	1
REPORTS	SER, circuit breaker, protection and history reports	1
EVENTS	EVE, CEV, COMTRADE and history reports	1
SYNCHROPHASORS[b]	Synchrophasor recording files	1

[a] Present only if the optional Ethernet card is installed.
[b] Only present in SEL-400 series relays that support synchrophasors.

System Data Format

Settings files and the CFG.TXT file use the system data format (SDF) unless otherwise specified. The files may contain keywords to aid external support software parsing. A keyword is defined as a string surrounded by the open and close bracket characters, followed by a carriage return and line feed. Only one keyword is allowed per line in the file. For example, the keyword INFO would look like this in the file: [INFO]<CR><LF>.

Records are defined as comma-delimited text followed by a carriage return and line feed. One line in a text file equals one record. Fields are defined as comma-delimited text strings.

Comma-Delimited Text Rules

Field strings are separated by commas or spaces and may be enclosed in optional double quotation marks. Double quotes within the field string are repeated to distinguish these double quotes from the quotes that surround the field string.

Delimiters are spaces and commas that are not contained within double quotes. Two adjacent commas indicate an empty string, but spaces that appear next to another delimiter are ignored. Consider the following examples for converting a list of fields to comma-delimited text. Consider the following list of fields.

Stri,ng 1

Stri"ng 2

String 3

String4

The translation to comma-delimited text is as follows:

"Stri,ng 1","Stri""ng 2","String 3","String4"

Root Directory

The root directory contains three or more subdirectories and two or three files (CFG.TXT, CFG.XML, and SWCFG.ZIP). CFG.XML is only present if the optional Ethernet card is installed. SWCFG.ZIP is for internal use.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each setting class. External support software retrieves the CFG.TXT file to interact automatically with the connected relay.

CFG.XML File (Read-Only)

Present only in units with the optional Ethernet card installed, the CFG.XML file is supplementary to the CFG.TXT file. The CFG.XML file describes the IED configuration, any options such as the Ethernet port, and includes firmware identification, settings class names, and configuration file information.

SWCFG.ZIP File (Read/Write)

The SWCFG.ZIP file is a compressed file used to store external support software settings. It is readable at Access Level 1 and above, and writable at Access Level 2 and above.

Settings Directory

You can access the relay settings through files in the SETTINGS directory. We recommend that you use support software to access the settings files, rather than directly accessing them via other means. External settings support software reads settings from all of these files to perform its functions. The relay only allows you to write to the individual SET_*cn* files, where c is the settings class code and *n* is the settings instance. Except for the SET_61850 CID file, changing settings with external support software involves the following steps:

Step 1. The PC software reads the CFG.TXT and SET_ALL.TXT files from the relay.

Step 2. You modify the settings at the PC. For each settings class that you modify, the software sends a SET_*cn*.TXT file to the relay.

Step 3. The PC software reads the ERR.TXT file. If it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat *Step 2–Step 4* for each settings class that you want to modify.

Step 6. Test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains the settings for all of the settings classes in the relay.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 15.12* summarizes the typical settings files. The exact list of settings files depends on the specific settings classes available in each relay model. The settings class is designated by *c*, and the settings instance number is *n*.

BAY_SCREEN.TXT

NOTE: Not all SEL-400 series relays support bay mimic screens.

The BAY_SCREEN.TXT file describes the content of the custom bay mimic screen that can be selected for display on the HMI. This file is generated by QuickSet and may be downloaded to the relay when Bay Control settings are changed.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_cn.TXT or SET_61850.CID file written to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

SET_61850.CID

Present if ordered with the IEC 61850 protocol option, the SET_61850.CID file contains the IEC 61850 configured IED description in XML. This file is generated by Architect and downloaded to the relay. See *Section 17: IEC 61850 Communication* for more information on the SET_61850.CID file.

Table 15.12 Typical Settings Directory Files (Sheet 1 of 2)

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
A	SET_A*n*.TXT	Automation; *n* in range 1–10 For relay-0, *n* = 1	1, B, P, A, O, 2	A, 2
B	SET_B1.TXT	Bay Control	1, B, P, A, O, 2	P, A, O, 2
D	SET_D*n*.TXT	DNP3 remapping; *n* in range 1–5	1, B, P, A, O, 2	P, A, O, 2
F	SET_F1.TXT	Front panel	1, B, P, A, O, 2	P, A, O, 2
G	SET_G1.TXT	Global	1, B, P, A, O, 2	P, A, O, 2
L	SET_L*n*.TXT	Protection logic; *n* in range 1–6	1, B, P, A, O, 2	P, 2
M	SET_SM.TXT	Breaker monitor settings	1, B, P, A, O, 2	P, 2
N	SET_N1.TXT	Notes	1, B, P, A, O, 2	P, A, O, 2
O	SET_O1.TXT	Contact outputs	1, B, P, A, O, 2	O, 2
P	SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F	1, B, P, A, O, 2	P, A, O, 2
R	SET_R1.TXT	Report	1, B, P, A, O, 2	P, A, O, 2

Table 15.12 Typical Settings Directory Files (Sheet 2 of 2)

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
S	SET_S*n*.TXT	Group *n*; *n* in range 1–6	1, B, P, A, O, 2	P, 2
T	SET_T1.TXT	Alias settings	1, B, P, A, O, 2	P, A, O, 2
All	SET_ALL.TXT	All instances of all setting classes	1, B, P, A, O, 2	N/A
All	ERR.TXT	Error log for most recently written settings file	1, B, P, A, O, 2	N/A
NA	SET_61850.CID	IEC 61850 configured IED description file	1, B, P, A, O, 2	2
NA	BAY_SCREEN.TXT	Custom bay mimic screen content	1, B, P, A, O, 2	P, A, O, 2

Reports Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 15.13*. Note that the relay provides a report file that contains the latest information each time you request the file.

NOTE: Not all SEL-400 series relays support breaker monitoring and corresponding breaker files.

Table 15.13 REPORTS Directory Files

File	Usage: All Are Read-Only Files
SER.TXT	ASCII SER report, clears SER when read
CSER.TXT	Compressed ASCII SER report
BRE_*n*.TXT	BRE *n* H report, *n* is the breaker reference
BRE_S*n*	BRE S*n* report, *n* is the breaker reference
CBRE.TXT	Compressed ASCII CBR report
HISTORY.TXT	History file
CHISTORY.TXT	Compressed ASCII History file
PRO.TXT	ASCII Profiling report
CPRO.TXT	Compressed ASCII profiling report

Events Directory

NOTE: Most SEL-400 series relays provide large resolution event reports of 8 samples/cycle. The SEL-487B provides large resolution event reports of 12 samples/cycle.

The relay provides history, event reports, and oscillography files in the EVENTS directory. Event reports are available in the following formats: SEL ASCII 4- or 8-samples/cycle reports and Compressed ASCII 4- or 8-samples/cycle reports. The size of each event report file is determined by the LER setting in effect at the time the event is triggered. Higher resolution oscillography is available in binary COMTRADE (IEEE C37.111-1999) format at the sample rate (SRATE) and length (LER) settings in effect at the time the event is triggered.

The 4- and 8-samples/cycle report files (files with names that begin with E or C) are text files with the same format as the **EVENT** and **CEVENT** command responses. Event file names start with the prefix E4_, E8_, E12, C4_, C8_, C12, or HR_, followed by a unique event serial number. For example, if one event is triggered, with serial number of “10001”, the EVENTS directory contains the files shown in *Table 15.14*. Event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR) that conform to the COMTRADE standard.

Table 15.14 EVENTS Directory Files (for Event 10001) (Sheet 1 of 2)

File	Usage
HISTORY.TXT	History file; read-only
CHISTORY.TXT	Compressed ASCII history file; read-only

Table 15.14 EVENTS Directory Files (for Event 10001) (Sheet 2 of 2)

File	Usage
C4_10001.TXT	4-samples/cycle Compressed ASCII event report; read-only
C8_10001.TXT[a]	8-samples/cycle Compressed ASCII event report; read-only
E4_10001.TXT	4-samples/cycle event report; read-only
E8_10001.TXT[b]	8-samples/cycle event report; read-only
HR_10001.CFG	Sample/second COMTRADE configuration file; read-only
HR_10001.DAT	Sample/second COMTRADE binary data file; read-only
HR_10001.HDR	Sample/second COMTRADE header file; read-only

[a] In the SEL-487B, this is replaced with C1210001.TXT which provides a 12-samples/cycle Compressed ASCII event report.

[b] In the SEL-487B, this is replaced with E1210001.TXT which provides a 12-samples/cycle event report.

Synchrophasors Directory

Table 15.15 shows an example SYNCHROPHASORS directory. Synchrophasor data recording is enabled when synchrophasors are enabled and EPMDR := Y. The filename includes a time stamp based on the first data frame in the file. The data in the file conforms to the C37.118 data format.

Table 15.15 SYNCHROPHASORS Directory File Sample

File	Description
080528,160910,0,ONA,1,ABC.PMU	080528 = date 160910 = time 0 = GMT (no time offset) ONA = Last three letter (spaces removed) of the PMSTN setting 1 = PMID setting ABC = CONAM setting (company name) PMU = file extension indicating synchrophasor recording file

Software Protocol Selections

The relay supports the protocols and command sets shown in *Table 15.16*.

Table 15.16 Supported Serial Command Sets (Sheet 1 of 2)

PROTO Setting Value	Command Set	Description
SEL	SEL ASCII	Commands and responses
SEL	SEL Compressed ASCII	Commands and comma-delimited responses
SEL	SEL Fast Meter	Binary meter and digital element commands and responses
SEL	SEL Fast Operate	Binary operation commands
SEL	SEL Fast Message	Fast Message database access, binary SER commands and responses
MBA, MBB, MBGA, or MBGB	SEL MIRRORED BITS communications	Binary high-speed control commands

NOTE: Not all SEL-400 series relays support MBGA and MBGB

NOTE: Not all SEL-400 series relays support synchrophasors (the PMU protocol choice).

NOTE: Not all SEL-400 series relays support RTD communications with the SEL-2600A.

Table 15.16 Supported Serial Command Sets (Sheet 2 of 2)

PROTO Setting Value	Command Set	Description
PMU	Phasor Measurement Unit	Binary Synchrophasor Protocol, as selected by Port Setting PMUMODE and Global Setting MFRMT (see *Section 18: Synchrophasors*).
PMU	SEL Fast Operate	Binary operation commands
RTD	SEL Fast Message protocol for Resistance Temperature Detector (RTD) data	As many as 12 analog temperature readings from the SEL-2600A.
DNP	DNP3 Level 2 Outstation	Binary commands and responses (see *Section 16: DNP3 Communication*).

Virtual Serial Ports

Actual serial ports are described in *Serial Port Hardware Protocol on page 15.5*. In addition to actual serial ports, the relay supports several virtual serial ports. A virtual serial port does the following:

- Transmits and receives characters through a different mechanism than the physical serial port
- “Encapsulates” characters in virtual terminal messages of a different protocol
- Simulates an actual serial port with setting PROTO := SEL
- May have restrictions imposed by the protocol that encapsulates the virtual serial data

You can set the relay to use virtual serial ports encapsulated in SEL MIRRORED BITS communications links, DNP3 links, and through Telnet over Ethernet.

SEL Protocol

This subsection describes the command sets that are active when the port setting PROTO := SEL. You can also access these protocols through virtual serial ports that simulate ports with PROTO := SEL.

SEL ASCII Commands

SEL originally designed the SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands.

The ASCII character set specifies numeric codes that represent printing characters and control characters. The complete ASCII command set is shown in *Section 14: ASCII Command Reference*. *Table 15.17* shows the subset of the ASCII control characters used in this section.

Table 15.17 Selected ASCII Control Characters

Decimal Code	Name	Usage	Keystroke(s)
13	CR	Carriage return	**<Enter>** or **<RETURN>** or **<Ctrl+M>**
10	LF	Line feed	**<Ctrl+J>**
02	STX	Start of transmission	**<Ctrl+B>**
03	ETX	End of transmission	**<Ctrl+C>**
24	CAN	Cancel	**<Ctrl+X>**
17	XON	Flow control on	**<Ctrl+Q>**
19	XOFF	Flow control off	**<Ctrl+S>**

The **<Enter>** key on standard keyboards sends the ASCII character CR for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the relay. A correctly formatted command transmitted to the relay consists of the command, including optional parameters, followed by either a CR character (carriage return) or CR and LF characters (carriage return and line feed). The following line contains this information in the format this manual uses to describe user input:

<command> <Enter> or <command> <Enter> <CR>

You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** is equivalent to **EVE 1 <Enter>**. You may use upper- and lowercase characters without distinction, except in passwords.

In response to a command, the relay may respond with an additional dialog line or message. The relay transmits dialog lines in the following format:

```
<DIALOG LINE ><CR><LF>
```

The relay transmits messages in the following format:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
…
<LAST MESSAGE LINE><CR><LF>< ETX>
```

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX. Each line of the message ends with a carriage return, CR, and line feed, LF.

Send the CAN character to the relay to abort a transmission in progress. For example, if you request a long report and want to terminate transmission of this report, depress the **<Ctrl>** and **<X>** keys (**<Ctrl+X>**) to terminate the report.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other white space between data fields to a single comma.

Compressed ASCII Message Format

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
...
<LAST MESSAGE LINE><CR><LF><ETX>
```

Each line in the message consists of one or more data fields, a checksum field, and a CRLF. Commas separate adjacent fields. Each field is either a number or a string. Number fields contain base-10 numbers using the ASCII characters 0–9, plus (+), minus (-), and period (.). String fields begin and end with quote marks and contain standard ASCII characters. Hexadecimal numbers are contained in string fields.

The checksum consists of four ASCII characters that are the hexadecimal representation of the two-byte binary checksum. The checksum value is the sum of the first byte on a line (first byte following `<STX>`, `<CR>`, or `<CR><LF>`) through the comma preceding the checksum.

If you request data with a Compressed ASCII command and these data are not available, (in the case of an empty history buffer or invalid event request), the relay responds with the following Compressed ASCII format message:

```
<STX>"No Data Available","0668"<CR><ETX>
```

where:

`No Data Available` is a text string field.

`0668` is the checksum field, which is a hexadecimal number represented by a character string.

Table 15.18 lists the typical Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 14: ASCII Command Reference*.

Table 15.18 Typical Compressed ASCII Commands (Sheet 1 of 2)

Command	Response	Access Level
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CBREAKER	Circuit breaker data	1
CEVENT	Event report	1
CHISTORY	List of events	1
CPR	Displays the first 20 rows of the profile report, with the oldest row at the bottom and the latest row at the top	
CSER	Sequential Events Recorder report	1
CSTATUS	Self-diagnostic status	1
CSUMMARY	Summary of an event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0

Table 15.18 Typical Compressed ASCII Commands (Sheet 2 of 2)

Command	Response	Access Level
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

CASCII Configuration Message for Compressed ASCII Commands

The CASCII message provides a block of data for each of the Compressed ASCII commands supported by an SEL device. The block of data for each command provides message description information to allow automatic data extraction. The relay arranges items in the Compressed ASCII configuration message in a pre-defined order. For the purpose of improving products and services, SEL sometimes changes the items and item order. The information presented below explains the message and serves as a guide to the items in Compressed ASCII configuration messages.

NOTE: Compressed ASCII is self-describing and may vary with the firmware version of your relay. Before you program a master device to send and parse Compressed ASCII commands and responses, you should perform a **CASCII** command on your relay or contact SEL for more detailed information.

A Compressed ASCII command can require multiple header and data configuration lines. The general format of a Compressed ASCII configuration message is the following:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
.
.
.
"COMMAND n",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF><ETX>
```

Definitions for the items and fields in a Compressed ASCII configuration message are the following:

- `n` is the number of Compressed ASCII command descriptions to follow.
- `COMMAND` is the ASCII name for the Compressed ASCII command that the requesting device (terminal or external software) sends. The naming convention for the Compressed ASCII commands is a C character preceding the typical command. For example, **CSTATUS**, abbreviated to **CST**, is the Compressed ASCII **STATUS** command.
- `#H` identifies a header line to precede one or more data lines; the # character represents the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.
- `xxxxx` is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is ten characters.
- `#D` identifies a data format line; the # character represents the maximum number of data lines in command response.
- `ddd` identifies a format field containing one of the following type designators:
  - I—Integer data
  - F—Floating point data
  - *z*S—String of maximum *z* characters (for example, enter 10S for a 10-character string)
- *yyyy* is the 4-byte hex ASCII representation of the checksum. Every checksum is followed by a new line indication (<CR><LF>).

Software Flow Control

Software handshaking is a form of flow control that two serial devices use to prevent input buffer overflow and loss of characters. The relay uses XON and XOFF control characters to implement software flow control for ASCII commands.

The relay transmits the XOFF character when the input buffer is more than 75 percent full. The connected device should monitor the data it receives for the XOFF character to prevent relay input buffer overflow. The external device should suspend transmission at the end of a message in progress when it receives the XOFF character. When the relay has processed the input buffer so that the buffer is less than 25 percent full, the relay transmits an XON character. The external device should resume normal transmission after receiving the XON character.

The relay also uses XON/XOFF flow control to delay data transmission to avoid overflow of the input buffer in a connected device. When the relay receives an XOFF character during transmission, it pauses transmission at the end of the message in progress. If there is no message in progress when the relay receives the XOFF character, it blocks transmission of any subsequent message. Normal transmission resumes after the relay receives an XON character.

Automatic Messages

If you enable automatic messages, **AUTO = Y**, the relay issues a message any time the relay turns on, asserts a self-test, changes to another settings group, or triggers an event. For virtual ports, the relay issues automatic messages only if the connection is active. Automatic messages contain the following information:

- Power-up: When you turn on the relay, the message provides the terminal ID and the present date and time.
- Self-test failure: When the relay detects an internal failure, the automatic message is the same as the relay response to the **STATUS** command.
- Group switch: Whenever a settings group change occurs, the message contains the relay ID, terminal ID, present date and time, and the selected settings group.
- Events: When the relay triggers an event, the automatic message is the same as the relay response to the **SUMMARY** command.

Timeout

Use the TIMEOUT setting to set the idle time for each port. Idle time is the period when no ASCII characters are transmitted and received (interleaved Fast Messages do not affect the idle time). When the idle time exceeds the TIMEOUT setting, the following takes place:

- The access level changes to Access Level 0.
- The front-panel targets reset to TAR 0 if the port had previously remapped the targets.
- Virtual connections are disconnected.
- The software flow control state changes to XON.

When set to OFF, the port never times out.

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams in order to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the relay communicates with an SEL communications processor. The communications processor performs autoconfiguration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the communications processor uses the binary data stream for Fast Meter, Fast Operate, and Fast SER messages to populate a local database and to perform SCADA operations. At the same time, you can use the ASCII data stream for commands and responses.

SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages and unsolicited synchrophasor messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction.

This section summarizes the binary commands and messages and includes our recommendation for using Fast Commands and Compressed ASCII configuration information to communicate with the relay. You need this information to develop or specify the software an external device uses to communicate using Fast Messages with the relay. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 15.19 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

NOTE: Not all SEL-400 series relays support demand metering and the corresponding fast commands.

Table 15.19 Fast Commands and Response Descriptions (Sheet 1 of 2)

Command (Hex)	Name	Response Description
A5B9h	Status acknowledge message	Clears Fast Meter status byte and sends current status.
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information.
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message.
A5C2h	Demand Fast Meter configuration block	Defines contents of demand Fast Meter data message.
A5C3h	Peak demand Fast Meter configuration block	Defines contents of peak demand Fast Meter data message.

Table 15.19 Fast Commands and Response Descriptions (Sheet 2 of 2)

Command (Hex)	Name	Response Description
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands.
A5D1h	Fast Meter data message	Defines present values of analog and digital data.
A5D2h	Demand Fast Meter data message	Defines values of most recently completed demand period.
A5D3h	Peak demand Fast Meter data message	Defines values for peak demands as of end of most recently completed demand periods.

Fast Operate commands use one of the two-byte command types shown in *Table 15.20*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

Table 15.20 Fast Operate Command Types

Command (Hex)	Name	Description
A5E0h	Fast Operate command for remote bits	Sends command code that will change the state of a remote bit, if setting FASTOP :=Y for this port.
A5E3h	Fast Operate command for circuit breaker bits	Sends command code that will change the state of a circuit breaker control bit, if setting FASTOP :=Y for this port.

The Fast Operate messages transfer control commands through the binary data stream. You must enable Fast Operate messages for a port before the relay accepts these messages on that port. In the port settings, when the protocol is set to SEL, the FASTOP setting is visible. Set FASTOP :=Y to enable Fast Operate commands or to N to disable Fast Operate commands.

General Fast Messages have a two byte identifier (A546h) and a function code. Fast SER messages are general Fast Messages that transport Sequential Event Recorder report information. The Fast SER messages include function codes to accomplish different tasks. *Table 15.21* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 15.21 Fast Message Command Function Codes Used With Fast Messages (A546 Message) and Relay Response Descriptions (Sheet 1 of 2)

Function Code (Hex)	Function	Relay Action
00h	Fast Message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80).
01h	Enable unsolicited transfers	Relay transmits Fast SER command acknowledged message (Function Code 81) and sets relay element bit FSERx. Relay will transmit subsequent SER events (Unsolicited SER broadcast, Function Code 18).
02h	Disable unsolicited transfers	Relay sends Fast SER command acknowledged message (Function Code 82) and clears relay element bit FSERx. Relay will not transmit subsequent SER messages.
05h	Ping—determine channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85).

Table 15.21 Fast Message Command Function Codes Used With Fast Messages (A546 Message) and Relay Response Descriptions (Sheet 2 of 2)

Function Code (Hex)	Function	Relay Action
98h	Fast SER Message acknowledge	Relay completes dialog processing for unsolicited message sequence.
30h	Device description request	Relay sends summary of data blocks available (Function Code B0h).
31h	Data format request	Relay sends description of requested data block, including data labels and types (Function Code B1h).
33h	Bit label request	Relay sends set of bit labels for specific data item (Function Code B3h).
10h	Data request	Relay responds with set of requested data (Function Code 90h).

The SEL Fast Message Synchrophasor Protocol is described in *Section 18: Synchrophasors*.

Recommended Use of Relay Self-Description Messages for Automatic Configuration

Compressed ASCII and Fast Message commands provide information to allow an external computer-based device to adapt to the special messages for each relay. The SEL communications processors use the self-description messages to configure a database and name the elements in the database.

Table 15.22 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 15.22 Commands in Recommended Sequence for Automatic Configuration

Command ASCII or hexadecimal (h suffix)	Response	Usage
ID	Relay identification	ID and FID
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information
A5C1h, A5C2h, A5C3h	Fast Meter configuration blocks	Defines contents of Fast Meter data messages
BNAME	Binary names	ASCII names of status bits
DNAME	Digital I/O name	ASCII names of digital I/O points
SNS	SER names	ASCII names for SER data points
CASCII	Compressed ASCII configuration block	Configuration data for Compressed ASCII commands with access levels > 0
A5CEh	Fast Operate configuration block	Defines available circuit breaker and remote bits, and associated commands, if setting FASTOP :=Y for this port

SEL MIRRORED BITS Communication

With SEL-patented MIRRORED BITS communications protocol, protective relays and other devices can directly exchange information quickly, securely, and with minimal cost. Use MIRRORED BITS communications for remote control, remote sensing, or communications-assisted protection schemes such as POTT and DCB.

SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the relay for compatible operation with SEL-300 series relays, the SEL-2505 or SEL-2506 Remote I/O Modules, and the SEL-2100 Protection Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits. You can also use settings to select extensions of the MIRRORED BITS communications protocols, available only in SEL-400 series relays, to exchange analog values, synchronize clocks, and engage in virtual terminal dialogs. *Table 15.23* summarizes MIRRORED BITS communications features.

Table 15.23 MIRRORED BITS Communications Features

Feature	Compatibility
Transmit and receive logic bits	SEL-300 series relays, SEL-2505, SEL-2506, SEL-2100, SEL-400 series relays
Transmit and receive analog values	SEL-400 series relays
Synchronize time	SEL-400 series relays
Send and receive virtual serial port characters	SEL-400 series relays
Support synchronous communications channel	SEL-400 series relays

Communications Channels and Logical Data Channels

The relay supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port: PROTO := MBA or MBGA for MIRRORED BITS communications Channel A or PROTO := MBB or MBGB for MIRRORED BITS communications Channel B.

Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates with which channel the bits are associated. These bits are controlled by SELOGIC control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as arguments in SELOGIC control equations. The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, DOKA, ANOKA, DOKB, and ANOKB. You can also use these bits as arguments in SELOGIC control equations. Use the **COM** command for additional channel status information.

Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1–TMB8. If you use fewer than eight transmit bits, Data Channel 8 is reserved to support data framing and time synchronization features. You can assign the eight logical data channels as follows:

- Logic bits: Setting MBNUM controls the number of channels used for logic bits, TMB1–TMB8, inclusive.
  - If you set MBNUM to 8, then you cannot use channels for any of the following features.
  - If you set MBNUM to less than 8, you can use the remaining channels (as many as eight total) for the features listed below.
- Message and time synchronization: If MBNUM is less than 8, the relay dedicates a logical data channel to message framing and time synchronization.
- Analog channels: Setting MBNUMAN controls the number of analog channels. It is not guaranteed that multiple analog quantities will come from the same relay sampling interval.
  - If MBNUM := 8, all channels are used for logic bits and MBNUMAN is forced to 0.
  - If MBNUM := 7, seven channels are used for logic bits and one channel is used for message and time synchronization.
  - If MBNUM is less than 7, you can use the remaining channels for analog channels by setting the desired number of channels in MBNUMAN (1 to 7 – MBNUM).

  Note: Analog quantities are converted to Integer values for transmission via MIRRORED BITS. Because of this, they will lose any fractional value they may have had. To maintain a fixed resolution, multiply the analog quantity by a set value before transmission, and divide by the same quantity upon reception. To maintain accuracy, add 0.5 to the analog quantity after any scaling.
- Virtual terminal sessions: Setting MBNUMVT controls the number of additional channels available for the virtual terminal session.
  - If MBNUMVT := OFF, the relay does not dedicate any additional channels to the virtual terminal session.
  - If there are spare channels (7 – MBNUM – MBNUMAN > 0), you can use MBNUMVT to dedicate these additional channels to the virtual terminal session.
  - With MBNUM = 7 or less and MBNUMVT = 0, virtual terminal is still possible because the relay uses the eighth element for time synchronization and virtual terminal.

  The virtual terminal session uses channels differently than other data exchange mechanisms. There can be only one active virtual terminal session across a MIRRORED BITS link. One channel, included in the synchronization data, is always dedicated to this virtual terminal session. If you assign additional channels to the virtual terminal session (set MBNUMVT > 0), you will improve the performance of the virtual terminal session. The relay uses the additional channels to exchange data more quickly.

Operation

MBG Protocol

The MBG protocol selection allows the user to move the MIRRORED BITS Transmit equations to the Group settings for more flexibility in bus transfer schemes. Using MBG will allow the MIRRORED BITS settings to transfer with a Group Switch when it occurs.

NOTE: The MBG protocol option is only available in some SEL-400 series relays.

To enable the MBG protocol, set the Port setting PROTO := MBGA to enable Channel A MIRRORED BITS, or PROTO := MBGB for Channel B MIRRORED BITS. Next, the protocol will need to be enabled in the Group settings.

Under Group settings, enable the MBG protocol for Channel A by setting EMBA := Y. When this setting is enabled, the transmit equation settings TX_IDA, RX_IDA, and TMB*n*A will be available in the Group settings and will be hidden from the Port settings.

The MBG protocol can also be enabled for Channel B by setting EMBB := Y. When this setting is enabled, the transmit equation settings TX_IDB, RX_IDB, and TMB*n*B will be available in the Group settings and will be hidden from the Port settings.

MB8

While the relay does not have a setting for the MB8 protocol implemented in some SEL products, you can configure the relay to communicate with devices set to MB8A or MB8B (such as the SEL-351S or SEL-2505). Set the protocol setting PROTO to MBA or MBB. Set the STOPBIT setting to 2. Set all other settings to match those in the other device.

Message Transmission

The relay transmits a MIRRORED BITS communications message as fast as it can for the configured data rate. At 9600 bps, this is approximately one message every
1/4-cycle. At 19200 bps, it is approximately every 1/8-cycle. At 38400 bps, it is approximately two every 1/8-cycle. However, if pacing is enabled, it slows to one message every 3 ms at 19200 and 38400 bps (see *Table 15.26*). Each message contains the most recent values of the transmit bits. If you enabled any of the extended features through the settings, note that the relay transmits a portion of the extended data in each message.

If you have specified virtual terminal data channels for this port, the designated data channels are normally idle. If you use the **PORT** command to open a virtual terminal session for this port and type characters, the relay transmits these characters through the virtual terminal logical data channels.

Message Reception Overview

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay performs the following operations:

- Sends each received logic bit (RMB*n*) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.
- Accumulates the analog data, and every 18th message, updates the received analog quantities.
- Accumulates the virtual terminal information, and every 18th message, makes the received character or characters available to the virtual terminal.

NOTE: *c* represents the MIRRORED BITS channel (A or B), *n* represents the MIRRORED BITS data channel data number (1–8).

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors
- Receive data redundancy error
- Receive message identification error
- No message received in the time three messages have been sent

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below.

While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RMB*n*FL, as follows:

- 1
- 0
- P (to use last valid value)

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMB*n* element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. An SEL relay communicating with another SEL relay typically sends and receives MIRRORED BITS communications messages eight times per power system cycle. Therefore, a security counter set to two counts will delay a bit by approximately 1/4 of a power system cycle. Reference *Table 15.26* for the message rates based on the settings. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Channel Synchronization

When an SEL relay detects a communications error, it deasserts ROKA or ROKB. The relay transmits an attention message until it receives an attention message that includes a match to the TX_ID setting value. If the attention message is successful, the relay has properly synchronized and data transmission will resume. If the attention message is not successful, the relay will repeat the attention message until it is successful.

Loopback Testing

Use the **LOOP** command to verify the communications channel. In this mode, the relay expects the transmitted data to be looped back to the relay to test the data transmissions, including communications data. At the remote end, jumper the send and receive communications channels to complete the path for the test. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks (described above), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout

Use the **COM** command to generate a long or summary report of the communications errors.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions using SELOGIC control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible flag, CBADA or CBADB.

MIRRORED BITS Communications Protocol for the Pulsar 9600-BPS Modem

NOTE: Use an SEL-C272 or SEL-C273 cable.

To use a Pulsar MBT modem, set setting MBT := Y. Setting MBT := Y hides setting SPEED and forces it to 9600, and hides setting RTSCTS and forces it to a value of N. The relay also injects a delay (idle time) of 3 ms between messages.

NOTE: You must consider the idle time in the calculations of data transfer latency through a Pulsar MBT modem system.

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that MIRRORED BITS communications matches this specification. Other relays may set RTS to a positive voltage at the EIA-232 connector to signify usage of the R6 version or the R version of MIRRORED BITS communications.

Settings

The port settings associated with MIRRORED BITS communications are shown in *Table 15.24* and *Table 15.25*.

Set PROTO := MBA or MBGA to enable the MIRRORED BITS communications protocol Channel A on this port. Set PROTO := MBB or MBGB to enable the MIRRORED BITS communications protocol Channel B on this port.

Table 15.24 General Port Settings Used With MIRRORED BITS Communications (Sheet 1 of 2)

Name	Description	Range	Default
PROTO	Protocol	None, SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU	SEL
MBT	Enable Pulsar 9600 modem	Y, N	N

Table 15.24 General Port Settings Used With MIRRORED BITS Communications (Sheet 2 of 2)

Name	Description	Range	Default
SPEED	Data speed. Hidden and set to 9600 if MBT := Y	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, SYNC	9600
STOPBIT	Stop bits. Hidden and set to 1 if MBT := Y	1, 2	1

Setting SPEED := SYNC (available only on the rear-panel serial ports for which PROTO := MBA, MBB, MBGA, or MBGB) places the serial port in synchronous (or externally-clocked) mode. The serial port hardware will synchronize transmit and receive data (TX/RX) to a clock signal applied to the Pin 8 input at any effective data rate as high as 64000. This setting choice will suit certain synchronous communications networks.

The relay uses the RBADPU setting to determine how long a channel error must persist before the relay asserts RBADA or RBADB. The relay deasserts RBADA and RBADB immediately when it no longer detects a channel error.

The relay uses the CBADPU setting to determine when to assert CBADA and CBADB. If the short-term channel down time ratio exceeds CBADPU, the relay asserts the appropriate CBAD bit.

The TXMODE setting provides compatibility with SEL devices that are not SEL-400 series relays. The relay can send messages more quickly than the SEL-300 series relays and other SEL devices can process these messages. This could lead to loss of data and a failure to communicate properly. When you set TXMODE to P, the relay sends new MIRRORED BITS messages every 3 ms even if the selected data speed (SPEED setting) would allow more frequent messages.

As a function of the settings for SPEED, TXMODE, and MBT, the message transmission periods are shown in *Table 15.26*.

Table 15.25 MIRRORED BITS Communications Protocol Settings (Sheet 1 of 2)

Name	Description	Range
TX_ID	MIRRORED BITS communications ID of this device	1–4
RX_ID	MIRRORED BITS communications ID of device connected to this port	1–4 (must be different than TX_ID)
RBADPU	Outage duration to set RBAD	1–10000 seconds
CBADPU	Channel unavailability to set CBAD	1–100000 parts per million
TXMODE	Transmission mode[a]	N (normal), P (paced)
MBNUM	Number of MIRRORED BITS communications data channels used for logic bits	0–8
RMB1FL[b]	RMB1 channel fail state	0, 1, P
RMB1PU[b]	RMB1 pickup message count	1–8
RMB1DO[b]	RMB1 dropout message count	1–8
• • •	• • •	
RMB8FL[b]	RMB8 channel fail state	0, 1, P
RMB8PU[b]	RMB8 pickup message count	1–8
RMB8DO[b]	RMB8 dropout message count	1–8
MBTIME	MIRRORED BITS time synchronize enable	Y, N

Table 15.25 MIRRORED BITS Communications Protocol Settings (Sheet 2 of 2)

Name	Description	Range
MBNUMAN	Number of analog data channels (hidden and set to 0 if MBNUM := 7 or 8)	0–*n*, *n* = 7–MBNUM
MBANA1[c]	Selection for analog Channel 1	Analog quantity label
MBANA2[c]	Selection for analog Channel 2	Analog quantity label
MBANA3[c]	Selection for analog Channel 3	Analog quantity label
MBANA4[c]	Selection for analog Channel 4	Analog quantity label
MBANA5[c]	Selection for analog Channel 5	Analog quantity label
MBANA6[c]	Selection for analog Channel 6	Analog quantity label
MBANA7[c]	Selection for analog Channel 7	Analog quantity label
MBNUMVT	Number of virtual terminal channels	OFF, 0–*n*, *n* = 7–MBNUM–MBNUMAN

[a] Must be P for connections to devices that are not SEL-400 series relays.
[b] Hidden based on MBNUM setting.
[c] Hidden based on MBNUMAN setting.

Table 15.26 MIRRORED BITS Communications Message Transmission Period

Speed in Bits per Second	TXMODE := NORMAL MBT := N	TXMODE := PACED MBT := N	MBT :=Y
38400	1.0 ms	3.0 ms	N/A
19200	2.0 ms	3.0 ms	N/A
9600	4.0 ms	4.0 ms	7.0 ms
4800	8.0 ms	8.0 ms	N/A

Set the RX_ID of the local relay to match the TX_ID of the remote relay. In a three-terminal case, Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X. *Table 15.27* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 15.27 MIRRORED BITS Communications ID Settings for Three-Terminal Application

Relay	TX_ID	RX_ID
X	1	3
Y	2	1
Z	3	2

SEL Distributed Port Switch Protocol (LMD)

SEL Distributed Port Switch Protocol (LMD) permits multiple devices to share a common communications channel. This protocol is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement. The relay does not have built in LMD protocol, but you can connect this relay to an SEL-2885 EIA-232/485 Protocol Converter and connect the SEL-2885 to an EIA-485 multidrop network. See the SEL-2885 EIA-232 to

EIA-485 Transceiver product flier for more information on the settings, configuration, and application of the SEL-2885. (Contact your local technical service center, the SEL factory, or visit our website at selinc.com for a copy of the SEL-2885 product flier.)

Initialization

For the first 30 seconds after applying power to the relay, the SEL-2885 listens for an initialization string from the relay. The initialization string must be enclosed in square brackets ([ ]). The following table describes the initialization string fields. To send this string automatically, set **AUTO** to **Y** and append the initialization string to the relay ID setting so that it is included in the relay power-up header.

Table 15.28 SEL-2885 Initialization String [MODE PREFIX ADDR:SPEED]

Field	Optional or Required	Value	Description
[	Required	[	Opening bracket is start of string
Mode	Optional	Not specified N B	Treat as N, below Addressing for ASCII device Addressing for binary devices
PREFIX	Required	@, #, $, %, or &	Prefix character
ADDR	Required	01–99	Two digit address in the range 01–99
:	Optional. Needed if SPEED is specified	Colon ":"	Colon ":", then one of the following codes to match the port SPEED setting
SPEED	Optional	12 24 48 96	1200 bps 2400 bps 4800 bps 9600 bps
]	Required	]	Closing bracket is end of string

Operation

The following steps describe how to use the LMD operation of the SEL-2885:

Step 1. When you send the prefix and address, the SEL-2885 enables echo and message transmission.

You must wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.

Step 2. You can use the commands that are available for the protocol setting of the port where the SEL-2885 is installed.

Step 3. If the port PROTO setting is set to SEL, you can use the **QUIT** command to terminate the connection.

If no data are sent to the relay before the port time-out period, this command automatically terminates the connection.

Step 4. If all relays in the multidrop network do not have the same prefix setting, enter the sequence **<Ctrl+X> OR QUIT <Enter>** before entering the prefix character to connect to another device.

SEL-2600A RTD Module Operation

NOTE: Not all SEL-400 series relays support communication with SEL-2600A RTD Modules.

The SEL-2600A RTD Module Protocol (RTD) enables communication with an SEL-2600A via an SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

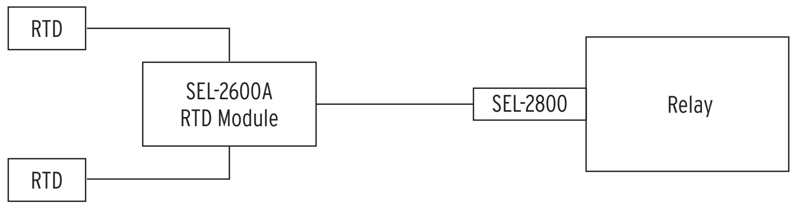

Figure 15.7 SEL-2600A RTD Module and the Relay

This protocol supports data acquisition of as many as 12 temperature channels and places the results directly into predefined analog quantities (RTD01–RTD12) inside the relay for use in freeform SELOGIC applications. For more information on the SEL-2600A or SEL-2800, contact your local technical service center, the SEL factory, or visit the SEL website at selinc.com for a copy of the SEL-2600A and SEL-2800 product fliers.

Initialization

Perform the following steps to prepare the relay for communicating with an SEL-2600A RTD module:

Step 1. Set the desired port to RTD protocol.

Step 2. Set the port setting RTDNUM to the number of RTDs attached to the SEL-2600A.

Step 3. Set the RTD type settings (RTD*nn*TY) to the appropriate RTD type.

Step 4. Connect the SEL-2600A RTD Module to the port via the SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

Operation

The SEL-2600A RTD module sends all temperature measurements to the relay every 0.5 seconds. The relay places the received temperature measurements into analog quantities RTD01–RTD12 for use in freeform SELOGIC applications. The data range is from –50 to +250 °C.

NOTE: When a channel status bit is not asserted, the data in the respective analog quantity is the last valid temperature, not the current temperature.

If the relay stops receiving valid analog quantities from a certain channel, the temperature stored in the relay freezes at the last received value. Fifteen status bits help supervise decisions based on temperature measurements. *Table 15.29* describes how to interpret the status bits.

Table 15.29 RTD Status Bits

RTD Status Bit	Description
RTDFL	Asserts if the SEL-2600A experiences an internal problem.
RTDCOMF	Asserts if the relay does not receive a valid measurement from the SEL-2600A for 1.25 seconds.
RTD01ST–RTD12ST	Assert when an RTD is attached to a channel and the SEL-2600A is able to read RTD.
RTDIN	SEL-2600 input status bit. Asserts when the SEL-2600 is healthy and the received data indicates the assertion of the input.

To view the temperature measurements received from the SEL-2600A, issue the **MET T** command, as depicted in *Figure 15.8*.

NOTE: In some SEL-400 series relays, you must use MET RTD instead of MET T.

```
=>>MET T <Enter>
Relay 1                                   Date: 05/17/2003  Time: 13:42:13.220
Station A                                 Serial Number: 0000000000
RTD Input Temperature Data (deg. C)
RTD  1 = -48

RTD  2 = Channel Failure
RTD  3 =   0
RTD  4 =  24
RTD  5 = Channel Not Used
RTD  6 =  72
RTD  7 = Channel Failure
RTD  8 = 120

RTD  9 = Channel Not Used
RTD 10 = 168
RTD 11 = 192
RTD 12 = 216
```

Figure 15.8 MET T Command Response

The **MET T** command displays the following messages:

- `Channel Failure`: This message is displayed for each channel whose channel status bit is not asserted.
- `Channel Not Used`: This message is displayed for each channel whose channel type is set to NA.

When there is a status problem with the SEL-2600A RTD module, the **MET T** command will respond with an informational message, as shown in *Figure 15.9*.

```
=>>MET T
SEL-2600 Failure
```

Figure 15.9 MET T Command Response for Status Problem

The four possible messages for status problems, with their interpretation, are indicated in *Table 15.30*.

Table 15.30 MET T Command Status Messages

Message	Interpretation
SEL-2600 Failure	RTDFL status bit asserted
Communication Failure	RTDCOMF status bit asserted
No data available	Port Protocol not set to RTD
Channel Failure	RTD*xx*ST status bit deasserted

Direct Networking Example

This direct networking example demonstrates direct networking to the relay using the Ethernet card. *Figure 15.10* shows the Ethernet network topology. This examples uses a SEL-421, but the same concepts apply to any SEL-400 series relay.

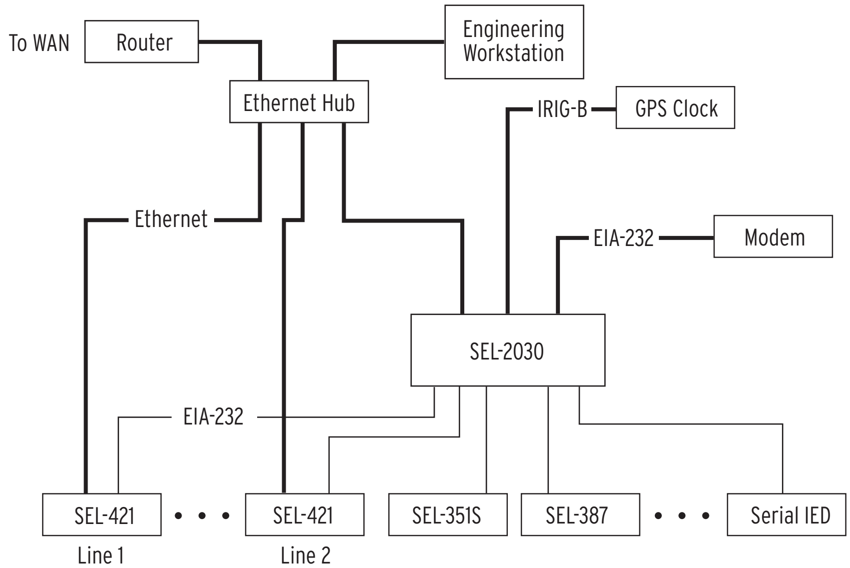

Figure 15.10 Example Direct Networking Topology

Application

NOTE: The IRIG-B time signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions.

In this application, all IEDs connect to the Ethernet network. The SEL-421 Relays and the SEL-2030 each have an Ethernet card installed. In this example, the Ethernet network is used primarily for an engineering connection to the devices in the substation either across the WAN or from the local computer. The engineer can use FTP to collect settings, oscillography, and other file data directly from the SEL-421 Relays. The engineer can also use Telnet to establish a terminal connection to the SEL-421 Relays or through the SEL-2030 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

There is a serial cable from the SEL-2030 to the SEL-421 Relays. This cable provides IRIG-B time synchronization from the SEL-2030 that is synchronized by the GPS clock attached to the SEL-2030. The SEL-2030 provides its output synchronization signal from its internal clock, so that loss of the signal from the GPS will not result in a loss of synchronization between substation devices as they will all be synchronized to the SEL-2030 clock. During long periods of loss of synchronization, the SEL-2030 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2030 clock. The serial cables also allow the SEL-2030 to provide a single point for dial-in communications with the substation IEDs avoiding the high cost of high bandwidth connections (for example, ISDN or DSL) for this backup to the Ethernet network engineering connection.

Settings

This example focuses on the relay labeled Line 1 shown in *Figure 15.10*. **PORT 5** settings for the SEL-421 configure the Ethernet card. **PORT 5** settings for this example are shown in *Table 15.31*.

Table 15.31 SEL-421 PORT 5 Direct Networking Settings

Setting Name	Setting	Description
TIMEOUT	5	Port inactivity time-out in minutes (drops to Access Level 0 on Telnet connections when this expires)
AUTO	N	Automessage disabled because engineering connection will not require unsolicited messages from SEL-2030
FASTOP	N	Fast Operate messages disabled because they are not required on engineering connection
TERTIM1	1	Length of time the channel must be idle before checking for the termination string in seconds
TERSTRN	\005	Transparent communications termination string default of CTRL+E
TERTIM2	0	Length of time the channel must be idle before accepting the termination string in seconds
IPADDR	10.201.0.112/16	IP network address
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality (IEC 61850 only)
KAIDLE	10	Length of time to wait with no detected activity before sending a keep-alive packet (must be greater than or equal to KAINTV)
KAINTV	1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet (must be less than or equal to KAIDLE)
KACNT	6	Maximum number of keep-alive packets to send
NETPORT	A	Primary network port selected to Port A
FTIME	5	Fail over time-out—not used in this application
NETCSPD	A	Automatically detect network speed on Port C
NETDSPD	A	Automatically detect network speed on Port D—not used in this application
FTPSERV	Y	FTP sessions enabled
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous login disabled so that passwords are required for all FTP users
FTPAUSR	“”	Host user from which anonymous FTP client inherits access rights—not used in this application
TCBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
TPORT	23	Host Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

FTP Session

Figure 15.11 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows operating system and accessible through a command prompt window. The operator connects to the relay, moves to the SETTINGS directory, and collects the **PORT 5** settings. *Figure 15.11* shows a portion of the **PORT 5** settings in the SET_P5.TXT file.

```
C:\>ftp 10.201.0.112 <Enter>
Connected to 10.201.0.112.
220 FTP SERVER:
User (10.201.0.112:(none)): 2AC
331 User name okay, need password.
Password:
230 User logged in, proceed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
CFG.XML
EVENTS
REPORTS
SETTINGS
SWCFG.ZIP
SYNCHROPHASORS
226 Closing data connection.
ftp: 72 bytes received in 0.00Seconds 72.00Kbytes/sec.
ftp> cd SETTINGS
250 CWD  requested file action okay, completed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
BAY_SCREEN.TXT
ERR.TXT
SET_A1.TXT
SET_A10.TXT
SET_A2.TXT
SET_A3.TXT
SET_A4.TXT
SET_A5.TXT
SET_A6.TXT
SET_A7.TXT
SET_A8.TXT
SET_A9.TXT
SET_ALL.TXT
SET_B1.TXT
SET_D1.TXT
SET_D2.TXT
SET_D3.TXT
SET_D4.TXT
SET_D5.TXT
SET_F1.TXT
SET_G1.TXT
SET_L1.TXT
SET_L2.TXT
SET_L3.TXT
SET_L4.TXT
SET_L5.TXT
SET_L6.TXT
SET_N1.TXT
SET_O1.TXT
SET_P1.TXT
SET_P2.TXT
SET_P3.TXT
SET_P5.TXT
SET_PF.TXT
SET_R1.TXT
SET_S1.TXT
SET_S2.TXT
SET_S3.TXT
SET_S4.TXT
SET_S5.TXT
SET_S6.TXT
SET_SM.TXT
SET_T1.TXT
UPGRADE_RPT.TXT
226 Closing data connection.
ftp: 536 bytes received in 0.01Seconds 53.60Kbytes/sec.
ftp> get SET_P5.TXT
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
ftp: 3853 bytes received in 0.01Seconds 428.11Kbytes/sec.
ftp> quit
221 Goodbye.

C:\>
```

Figure 15.11 Example FTP Session

```
[INFO]
RELAYTYPE=SEL
FID=SEL-421-X045-V0-Z001001-D20010106
BFID=SLBT-CFS-X000
PARTNO=SEL-400H1234
[IOBOARDS]
[COMCARDS]
, SEL-2701-X061-V0-Z000000-D20010117, SLBT-2701-X021-V0-Z000000-D20010109, 1
[P5]

"TIMEOUT",5
"AUTO",Y
"FASTOP",N
"TERTIM1",1
"TERSTRN","\005"
"TERTIM2",0

"IPADDR","10.201.0.112"
"SUBNETM","255.255.0.0"
"DEFRTR","10.201.0.1"
"NETPORT","A"
"FAILOVR","N"

"FTIME",5
"NETASPD","A"
"NETBSPD","A"
"FTPSERV","Y"

"FTPCBAN","FTP SERVER:"
"FTPIDLE",5
"FTPANMS","N"
"FTPAUSR","ACC"

"T1CBAN","HOST TERMINAL SERVER:"
"T1INIT","N"
"T1RECV","Y"
"T1PNUM",23

"T2CBAN","CARD TERMINAL SERVER:"
"T2RECV","Y"
"T2PNUM",1024
"TIDLE",5
Remaining settings not shown
```

Figure 15.12 Partial Contents of SET_P5.TXT

Telnet Session

This section contains screen captures of a Telnet session with the Line 1 SEL-421. The Telnet application is included with the Windows operating system. *Figure 15.13* shows the login dialog box and the entries required to connect to the SEL-421.

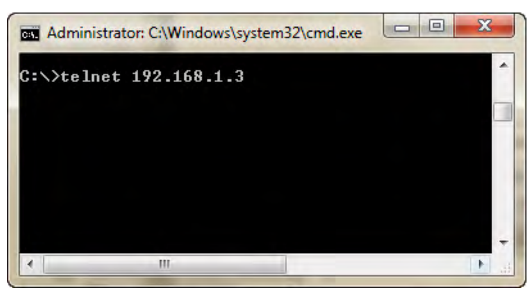

Figure 15.13 Telnet Connection Dialog Box

Figure 15.14 is a screen capture of a Telnet session with the relay. The operator connects to the relay, and displays the PORT 5 settings. Only a portion of the PORT 5 settings are shown.

```
TERMINAL SERVER:
=ACC <Enter>

Password: ?OTTER <Enter>

Relay 1                                     Date: 02/04/2016  Time: 01:17:08.142
Station A                                   Serial Number: 0000000000

Level 1

=>2AC <Enter>

Password: ?TAIL <Enter>

Relay 1                                     Date: 02/04/2016  Time: 01:17:23.082
Station A                                   Serial Number: 0000000000

Level 2

=>>SHO P 5 <Enter>
Port 5


Protocol Selection

EPORT   := Y        MAXACC  := C

SEL Protocol Settings

AUTO    := Y        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0


Fast Message Read Data Access

FMRENAB := Y        FMRLCL  := N        FMRMTR  := Y        FMRDMND := Y
FMRTAR  := Y        FMRHIS  := N        FMRBRKR := N        FMRSTAT := N
FMRANA  := Y


IP Configuration

IPADDR  := 10.201.0.112/16
DEFRTR  := "10.201.0.1"
ETCPKA  := Y        KAIDLE  := 10       KAINTV  := 1        KACNT   := 6
NETMODE := FIXED    NETPORT := A        NETASPD := AUTO     NETBSPD := AUTO
NETCSPD := AUTO     NETDSPD := AUTO


FTP Configuration

FTPSERV := N

HTTP Server Configuration

EHTTP   := N


Telnet Configuration

ETELNET := Y
TCBAN   := "TERMINAL SERVER:"
TPORT   := 23       TIDLE   := 15

DNP Configuration

EDNP    := 0


Phasor Measurement Configuration

EPMIP   := N

SNTP Protocol Selection

ESNTP   := OFF

PTP Settings

EPTP    := N
=>>QUI <Enter>
```

Figure 15.14 Example Telnet Session

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SECTION 16

DNP3 Communication

The relay provides a DNP3-2009 Level 2 outstation interface for direct network connections to the relay. This section covers the following topics:

Introduction to DNP3

A SCADA (supervisory control and data acquisition) manufacturer developed DNP3 from the lower layers of IEC 60870-5. Originally designed for use in telecontrol applications, version 3 of the protocol has also become popular for local substation data collection. DNP3 has been standardized as IEEE 1815.

Rather than wiring individual input and output points from the station RTU to the station IEDs, many stations use DNP3 to convey measurement and control data over a single serial or Ethernet cable to the RTU. The RTU then forwards data to the offsite master station. By using a data communications protocol rather than hard wiring, designers have reduced installation, commissioning, and maintenance costs while increasing remote control and monitoring flexibility.

The DNP User's Group maintains and publishes DNP3 standards in cooperation with IEEE. See the DNP User's Group web site (www.dnp.org) for more information on DNP3 standards, implementers of DNP3, and tools for working with DNP3.

DNP3 Specifications

DNP3 is a feature-rich protocol with many ways to accomplish tasks. The *Interoperability* section of IEEE 1815 defines four levels of subsets to help improve interoperability. The levels are listed in *Table 16.1*.

Table 16.1 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communications requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communications requirements	Large RTUs, SCADA masters
4	Enhanced: additional data types and functionality for more complex requirements	Large RTUs, SCADA masters

Each level is a proper superset of the next lower-numbered level. A higher level device can act as a master to a lower level device, but can only use the data types and functions implemented in the lower level device. For example, a typical SCADA master is a Level 3 device and can use Level 2 (or lower) functions to poll a Level 2 (or lower) device by using only the data types and functions that the lower-level device uses. A lower-level device can also poll a higher-level device, but the lower level device can only access the features and data available to its level.

Data Handling Objects

DNP3 uses a system of data references called object types, commonly referred to as objects. Each subset level specification requires a minimum implementation of objects and also recommends several optional objects. DNP3 objects are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for collections of data or even all data within the DNP3 device.

Each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15. Note that index numbers are 0-based.

Each object also includes multiple versions called variations. For example, Object 1 has three variations: 0, 1, and 2. Variation 0 is used to request Object 1 data from a DNP3 device using its default variation. Variation 1 is used to specify binary input values only and Variation 2 is used to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the outstation are called binary outputs, while binary status points within the outstation are called binary inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table 16.2*.

Table 16.2 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the outstation
2	Write	Send data to the outstation
3	Select	First part of a select-before-execute operate
4	Execute	Second part of a select-before-execute operate
5	Direct operate	One-step operation with acknowledgment
6	Direct operate, no ack.	One-step operation with no acknowledgment

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 remote.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four-hexadecimal byte range field, 00h 04h 00h 10h, that specifies points in the range 4–16.

Access Methods

DNP3 has many features that help it obtain maximum possible message efficiency. DNP3 Masters send requests with the least number of bytes using special objects, variations, and qualifiers that reduce the message size. Other features eliminate the continual exchange of static (unchanging) data values. These features optimize use of bandwidth and maximize performance over a connection of any speed.

DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are time-stamped records that show when observed measurements changed. For binary points, the outstation device logs changes from logical 1 to logical 0 and from logical 0 to logical 1. For analog points, the remote device logs changes that exceed a dead band. DNP3 outstation devices collect event data in a buffer that either the master can request or the device can send to the master without a request message. Data sent from the outstation to the master without a polling request are called unsolicited data.

DNP3 data fit into one of four event classes: 0, 1, 2, or 3. Class 0 is reserved for reading the present value (static data). Classes 1, 2, and 3 are event data classes. The meaning of Classes 1 to 3 is arbitrary and defined by the application at hand. With remotes that contain great amounts of data or in large systems, the three event classes provide a framework for prioritizing different types of data. For example, you can poll once a minute for Class 1 data, once an hour for Class 2 data, and once a day for Class 3 data.

Class 0 polling is also known as static polling, or simple polling of the present value of data points within the outstation. By combining event data polls, unsolicited messaging, and static polling, you can operate your system in one of the four access methods shown in *Table 16.3*.

The access methods listed in *Table 16.3* are in order of increasing communications efficiency. With various trade-offs, each method is less demanding of communications bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communications bandwidth because of the elimination of polling messages from the master required by polled report-by-exception. You must also consider overall system size and the volume of data communication expected in order to properly evaluate which access method provides optimum performance for your application.

Table 16.3 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only.
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data.
Unsolicited report-by-exception	Remote devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data.
Quiescent	Master never polls and relies on unsolicited reports only.

Binary Control Operations

DNP3 masters use Object 12 control relay output block to perform binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single index to operate two related control points, such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 outstations have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 outstations assign special operation characteristics to the latch and pulse selections.

Conformance Testing

In addition to the protocol specifications, the DNP User's Group has approved conformance testing requirements for all levels of outstation devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and remote will be fully interoperable (work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

DNP3 Serial Network Issues

You can build a DNP3 network using either a multidrop or star topology. Each DNP3 network has one or more DNP3 masters and DNP3 outstations. *Figure 16.1* shows the DNP3 multidrop network topology.

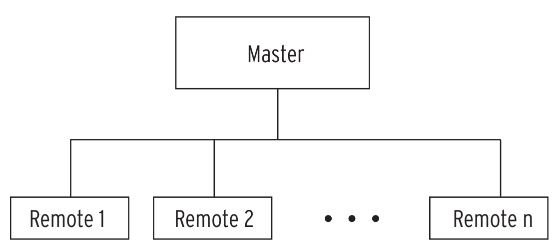

Figure 16.1 DNP3 Multidrop Network Topology

Figure 16.2 shows the DNP3 star network topology.

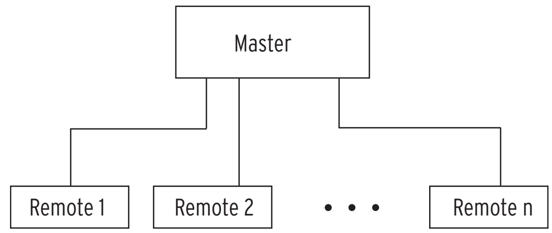

Figure 16.2 DNP3 Star Network Topology

DNP3 multidrop networks that are used within substations often use an EIA-485 physical layer. The multidrop network is vulnerable to the failure of a single transmitter. If any one transmitter fails in a state that disrupts signals on the network, the network will fail. The DNP3 star network topology eliminates the network transmitters and other single points of failure related to the physical medium.

If you are planning either a DNP3 star or network topology, you should consider the benefits of including an SEL communications processor such as the SEL-2032 or SEL-3530 RTAC in your design. A network with a communications processor is shown in *Figure 16.3*. A DNP3 network that includes a communications processor has a lower data latency and shorter scan time than comparable networks through two primary mechanisms. First, the communications processor collects data from all remotes in parallel rather than one-by-one. Second, the master can collect all data with one message and response, drastically reducing message overhead.

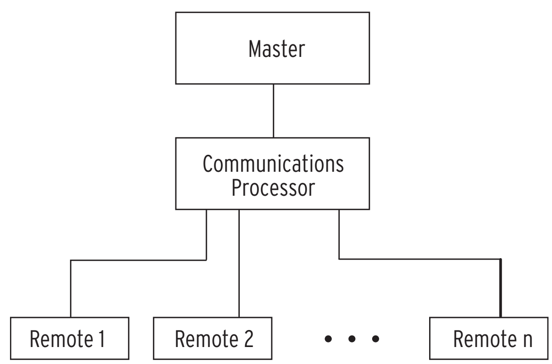

Figure 16.3 DNP3 Network With Communications Processor

In the communications processor DNP3 network, you can also collect data from devices that do not support the DNP3 protocol. The communications processor can collect data and present it to the master as DNP3 data regardless of the protocol between the communications processor and the remote device.

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (open systems interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the data link layer, includes several functions for error checking and media access control.

A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP3 specification recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before rechecking for a carrier signal. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost as a result of data collisions.

DNP3 LAN/WAN Considerations

The main process for carrying DNP3 over an Ethernet network (LAN/WAN) involves encapsulating the DNP3 data link layer data frames within the transport layer frames of the IP suite. This allows the IP stack to deliver the DNP3 data link layer frames to the destination in place of the original DNP3 physical layer.

- The DNP User's Group Technical Committee has recommended the following guidelines for carrying DNP3 over a network:
- DNP3 shall use the IP suite to transport messages over a LAN/WAN
- Ethernet is the recommended physical link, though others may be used
- TCP must be used for WANs
- TCP is strongly recommended for LANs
- UDP may be used for highly reliable single segment LANs
- UDP is necessary if broadcast messages are required
- The DNP3 protocol stack shall be retained in full
- Link layer confirmations shall be disabled

The Technical Committee has registered a standard port number, 20000, for DNP3 with the Internet Assigned Numbers Authority (IANA). This port is used for either TCP or UDP.

The Committee recommends the selection of TCP or UDP protocol as per the guidelines in *Table 16.4*.

Table 16.4 TCP/UDP Selection Guidelines

Use in the case of...	TCP	UDP
Most situations	X	
Non-broadcast or multicast	X	
Mesh Topology WAN	X	
Broadcast		X
Multicast		X
High-reliability single-segment LAN		X
Pay-per-byte, non-mesh WAN, for example, Cellular Digital Packet Data (CDPD)		X
Low priority data, for example, data monitor or configuration information		X

DNP3 in the Relay

The relay is a DNP3-2009 Level 2 outstation device. The relay DNP3 interface has the capabilities summarized in *Table 16.5*.

Table 16.5 Relay DNP3 Feature Summary

Feature	Application
DNP3 event data reporting	More efficient polling through event collection or unsolicited data
Time-tagged events	Time-stamped SER data
Control output relay blocks	Operator-initiated control
Write analog set point	Change the active protection settings group
Time synchronization	Set the relay time from the master station or automatically request time synchronization from the master
Custom mapping	Increase communications efficiency by organizing data and reducing available data to what you need for your application
Modem support	Reduce the cost of the communications channel by either master dialing to relay or relay dialing to master
Analog dead-band settings per session	Dead bands may be set to different values per session depending on desired application
Virtual Terminal	Provides engineering access for configuration, diagnostics, and other tasks over the existing DNP3 connection
TEST DB2 command	Test DNP3 protocol interface without disturbing protection
Support for Object 0 Device Attributes	Provides Device Attributes (Device ID, Number of binary, analog and counter points, Manufacturer information, etc.) for the device specific to the current connected DNP3 session in use
XML DNP3 Device Profile Document	The DNP3 Device Profile document contains the complete information on DNP3 Protocol support in the relay. This information is available in XML format.

Data Access

You can use any of the data access methods listed in *Table 16.6*. *Table 16.6* also lists the relay DNP3 settings. You must configure the DNP3 master for the data access method you select.

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, SEL recommends the polled report-by-exception access method.

Table 16.6 DNP3 Access Methods

Access Method	Master Polling	Relay Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to OFF, UNSOL to N.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, UNSOL to N.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, set UNSOL to Y and PUNSOL to Y or N.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to the desired event class, set UNSOL and PUNSOL to Y.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table 16.6*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting when you turn the relay on. If your master can send the DNP3 message to enable unsolicited reporting from the relay, you should set PUNSOL to No.

NOTE: The DNP3 LAN/WAN settings have names similar to the serial port settings above, but include the session number n as a suffix ranging from 1 to 6 (for example, CLASSB1, UNSOL1, PUNSOL1). All settings with the same numerical suffix comprise the complete DNP3 LAN/WAN session configuration.

While automatic unsolicited data transmission on power-up is convenient, problems can result if your master is not prepared to start receiving data immediately when you turn on the relay. If the master does not acknowledge the unsolicited data with an application confirm, the relay will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several outstations simultaneously begin sending data and waiting for acknowledgment messages.

Collision Avoidance

If your application requires unsolicited reporting from multiple devices on a single (serial) network medium, you must select a half-duplex medium or a medium that supports carrier detection to avoid data collisions. EIA-485 two-wire networks are half-duplex. EIA-485 four-wire networks do not provide carrier detection.

The relay uses application confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The relay pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. If you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the relay will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission.

Transmission Control

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your serial DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission. For example, an EIA-485 transceiver typically requires 10–20 ms to change from receive to transmit. If you set the predelay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

DNP3 event data objects contain change-of-state and time-stamp information that the relay collects and stores in a buffer. You can configure the relay to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, ECLASSA, and ECLASSV you can set the event class for binary, counter, analog, and virtual terminal information. You can use the classes as a simple priority system for collecting event data. The relay does not treat data of different classes differently with respect to unsolicited messages, but the relay does allow the master to perform independent class polls.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the relay.

For event data collection you must also consider and enter appropriate settings for dead band and scaling operation on analog points shown in *DNP3 Settings—Custom Maps on page 12.15*. You can either set and use default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Configurable Data Mapping on page 16.23* for a discussion of how to set scaling and dead-band operation on a point-by-point basis.

The serial port settings ANADBA, ANADBV, and ANADBM (ANADBA*n*, ANADBV*n*, and ANADBM*n* for Ethernet port settings on session *n*) control default dead-band operation for the specified data type. Because DNP3 Objects 30 and 32 use integer data by default, you can use scaling to send digits after the decimal point and avoid truncating to a simple integer value.

With no scaling, the value of 12.632 would be sent as 12. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

Set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings (DECPLA*n*, DECPLV*n*, and DECPLM*n* for Ethernet port settings on session *n*). Application of event reporting dead bands occurs after scaling in the DECPLA, DECPLV, and DECPLM. For example, if you set DECPLA to 2 and ANADBA to 10, a measured current of 10.14 amperes would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a dead band of 0.2 amperes) for the relay to report a new event value.

The relay uses the NUMEVE and AGEEVE settings (NUMEVE*n* and AGEEVE*n* Ethernet port settings for session *n*) to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE. The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The relay has the buffer capacities listed in *Table 16.7*.

Table 16.7 Relay Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	One event per analog input in the DNP3 Map
Counters	One event per counter input in the DNP3 Map
Virtual Terminal Objects	5

Binary Controls

The relay provides more than one way to control individual points within the relay. The relay maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations.

NOTE: The port setting DNPCL (or DNPCL*n* for DNP3 LAN/WAN session n) must be set to Y to enable binary controls for the DNP3 session. Binary Output Status requests (Object 10, Variation 2) and Class 0 requests will have no Binary Outputs in the response unless DNPCL := Y.

A DNP3 technical bulletin (*Control Relay Output Block Minimum Implementation 9701-002*) recommends that you use one point per Object 12, control block output relay. You can use this method to perform pulse on, latch on, and latch off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single-operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation on page 16.20*.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the relay loses primary synchronization through the IRIG-B TIME input or some other high accuracy source.

Enable time synchronization with the TIMERQ setting (TIMERQ*n* for DNP3 LAN/WAN Session *n*) and use Object 50, Variation 1, and Object 52, Variation 2 (Object 50, Variation 3 for DNP3 LAN/WAN), to set the time via a DNP3 master.

TIMERQ can be set in one of three ways:

- A numeric setting of 1–32767 minutes specifies the rate at which the relay shall request a time synchronization.
- A setting of M disables the relay from requesting a time synchronization, but still allows the relay to accept and apply time synchronization messages from the master.
- A setting of I disables the relay from requesting a time synchronization, and sets the relay to ignore time synchronization messages from the master.

Effective January 1, 2008, the DNP3 standard requires that DNP3 time correspond to Coordinated Universal Time (UTC). To help ease into the transition to this standard, you can use the DNPSRC Global setting to determine whether the relay will use local or UTC time for DNP3.

When requesting time synchronization with DNPSRC := UTC, the relay will treat incoming DNP3 time set messages as UTC time. All DNP3 event timestamps (binary input changes with time, analog input changes with time, etc.) will be in UTC time.

When requesting time synchronization with DNPSRC := LOCAL, the relay will treat incoming time set by the DNP3 master as local time. All DNP3 event timestamps will be in local time.

When setting the time with local time, there is an ambiguity during the last hour of daylight-saving time (DST) and to resolve this ambiguity, if the relay accepts a Time Set request in this hour, it will assume the time is in DST.

Modem Support

The relay DNP3 implementation includes modem support. Your DNP3 master can dial-in to the relay and establish a DNP3 connection. The relay can automatically dial out and deliver unsolicited DNP3 event data. When the relay dials out, it waits for the CONNECT message from the local modem and for assertion of the relay CTS line before continuing the DNP3 transaction. This requires a connection from the modem DCD to the relay CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your relay to other devices.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must set the port data speed slower than the effective data rate of the modem.

Either connect the modem to a computer and configure it before connecting it to the relay, or program the appropriate modem setup string in the modem startup string setting MSTR. Use the PH_NUM1 setting to set the phone number that you want the relay to dial. The relay will automatically send the ATDT modem dial command and then the contents of the PH_NUM1 setting when dialing the modem. PH_NUM1 is a text setting that must conform to the AT modem command set dialing string standard. Use a comma (,) for a pause of four seconds. You may need to include a nine to reach an outside line or a one if the number requires long distance access. You can also insert other special codes your telephone service provider designates for block call waiting and other telephone line features.

The relay supports backup dial-out to a second phone number. If PH_NUM2 is set, the RETRY1 setting is used to configure the number of times the relay tries to dial PH_NUM1 before dialing PH_NUM2. Similarly, the RETRY2 setting configures the number of times the relay tries to dial PH_NUM2 before trying PH_NUM1. MDTIME sets the length of time from initiating the call to declaring it failed because of no connection, and MDRET sets the time between dial-out attempts.

DNP3 Settings

DNP3 configuration involves both Global (SET G) and Port (SET P) settings. The Global settings govern behavior for all DNP3 sessions, serial or LAN/WAN. The Port settings apply to specific DNP3 sessions only.

There are two Global settings that directly configure DNP3. These settings, EVELOCK and DNPSRC, define the behavior of Fault Summary event retrieval and the DNP3 session time base. See *Reading Relay Event Data on page 16.21* for more information on EVELOCK. The DNPSRC setting can be either LOCAL or UTC (default). See *Time Synchronization on page 16.10* for more information on the DNPSRC setting.

The DNP3 protocol settings are shown in *Table 12.16 on page 12.10* and *Table 12.17 on page 12.11*. The DNP3 protocol settings are in the port settings for the port that you select for the DNP3 protocol. You can use DNP3 on any of the serial ports (**PORT F** and **PORT 1–PORT 3**) or Ethernet port (**PORT 5**), but you can only enable DNP3 on one serial port at a time. You may enable as many as six DNP3 sessions on the Ethernet port, independent of the number of serial DNP3 sessions enabled.

Warm Start and Cold Start

The DNP3 function codes for warm start and cold start reset the relay serial port or DNP3 Ethernet session. These function codes do not interrupt protection processes within the relay.

Testing

NOTE: The **TEST DB2** command will override the state of all instances of the forced bit or value for all active CADI2 protocols. This includes DNP3 serial and LAN/WAN and IEC 61850 GOOSE and MMS. Before using the command, take precautions to ensure against unintended operations from inadvertent messages sent as the result of a **TEST DB2** override, for example, a bit used to trip a breaker on a remote relay via IEC 61850 GOOSE.

Use the **TEST DB2** command to test the data mapping from the relay to your DNP3 master. You can use the **TEST DB2** command to force DNP3 values by object type and label. Although the relay reports forced values to the DNP3 host, these values do not affect protection processing within the relay. The **TEST DB2** command operates by object type and label, so it works equally well with custom mapping and the default DNP3 maps. See *TEST DB2 on page 14.56* for more information.

When you are using the **TEST DB2** command to test DNP3 operation, the Relay Word bit TESTDB2 will be asserted to indicate that test mode is active. The DNP3 status bit will also show forced status for any object variations that include status.

DNP3 Documentation

Object List

Table 16.8 lists the objects and variations with supported function codes and qualifier codes available in the relay. The list of supported objects conforms to the format laid out in the DNP3 specifications and includes both supported and unsupported objects. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table 16.8 Relay DNP3 Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
0	211	Device attributes—User-specific sets of attributes	1	0	129	0, 17
0	212	Device attributes—Master data set prototypes	1	0	129	0, 17
0	213	Device attributes—Outstation data set prototypes	1	0	129	0, 17
0	214	Device attributes—Master data sets	1	0	129	0, 17
0	215	Device attributes—Outstation data sets	1	0	129	0, 17
0	216	Device attributes—Max. binary outputs per request	1	0	129	0, 17
0	219	Device attributes—Support for analog output events	1	0	129	0, 17
0	220	Device attributes—Max. analog output index	1	0	129	0, 17
0	221	Device attributes—Number of analog outputs	1	0	129	0, 17
0	222	Device attributes—Support for binary output events	1	0	129	0, 17
0	223	Device attributes—Max. binary output index	1	0	129	0, 17
0	224	Device attributes—Number of binary outputs	1	0	129	0, 17
0	225	Device attributes—Support for frozen counter events	1	0	129	0, 17
0	226	Device attributes—Support for frozen counters	1	0	129	0, 17
0	227	Device attributes—support for counter events	1	0	129	0, 17
0	228	Device attributes—Max. counter index	1	0	129	0, 17
0	229	Device attributes—Number of counters	1	0	129	0, 17
0	230	Device attributes—Support for frozen analog inputs	1	0	129	0, 17
0	231	Device attributes—Support for analog input events	1	0	129	0, 17

Table 16.8 Relay DNP3 Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
0	232	Device attributes—Max. analog input index	1	0	129	0, 17
0	233	Device attributes—Number of analog inputs	1	0	129	0, 17
0	234	Device attributes—Support for double-bit events	1	0	129	0, 17
0	235	Device attributes—Max. double-bit binary index	1	0	129	0, 17
0	236	Device attributes—Number of double-bit binaries	1	0	129	0, 17
0	237	Device attributes—Support for binary input events	1	0	129	0, 17
0	238	Device attributes—Max. binary input index	1	0	129	0, 17
0	239	Device Attributes—Number of binary inputs	1	0	129	0, 17
0	240	Device attributes—Max. transmit fragment size	1	0	129	0, 17
0	241	Device attributes—Max. receive fragment size	1	0	129	0, 17
0	242	Device attributes—Device manufacturer's software version	1	0	129	0, 17
0	243	Device attributes—Device manufacturer's hardware version	1	0	129	0, 17
0	245	Device attributes—User-assigned location name	1	0	129	0, 17
0	246	Device attributes—User assigned ID code/number	1	0	129	0, 17
0	247	Device attributes—User-assigned device name	1	0	129	0, 17
0	248	Device attributes—Device serial number	1	0	129	0, 17
0	249	Device attributes—DNP3 subset and conformance	1	0	129	0, 17
0	250	Device attributes—Device manufacturer's product name and model	1	0	129	0, 17
0	252	Device attributes—Device manufacturer's name	1	0	129	0, 17
0	254	Device attributes—Non-specific all attributes request	1	0, 6	129	0, 17
0	255	Device attributes—List of attribute variations	1	0, 6	129	0, 17
1	0	Binary input—All variations	1	0, 1, 6, 7, 8, 17, 28		
1	1	Binary input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	2[a]	Binary input with status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary input change—All variations	1	6, 7, 8		
2	1	Binary input change without time	1	6, 7, 8	129	17, 28
2	2	Binary input change with time	1	6, 7, 8	129, 130	17, 28
2	3	Binary input change with relative time	1	6, 7, 8	129	17, 28
10	0	Binary output—All variations	1	0, 1, 6, 7, 8		
10	1	Binary output				
10	2[a]	Binary output status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control block—All variations				
12	1	Control relay output block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern control block	3, 4, 5, 6	7	129	echo of request
12	3	Pattern mask	3, 4, 5, 6	0, 1	129	echo of request

Table 16.8 Relay DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
20	0	Binary counter—All variations	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit binary counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	2	16-Bit binary counter	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28		
20	3	32-Bit delta counter				
20	4	16-Bit delta counter				
20	5	32-Bit binary counter without flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[a]	16-Bit binary counter without flag	1, 7, 8, 9, 10	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit delta counter without flag				
20	8	16-Bit delta counter without flag				
21	0	Frozen counter—All variations				
21	1	32-Bit frozen counter				
21	2	16-Bit frozen counter				
21	3	32-Bit frozen delta counter				
21	4	16-Bit frozen delta counter				
21	5	32-Bit frozen counter with time of freeze				
21	6	16-Bit frozen counter with time of freeze				
21	7	32-Bit frozen delta counter with time of freeze				
21	8	16-Bit frozen delta counter with time of freeze				
21	9	32-Bit frozen counter without flag				
21	10	16-Bit frozen counter without flag				
21	11	32-Bit frozen delta counter without flag				
21	12	16-Bit frozen delta counter without flag				
22	0	Counter change event—All variations	1	6, 7, 8		
22	1	32-Bit counter change event without time	1	6, 7, 8	129	17, 28
22	2[a]	16-Bit counter change event without time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit delta counter change event without time				
22	4	16-Bit delta counter change event without time				
22	5	32-Bit counter change event with time	1	6, 7, 8	129	17, 28
22	6	16-Bit counter change event with time	1	6, 7, 8	129	17, 28
22	7	32-Bit delta counter change event with time				
22	8	16-Bit delta counter change event with time				
23	0	Frozen counter event—All variations				
23	1	32-Bit frozen counter event without time				
23	2	16-Bit frozen counter event without time				
23	3	32-Bit frozen delta counter event without time				
23	4	16-Bit frozen delta counter event without time				

Table 16.8 Relay DNP3 Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
23	5	32-Bit frozen counter event with time				
23	6	16-Bit frozen counter event with time				
23	7	32-Bit frozen delta counter event with time				
23	8	16-Bit frozen delta counter event with time				
30	0	Analog input—All variations	1	0, 1, 6, 7, 8, 17, 28		
30	1[b]	32-Bit analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2[b]	16-Bit analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129, 130	0, 1, 17, 28
30	3[b]	32-Bit analog input without flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[b]	16-Bit analog input without flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	5[b]	Single-precision floating point analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6[b]	Double-precision floating point analog input with flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen analog input—All variations				
31	1	32-Bit frozen analog input				
31	2	16-Bit frozen analog input				
31	3	32-Bit frozen analog input with time of freeze				
31	4	16-Bit frozen analog input with time of freeze				
31	5	32-Bit frozen analog input without flag				
31	6	16-Bit frozen analog input without flag				
32	0	Analog change event—All variations	1	6, 7, 8		
32	1[b]	32-Bit analog change event without time	1	6, 7, 8	129	17, 28
32	2[b]	16-Bit analog change event without time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit analog change event with time	1	6, 7, 8	129	17, 28
32	4	16-Bit analog change event with time	1	6, 7, 8	129	17, 28
32	5[b]	Single-precision floating point analog change event without time	1	6, 7, 8	129	17, 18
32	6[b]	Double-precision floating point analog change event without time	1	6, 7, 8	129	17, 18
32	7[b]	Single-precision floating point analog change event with time	1	6, 7, 8	129	17, 28
32	8[b]	Double-precision floating point analog change event with time	1	6, 7, 8	129	17, 28
33	0	Frozen analog event—All variations				
33	1	32-Bit frozen analog event without time				
33	2	16-Bit frozen analog event without time				
33	3	32-Bit frozen analog event with time				
33	4	16-Bit frozen analog event with time				

Table 16.8 Relay DNP3 Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
34	0	Analog input dead band—All variations	1	0, 1, 6, 7, 8, 17, 28		
34	1	16-Bit analog input dead band	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2[a]	32-Bit analog input dead band	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Single-precision floating point analog input dead band	1, 2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog output status—All variations	1	0, 1, 6, 7, 8		
40	1	32-Bit analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[a]	16-Bit analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	3	Single-precision floating point analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	4	Double-precision floating point analog output status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
41	0	Analog output block—All variations				
41	1	32-Bit analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	3	Single-precision floating point analog output block	3, 4, 5, 6	17, 28	129	echo of request
41	4	Double-precision floating point analog output block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and date—All variations				
50	1	Time and date	1, 2	7, 8 index = 0	129	07, quantity = 1
50	2	Time and date with interval				
50	3	Time and date at last recorded time	2	7 quantity = 1	129	
51	0	Time and date CTO—All variations				
51	1	Time and date CTO			129	07, quantity = 1
51	2	Unsynchronized time and date CTO			129	07, quantity = 1
52	0	Time delay—All variations				
52	1	Time delay, coarse				
52	2	Time delay, fine			129	07, quantity = 1
60	0	All classes of data	1, 20, 21, 22	6, 7, 8		
60	1	Class 0 data	1, 22	6, 7, 8		
60	2	Class 1 data	1, 20, 21, 22	6, 7, 8		
60	3	Class 2 data	1, 20, 21, 22	6, 7, 8		
60	4	Class 3 data	1, 20, 21, 22	6, 7, 8		
70	1	File identifier				
80	1	Internal indications	2	0, 1 index = 4, 7		

Table 16.8 Relay DNP3 Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a]		Response[a]	
			Funct. Codes	Qual. Codes	Funct. Codes	Qual. Codes
81	1	Storage object				
82	1	Device profile				
83	1	Private registration object				
83	2	Private registration object descriptor				
90	1	Application identifier				
100	1	Short floating point				
100	2	Long floating point				
100	3	Extended floating point				
101	1	Small packed binary—Coded decimal				
101	2	Medium packed binary—Coded decimal				
101	3	Large packed binary—Coded decimal				
112	All	Virtual terminal output block	2	6		
113	All	Virtual terminal event data	1	6	129, 130	17, 28
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Default variation.
[b] Setting AIVAR determines default variation.

Device Profile

The DNP3 Device Profile document, available on the supplied CD or as a download from the SEL website, contains the standard device profile information for the relay. This information is also available in XML format. Please refer to this document for complete information on DNP3 Protocol support in the relay.

Reference Data Map

Table 16.9 shows the common portions of the relay DNP3 reference data map. See *Section 10: Communications Interfaces* in the product-specific instruction manual for a complete DNP3 reference map for that relay. You can use the default map or the custom DNP3 mapping functions of the relay to include only the points required by your application.

The entire Relay Word (see *Section 11: Relay Word Bits* in the product-specific instruction manual) is part of the DNP3 reference map. You may include any label in the Relay Word as part of a DNP3 custom map.

The relay scales analog values by the indicated settings or fixed scaling. Analog inputs for event (fault) summary reporting use a default scale factor of 1 and dead band of ANADBM. Per-point scaling and dead band settings specified in a custom DNP3 map will override defaults.

Table 16.9 Relay DNP3 Reference Data Map (Sheet 1 of 2)

Object	Label	Description
Binary Inputs		
01, 02	RLYDIS	Relay disabled
01, 02	STFAIL	Relay diagnostic failure
01, 02	STWARN	Relay diagnostic warning
01, 02	STSET	Settings change or relay restart
01, 02	UNRDEV	New relay event available
01, 02	NUNREV	An unread event exists, newer than the event in the event summary AIs
01, 02	LDATPFW	Leading true power factor A-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDBTPFW	Leading true power factor B-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LDCTPFW	Leading true power factor C-Phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	LD3TPFW	Leading true power factor three-phase, Terminal W (1 if leading, 0 if lagging or zero)
01, 02	Relay Word	Relay Word bit label
Binary Outputs		
10, 12	RB01–RB*nn*	Remote bits RB01–RB*nn*[a]
10, 12	RB01:RB02 RB03:RB04 RB05:RB06 • • • RB29:RB30 RB31:RB*nn*	Remote bit pairs RB01–RB*nn*[a]
10, 12	OC*m*	Pulse open Circuit Breaker *m* command[b]
10, 12	CC*m*	Pulse close Circuit Breaker *m* command[b]
10, 12	OC*m*:CC*m*	Open/close pair for Circuit Breaker *m*[b]
10, 12	89OC01–89OC*dd*	Open Disconnect Switch Control 1–*dd*[c]
10, 12	89CC01–89CC*dd*	Close Disconnect Switch Control 1–*dd*[c]
10, 12	89OC01:89CC01 89OC02:89CC02 89OC03:89CC03 • • • 89OC*dd*:89CC*dd*	Open/close Disconnect Switch Control Pair 1–*dd*[c]
10, 12	RST_DEM	Reset demands[d]
10, 12	RST_PDM	Reset demand peaks[d]
10, 12	RST_ENE	Reset energies[d]
10, 12	RSTMML	Reset min/max metering data for the line[d]
10, 12	RSTMMB*m*	Reset min/max metering data for Circuit Breaker *m*[d]
10, 12	RST_BK*m*	Reset Breaker *m* monitor data[d]
10, 12	RST_BAT	Reset battery monitor data[d]
10, 12	RST_79C	Reset recloser shot counter[d]
10, 12	RSTFLOC	Reset fault location data[d]
10, 12	RSTTRGT	Reset front-panel targets[d]

Table 16.9 Relay DNP3 Reference Data Map (Sheet 2 of 2)

Object	Label	Description
10, 12	RSTDNPE	Reset (clear) DNP3 event summary AIs[d]
10, 12	NXTEVE	Load next fault event into DNP3 event summary AIs
Binary Counters		
20, 22	ACTGRP	Active settings group
NOTE: Additional binary counters are relay specific. See the relay instruction manual to see what counter objects are available.		
Analog Inputs		
NOTE: The analog inputs available is relay dependent. See the relay instruction manual to determine what analog inputs are available.		
Analog Outputs		
40, 41	ACTGRP0	Active settings group
40, 41	TECORR[e]	Time-error preload value
40, 41	RA001–RA256	Remote analogs

[a] The number of remote bits available, *nn*, depends on the specific relay. See the relay instruction manual to see how many are available.
[b] The number of breakers to control and their designations, *m*, depends on the specific relay. See the relay instruction manual to determine which breakers are available.
[c] The number of disconnect controls, *dd*, available depends on the relay. See the relay instruction manual to determine how many disconnects are supported. Not all SEL-400 series relays support disconnect controls.
[d] Not all SEL-400 series relays support all of these resets. See the relay instruction manual to see which specific controls are available.
[e] In milliseconds, $-30000 \le \text{time} \le 30000$. Relay Word bit PLDTE asserts for approximately 1.5 cycles after this value is written.

Device Attributes (Object 0)

Table 16.8 includes the supported Object 0 device attributes and variations. In response to Object 0 requests, the relay will send attributes that apply to that particular DNP3 session. Because the relay supports custom DNP3 maps, these values will likely be different for each session.

The relay uses its internal settings for the following variations:

- Variation 245—SID Global setting
- Variation 246—DNPID port setting
- Variation 247—RID Global setting

Binary Inputs

Binary inputs (Objects 1 and 2) are supported as defined by *Table 16.8*. The default variation for both static and event inputs is 2. Only the Read function code (1) is allowed with these objects. The relay will respond to an Object 2, Variation 3 request, but the response will contain no data.

The relay scans binary inputs approximately twice per second to generate DNP3 change events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. Binary inputs registered with SER are derived from the SER process and carry the time stamp of actual occurrence. Some additional binary inputs are available to DNP3, most without SER time stamps. For example, RLYDIS is derived from the relay status variable, STWARN and STFAIL are derived from the diagnostic task data, and UNRDEV and NUNREV are derived from the event queue. Another binary input, STSET, is derived from the SER and carries the time stamp of actual occurrence.

Binary Outputs

Binary output status (Object 10, Variation 2) is supported as defined by *Table 16.8*. Static reads of points RB01–RB*nn*, OC*m*, CC*m*, 89OC01–89OC*dd*, and 89CC01–89CC*dd* respond with the online bit set and the state of the requested bit. Reads from control-only binary output points (such as the data reset controls RSTTRGT and RSTDNPE) respond with the online bit set and a state of 0.

The relay supports control relay output block objects (Object 12, Variation 1). The control relays correspond to the remote bits and other functions as shown above. Each DNP3 control message contains a trip/close code (TRIP, CLOSE, or NUL) and an operation type (PULSE ON, LATCH ON, LATCH OFF, or NUL). The trip/close code works with the operation type to produce set, clear, and pulse operations.

Control operations differ slightly for single-point controls compared to paired outputs. Paired outputs correspond to the complementary two-output model, and single-point controls follow the complementary latch or activation model. In the complementary two-output model, paired points only support close or trip operations, which, when issued, will pulse on the first or second point in the pair, respectively. Latch commands and pulse operations without a trip code are not supported. An operation in progress may be canceled by issuing a NUL trip/close code with a NUL operation type. Single output points support both pulse and latch operations. See *Control Point Operation on page 16.20* for details on control operations.

The status field is used exactly as defined. All other fields are ignored. A pulse operation is asserted for a single processing interval. You should exercise caution if sending multiple remote bit pulses in a single message (i.e., point count > 1), because this may result in some of the pulse commands being ignored and the return of an already active status message. The relay will only honor the first ten points in an Object 12, Variation 1 request. Any additional points in the request will return the DNP3 status code `TOO_MANY_OBJS`.

The relay also supports pattern control blocks (Object 12, Variations 2 and 3) to control multiple binary output points. Variation 2 defines the control type (trip/close, set/clear, or pulse) and the range of points to operate. Variation 3 provides a pattern mask that indicates which points in that range should be operated. Object 12, Variations 2 and 3 define the entire control command: the DNP3 master must send both for a successful control. For example, the DNP3 master sends an Object 12, Variation 2 message to request a trip of the range of indices 0–7. The DNP3 master then sends an Object 12, Variation 3 message with a hexadecimal value of “BB” as the pattern mask (converted to binary notation: 10111011). Read right to left in increasing bit order, the pattern block control command will result in a TRIP of indexes 0, 1, 3 to 5, and 7.

Control Point Operation

Use the trip and close, latch on/off and pulse on operations with Object 12 control relay output block command messages to operate the binary output points. See *Section 10: Communications Interfaces* in the product-specific instruction manual for a complete table of object 12 controls available in that relay. Pulse operations provide a pulse with duration of one protection processing interval. Cancel an operation in progress by issuing a NUL trip/close code with a NUL operation type.

Analog Inputs

Analog inputs (Objects 30 and 32) are supported as defined by *Table 16.8* The default variation for both static and event inputs is defined by the AIVAR (AIVAR*n* for DNP3 LAN/WAN session *n*) setting. Only the Read function code (1) is allowed with these objects.

Unless otherwise indicated, analog values are reported in primary units. Voltage magnitudes below 0.10 volts and current magnitudes below 5 percent of I_{NOM} are forced to 0, as are their corresponding angles. Default scaling is indicated in the product-specific instruction manual, but default scaling can be overridden by per-point scaling in a custom DNP3 map. The DECPLA, DECPLV, and DECPLM settings are the default scaling factors (in powers of 10) for current magnitudes, voltage magnitudes, and miscellaneous magnitudes, respectively. See *Configurable Data Mapping on page 16.23* for more information.

Default dead bands are also indicated in the product-specific instruction manual and may be overridden by per-point dead-band configuration. In general, the ANADBA, ANADBV, and ANADBM settings are the default dead bands for current magnitudes, voltage magnitudes, and miscellaneous magnitudes, respectively. Dead bands are applied after any custom or default scaling factors. Events are generated when values exceed dead bands.

Reading Relay Event Data

The relay provides protective relay event history information in one of two modes: single-event or multiple-event access. Each DNP3 session begins in the mode specified by Port setting EVEMOD*n* (where *n* = 1–6 for Ethernet sessions and not present for serial sessions). The selected mode is entered when the relay is first enabled, when there is a DNP3 settings change, a DNP3 map change, or an SER settings change. When EVEMOD*n* = SINGLE, the relay powers up in single-event mode. When EVEMOD*n* = MULTI, the relay powers up in multiple-event mode. A DNP3 session will switch to multiple-event mode if the session DNP3 master sends a control to the NXTEVE binary output control point. The DNP3 session will revert to the default mode after a power cycle or relay restart.

When a relay event occurs, (TRIP asserts, ER asserts, or TRI asserts) whose fault location is in the range of MINDIST to MAXDIST, the data shall be made available to DNP3. If MINDIST is set to OFF, then there is no minimum. Similarly, if MAXDIST is set to OFF, there is no maximum. Only SEL-4XX line relays support the MINDIST and MAXDIST settings.

In either mode, DNP3 events for all event summary analog inputs will be generated if any of them change beyond their dead band value after scaling (usually whenever a new relay event occurs and is loaded into the event summary analog inputs). Events are detected approximately twice a second by the scanning process.

The specific fault data available and its encoding is relay specific. See *Section 10: Communications Interfaces* in the product-specific instruction manual for information on the relay reports fault data.

Single-Event Mode

Single-event mode provides the most recent tripping event. When a relay event occurs and FLOC is in range of MINDIST and MAXDIST, these data are copied to the DNP3 fault summary analog inputs, generating appropriate DNP3 events. The relay shall then ignore any subsequent events for EVELOCK (Global setting) time. When the EVELOCK setting is zero, single-event mode effectively acts as a zero-buffer FIFO queue. In this mode, relay events are presented to generate DNP3 events for the fault summary analog inputs as they occur. Fault summary analog inputs shall be reset to 0 on a rising edge of RSTDNPE (Global SELOGIC equation result). The relay element EVELOCK shall be set when a relay event is triggered and reset when EVELOCK time expires.

Multiple-Event Mode

Relay multiple-event summary data can be read in two ways: first in, first out (FIFO); or last in, first out (LIFO).

See *FIFO on page 16.22* and *LIFO on page 16.22* below for procedures to retrieve relay events that occur when FLOC is in range of MINDIST and MAXDIST. Event retrieval as shown below is a manual monitor, control, and poll process. A DNP3 master can collect relay event summaries using event data rather than the static data polling described below. For best results, the master must control the NXTEVE binary output no faster than once every two seconds to load a new event into the event summary analog inputs. If the NXTEVE binary output is controlled at a faster rate, some DNP3 events may not be recognized and processed by the DNP3 event scanner.

FIFO

Multiple-event FIFO mode shall be initiated if the DNP3 session master operates the NXTEVE (next event) control. The master should monitor the UNRDEV binary input point, which will be asserted when there is an unread relay event summary. The NUNREV bit will also be asserted as long as there remain any unread events newer than the currently loaded event summary. To read the oldest unread relay event summary, the master should send a close, latch on, or pulse-on control to the NXTEVE binary output point. This will load the relay event summary analogs with information from the oldest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check the UNRDEV binary input point, which will be on if there is another unread relay event summary. The master should continue this process until the UNRDEV binary input point deasserts. If the master attempts to load values by controlling the NXTEVE output point when the UNRDEV binary input point is deasserted, the relay event type analog (FTYPE) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

LIFO

Multiple-event LIFO mode event summary retrieval is similar to FIFO retrieval, with the following difference: to read the newest unread relay event summary, the master should send a latch off control to the NXTEVE binary output point. As with FIFO retrieval, the master should monitor the UNRDEV binary input to determine if there are any unread events. Users must be aware of one caveat with LIFO retrieval: if an event occurs while in the process of reading the newest event(s) event collection will no longer continue in reverse chronological order. The next event read will be the newest event, and will proceed with the next newest, but any events that have already been read shall be skipped. The NUNREV bit will be asserted if this happens, signifying that the currently loaded event summary is no longer the newest event.

Analog Outputs

Analog outputs (Objects 40 and 41) are supported as defined by *Table 16.8*. The default variation for both static and event inputs is Variation 2. If an invalid value is written, the relay will ignore the value without generating an error.

The relay will only honor the first ten points in a request. Any additional points in the request will be ignored without generating an error.

Counters

Counters (Object 20 and 22) are supported as defined by *Table 16.8*. The default variation for Object 20 is Variation 6, and Variation 2 is the default for Object 22. Counters shall only support the Read function code (1). A Read of Object 21 will receive a Null response. The default dead band is 0, which may be overridden by a per-point dead band in a custom map. Scaling for counters is always 1.

Default Data Map

See *Section 10: Communications Interfaces* in the product-specific instruction manual to see the relay default map. If the default maps are not appropriate, you can also use the custom DNP3 mapping commands **SET D *n*** and **SHOW D *n***, where *n* is the map number, to edit or create the map required for your application.

Configurable Data Mapping

One of the most powerful features of the relay DNP3 implementation is the ability to remap DNP3 data and, for analog and counter inputs, specify per-point scaling and dead bands. Remapping is the process of selecting data from the default or reference map and organizing it into a dataset optimized for your application. The relay uses point labels rather than point indexes in a reference map to streamline the remapping process. This enables you to quickly create a custom map without having to search for point indexes in a large reference map.

You may use any of the six available DNP3 maps to exchange data with any DNP3 master. Each map is initially populated with default data points, as described in the Default DNP3 Map. You may remap the points in a default map to create a custom map with as many as:

- 400 binary inputs
- 100 binary outputs
- 20 counters
- 200 analog inputs
- 100 analog outputs

Use the settings Class D to access the relay DNP3 map settings shown in *DNP3 Settings—Custom Maps on page 12.15*. There are five DNP3 maps available to customize, or leave as default.

The mapping settings are entered in a line-based freeform format. An example of these settings is shown in *Figure 16.4*. You can program a custom scaling and dead band for each point where indicated. If you do not specify a custom scaling or dead band, the relay will use the default for the type of value you are mapping. For example, if you enter the label 3P_F in Row 1 of the custom analog map with no other parameters, the power in MW will be available as Objects 30 and 32, Index 0 and the relay will use the default scaling DECPLM and default dead band of ANADBM.

You can use the **SHOW D *x*** command to view the DNP3 data map settings, where *x* is the DNP3 map number from 1 to 6. See *Figure 16.4* for an example display of Map 1.

```
=>>SHO D 1 <Enter>
DNP 1

DNP Object Default Map Enables

DNPBID  := N       DNPBOD  := N       DNPCOD  := N       DNPAID  := N
DNPAOD  := N       MINDIST := OFF     MAXDIST := OFF


Binary Input Map
(Binary Input Label)

1: EN_RLY
2: TRIPLED
.
.
.
13: RB04
14: RB05
15: RB06


Binary Output Map
(Binary Output Label)

1: RB01
2: RB02
.
.
.
5: RB05
6: RB06


Counter Map
(Counter Label, Deadband)

1: ACTGRP

Analog Input Map
(Analog Input Label, Scale Factor, Deadband)

1: IAWFMC
2: IAWFAC
.
.
.
15: 3SWFC
16: VDC1


Analog Output Map
(Analog Output Label)

1: ACTGRP
```

Figure 16.4 Sample Response to SHO D Command

You can use the **SET D *x*** command (where *x* is the map number), to edit or create custom DNP3 data maps. You can also use QuickSet, which is recommended for this purpose.

See the Reference Map to determine the available choices for each object type.

For binary inputs, a value of 0 or 1 may be used instead of a label; this will cause the relay to report that value for that point. Similarly, for counters and analog inputs, a value of 0 may be used instead of a label which will cause the relay to report 0 for that point. A NOOP can be used as a placeholder for binary or analog outputs-control of a point with this label does not change any relay values nor respond with an error message. Duplicate point labels are not allowed within a map, except for the values 0 or 1 or NOOP.

You can customize the DNP3 analog input map with per-point scaling and dead-band settings. Class scaling (DECPLA*n*, DECPLV*n*, and DECPLM*n*) and dead-band settings (ANADBA*n*, ANADBV*n*, and ANADBM*n*) are applied to indices that do not have per-point entries. Per-point scaling overrides any class scaling and dead-band settings. Unlike per-point scaling, class-level scaling is specified by an integer in the range 0–3 (inclusive), which indicates the number of decimal place shifts. In other words, you should select 0 to multiply by 1, 1 for 10, 2 for 100, or 3 for 1000.

NOTE: The settings above contain the DNP3 LAN/WAN session suffix n. This suffix is not present in serial port DNP3 settings.

Scaling factors allow you to overcome the limitations imposed, by default, of the integer nature of Objects 30 and 32. For example, DNP3, by default, truncates a value of 11.4 A to 11 A. You may use scaling to include decimal point values by multiplying by a power of 10. For example, if you use 10 as a scaling factor, 11.4 A will be transmitted as 114. You must divide the value by 10 in the master to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. For example, if you have a value that can reach 157834, you cannot send it using DNP3 16-bit analog object variations. You could use a scaling factor of 0.1 so that the maximum value reported is 15783. You can then multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is dropped in the scaling process, but you can transmit the scaled value using the default variations for DNP3 Objects 30 and 32.

If your DNP3 master has the capability to request floating-point analog input variations, the relay will support them. These floating point variations, 5 and 6 for Object 30 and 5–8 for Object 32, allow the transmission of 16- or 32-bit floating point values to DNP3 masters. When used, these variations eliminate the need for scaling and maintain the resolution of the relay analog values. Note that this support is greater than DNP3 Level 4 functionality, so you must confirm that your DNP3 master can work with these variations before you consider using floating point analog variations.

The following example describes how to create a custom DNP3 map by point type. The example demonstrates the **SET D** command for analog inputs. Alternately, you can use the QuickSet software to simplify custom data map creation. The example uses quantities available in the SEL-411L, but similar operations can be performed on any SEL-400 series relay.

Consider a case where you want to set the analog input points in a map as shown in *Table 16.10*.

Table 16.10 Sample Custom DNP3 Analog Input Map

Point Index	Description	Label	Scaling	Dead band
0	Fundamental IA magnitude	LIAFM	Default	Default
1	Fundamental IB magnitude	LIBFM	Default	Default
2	Fundamental IC magnitude	LICFM	Default	Default
3	Fundamental IC magnitude	LIAFM	Default	Default
4	Fundamental three-phase power	3P_F	5	Default
5	Fundamental A-Phase magnitude	VAFM	Default	Default
6	Fundamental A-Phase angle	VAFA	1	15
7	Frequency	FREQ	0.01	1

To set these points as part of custom map 1, you can use the **SET D 1 TERSE** command as shown in *Figure 16.5*.

```
=>>SET D 1 TERSE <Enter>
DNP 1

DNP Object Default Map Enables


Use default DNP map for Binary Inputs (Y/N) DNPBID := Y ?<Enter>
Use default DNP map for Binary Outputs (Y/N) DNPBOD := Y ?<Enter>
Use default DNP map for Counters (Y/N) DNPCOD := Y ?<Enter>
Use default DNP map for Analog Inputs (Y/N) DNPAID := Y ?N <Enter>
Use default DNP map for Analog Outputs (Y/N) DNPAOD := Y ?<Enter>
Min Fault Location to Capture (OFF,-10000 - 10000)   MINDIST := OFF    ?
Max Fault Location to Capture (OFF,-10000 - 10000)   MAXDIST := OFF    ?

Analog Input Map
(Analog Input Label, Scale Factor, Deadband)
1:
? LIBFM <Enter>
2:
? LICFM <Enter>
3:
? LIAFM <Enter>
4:
? 3P_F,5 <Enter>

5:
? VAFM <Enter>
6:
? VAFA,1,15 <Enter>
7:
? FREQ,.01,1 <Enter>
8:
? END
Save settings (Y,N) ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
```

Figure 16.5 Sample Custom DNP3 Analog Input Map Settings

DNP3 Serial Application Example

Application

This example uses an SEL-421 connected to an RTU over an EIA-485 network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure 16.6*.

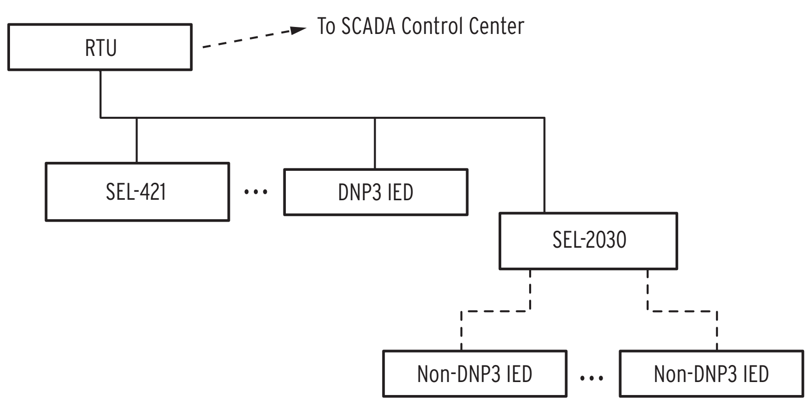

Figure 16.6 DNP3 Application Network Diagram

The metering and status data that the RTU collects from the relay are listed in *Table 16.11*.

Table 16.11 DNP3 Application Example Data Map

Label	Object	Custom Map Index	Description
EN	1, 2	0	Relay enabled
TRIPLED	1, 2	1	Circuit Breaker tripped
IN101	1, 2	2	Relay Discrete Input 1
IN102	1, 2	3	Relay Discrete Input 2
IN103	1, 2	4	Relay Discrete Input 3
IN104	1, 2	5	Relay Discrete Input 4
SALARM	1, 2	6	Relay software alarm
HALARM	1, 2	7	Relay hardware alarm
TESTDB2	1, 2	8	Test mode enabled
RB01	10, 12	0	Remote Bit 1
RB02	10, 12	1	Remote Bit 2
RB03	10, 12	2	Remote Bit 3
RB04	10, 12	3	Remote Bit 4
RB05	10, 12	4	Remote Bit 5
RB06	10, 12	5	Remote Bit 6
OC1:CC1	10, 12	6	Circuit Breaker 1 trip/close pair
LIAFM	30, 32	0	IA magnitude
LIAFA	30, 32	1	IA angle
LIBFM[a]	30, 32	2	IB magnitude
LIBFA[b]	30, 32	3	IB angle
LICFM[a]	30, 32	4	IC magnitude
LICFA[b]	30, 32	5	IC angle
VAFM[c]	30, 32	6	VAY magnitude
VAFA[b]	30, 32	7	VAY angle
VBFM[c]	30, 32	8	VBY magnitude
VBFA[b]	30, 32	9	VBY angle
VCFM[c]	30, 32	10	VCY magnitude
VCFA[b]	30, 32	11	VCY angle
3P_F[d]	30, 32	12	Three-phase real power in MW
3Q_F[d]	30, 32	13	Three-phase reactive power in MVAR
DC1[e]	30, 32	14	DC1 voltage multiplied by 100
ACTGRP	40	0	Active settings group

[a] Assume the largest expected current is 2000 A and scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.

[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.

[d] For a maximum load of 800 MW (or 800 mVar), scale the power by a factor of 40 to provide a resolution of 0.025 MW and a maximum value of 819.175 MW. Report 1 MW for change event reporting.

[e] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Figure 16.7 shows how to enter the new map into the relay. Use the **SET D** command and enter N at the prompts shown in *Figure 16.7* to allow changes to the existing maps. Press **<Enter>** at the empty line prompt to advance to the next map. For example, press **<Enter>** at line 10 of the Binary Input Map to advance to the Binary Output Map. If the prompt contains an entry, you can enter the greater-than symbol (>) and press **<Enter>** to advance to the next step.

```
=>>SET D 1 TERSE <Enter>
DNP 1

DNP Object Default Map Enables

Min Fault Location to Capture (OFF,-10000 - 10000)   MINDIST := OFF    ? <Enter>
Max Fault Location to Capture (OFF,-10000 - 10000)   MAXDIST := OFF    ? <Enter>

Binary Input Map
(Binary Input Label)

1: RLYDIS
?  DELETE 100 <Enter>
1:
?  EN <Enter>
2:
?  TRIPLED <Enter>
3:
?  IN101 <Enter>
4:
?  IN102 <Enter>
5:
?  IN103 <Enter>
6:
?  IN104 <Enter>
7:
?  SALARM <Enter>
8:
?  HALARM <Enter>
9:
?  TESTDB2 <Enter>
10:
? <Enter>

Binary Output Map
(Binary Output Label)

1: RB01
?  DELETE 100 <Enter>
1:
?  RB01 <Enter>
2:
?  RB02 <Enter>
3:
?  RB03 <Enter>
4:
?  RB04 <Enter>
5:
?  RB05 <Enter>
6:
?  RB06 <Enter>
7:
?  OC1:CC1 <Enter>
8:
? <Enter>

Counter Map
(Counter Label, Deadband)

1: ACTGRP
?
2: BKR1OPA
? DELETE 100 <Enter>
2:
? <Enter>
```

Figure 16.7 SEL-421 Example DNP Map Settings

```
Analog Input Map
(Analog Input Label, Scale Factor, Deadband)

1: LIAFM
?  <Enter>
2: LIAFA
?  LIAFA,1,200 <Enter>
3: LIBFM
? <Enter>
4: LIBFA
?  LIBFA,1,200 <Enter>
5: LICFM
? <Enter>
6: LICFA
?  LICFA,1,200 <Enter>
7: B1IAFM
?  VAFM <Enter>
8: B1IAFA
?  VAFA,1,200 <Enter>
9: B1IBFM
?  VBFM <Enter>
10: B1IBFA
?  VBFA,1,200 <Enter>
11: B1ICFM
?  VCFM <Enter>
12: B1ICFA
?  VCFA,1,200 <Enter>
13: B2IAFM
?  3P_F,40,40 <Enter>
14: B2IAFA
?  3Q_F,40,40 <Enter>
15: B2IBFM
?  DC1,,200 <Enter>
16: B2IBFA
?  DELETE 200 <Enter>
16:
? <Enter>


Analog Output Map
(Analog Output Label)

1: ACTGRP
? <Enter>
2:
? <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved
=>>
```

Figure 16.7 SEL-421 Example DNP Map Settings (Continued)

Table 16.12 lists the settings for **PORT 3** for this example. The physical connection between the relay and the DNP3 master is an EIA-485 network. An SEL-2884 interface converter on the relay **PORT 3** provides conversion from EIA-232 to EIA-485. Unsolicited reporting has been disabled because the network is wired as a four-wire connection and does not provide carrier detection or the opportunity to monitor for data traffic on the network.

Table 16.12 SEL-421 Port 3 Example Settings (Sheet 1 of 2)

Setting Name	Setting	Description
EPORT	Y	Enable port
MAXACC	2	Maximum access level for virtual terminal sessions
PROTO	DNP	DNP3 protocol
SPEED	9600	Data speed
PARITY	N	No parity bit
STOPBIT	1	1 stop bit
TIMEOUT	5	Time out virtual terminal session after 5 minutes
TERTIM1	1	Check for termination after 1 second idle time
TERSTRN	“\005”	Virtual terminal termination string

Table 16.12 SEL-421 Port 3 Example Settings (Sheet 2 of 2)

Setting Name	Setting	Description
TERTIM2	0	No delay before accepting termination string
DNPADR	101	DNP3 address = 101
DNPID	“RELAY1-DNP”	DNP ID for Object 0 self-description
DNPMAP	1	Use DNP3 Map 1
ECLASSB	1	Event Class 1 for binary event data
ECLASSC	1	Event Class 1 for counter event data
ECLASSA	1	Event Class 1 for analog event data
ECLASSV	OFF	Disable virtual terminal event data (this feature is not supported by the DNP3 master)
TIMERQ	I	Ignore time-set request because IRIG-B is used for time synchronization
DECPLA	1	Scale current, multiplying by 10 to send amperes and tenths of an ampere. The relay would report a value of 10.4 as 104, which would remain unscaled at the master.
DECPLV	2	Scale voltage, multiplying by 100 to send kilovolts, tenths, and hundredths of a kilovolt
DECPLM	2	Scale miscellaneous analog data, multiplying by 100 to send whole numbers and hundredths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master.
STIMEO	10.0	10 second select before operate time-out
DRETRY	OFF	Turn off data link retries
MINDLY	0.05	Minimum delay from DCD to TX
MAXDLY	0.10	Maximum delay from DCD to TX
PREDLY	0.025	Settle time from RTS on to TX to allow EIA-485 transceiver to switch to transmit mode
PSTDLY	0.00	Settle time from TX to RTS off—not required in this application
DNPCL	Y	Enable controls for DNP3
AIVAR	2	Default AI variation
ANADBA	50	Analog reporting dead band for currents, 5 A based on DECPLA scaling factor
ANADBV	100	Analog reporting dead band for voltages, 1 kV based on DECPLV scaling factor
ANADBM	100	Miscellaneous analog value dead band, based on DECPLM scaling factor
ETIMEO	10	Event Message Confirm Time-Out, 10 seconds
UNSOL	N	Unsolicited reporting disabled (data retrieval method is polled report-by-exception)
MODEM	N	No modem connected to port

In this example, the polling method employed by the RTU DNP3 master is polled report-by-exception. The master device normally polls for events only. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by not continuously polling and receiving data that are not changing.

DNP3 LAN/WAN Application Example

Application

This example uses an SEL-487E connected to an RTU over an Ethernet (TCP) network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure 16.8*.

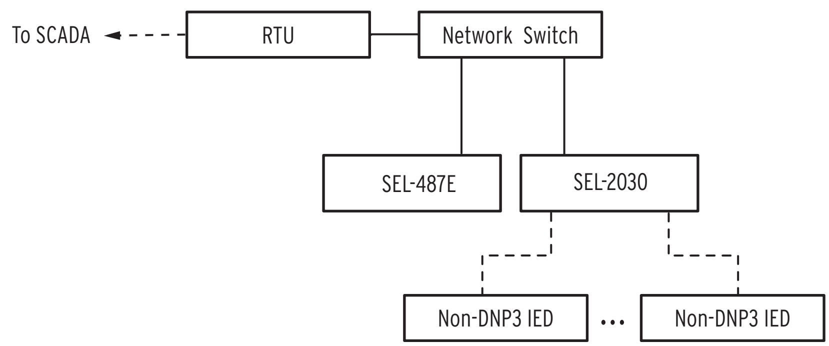

Figure 16.8 DNP3 LAN/WAN Application Example Ethernet Network

The polling method employed by the RTU DNP3 master is polled report-by-exception, so it normally only does event polls. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by only polling and receiving data that has changed.

The RTU, which will act as the DNP3 master to the SEL-487E outstation, has an IP address of 192.9.0.3 and a DNP3 address of 12. The SEL-487E should be assigned an IP address of 192.9.0.2, default router of 192.9.0.1, and DNP3 address of 101.

All event data (analog, binary, counter) should be assigned to CLASS 1. All Binary Inputs should have SOE-quality time stamps.

The desired DNP3 data map is shown in *Table 16.13*.

Table 16.13 DNP3 Application Example Data Map (Sheet 1 of 2)

Label	Object	Custom Map Index	Description
EN	1, 2	0	Relay enabled
TRIPLED	1, 2	1	Circuit Breaker tripped
IN101	1, 2	2	Relay Discrete Input 1
IN102	1, 2	3	Relay Discrete Input 2
IN103	1, 2	4	Relay Discrete Input 3
IN104	1, 2	5	Relay Discrete Input 4
SALARM	1, 2	6	Relay software alarm
HALARM	1, 2	7	Relay hardware alarm
TESTDB2	1, 2	8	Test mode enabled
RB01	10, 12	0	Remote Bit 1
RB02	10, 12	1	Remote Bit 2
RB03	10, 12	2	Remote Bit 3
RB04	10, 12	3	Remote Bit 4

Table 16.13 DNP3 Application Example Data Map (Sheet 2 of 2)

Label	Object	Custom Map Index	Description
RB05	10, 12	4	Remote Bit 5
RB06	10, 12	5	Remote Bit 6
OCS:CCS	10, 12	6	Circuit Breaker S trip/close pair
IASFMC	30, 32	0	A-Phase Current magnitude
IASFAC	30, 32	1	A-Phase Current angle
IBSFMC[a]	30, 32	2	B-Phase Current magnitude
IBSFAC[b]	30, 32	3	B-Phase Current angle
ICSFMC[a]	30, 32	4	C-Phase Current magnitude
ICSFAC[b]	30, 32	5	C-Phase Current angle
VAVFMC	30, 32	6	VA Phase Voltage magnitude, Terminal V
VAVFAC[b]	30, 32	7	VA Phase Voltage angle, Terminal V
VBVFMC[c]	30, 32	8	VB Phase Voltage magnitude, Terminal V
VBVFAC[b]	30, 32	9	VB Phase Voltage angle, Terminal V
VCVFMC[c]	30, 32	10	VC Phase Voltage magnitude, Terminal V
VCVFAC[b]	30, 32	11	VC Phase Voltage angle, Terminal V
VDC[d]	30, 32	12	VDC voltage multiplied by 100
ACTGRP	40	0	Active settings group

[a] Assume the largest expected current is 2000 A, scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.

[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.

[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.

[d] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Use QuickSet to enter the DNP3 protocol settings and new data map into the relay.

Table 16.14 DNP3 LAN/WAN Application Example Protocol Settings (Sheet 1 of 2)

Setting Name	Setting	Description
EPORT	Y	Enable Ethernet port
IPADDR	192.9.0.2/16	Relay IP address and network in CIDR notation
DEFRTR	192.9.0.1	Default router
EDNP	1	Enable DNP3 LAN/WAN Session 1
DNPADR	101	DNP3 address for relay is 101
DNPPNUM	20000[a]	DNP3 port number for TCP
DNPID	RELAY1DNP	DNP3 ID for Object 0 self-description
DNPIP1	192.9.0.3	DNP3 Master (RTU) IP address
DNPTR1	TCP	Use TCP transport
DNPMAP1	1	Use DNP3 Map 1 for DNP3 LAN/WAN Session 1
CLASSB1	1	Binary event data = Class 1
CLASSC1	1	Counter event data = Class 1

Table 16.14 DNP3 LAN/WAN Application Example Protocol Settings (Sheet 2 of 2)

Setting Name	Setting	Description
CLASSA1	1	Analog event data = Class 1
TIMERQ1	1	Ignore time synchronization requests from DNP3 Master
DECPLA1	2	Scale analog current data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. ($10^2 = 100$)
DECPLV1	2	Scale analog voltage data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. ($10^2 = 100$)
DECPLM1	2	Scale analog miscellaneous data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. ($10^2 = 100$)
STIMEO1	1.0[a]	1.0 second to select before operate time-out
DNPINA1	120[a]	Wait 120 seconds to send inactive heartbeat
DNPCL1	Y	Allow DNP3 controls for this session
AIVAR1	2	Default AI variation
ANADBA1	200	Analog dead band counts, set to 2 engineering units, based on DECPLA scaling factor
ANADBV1	200	Analog dead band counts, set to 2 engineering units, based on DECPLV scaling factor
ANADBM1	200	Analog dead band counts, set to 2 engineering units, based on DECPLM scaling factor
ETIMEO1	2[a]	Event message confirm time-out (2 s)
UNSOL1	N	Disable unsolicited reporting for Master 1

[a] Default value.

To meet the requirement for SOE-quality time stamps, enter all binary inputs into the SER report. See *Figure 16.9* for a screen shot of the process.

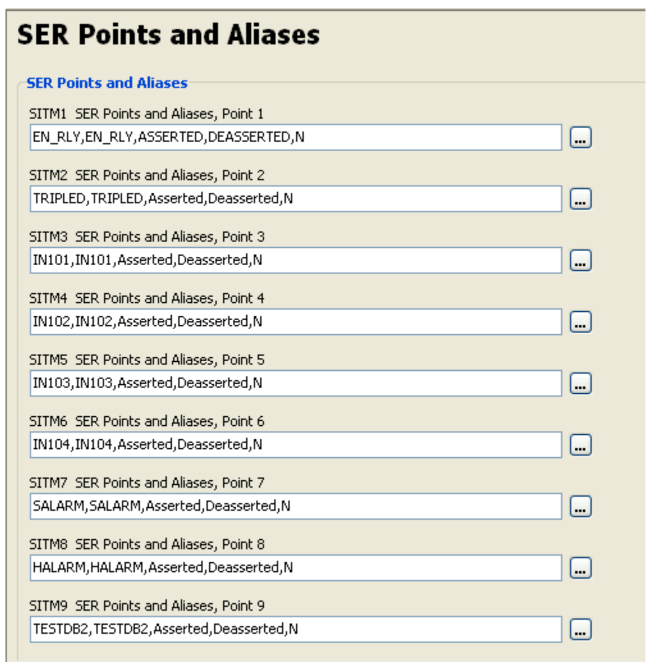

Figure 16.9 Add Binary Inputs to SER Point List

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SECTION 17

IEC 61850 Communication

The relay supports the following features using Ethernet and IEC 61850.

- **SCADA**—Connect as many as seven simultaneous IEC 61850 MMS client sessions. The relay also supports as many as seven buffered and seven unbuffered report control blocks. See *Table 17.16* for logical node mapping that enables SCADA control (including Setting Group Switch) via a manufacturing messaging specification (MMS) browser. Controls support the Direct Normal Security and Enhanced Security (Direct or Select Before Operate) control models.
- **Peer-to-Peer Real-Time Status and Control**—Use GOOSE with as many as 128 incoming (receive) and 8 outgoing (transmit) messages. Virtual Bits (VB001–VB256) and Remote Analogs (RA001–RA256) can be mapped from incoming GOOSE messages. Remote Analog Outputs (RAO01–RAO64) provide peer-to-peer real-time analog data transmission.

NOTE: Not all SEL-400 series relays support SV publication or subscription.

- **Sampled Values—**Use Sampled Values (SV) to replace the traditional copper wiring between instrument transformers and the relay. Connect an SEL SV publisher to CTs and VTs to publish Sampled Values. Use SV subscriber relays to subscribe to these SV messages. SEL-400 series SV products are compliant to the UCA 61850 9-2LE guidelines. In accordance with the guideline, each publication includes one application service data unit (ASDU), with four current and four voltage channels. Supported publication rates are 4.8 kHz for a 60 Hz power system and 4 kHz for a 50 Hz power system. SEL SV publishers support as many as seven SV streams. SEL SV subscriber relays support subscribing to as many as seven streams.

NOTE: The relay ships with a default CID file installed which supports basic IEC 61850 functionality. A new CID file should be loaded if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will reject the file and revert to the previous valid CID file.

- **Configuration**—Use FTP client software or ACSELERATOR Architect SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay. SEL-400 series SV products also support SV configuration via Port 5 settings.
- **Commissioning and Troubleshooting**—Use software such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This section presents the information you need to use the IEC 61850 features of the relay.

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

The IEC 61850 standard consists of the parts listed in *Table 17.1*. These parts were first published between 2001 and 2004, and they are often referred to as IEC 61850 Edition 1 (Ed1). Selected parts of these standards were released in 2011 and tagged as Edition 2 (Ed2). Some SEL-400 series devices are compliant with Ed2. Please refer to the product-specific manual to identify such devices.

It is possible and even likely, that an installation can have a mixture of devices that conform to either Ed1 or Ed2. The standard supports backwards compatibility, i.e., Ed2 devices can send and receive messages to and from Ed1 devices. However, there are important considerations to be made when adding Ed2 devices to an existing Ed1 system. Please refer to *Potential Client and Automation Application Issues With Edition 2 Upgrades on page 17.54* for more information.

Table 17.1 IEC 61850 Document Set (Sheet 1 of 2)

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment—Abstract communication service interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment—Common data classes
IEC 61850-7-4	Basic communication structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM—Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM—Sampled values over serial multidrop point-to-point link

Table 17.1 IEC 61850 Document Set (Sheet 2 of 2)

IEC 61850 Sections	Definitions
IEC 61850-9-2	SCSM—Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of this standard.

IEC 61850 Operation

IEC 61850 and Ethernet networking model options are available when ordering a new relay and may also be available as field upgrades to relays equipped with the Ethernet card. In addition to IEC 61850, the Ethernet card provides support protocols and data exchange, including FTP and Telnet, to SEL devices. Access the relay Port 5 settings to configure all of the Ethernet settings, including IEC 61850 network settings.

The relay supports IEC 61850 services, including transport of logical node objects, over TCP/IP. The relay can coordinate a maximum of seven concurrent IEC 61850 MMS sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) models to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST) and description (DC). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining logical nodes.

UCA2 used GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other supervisory control and data acquisition protocols (SCADA) that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table 17.2* shows how the A-Phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table 17.2 Example IEC 61850 Descriptor Components

Component		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Subdata Object	A-Phase
cVal	Data Attribute	Complex value

Data Mapping

Device data are mapped to IEC 61850 logical nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2013(E) and IEC 61850-7-4:2010(E) for the mandatory content and usage of these LNs. The relay logical nodes are grouped under Logical Devices for organization based on function. See *Table 17.3* for descriptions of the logical devices in a relay. See *Logical Nodes on page 17.29* for a description of the LNs that make up these logical devices.

Table 17.3 Relay Logical Devices

Logical Device	Description
CFG	Configuration elements—datasets and report control blocks
PRO	Protection elements—protection functions and breaker control
MET	Metering or Measurement elements—currents, voltages, power, etc.
CON	Control elements—remote bits
ANN	Annunciator elements—alarms, status values
MU[a]	Merging unit elements—voltage and current channels

[a] This only applies to merging units.

MMS

Manufacturing messaging specification (MMS) provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can become unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850. MMS associations are discussed within IEC61850-8-1, clause 10 of the edition 1 standard.

If MMS authentication is enabled, the device will authenticate each MMS association by requiring the client to provide the password authentication parameter with a value that is equal to the 2AC password of the relay.

- ➤ If the correct password authentication parameter value is not received, the device will return a not authenticated error code.
- ➤ If the correct password authentication parameter value is received, the device will provide a successful association response. The device will allow access to all supported MMS services for that association.

Control

IEC 61850 Controls

An IEC 61850 server may allow a client to manipulate data related to its outputs, external devices, or internal functions. This is accomplished by the IEC 61850 control model, which provides services to execute control commands. The control models are defined in IEC 61850-7-2 and the mapping to the MMS (Manufacturing Message Specification) application protocol is defined in IEC 61850-8-1. The former describes control functionality while the latter maps the IEC 61850 control primitives to MMS.

SEL-400 series relays support four different control models:

- ➤ Status Only
- ➤ Direct with Normal Security
- ➤ Direct with Enhanced Security
- ➤ SBO with Enhanced Security

SEL-400 series devices support the above control models for SPC and DPC controllable common data classes (CDCs) as defined in IEC 61850-8-1:2004. Other controllable CDCs defined in the standard are either unsupported or must be configured with the status-only control model. Supported CDCs include remote bits RBGGIO*n* in the CON Logical Device (LD), and breaker and disconnect switch controls *xx*XCBR*nn* and *xx*XSWI*nn* in the PRO LD. One control model must be selected during initial IED configuration in Architect and is applied throughout the CID file. This control model will apply to all controls in the IED.

Direct Control Models

The "Direct" control models provide the simplest means to initiate actions on the server. In these models, the client issues a control request via MMS, the server validates the request. Once validated, the server attempts to act upon the request. Note that if multiple clients are trying to perform control actions, the server will do nothing to prevent this.

SBO Control Model

The SBO control model supports the Select or SelectWithValue Service and can be used to prevent multiple clients from performing simultaneous control actions. In this mode, a client has to "reserve" the control object by sending a "select" control command. Once an object is selected, only the client that made the selection is allowed to perform control actions on it. If that client does not send a valid operate request for the object by the time the ten-second selection timer runs out, the object becomes available for selection again. The relay will support as many as ten pending control object selections at any time.

NOTE: When an IED is configured with the SBO with Enhanced Security control model, the sboTimeout attribute of the controllable CDCs in the CID file is set to ten seconds. This time-out is not configurable via Architect.

The attribute stSeld (selected status) of the controllable CDC is set to TRUE when a client successfully selects the control object. The attribute is reset to FALSE when either the control (operate) command is successfully executed, an error occurs, or no operate command is received within the select time-out period. The stSeld attribute may trigger a report just like any data attribute with trigger option.

Security in Control Models

"Security" in the control model context refers to additional supervision of the status value by the control object. The "enhanced security" models report additional error information on failed operations to the requesting client than the models with "normal security". Enhanced security control models also provide a command termination report indicating if the control actually reached the new state as commanded within a configurable time-out period.

NOTE: The maximum time required for a control operation to be completed should be less than the configured time-out period in order to avoid erroneous command termination reports indicating failure.

The time-out period between the execution of a control and the generation of a command termination report indicating failure has a default value of 1 s and is configurable via the CID file. This time-out is not configurable via Architect.

Optional Control Configurations

SEL-400 series relays do not support (by default) the pulse configuration option specified in Clause 6.7 of IEC 61850-7-3. However, control objects may be configured to be pulsed by direct modification of the CID file of the device.

SEL-400 series relays do not support the concept of local/remote control authority defined in Annex B of IEC 61850-7-4:2010. However, a similar behavior can be achieved by associating some variable device data with the appropriate originator categories (orCats) by direct modification of the CID file of the device.

Contact the factory if any of these features is necessary for your application.

Control Requests

IEC 61850 control services are implemented by reading and writing to pseudo-variables in the relay in response to MMS requests. Similar to how client requests are generated and mapped to MMS read or write service requests, server actions are also mapped to internal commands, read and write actions and MMS information report messages. In the case of an unsuccessful control request, the relay will send the appropriate response PDU indicating that there was a problem and an MMS information report that contains more detailed information about the problem that occurred.

When writing controls, the client must select and write the entire Oper, SBOw or Cancel structure to the relay. See *Figure 17.1* for the attributes of the CON Logical Device and ST and CO functional constraints (FC) of LN RBGGIO1 used for controls of RB01 through RB08.

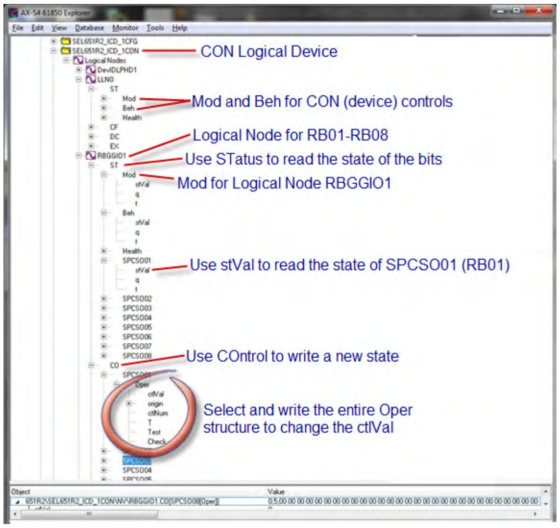


Figure 17.1 MMS Client View of the CON Logical Device

Control Error Messages

If a control request results in an error condition, the relay will respond with an AddCause value in an MMS information report. See Clause 20.5.2.9 of IEC 61850-7-2 for additional information on the AddCause values.

SEL-400 series relays support the AddCause values in *Table 17.4* as part of the LastApplError information report.

Table 17.4 AddCause Descriptions (Sheet 1 of 2)

AddCause Enumeration	AddCause Description	Error Condition
0	Unknown	No other AddCause value defined within this section applies
2	Blocked-by-switching-hierarchy	Logical node is set to local mode, i.e. Loc.stVal = true
3	Select-failed	Originator category not allowed to issue control commands or SelectWithValue operation fails
4	Invalid-position	For controls with enhanced security, an AddCause of “Invalid-position” (4) will be sent if the control status changes to an unexpected value. If no control status change is detected after the operate time-out period, an AddCause of “Time-limit-over” (16) will be sent.
5	Position-reached	Control status is already at the desired state

Table 17.4 AddCause Descriptions (Sheet 2 of 2)

AddCause Enumeration	AddCause Description	Error Condition
6	Parameter-change-in-execution	Control object is already selected by the client, and 1. Logical node is set to local mode i.e., Loc.stVal = true, or 2. Originator category not allowed to issue control commands
8	Blocked-by-mode	Mode of logical device or node is not ON
12	Command-already-in-execution	Execution of a previous control is not completed
13	Blocked-by-health	Health of logical device or node is not OK
16	Time-limit-over	CommandTermination gives a negative response. (The control failed to reach its intended state prior to time-out.)
18	Object-not-selected	Cancel operation fails

Any AddCause value not specified above is not supported. Control CDC data attributes which are associated with unsupported AddCause values and are not part of a control structure will be accepted but ignored. For example, the attribute CmdBlk.stVal which is associated with the AddCause value “blocked-by-command” and is not part of a SBOw, Oper or Cancel structure will be ignored.

Group Switch Via MMS

The Group Switch feature in IEC 61850 is primarily a convenience feature for users so that they can institute a settings group switch from an IEC 61850 client without having to revert to the command line or some other tool. However, this has great potential for integration with IEC 61850 SCADA systems which would be able to control setting groups through IEC 61850 MMS.

The IEC 61850 specification outlines a method for switching the current settings group to another preconfigured settings group. The setting group control block, or SGCB, contains the SettingControl element which enables settings group control. An SEL-400 series CID file that supports group switch functionality will only contain one SGCB. The SGCB contains the number of settings groups in the relay and may also contain the current active setting group, ActSG. Note that if the CID file contains a value for ActSG, it will be ignored and the relay will use the actual active setting group value for ActSG at the time of CID file download.

When the IEC 61850 functions of the relay are enabled, the selectActiveSG service allows an MMS client to request that the relay change the active setting group. The MMS client can request a group switch by writing a valid setting group number to ActSG. The relay updates the ActSG value under the following conditions:

- The value written to ActSG is valid and not the current active group
- There is no group switch in progress
- The setting of the active group was successful.

Note that if the value written to ActSG is the same as the current group, the relay will not attempt to switch settings groups. Please refer to *Multiple Setting Groups on page 12.4* for more information on group settings.

File Services

The Ethernet file system allows reading or writing data as files. The file system supports FTP and MMS file transfer. The file system provides:

- ➤ A means for the device to transfer data as files.
- ➤ A hierarchal file structure for the device data.

The relay supports MMS file transfer with or without authentication. Note that the MMS File Transfer service will still be supported even if the relay contains an invalid CID file. The service is intended to support:

- ➤ Settings file download and upload
- ➤ CID file download and upload
- ➤ Event report retrieval

MMS File Services are enabled or disabled via Port 5 settings, EMMSFS. Permissions for the 2AC level apply to MMS File Services requests. All files and directories that are available at the 2AC access level via any supported file transfer mechanism (FTP, file read/write, etc.) are also available for transfer via MMS File Services.

SCL Files

Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- ➤ IED Capability Description file (.ICD)
- ➤ System Specification Description (.SSD) file
- ➤ Substation Configuration Description file (.SCD)
- ➤ Configured IED Description file (.CID)

The ICD file describes the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Reports

The relay supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2011. The predefined reports shown in *Figure 17.2* are available by default via IEC 61850.

Reports

Type	Name	ID	Dataset	Description
Buffered	BRep01	BRep01	BRDSet01	Predefined Buffered Report 01
Buffered	BRep02	BRep02	BRDSet02	Predefined Buffered Report 02
Buffered	BRep03	BRep03	BRDSet03	Predefined Buffered Report 03
Buffered	BRep04	BRep04	BRDSet04	Predefined Buffered Report 04
Buffered	BRep05	BRep05	BRDSet05	Predefined Buffered Report 05
Buffered	BRep06	BRep06	BRDSet06	Predefined Buffered Report 06
Buffered	BRep07	BRep07	BRDSet07	Predefined Buffered Report 07
Unbuffered	URep01	URep01	URDSet01	Predefined Unbuffered Report 01
Unbuffered	URep02	URep02	URDSet02	Predefined Unbuffered Report 02
Unbuffered	URep03	URep03	URDSet03	Predefined Unbuffered Report 03
Unbuffered	URep04	URep04	URDSet04	Predefined Unbuffered Report 04
Unbuffered	URep05	URep05	URDSet05	Predefined Unbuffered Report 05
Unbuffered	URep06	URep06	URDSet06	Predefined Unbuffered Report 06
Unbuffered	URep07	URep07	URDSet07	Predefined Unbuffered Report 07

Figure 17.2 Relay Predefined Reports

There are 14 report control blocks (7 each of buffered and unbuffered reports). For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (14) and the type of reports (buffered or unbuffered) cannot be changed. However, by using Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets.

For buffered reports, connected clients may edit the report parameters shown in *Table 17.5*.

Table 17.5 Buffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptID	YES		BRep01–BRep07
RptEna	YES	YES	FALSE
OptFlds	YES		seqNum
			timeStamp
			dataSet
			reasonCode
			entryID
BufTm	YES		500
TrgOps	YES		dchg
			qchg
			period
IntgPd	YES		0
GI	YES[a, b]	YES[a]	0
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

[b] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. Buffered reports begin buffering at startup.

Similarly, for unbuffered reports, connected clients may edit the report parameters shown in *Table 17.6*.

Table 17.6 Unbuffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptID	YES		URep01–URep07
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		seqNum
			timeStamp
			dataSet
			reasonCode
BufTm	YES		250
TrgOps	YES		dchg
			qchg
			period
IntgPd	YES		0
GI		YES[a]	FALSE

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

For buffered reports, only one client can enable the RptEna attribute of the BRCB at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For unbuffered reports, as many as seven clients can enable the RptEna attribute of an URCB at a time resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB.

The Resv attribute is writable, however, the relay does not support reservations. Writing any field of the URCB causes the client to obtain their own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd will begin at the time that the current report is serviced.

Datasets

IEC 61850 datasets are lists of references to DataObject attributes for the purpose of efficient observation and transmission of data. Architect ICD files come with predefined datasets that can be used to transfer data via GOOSE messages, SV messages, or MMS reports.

- GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.
- SV: Four predefined datasets are provided. Each dataset includes three phase currents and the neutral current as well as three phase voltages and the neutral voltage.

➤ Reports: Fourteen predefined datasets (BRDSet01–BRDSet07 and URDSet01–URDSet07) correspond to the default seven buffered and seven unbuffered reports. Note that you cannot change the number (14) of each type of report (buffered or unbuffered) within Architect. However, you can alter the data attributes that a dataset contains or even create new datasets, and so define what data an IEC 61850 client receives with a report.

Supplemental Software Support

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 61850 from Sisco, Inc.

The settings needed to browse the relay with an MMS browser are shown below.

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The time stamp is determined when data or quality change is detected. A change in the quality attribute can also be used to issue an internal event.

The time stamp is applied to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion when a data or quality change is detected. However, there is a difference in how the change is detected between the different attribute types. For points in a dataset that are also listed in the SER, the change is detected by the SER process. For all other Booleans or Bstrings, the change is detected via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the dead band configured for the point to indicate a change and apply the time stamp. In all cases, these timestamps are used for the reporting model.

LN data attributes listed in the SER will have SER timestamps of 1 ms accuracy for data change events. All other LN data attributes are scanned on a 1/2-second interval for data change and have 1/2-second time stamp accuracy.

The relay uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure 17.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from relay datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes. For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the relay will set the Validity attribute to INVALID and the Failure attribute to TRUE. Note that the relay does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the Architect help for additional information on GOOSE Quality attributes.

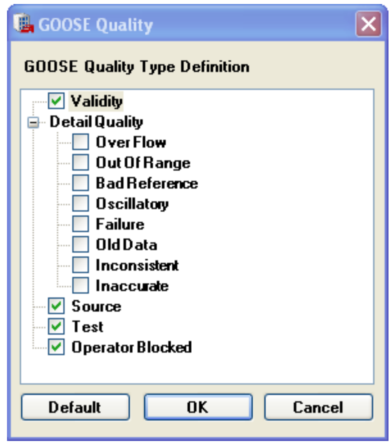


Figure 17.3 GOOSE Quality Attributes

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the message several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network devices with Architect. Also, configure outgoing GOOSE messages for SEL devices in Architect. See the Architect help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

Virtual bits (VB001–VB256) are control inputs that you can map to values from incoming GOOSE messages using the Architect software. See the VB*nnn* bits in *Table 17.10*, *Table 17.11*, and *Table 17.12* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any relay Virtual bits for controls, you must create SELOGIC equations to define these operations. The relay is capable of receiving and sending analog values via peer-to-peer GOOSE messages. Remote Analogs (RA001–RA256) are analog inputs that you can map to values from incoming GOOSE messages. Remote Analog Outputs (RAO01–RAO64) can be used to transmit analog values via GOOSE messages. You must create SELOGIC control equations to assign internal relay values to RAO points in order to transmit them via GOOSE.

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2011(E), IEC 61850-7-2:2010(E), and IEC 61850-8-1:2011(E) via the installed Ethernet port.

Outgoing GOOSE messages are processed in accordance with the following constraints.

- The user can define as many as eight datasets for outgoing GOOSE messages consisting of any data attribute (DA) from any logical node. A single DA can be mapped to one or more outgoing GOOSE datasets, or one or more times within the same outgoing GOOSE dataset. A user can also map a single GOOSE dataset to multiple GOOSE control blocks. The number of unique Boolean variables is limited to a combined total of 512 digital bits across all eight outgoing messages.
- High-speed GOOSE messaging (as defined under GOOSE Performance) is available for GOOSE messages that contain either all Boolean data or a combination of Boolean data and remote analog output (RAO01–RAO64) data.
- The relay will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE message is not retriggered, then following the initial transmission, the relay shall retransmit that GOOSE based on the Min. Time and Max. Time configured for that GOOSE message. The first transmission shall occur immediately upon triggering of an element within the GOOSE dataset. The second transmission shall occur Min. Time later. The third shall occur Min. Time after the second. The fourth shall occur twice Min. Time after the third. All subsequent transmissions shall occur at the Max Time interval. For example, a message with a Min. Time of 4 ms and Max. Time of 1000 ms, will be transmitted upon triggering, then retransmitted at intervals of 4 ms, 4 ms, 8 ms, and then at 1000 ms indefinitely or until another change triggers a new GOOSE message (See IEC 61850-8-1, Sec. 18.1).
- Each outgoing GOOSE includes communications parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- The relay will maintain the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints.

- The user can configure the relay to subscribe to as many as 128 incoming GOOSE messages.
- Control bits in the relay get data from incoming GOOSE messages which are mapped to Virtual Bits (VB*nnn*). Virtual bits are volatile and are reset to zero when a new CID file is loaded, the device is restarted, or they are overwritten by data from a subscribed GOOSE message.
- The relay will recognize incoming GOOSE messages as valid based on the following content:
  - Source broadcast MAC address
  - Dataset Reference

    - Application ID
    - GOOSE Control Reference

  Any GOOSE message that fails these checks shall be rejected.

- Every received and validated GOOSE message that indicates a data change, by an incremented status number, is evaluated as follows:
    - Data within the received GOOSE dataset that are mapped to host data bits are identified.
    - Mapped bits are compared against a local version of the available host data bits.
    - If the state of the received bits is different than the local version:
        - Update the local version with the new state for that bit.
        - Pass the new state for the bit to the relay.
- Reject all DA contained in an incoming GOOSE based on the presence of the following error indications created by inspection of the received GOOSE:
    - Configuration Mismatch: The configuration number of the incoming GOOSE changes.
    - Needs Commissioning: This Boolean parameter of the incoming GOOSE is true.
    - Test Mode: This Boolean parameter of the incoming GOOSE is true.
    - Decode Error: The format of the incoming GOOSE is not as configured.
- The relay will discard incoming GOOSE under the following conditions:
    - After a permanent (latching) self-test failure
    - When EGSE is set to No

Link-layer priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2011.

GOOSE Performance

For outgoing high-speed data (as identified under GOOSE Processing), transmission of GOOSE begins within 2 ms of transition of digital data within the relay. Note that you can include RAO points in outgoing GOOSE for high-speed transmission—only the transition of a digital point will trigger the transmission within 2 ms. Please refer to Logical Nodes for data attributes that can trigger high-speed GOOSE, if included in a dataset for outgoing GOOSE transmission. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the relay. Appropriate control commands are issued to the relay within 2 ms of a GOOSE reception.

Sampled Values

NOTE: Not all SEL-400 series products support SV.

IEC 61850 9-2, also known as Sampled Values (SV), describes a service that brings digital analog samples from the substation yard to the control house. Multiple components are essential to successful implementation of such a service. SV publishers, also known as merging units, locally sample and convert analog samples to digital samples with a time stamp. They then publish these samples with minimum delays via an Ethernet connection. Fiber-optic based Ethernet connections are established between SV publishers and SV subscribers for transmitting SV samples and GOOSE messages. This network is also called the process bus network. The information exchange between the SV publisher and the SV subscribing relays is based on a publisher/subscriber mechanism that is similar to GOOSE messaging. The SV subscribing relay receives the time-stamped SV messages and checks the timeliness of the samples. Messages are buffered and then used by the relays.

To promote interoperability and fast deployment of SV, UCA International Users Group released "Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2" and described a subset of IEC 61850-9-2, also known as UCA 61850 9-2LE or simply 9-2LE. The SEL-400 series SV products are compliant with the 9-2LE guideline, also known as the 9-2LE profile in this manual.

You can configure the SEL-400 series SV products via Architect or using Port 5 settings. See *IEC 61850 Configuration on page 17.22* for more information on SV product configuration.

SV Processing

SV Publication

An SV publisher is an interface to the non-conventional instrument transformers (NCIT) and traditional instrument transformers. When an SV publisher is connected to a traditional instrument transformer, it is also called a standalone merging unit. The SV publisher samples the analog data at 8 kHz and down-samples to 4.8 kHz/4.0 kHz when the nominal frequency is 60 Hz/50 Hz. A time stamp representation, known as smpCnt, is encoded with each published SV message. Given the sampling rate and the need to maintain the time coherence of samples from multiple merging units, merging units must be time-synchronized to high-accuracy time source. See *Section 11: Time and Date Management* for time-synchronization methods. The difference between the time encoded by the smpCnt in an SV message and the time that the message is published at the Ethernet interface is the merging unit processing delay. This delay and the transmitting delay over a process bus network is the total network delay. See *SV Network Delays on page 17.18* for more about network delay.

SV Dataset

SEL SV publishers can transmit multiple SV data streams. Each SV message includes four currents and four voltages. For example, the SEL-401 has inputs for 12 analog measurements (6 currents and 6 voltages). This means that the merging unit function requires at least two streams to send all available voltage/current inputs. Merging units support as many as seven output streams, allowing unmatched flexibility with measurement channel assignment and precise routing of duplicate streams.

Primary/Secondary Scale Factor

The analog measurements inside SV messages represent the primary side of the instrumental transformer. When connecting a standalone merging unit to a conventional transformer, a scale factor should be applied such that the measured secondary quantity is scaled to primary values. For example, if the SEL-401 IW terminal is connected to an ANSI C600 1200/5 CT, the merging unit CT ratio CTRW should be set as 1200/5 = 240. Once CTRW is set, the measured secondary quantity on IW is scaled by CTRW before it is transmitted.

Time Synchronization

SmpCnt is a representation of the time stamp, which is encoded in each SV message. If SV messages from multiple merging units are used for an application, the smpCnt from these merging units must represent the same time instance to correctly align the data. High-accuracy time synchronization is critical. SEL-400 series relays can be synchronized with high-quality IRIG-B or high-quality Precision Time Protocol (PTP). The quality of smpCnt at the time the sample was taken is indicated by the SmpSynch value included in each SV message. When a merging unit is not time synchronized to any time source, its sample time error is unknown. Without time synchronization, the relay sets the smpSynch to 0. When the merging unit is synchronized to a high-quality local time source (TLOCAL = 1), the smpSynch is set to 1. When the merging unit is synchronized to a high-quality global time source (TGLOBAL = 1), the smpSynch is set to 2. TLOCAL and TGLOBAL are indicators of the time-synchronization source. See *Section 11: Time and Date Management* for information about TLOCAL and TGLOBAL.

SEL merging units use the information in *Table 17.7* and *Table 17.8* to determine the quality of sample timing and the smpSynch values. See *Table 17.7* and *Table 17.8* for smpSynch values.

When high-quality IRIG-B is the current time source (CUR_SRC = BNC_IRIG or CUR_SRC = SER_IRIG):

Table 17.7 Mechanism of Determining smpSynch Values With an IRIG-B Time Source

Time Synchronization Status	smpSynch Value
TGLOBAL = 1	2
TLOCAL = 1	1
TGLOBAL = 0 TLOCAL = 0	0

When high-quality PTP is the current time source (CUR_SRC = PTP):

Table 17.8 Mechanism of Determining smpSynch Values With a PTP Time Source

Profile	MU Sync State	smpSynch Value
Power System or Default Profile	TGLOBAL = 1	2
Power System Profile	TLOCAL = 1	GMID[a]
Default Profile	TLOCAL = 1	1
Power System or Default Profile	TGLOBAL = 0 TLOCAL = 0	0

[a] Grand Master ID

SV Subscription

An SEL SV relay can receive one or more SV streams from one or more merging units. SEL SV relays only support receiving 9-2LE-compliant SV messages. Once messages are received, samples are buffered to ensure that samples used to calculate protection elements are from the same time. The SV message attribute, smpCnt, is used to check and align samples. SV messages can be published at different frequencies based on the nominal frequency. The SEL SV relay nominal frequency setting must match the merging unit nominal frequency.

Primary/Secondary Scale Factor

SV messages provide current and voltage measurements in terms of the primary side of the instrumental transformers. SEL SV relay protection calculations are based on traditional secondary quantities. Thus, the received digital samples must be scaled to the secondary properly. For example, if the SV stream comes from a merging unit that is connected to a 1200/5 CT, the SEL SV relay CT ratio settings should be 240.

SV Network Delays

The SV merging unit and process bus network act as the remote data acquisition system for an SV relay. There are time delays introduced by this remote data acquisition system. The delays of an SV stream include the merging unit processing delay and the process bus network delay. The sum of these is called the network delay. SEL SV relays measure and report this network delay. The measured network delay for each SV subscription is stored as an analog quantity and reported via the **COM SV** ASCII command. See *Section 9: ASCII Command Reference* in the product-specific instruction manual for more detailed information.

SEL SV relays buffer samples, and the buffer length is controlled by the CH_DLY settings. Set the CH_DLY settings to at least one sample interval greater than the total network delay. SEL SV relays wait to start resampling until samples arrive for the configured CH_DLY. This design also provides a consistent delay (CH_DLY) to protection and control operations, which overcomes the non-deterministic delays caused by the Ethernet process bus network.

If SV messages of the first SV subscription, which is listed first in the **COM SV** command response, are delayed by more than CH_DLY, they are considered lost. If less than three consecutive messages are delayed or missing, the SEL SV relay interpolates for these delayed or lost messages. If more than three samples are delayed or missing, the SEL relay ASCII command **COM SV** reports `SV STREAM LOST` for this scenario.

The protection and control operation times are delayed by the configured CH_DLY. Use caution when setting the relay coordination times to account for this added delay.

Coupled Clocks Mode

SEL recommends configuring a high-quality time source for the SV relays. Depending on the time-synchronization status, an SEL SV relay operates in one of two modes: the freewheeling mode and the coupled clock mode. SEL SV subscribers use the same logic as SEL SV publishers to determine a local smpSynch based on its time-synchronization status. When the incoming smpSynch of the first SV subscription is non-zero and matches the local smpSynch, the relay operates in coupled clocks mode and SVCC asserts. When operating in coupled clocks mode, the relay can calculate the network delay for incoming SV streams. These delays are stored in analog quantities SVND*mm* where *mm* is the subscription number. The delays are also reported in the **COM SV** command response. When operating in the freewheeling mode, the SV relay will not provide the network delay statistics.

Subscription Reference Stream

SEL SV relays store the smpSynch of each subscribed SV stream in analog quantities SV*mm*SNC, where *mm* is the subscription number. If a CID file is used, the first subscription stream in the CID file is used as the smpSynch reference. If the Port 5 SV setting is used, the subscription with the subscribed MAC address set by SVRADR1 is the first subscription and is used as the smpSynch reference. In coupled clock mode, any subsequent streams that do not have the same smpSynch as the time reference are discarded. If the relay stops receiving data for the first subscription stream, the last smpSynch value received from the first subscription stream continues to remain as the time reference. If the smpSynch value of the first subscription stream is zero, only the first subscription stream is accepted. If the relay operates in freewheeling mode, only the first subscription stream is accepted.

Station Bus and Process Bus

NOTE: The MERGED BUSMODE is not recommended for long-term operations, as the large amount of process bus traffic can adversely affect station bus functions when the buses are combined.

The SEL SV publishers and subscribers allow flexible station bus and process bus configurations. If BUSMODE := INDEPEND, station bus traffic (typically MMS and GOOSE) will only be transmitted out on the station bus ports, and process bus traffic (typically SV and GOOSE) will only be transmitted on process bus ports. If BUSMODE := MERGED, all communications use Port 5A and Port 5B, with process bus and station bus traffic merged on the same physical network, and the process bus ports are disabled. The designation of station bus and process bus is controlled by NETPORT settings. The station bus port is the same as the primary port, as specified by NETPORT settings. If NETPORT := A or NETPORT := B, then Port 5A and Port 5B are used for station bus communication and Port 5C and Port 5D are used for process bus communication. If NETPORT := C or NETPORT := D, then Port 5C and Port 5D are used for station bus communication and Port 5A and Port 5B are used for process bus communication. IEEE 1588-based time synchronization is only available on Port 5A and Port 5B. If you want PTP time synchronization on the process bus, use Port 5A and Port 5B for process-bus communications. *Figure 17.4* shows some common network configurations, including the NETPORT and BUSMODE settings used.

Figure 17.4 shows an independent bus mode network schematic with PTP time synchronization on the process bus. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := C.

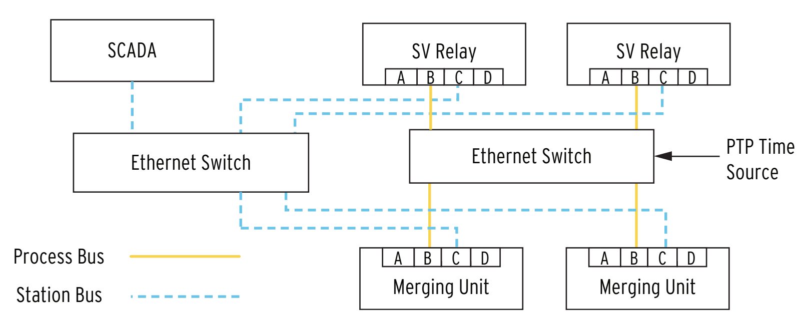


Figure 17.4 Independent Bus Mode With PTP Time Synchronization on the Process Bus

Figure 17.5 shows an independent bus mode network schematic with PTP time synchronization on the station bus. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := A.

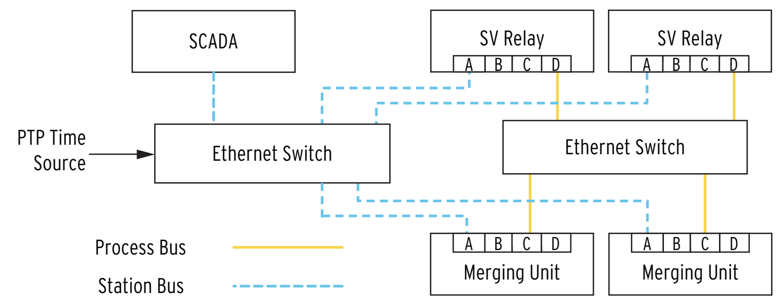


Figure 17.5 Independent Bus Mode With PTP Time Synchronization on the Station Bus

Figure 17.6 shows an independent bus mode network schematic with local IRIG time source. In this schematic, the merging unit has settings BUSMODE := INDEPEND and NETPORT := A.

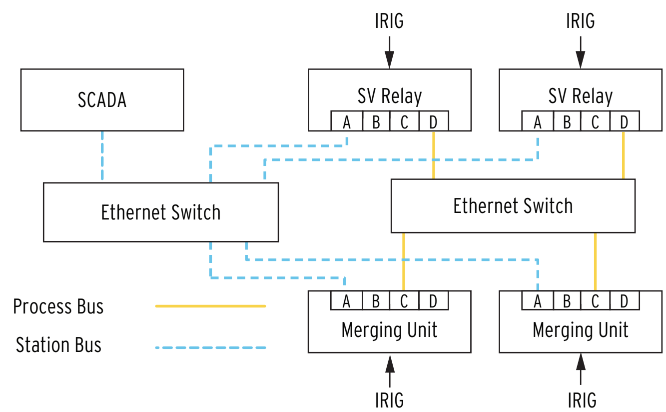


Figure 17.6 Independent Bus Mode With IRIG Time Synchronization

Figure 17.7 shows a merged bus mode network schematic with PTP time synchronization. Process bus and station bus traffic are all processed in Port A. In this schematic, the merging unit has settings BUSMODE := MERGED and NETPORT := A.

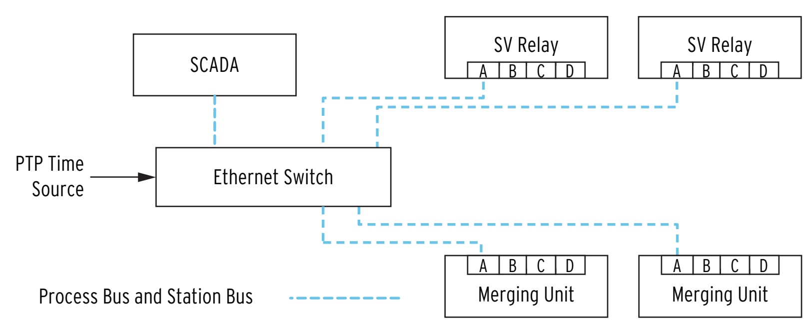


Figure 17.7 Merged Bus Mode With PTP Time Synchronization

GOOSE and SV Messaging

SEL-400 series SV products publish and subscribe GOOSE messages on both the station bus and the process bus ports. GOOSE subscription error out of sequence may be reported. For example, *Figure 17.8* shows an SEL merging unit publishing two GOOSE messages from the station bus and process bus. Without proper GOOSE messages routing on the Ethernet switch, the SV relay receives GOOSE messages #1 and #2 from the process bus and the station bus, and out-of-sequence error is reported for GOOSE messages #1 and #2 subscriptions. Proper management and segregation of GOOSE messages from the station bus and the process resolves this. For example, if GOOSE message #1 is designed for the process bus only, engineers can configure the station bus Ethernet switch to only forward GOOSE message #2 and the process bus Ethernet switch to only forward GOOSE message #1 via VLAN management.

SEL recommends using an SEL Software Defined Network (SDN) Ethernet switch to engineer each Ethernet traffic flow. Engineers can plan the network path for process bus GOOSE messages to flow through the process bus SDN switch only and discard the station bus GOOSE messages.

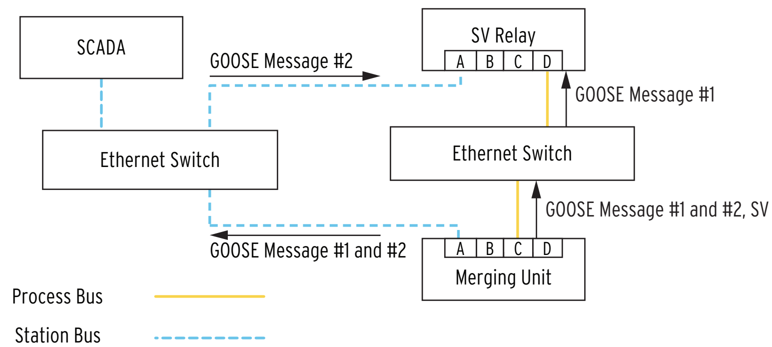


Figure 17.8 Use Ethernet Switch to Engineer Network Path for GOOSE Messages.

Simulation Mode

NOTE: SV Simulation is only applicable in IEDs with SV subscription capability.

SEL-400 series relays (including the SEL-401) can be configured to operate in simulation mode. In this mode, the SEL-400 series relays continue to process normal SV or GOOSE messages until a simulated SV or GOOSE message is received for a subscription. Once a simulated SV or GOOSE message is received, only simulated SV or GOOSE messages are processed for that subscription. The simulated mode only terminates when LPHDSIM is returned to FALSE. When the relay is not in the simulation mode, only normal SV messages are processed for all subscriptions.

A user can place the SEL-421 in SV simulation mode by setting LPHDSIM (CFG.DevIDLPHD1.Sim.stVal) to true via MMS messaging.

IEC 61850 Configuration

Settings

Table 17.9 lists IEC 61850 settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Table 17.9 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE	Outgoing IEC 61850 GSE message enable	Y, N	N
EMMSFS	Enable MMS File Services	Y, N	N

Architect

NOTE: Not all SEL-400 series relays support SV.

The Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Engineers can use Architect to perform the following configuration tasks.

- Organize and configure all SEL IEDs in a substation project.
- Configure incoming and outgoing GOOSE messages.
- Configure SV publication and subscription, if supported.
- Edit and create GOOSE and SV datasets.
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- Use or edit preconfigured datasets for reports.
- Load device settings as part of IEC 61850 CID files into SEL IEDs.
- Generate ICD files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.

NOTE: Other manufacturers' ICD and CID files must have IEC 61850 outgoing GOOSE messages with Application IDs (APPIDs) of exactly four characters and VLAN IDs of exactly three characters so that the relay can successfully subscribe to them. If you attempt to configure a relay to subscribe to a GOOSE message that does not meet this criteria, the relay will reject the CID file upon download. Edit other manufacturers' ICD and CID files prior to importing them into Architect by adding leading zeros to the APPID and VLAN ID of outgoing GOOSE messages, as necessary.

Architect provides a GUI for engineers to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the engineer first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The engineer may also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain. Architect has the capability to read other manufacturers' ICD and CID files, enabling the engineer to map the data seamlessly into SEL IED logic. See the Architect help for more information.

Architect also provides a GUI for engineers to configure SV publications and SV subscriptions when the IED supports SV. The process is similar to that described for GOOSE, except that SEL SV devices can either publish or subscribe to SV, but not both. The engineer edits or creates SV publication datasets to configure the SEL SV publisher(s). Architect then displays the available SV publications in the project, using any SV publications defined in the project, including those from imported CID files from other manufacturers' SV publishers. The engineer then configures subscriptions by mapping the published data to the available analog channels in the SEL SV subscriber.

The following example includes configurations via the Architect software. The software supports IEC 61850 MMS, GOOSE, and SV configurations. This example shows how to use the software to configure two SV publications on an SEL-401 and an SEL-421.

Example 17.1 SV Application

Step 1. Open Architect.

Step 2. Insert the SEL-401 ICD and the SEL-421-7 SV Subscriber Relay ICD in the project tree.

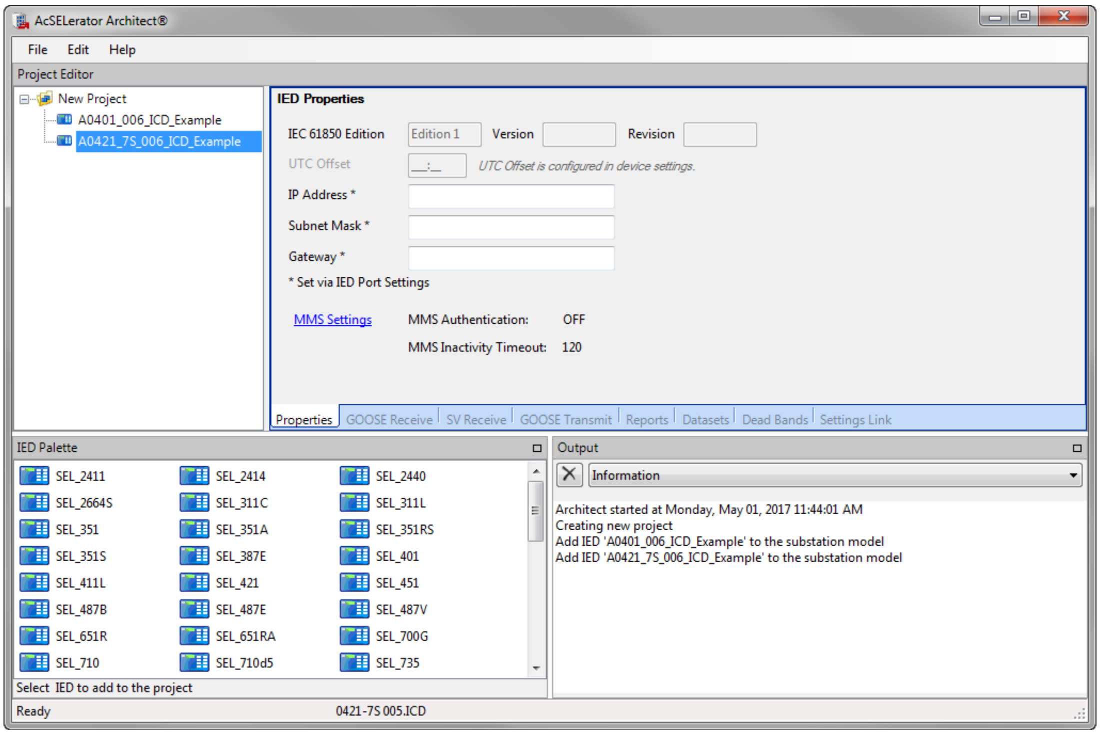


Figure 17.9 Add ICD to Project Tree

Step 3. Create an SV Publication for the SEL-401. Configure SVID, MAC address, APP ID, and VLAN information as desired. Select an SV dataset to associate it with the SV publication.

Example 17.1 SV Application (Continued)

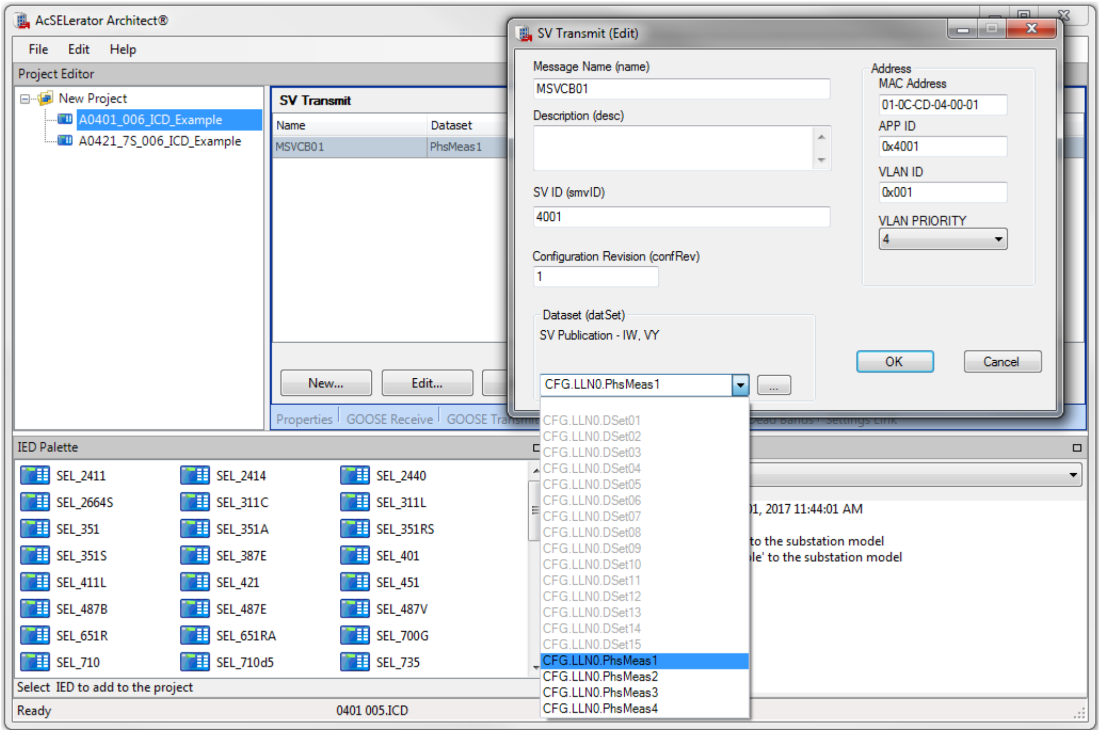


Figure 17.10 Configure an SV Publication

Step 4. To view the content of the dataset, click the **...** icon next to the dataset.

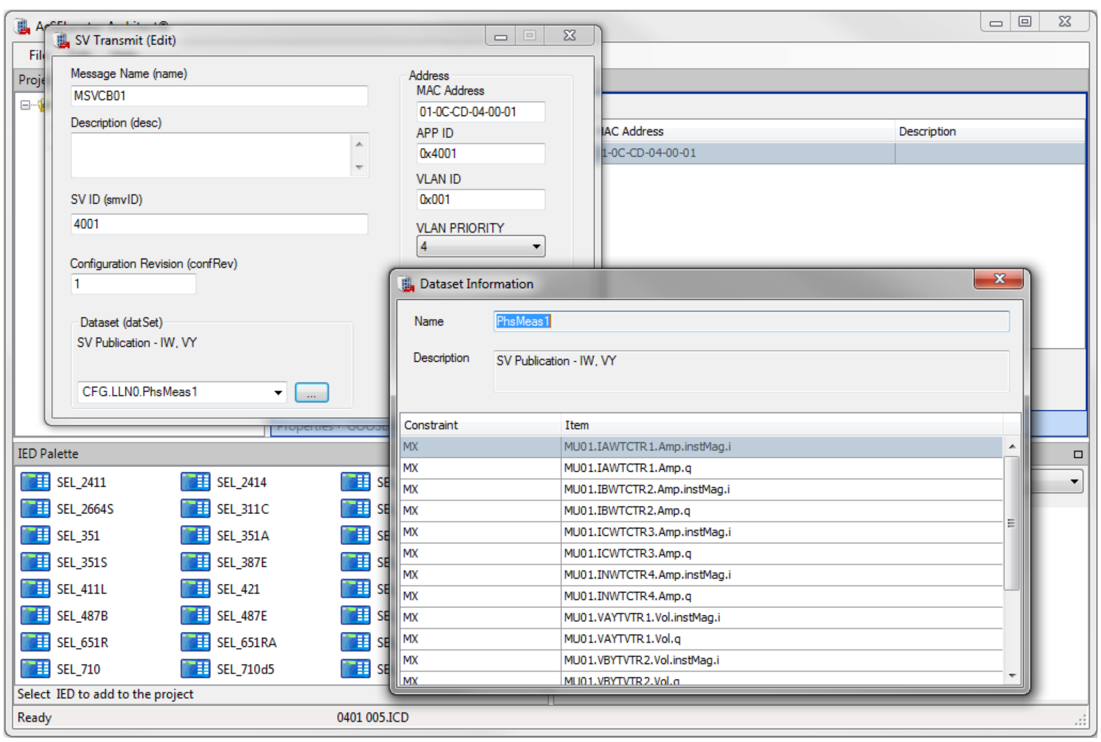


Figure 17.11 Example SV Publication Dataset

Example 17.1 SV Application (Continued)

Step 5. Select the SEL-421 and click the **SV Receive** tab to configure the SV subscriptions as shown in *Figure 17.12*.

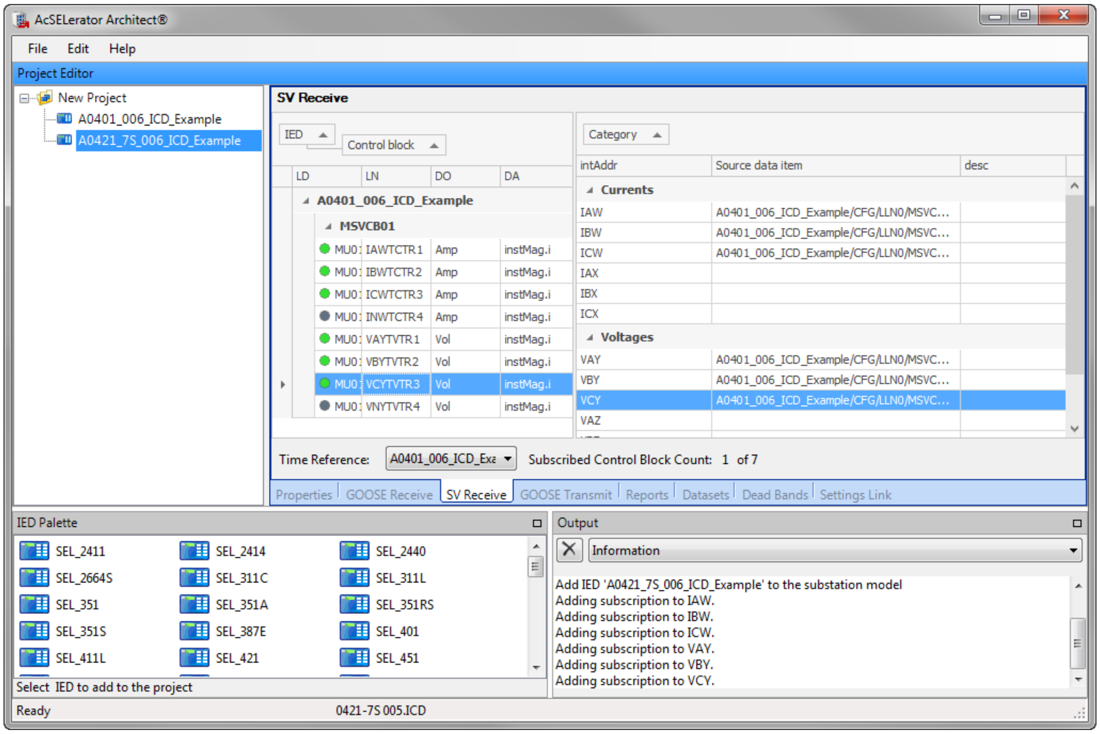


Figure 17.12 Configure SV Subscription

Step 6. Right-click the IED, and choose to send the CID file. Ensure that the FTP function is enabled on the IEDs before sending CID files.

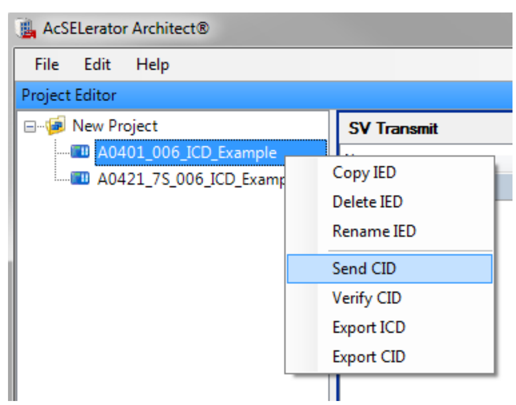


Figure 17.13 Send SEL-401 CID File

Example 17.1 SV Application (Continued)

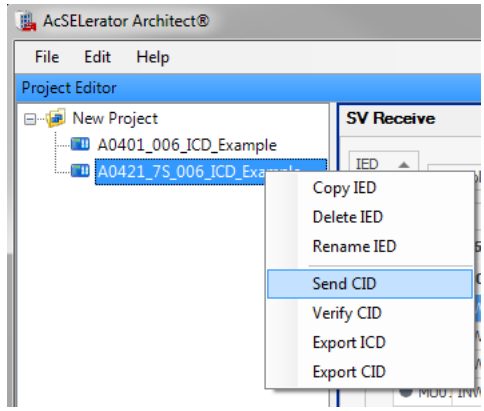


Figure 17.14 Send SEL-421-7 CID File

Step 7. Issue the **COM SV** command on the merging unit and the relay to verify successful publication and subscription.

```
=>>COM SV <Enter>

TEST SV Mode: OFF

SV Publication Information

 MulticastAddr   Ptag:Vlan AppID  smpSynch
________________________________________________________________________________
A0401_006_ICD_ExampleCFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-11  4:1    4001      0
 SV ID: 4001
 Data Set: A0401_006_ICD_ExampleCFG/LLN0$PhsMeas1
```

Figure 17.15 SEL-401 Publication Status

```
=>>COM SV <Enter>

TEST SV Mode: OFF

SIMULATED Mode: OFF

SV Subscription Status

 MulticastAddr   Ptag:Vlan AppID  smpSynch    Code          Network Delay (ms)
________________________________________________________________________________
A0401_006_ICD_ExampleCFG/LLN0$MS$MSVCB01
 01-0C-CD-04-00-11  4:1    4001      1
 SV ID: 4001
 Data Set: A0401_006_ICD_ExampleCFG/LLN0$PhsMeas1
```

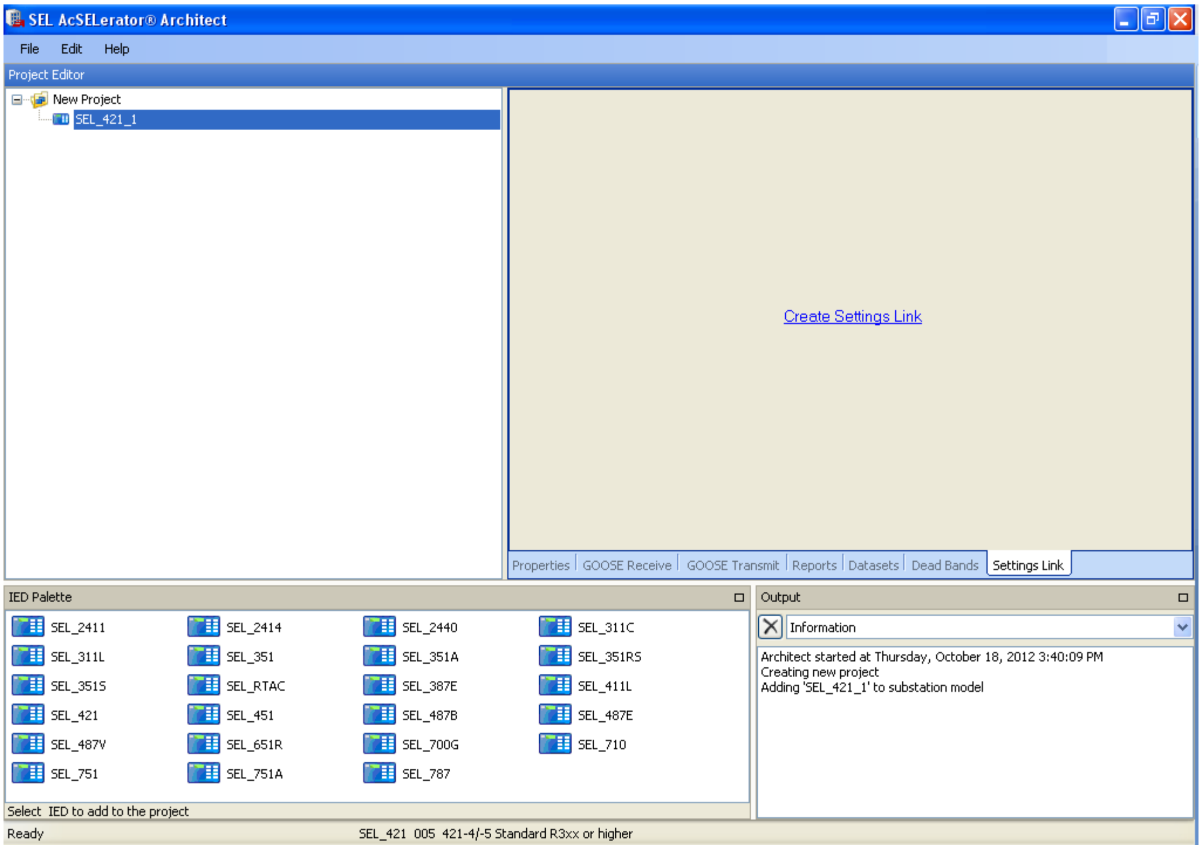
Figure 17.16 SEL-421 SV Subscription Status

Load Device Setting With CID File Download

NOTE: CID file settings are applied only when the file is initially downloaded to the relay. If a file is downloaded to the relay that is identical to one it already has, it will not be processed.

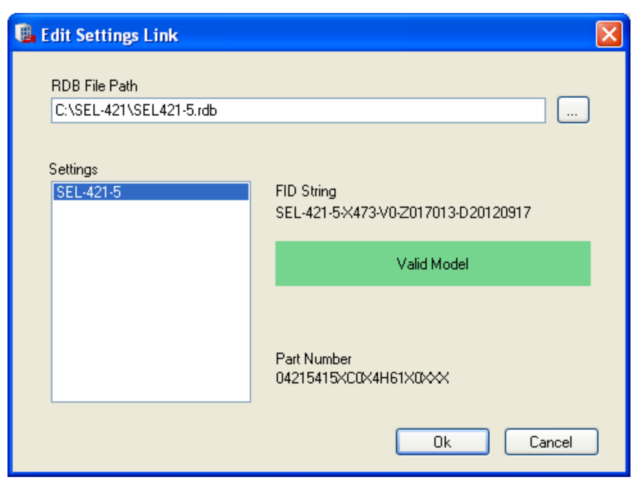
One of the features of the Architect software is enabling users to send device settings as part of the CID file. Refer to *Settings in QuickSet on page 3.28* for steps on how to establish communication with the device and how to modify and save settings using ACSELERATOR QuickSet SEL-5030 Software. The procedure in the following steps shows how to use Architect to open the settings file previously saved in QuickSet and include it in the CID file to be sent to the device.

Step 1. Open Architect.

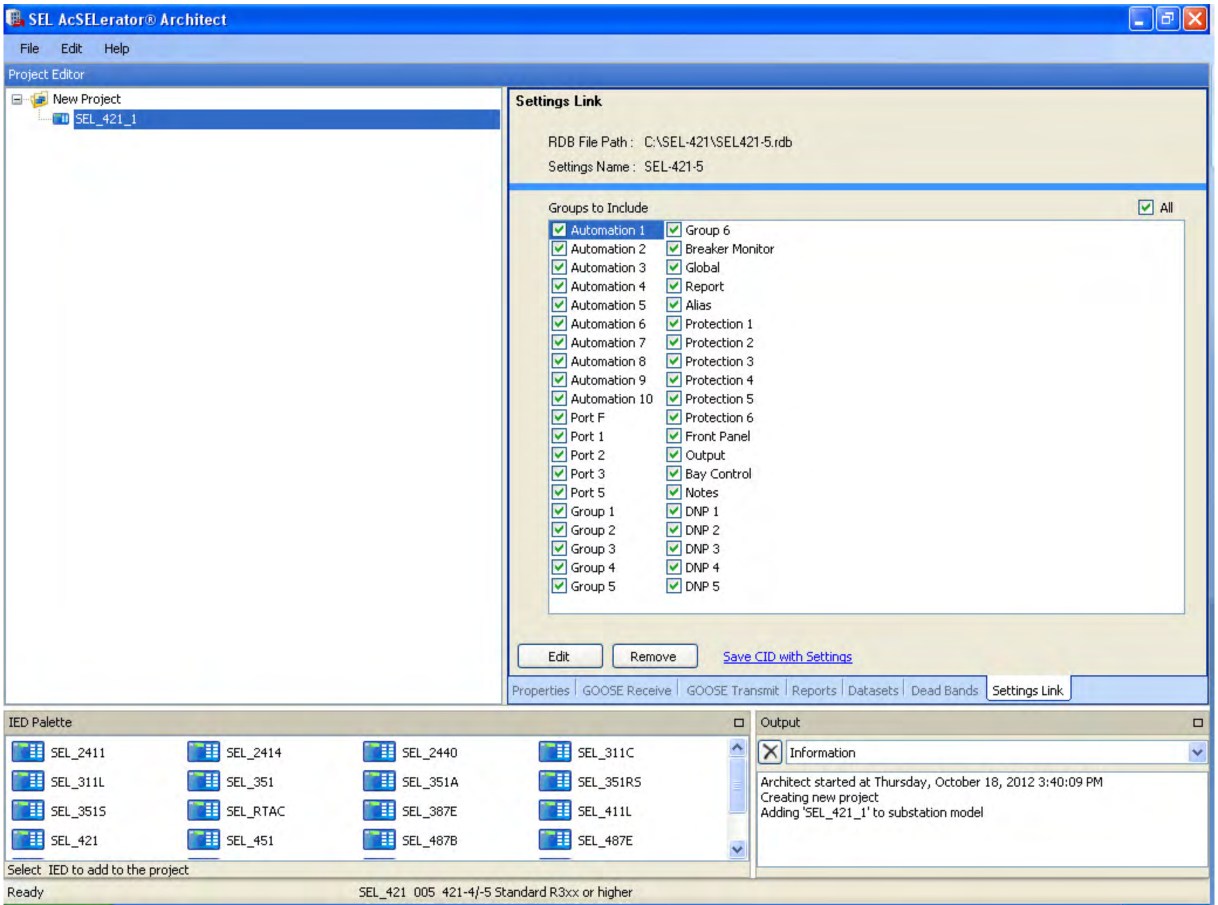


Step 2. Click on the **Settings Link** tab, and then click on **Create Settings Link**.

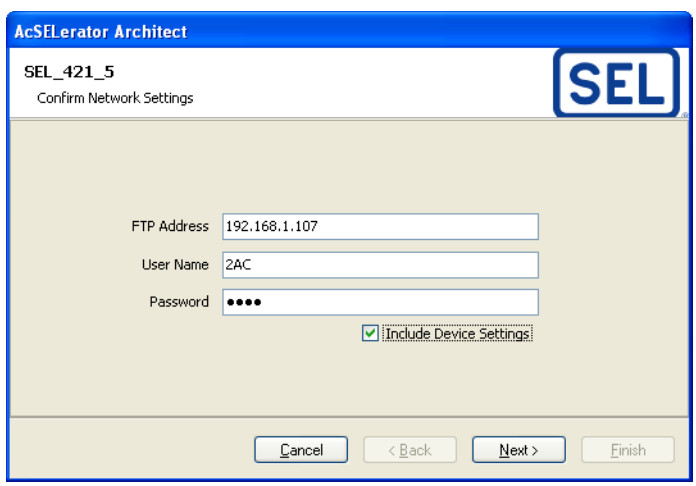
Step 3. Select the settings file and then press **OK**.



Step 4. Select which settings to embed in the CID file. You can also save a local CID file with settings by clicking on **Save CID with Settings**.



Step 5. In the ACSELERATOR project editor window, right-click on the device to send the CID file. Make sure to check the **Include Device Settings** box.



SEL ICD File Versions

Architect version 1.1.69.0 and higher supports multiple ICD file versions for each IED in a project. Because relays with different firmware may require different CID file versions, this allows users to manage the CID files of all IEDs within a single project.

Ensure that you work with the appropriate version of Architect relative to your current configuration, existing project files, and ultimate goals. If you desire the best available IEC 61850 functionality for your SEL relay, obtain the latest version of Architect and select the appropriate ICD version(s) for your needs. Architect generates CID files from ICD files so the ICD file version Architect uses also determines the CID file version generated.

As of this writing, Architect comes with several versions of relay ICD files. ICD file descriptions in Architect indicate the minimum firmware versions required to use that particular file. Unless otherwise indicated, ICD files will work with firmware higher than the firmware in the description. but not with lower firmware versions.

See *Appendix A: Firmware, ICD File, and Manual Versions* in the product-specific instruction manual for a list of ICD versions and corresponding firmware versions.

Logical Nodes

Each logical device (LD) has a set of common data objects at the top level LN0. These represent the current state of the device, as well as some informational data. These data objects are: Mod (Mode), Beh (Behavior), Health, and NamPlt. See below for a brief description of each object.

Mode

SEL-400 series relay includes at the top-level LN0 within each LD the following enumerations for **Mod stVal**:

Mod stVal Enumeration	Mod stVal Value	Description
1	on	EN Relay Word bit = 1
5	off	EN Relay Word bit = 0

The top-level logical node of each LD also includes the following Mod attributes:

Mod q and **Mod t** per the Time Stamps and Quality subsection.

Mod ctlModel enumeration 0 (Status-only).

Behavior

SEL-400 series relay LNs include the following enumerations for **Beh stVal**:

Beh stVal Enumeration	Beh stVal Value	Description
1	on	EN Relay Word bit = 1
5	off	EN Relay Word bit = 0

Logical nodes also include the following Beh attributes:

Beh q and **Beh t** per the Time Stamps and Quality subsection.

Health

The SEL-400 series relay includes at the top-level LN0 within each LD the following enumerations for **Health stVal**:

Health stVal Enumeration	Health stVal Value	Description
1	Ok	EN Relay Word bit = 1
5	Alarm	EN Relay Word bit = 0

The top-level logical node of each LD also includes the following Health attributes:

Health q and **Health t** per the Time Stamps and Quality subsection.

NamPlt

The top-level LN0 of each LD includes the following NamPlt attributes:

- NamPlt vendor which is set to "SEL".
- NamPlt swRev which contains the relay FID string value.
- NamPlt d, which is the LD description.

Common Logical Nodes

Table 17.10–Table 17.13 show the logical nodes (LNs) supported in all SEL-400 series relays. See the respective product-specific instruction manuals to see which additional logical nodes are available in that relay.

Table 17.10 shows the LNs associated with the Logical Node CFG.

Table 17.10 Logical Device: CFG (Configuration)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
DevIDLPHD1	Sim.Oper.ctlVal	LPHDSIM	IEC 61850 Logical Node for Physical Device Simulation
Functional Constraint = DC			
DevIDLPHD1	PhyNam.model	PARNUM	Relay Part Number String
DevIDLPHD1	PhyNam.serNum	SERNUM	Relay Serial Number String
LLN0	NamPlt.swRev	VERFID	Relay FID String
Functional Constraint = ST			
DevIDLPHD1	Sim.stVal	LPHDSIM	IEC 61850 Logical Node for Physical Device Simulation

Table 17.11 shows the LNs associated with control elements, defined as Logical Device CON.

Table 17.11 Logical Device: CON (Remote Control) (Sheet 1 of 2)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = CO			
RBGGIO1	SPCSO01.Oper.ctlVal	RB01	Remote Bit 1
RBGGIO1	SPCSO02.Oper.ctlVal	RB02	Remote Bit 2
RBGGIO1	SPCSO03.Oper.ctlVal	RB03	Remote Bit 3
RBGGIO1	SPCSO04.Oper.ctlVal	RB04	Remote Bit 4
RBGGIO1	SPCSO05.Oper.ctlVal	RB05	Remote Bit 5
RBGGIO1	SPCSO06.Oper.ctlVal	RB06	Remote Bit 6
RBGGIO1	SPCSO07.Oper.ctlVal	RB07	Remote Bit 7
RBGGIO1	SPCSO08.Oper.ctlVal	RB08	Remote Bit 8
RBGGIO2	SPCSO09.Oper.ctlVal	RB09	Remote Bit 9
RBGGIO2	SPCSO10.Oper.ctlVal	RB10	Remote Bit 10
RBGGIO2	SPCSO11.Oper.ctlVal	RB11	Remote Bit 11
RBGGIO2	SPCSO12.Oper.ctlVal	RB12	Remote Bit 12
RBGGIO2	SPCSO13.Oper.ctlVal	RB13	Remote Bit 13
RBGGIO2	SPCSO14.Oper.ctlVal	RB14	Remote Bit 14
RBGGIO2	SPCSO15.Oper.ctlVal	RB15	Remote Bit 15
RBGGIO2	SPCSO16.Oper.ctlVal	RB16	Remote Bit 16
RBGGIO3	SPCSO17.Oper.ctlVal	RB17	Remote Bit 17
RBGGIO3	SPCSO18.Oper.ctlVal	RB18	Remote Bit 18
RBGGIO3	SPCSO19.Oper.ctlVal	RB19	Remote Bit 19
RBGGIO3	SPCSO20.Oper.ctlVal	RB20	Remote Bit 20
RBGGIO3	SPCSO21.Oper.ctlVal	RB21	Remote Bit 21
RBGGIO3	SPCSO22.Oper.ctlVal	RB22	Remote Bit 22
RBGGIO3	SPCSO23.Oper.ctlVal	RB23	Remote Bit 23
RBGGIO3	SPCSO24.Oper.ctlVal	RB24	Remote Bit 24
RBGGIO4	SPCSO25.Oper.ctlVal	RB25	Remote Bit 25
RBGGIO4	SPCSO26.Oper.ctlVal	RB26	Remote Bit 26
RBGGIO4	SPCSO27.Oper.ctlVal	RB27	Remote Bit 27
RBGGIO4	SPCSO28.Oper.ctlVal	RB28	Remote Bit 28
RBGGIO4	SPCSO29.Oper.ctlVal	RB29	Remote Bit 29
RBGGIO4	SPCSO30.Oper.ctlVal	RB30	Remote Bit 30
RBGGIO4	SPCSO31.Oper.ctlVal	RB31	Remote Bit 31
RBGGIO4	SPCSO32.Oper.ctlVal	RB32	Remote Bit 32
Functional Constraint = DC			
CTRLLPHD1	PhyNam.model	PARNUM	Relay part number string
Functional Constraint = ST			
RBGGIO1[a]	SPCSO01.stVal	RB01	Remote Bit 1
RBGGIO1[a]	SPCSO02.stVal	RB02	Remote Bit 2

Table 17.11 Logical Device: CON (Remote Control) (Sheet 2 of 2)

Logical Node	Attribute	Data Source	Comment
RBGGIO1[a]	SPCSO03.stVal	RB03	Remote Bit 3
RBGGIO1[a]	SPCSO04.stVal	RB04	Remote Bit 4
RBGGIO1[a]	SPCSO05.stVal	RB05	Remote Bit 5
RBGGIO1[a]	SPCSO06.stVal	RB06	Remote Bit 6
RBGGIO1[a]	SPCSO07.stVal	RB07	Remote Bit 7
RBGGIO1[a]	SPCSO08.stVal	RB08	Remote Bit 8
RBGGIO2[a]	SPCSO09.stVal	RB09	Remote Bit 9
RBGGIO2[a]	SPCSO10.stVal	RB10	Remote Bit 10
RBGGIO2[a]	SPCSO11.stVal	RB11	Remote Bit 11
RBGGIO2[a]	SPCSO12.stVal	RB12	Remote Bit 12
RBGGIO2[a]	SPCSO13.stVal	RB13	Remote Bit 13
RBGGIO2[a]	SPCSO14.stVal	RB14	Remote Bit 14
RBGGIO2[a]	SPCSO15.stVal	RB15	Remote Bit 15
RBGGIO2[a]	SPCSO16.stVal	RB16	Remote Bit 16
RBGGIO3[a]	SPCSO17.stVal	RB17	Remote Bit 17
RBGGIO3[a]	SPCSO18.stVal	RB18	Remote Bit 18
RBGGIO3[a]	SPCSO19.stVal	RB19	Remote Bit 19
RBGGIO3[a]	SPCSO20.stVal	RB20	Remote Bit 20
RBGGIO3[a]	SPCSO21.stVal	RB21	Remote Bit 21
RBGGIO3[a]	SPCSO22.stVal	RB22	Remote Bit 22
RBGGIO3[a]	SPCSO23.stVal	RB23	Remote Bit 23
RBGGIO3[a]	SPCSO24.stVal	RB24	Remote Bit 24
RBGGIO4[a]	SPCSO25.stVal	RB25	Remote Bit 25
RBGGIO4[a]	SPCSO26.stVal	RB26	Remote Bit 26
RBGGIO4[a]	SPCSO27.stVal	RB27	Remote Bit 27
RBGGIO4[a]	SPCSO28.stVal	RB28	Remote Bit 28
RBGGIO4[a]	SPCSO29.stVal	RB29	Remote Bit 29
RBGGIO4[a]	SPCSO30.stVal	RB30	Remote Bit 30
RBGGIO4[a]	SPCSO31.stVal	RB31	Remote Bit 31
RBGGIO4[a]	SPCSO32.stVal	RB32	Remote Bit 32

[a] Data source is high-speed GOOSE data if included in an outgoing GOOSE dataset.

Table 17.12 shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 1 of 11)

Logical Node	Attribute	Data Source	Comment
Functional Constraint = DC			
STALPHD1	PhyNam.model	PARNUM	Relay part number string
Functional Constraint = MX			
ACNGGIO2	AnIn001.instMag.f	ACN01CV	Automation SELOGIC Counter 01 current value
ACNGGIO2	AnIn002.instMag.f	ACN02CV	Automation SELOGIC Counter 02 current value
ACNGGIO2	AnIn003.instMag.f	ACN03CV	Automation SELOGIC Counter 03 current value
• • •			
ACNGGIO2	AnIn014.instMag.f	ACN14CV	Automation SELOGIC Counter 14 current value
ACNGGIO2	AnIn015.instMag.f	ACN15CV	Automation SELOGIC Counter 15 current value
ACNGGIO2	AnIn016.instMag.f	ACN16CV	Automation SELOGIC Counter 16 current value
AMVGGIO1	AnIn001.instMag.f	AMV001	Automation SELOGIC Math Variable 001
AMVGGIO1	AnIn002.instMag.f	AMV002	Automation SELOGIC Math Variable 002
AMVGGIO1	AnIn003.instMag.f	AMV003	Automation SELOGIC Math Variable 003
• • •			
AMVGGIO1	AnIn062.instMag.f	AMV062	Automation SELOGIC Math Variable 062
AMVGGIO1	AnIn063.instMag.f	AMV063	Automation SELOGIC Math Variable 063
AMVGGIO1	AnIn064.instMag.f	AMV064	Automation SELOGIC Math Variable 064
AMVGGIO2	AnIn065.instMag.f	AMV065	Automation SELOGIC Math Variable 065
AMVGGIO2	AnIn066.instMag.f	AMV066	Automation SELOGIC Math Variable 066
AMVGGIO2	AnIn067.instMag.f	AMV067	Automation SELOGIC Math Variable 067
• • •			
AMVGGIO2	AnIn126.instMag.f	AMV126	Automation SELOGIC Math Variable 126
AMVGGIO2	AnIn127.instMag.f	AMV127	Automation SELOGIC Math Variable 127
AMVGGIO2	AnIn128.instMag.f	AMV128	Automation SELOGIC Math Variable 128
PCNGGIO1	AnIn001.instMag.f	PCN01CV	Protection SELOGIC Counter 01 current value
PCNGGIO1	AnIn002.instMag.f	PCN02CV	Protection SELOGIC Counter 02 current value
PCNGGIO1	AnIn003.instMag.f	PCN03CV	Protection SELOGIC Counter 03 current value

NOTE: Some products support only 64 AMVs in their ANN Logical Device.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 2 of 11)

Logical Node	Attribute	Data Source	Comment
• • •			
PCNGGIO1	AnIn014.instMag.f	PCN14CV	Protection SELOGIC Counter 14 current value
PCNGGIO1	AnIn015.instMag.f	PCN15CV	Protection SELOGIC Counter 15 current value
PCNGGIO1	AnIn016.instMag.f	PCN16CV	Protection SELOGIC Counter 16 current value
PMVGGIO3	AnIn01.instMag.f	PMV01	Protection SELOGIC Math Variable 01
PMVGGIO3	AnIn02.instMag.f	PMV02	Protection SELOGIC Math Variable 02
PMVGGIO3	AnIn03.instMag.f	PMV03	Protection SELOGIC Math Variable 03
• • •			
PMVGGIO3	AnIn62.instMag.f	PMV62	Protection SELOGIC Math Variable 62
PMVGGIO3	AnIn63.instMag.f	PMV63	Protection SELOGIC Math Variable 63
PMVGGIO3	AnIn64.instMag.f	PMV64	Protection SELOGIC Math Variable 64
RAGGIO1	Ra001.instMag.f	RA001	Remote Analog Input 001
RAGGIO1	Ra002.instMag.f	RA002	Remote Analog Input 002
RAGGIO1	Ra003.instMag.f	RA003	Remote Analog Input 003
• • •			
RAGGIO1	Ra030.instMag.f	RA030	Remote Analog Input 030
RAGGIO1	Ra031.instMag.f	RA031	Remote Analog Input 031
RAGGIO1	Ra032.instMag.f	RA032	Remote Analog Input 032
RAGGIO2	Ra033.instMag.f	RA033	Remote Analog Input 033
RAGGIO2	Ra034.instMag.f	RA034	Remote Analog Input 034
RAGGIO2	Ra035.instMag.f	RA035	Remote Analog Input 035
• • •			
RAGGIO2	Ra062.instMag.f	RA062	Remote Analog Input 062
RAGGIO2	Ra063.instMag.f	RA063	Remote Analog Input 063
RAGGIO2	Ra064.instMag.f	RA064	Remote Analog Input 064
RAGGIO3	Ra065.instMag.f	RA065	Remote Analog Input 065
RAGGIO3	Ra066.instMag.f	RA066	Remote Analog Input 066
RAGGIO3	Ra067.instMag.f	RA067	Remote Analog Input 067
• • •			
RAGGIO3	Ra094.instMag.f	RA094	Remote Analog Input 094
RAGGIO3	Ra095.instMag.f	RA095	Remote Analog Input 095
RAGGIO3	Ra096.instMag.f	RA096	Remote Analog Input 096

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 3 of 11)

Logical Node	Attribute	Data Source	Comment
RAGGIO4	Ra097.instMag.f	RA097	Remote Analog Input 097
RAGGIO4	Ra098.instMag.f	RA098	Remote Analog Input 098
RAGGIO4	Ra099.instMag.f	RA099	Remote Analog Input 099
• • •			
RAGGIO4	Ra126.instMag.f	RA126	Remote Analog Input 126
RAGGIO4	Ra127.instMag.f	RA127	Remote Analog Input 127
RAGGIO4	Ra128.instMag.f	RA128	Remote Analog Input 128
RAGGIO5	Ra129.instMag.f	RA129	Remote Analog Input 129
RAGGIO5	Ra130.instMag.f	RA130	Remote Analog Input 130
RAGGIO5	Ra131.instMag.f	RA131	Remote Analog Input 131
• • •			
RAGGIO5	Ra158.instMag.f	RA158	Remote Analog Input 158
RAGGIO5	Ra159.instMag.f	RA159	Remote Analog Input 159
RAGGIO5	Ra160.instMag.f	RA160	Remote Analog Input 160
RAGGIO6	Ra161.instMag.f	RA161	Remote Analog Input 161
RAGGIO6	Ra162.instMag.f	RA162	Remote Analog Input 162
RAGGIO6	Ra163.instMag.f	RA163	Remote Analog Input 163
• • •			
RAGGIO6	Ra190.instMag.f	RA190	Remote Analog Input 190
RAGGIO6	Ra191.instMag.f	RA191	Remote Analog Input 191
RAGGIO6	Ra192.instMag.f	RA192	Remote Analog Input 192
RAGGIO7	Ra193.instMag.f	RA193	Remote Analog Input 193
RAGGIO7	Ra194.instMag.f	RA194	Remote Analog Input 194
RAGGIO7	Ra195.instMag.f	RA195	Remote Analog Input 195
• • •			
RAGGIO7	Ra222.instMag.f	RA222	Remote Analog Input 222
RAGGIO7	Ra223.instMag.f	RA223	Remote Analog Input 223
RAGGIO7	Ra224.instMag.f	RA224	Remote Analog Input 224
RAGGIO8	Ra225.instMag.f	RA225	Remote Analog Input 225
RAGGIO8	Ra226.instMag.f	RA226	Remote Analog Input 226
RAGGIO8	Ra227.instMag.f	RA227	Remote Analog Input 227
• • •			
RAGGIO8	Ra254.instMag.f	RA254	Remote Analog Input 254
RAGGIO8	Ra255.instMag.f	RA255	Remote Analog Input 255

NOTE: Some products support only 128 Remote Analogs in their ANN Logical Device.

NOTE: Some relays support only 64 Automation SELOGIC Variables.

NOTE: Some relays do not support the ETHGGIO1 Logical Node.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 4 of 11)

Logical Node	Attribute	Data Source	Comment
RAGGIO8	Ra256.instMag.f	RA256	Remote Analog Input 256
RAOGGIO1	Rao01.instMag.f	RAO01	Remote Analog Output 01
RAOGGIO1	Rao02.instMag.f	RAO02	Remote Analog Output 02
RAOGGIO1	Rao03.instMag.f	RAO03	Remote Analog Output 03
• • •			
RAOGGIO1	Rao30.instMag.f	RAO30	Remote Analog Output 30
RAOGGIO1	Rao31.instMag.f	RAO31	Remote Analog Output 31
RAOGGIO1	Rao32.instMag.f	RAO32	Remote Analog Output 32
RAOGGIO2	Rao33.instMag.f	RAO33	Remote Analog Output 33
RAOGGIO2	Rao34.instMag.f	RAO34	Remote Analog Output 34
RAOGGIO2	Rao35.instMag.f	RAO35	Remote Analog Output 35
• • •			
RAOGGIO2	Rao62.instMag.f	RAO62	Remote Analog Output 62
RAOGGIO2	Rao63.instMag.f	RAO63	Remote Analog Output 63
RAOGGIO2	Rao64.instMag.f	RAO64	Remote Analog Output 64
Functional Constraint = ST[a]			
ALTGGIO5	Ind01.stVal	ALT01	Automation Latch 1
ALTGGIO5	Ind02.stVal	ALT02	Automation Latch 2
ALTGGIO5	Ind03.stVal	ALT03	Automation Latch 3
• • •			
ALTGGIO5	Ind30.stVal	ALT30	Automation Latch 30
ALTGGIO5	Ind31.stVal	ALT31	Automation Latch 31
ALTGGIO5	Ind32.stVal	ALT32	Automation Latch 32
ASVGGIO4	Ind001.stVal	ASV001	Automation SELOGIC Variable 1
ASVGGIO4	Ind002.stVal	ASV002	Automation SELOGIC Variable 2
ASVGGIO4	Ind003.stVal	ASV003	Automation SELOGIC Variable 3
• • •			
ASVGGIO4	Ind126.stVal	ASV126	Automation SELOGIC Variable 126
ASVGGIO4	Ind127.stVal	ASV127	Automation SELOGIC Variable 127
ASVGGIO4	Ind128.stVal	ASV128	Automation SELOGIC Variable 128
ETHGGIO1	Ind01.stVal	P5ASEL	Port 5A active/inactive
ETHGGIO1	Ind02.stVal	LINK5A	Link status of Port 5A connection
ETHGGIO1	Ind03.stVal	P5BSEL	Port 5B active/inactive
ETHGGIO1	Ind04.stVal	LINK5B	Link status of Port 5B connection
ETHGGIO1	Ind05.stVal	P5CSEL	Port 5C active/inactive

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 5 of 11)

Logical Node	Attribute	Data Source	Comment
ETHGGIO1	Ind06.stVal	LINK5C	Link status of Port 5C connection
ETHGGIO1	Ind07.stVal	P5DSEL	Port 5D active/inactive
ETHGGIO1	Ind08.stVal	LINK5D	Link status of Port 5D connection
ETHGGIO1	Ind09.stVal	LNKFAIL	Link status of the active port
IN1GGIO14[b]	Ind01.stVal	IN101	Main Board Input 1
IN1GGIO14[b]	Ind02.stVal	IN102	Main Board Input 2
IN1GGIO14[b]	Ind03.stVal	IN103	Main Board Input 3
IN1GGIO14[b]	Ind04.stVal	IN104	Main Board Input 4
IN1GGIO14[b]	Ind05.stVal	IN105	Main Board Input 5
IN1GGIO14[b]	Ind06.stVal	IN106	Main Board Input 6
IN1GGIO14[b]	Ind07.stVal	IN107	Main Board Input 7
IN2GGIO15	Ind01.stVal	IN201	First Optional I/O Board Input 1 (if installed)
IN2GGIO15	Ind02.stVal	IN202	First Optional I/O Board Input 2 (if installed)
IN2GGIO15	Ind03.stVal	IN203	First Optional I/O Board Input 3 (if installed)
• • •			
IN2GGIO15	Ind22.stVal	IN222	First Optional I/O Board Input 22 (if installed)
IN2GGIO15	Ind23.stVal	IN223	First Optional I/O Board Input 23 (if installed)
IN2GGIO15	Ind24.stVal	IN224	First Optional I/O Board Input 24 (if installed)
IN3GGIO16	Ind01.stVal	IN301	Second Optional I/O Board Input 1 (if installed)
IN3GGIO16	Ind02.stVal	IN302	Second Optional I/O Board Input 2 (if installed)
IN3GGIO16	Ind03.stVal	IN303	Second Optional I/O Board Input 3 (if installed)
• • •			
IN3GGIO16	Ind22.stVal	IN322	Second Optional I/O Board Input 22 (if installed)
IN3GGIO16	Ind23.stVal	IN323	Second Optional I/O Board Input 23 (if installed)
IN3GGIO16	Ind24.stVal	IN324	Second Optional I/O Board Input 24 (if installed)
IN4GGIO18[c]	Ind01.stVal	IN401	Third Optional I/O Board Input 1 (if installed)
IN4GGIO18[c]	Ind02.stVal	IN402	Third Optional I/O Board Input 2 (if installed)
IN4GGIO18[c]	Ind03.stVal	IN403	Third Optional I/O Board Input 3 (if installed)
• • •			

NOTE: Some relays do not support the LBGGIO1 Logical Node.

NOTE: Some relays do not support the MBOKGGIO13 Logical Node.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 6 of 11)

Logical Node	Attribute	Data Source	Comment
IN4GGIO18[c]	Ind22.stVal	IN422	Third Optional I/O Board Input 22 (if installed)
IN4GGIO18[c]	Ind23.stVal	IN423	Third Optional I/O Board Input 23 (if installed)
IN4GGIO18[c]	Ind24.stVal	IN424	Third Optional I/O Board Input 24 (if installed)
IN5GGIO13[d]	Ind01.stVal	IN501	Fourth Optional I/O Board Input 01 (if installed)
IN5GGIO13[d]	Ind02.stVal	IN502	Fourth Optional I/O Board Input 02 (if installed)
IN5GGIO13[d]	Ind03.stVal	IN503	Fourth Optional I/O Board Input 03 (if installed)
• • •			
IN5GGIO13[d]	Ind22.stVal	IN522	Fourth Optional I/O Board Input 22 (if installed)
IN5GGIO13[d]	Ind23.stVal	IN523	Fourth Optional I/O Board Input 23 (if installed)
IN5GGIO13[d]	Ind24.stVal	IN524	Fourth Optional I/O Board Input 24 (if installed)
LBGGIO1	Ind01.stVal	LB01	Local Bit 1
LBGGIO1	Ind02.stVal	LB02	Local Bit 2
LBGGIO1	Ind03.stVal	LB03	Local Bit 3
• • •			
LBGGIO1	Ind30.stVal	LB30	Local Bit 30
LBGGIO1	Ind31.stVal	LB31	Local Bit 31
LBGGIO1	Ind32.stVal	LB32	Local Bit 32
MBOKGGIO13	Ind01.stVal	ROKA	Normal MIRRORED BITS communications Channel A status while not in loopback mode
MBOKGGIO13	Ind02.stVal	RBADA	Outage too long on MIRRORED BITS communications Channel A
MBOKGGIO13	Ind03.stVal	CBADA	Unavailability threshold exceeded for MIRRORED BITS communications Channel A
MBOKGGIO13	Ind04.stVal	LBOKA	Normal MIRRORED BITS communications Channel A status while in loopback mode
MBOKGGIO13	Ind05.stVal	ANOKA	Analog transfer OK on MIRRORED BITS communications Channel A
MBOKGGIO13	Ind06.stVal	DOKA	Normal MIRRORED BITS communications Channel A status
MBOKGGIO13	Ind07.stVal	ROKB	Normal MIRRORED BITS communications Channel B status while not in loopback mode
MBOKGGIO13	Ind08.stVal	RBADB	Outage too long on MIRRORED BITS communications Channel B

NOTE: The instance number *n* for the I/O Board logical nodes (INxGGIO*n* and OUTxGGIO*n*) may vary between relays

NOTE: OUT401–OUT416 are not present in the SEL-451.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 7 of 11)

Logical Node	Attribute	Data Source	Comment
MBOKGGIO13	Ind09.stVal	CBADB	Unavailability threshold exceeded for MIRRORED BITS communications Channel B
MBOKGGIO13	Ind10.stVal	LBOKB	Normal MIRRORED BITS communications Channel B status while in loopback mode
MBOKGGIO13	Ind11.stVal	ANOKB	Analog transfer OK on MIRRORED BITS communications Channel B
MBOKGGIO13	Ind12.stVal	DOKB	Normal MIRRORED BITS communications Channel B status
OUT1GGIO17[e]	Ind01.stVal	OUT101	Main Board Output 1
OUT1GGIO17[e]	Ind02.stVal	OUT102	Main Board Output 2
OUT1GGIO17[e]	Ind03.stVal	OUT103	Main Board Output 3
OUT1GGIO17[e]	Ind04.stVal	OUT104	Main Board Output 4
OUT1GGIO17[e]	Ind05.stVal	OUT105	Main Board Output 5
OUT1GGIO17[e]	Ind06.stVal	OUT106	Main Board Output 6
OUT1GGIO17[e]	Ind07.stVal	OUT107	Main Board Output 7
OUT1GGIO17[e]	Ind08.stVal	OUT108	Main Board Output 8
OUT2GGIO16	Ind01.stVal	OUT201	First Optional I/O Board Output 1
OUT2GGIO16	Ind02.stVal	OUT202	First Optional I/O Board Output 2
OUT2GGIO16	Ind03.stVal	OUT203	First Optional I/O Board Output 3
• • •			
OUT2GGIO16	Ind14.stVal	OUT214	First Optional I/O Board Output 14
OUT2GGIO16	Ind15.stVal	OUT215	First Optional I/O Board Output 15
OUT2GGIO16	Ind16.stVal	OUT216	First Optional I/O Board Output 16
OUT3GGIO17	Ind01.stVal	OUT301	Second Optional I/O Board Output 1
OUT3GGIO17	Ind02.stVal	OUT302	Second Optional I/O Board Output 2
OUT3GGIO17	Ind03.stVal	OUT303	Second Optional I/O Board Output 3
• • •			
OUT3GGIO17	Ind14.stVal	OUT314	Second Optional I/O Board Output 14
OUT3GGIO17	Ind15.stVal	OUT315	Second Optional I/O Board Output 15
OUT3GGIO17	Ind16.stVal	OUT316	Second Optional I/O Board Output 16
OUT4GGIO19[c]	Ind01.stVal	OUT401	Third Optional I/O Board Output 1
OUT4GGIO19[c]	Ind02.stVal	OUT402	Third Optional I/O Board Output 2
OUT4GGIO19[c]	Ind03.stVal	OUT403	Third Optional I/O Board Output 3
• • •			
OUT4GGIO19[c]	Ind14.stVal	OUT414	Third Optional I/O Board Output 14
OUT4GGIO19[c]	Ind15.stVal	OUT415	Third Optional I/O Board Output 15
OUT4GGIO19[c]	Ind16.stVal	OUT416	Third Optional I/O Board Output 16
OUT5GGIO18[d]	Ind01.stVal	OUT501	Fourth Optional I/O Board Output 1

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 8 of 11)

Logical Node	Attribute	Data Source	Comment
OUT5GGIO18[d]	Ind02.stVal	OUT502	Fourth Optional I/O Board Output 2
OUT5GGIO18[d]	Ind03.stVal	OUT503	Fourth Optional I/O Board Output 3
• • •			
OUT5GGIO18[d]	Ind14.stVal	OUT514	Fourth Optional I/O Board Output 14
OUT5GGIO18[d]	Ind15.stVal	OUT515	Fourth Optional I/O Board Output 15
OUT5GGIO18[d]	Ind16.stVal	OUT516	Fourth Optional I/O Board Output 16
PBLEDGGIO8	Ind01.stVal	PB1_LED	Pushbutton 1 LED
PBLEDGGIO8	Ind02.stVal	PB2_LED	Pushbutton 2 LED
PBLEDGGIO8	Ind03.stVal	PB3_LED	Pushbutton 3 LED
PBLEDGGIO8	Ind04.stVal	PB4_LED	Pushbutton 4 LED
PBLEDGGIO8	Ind05.stVal	PB5_LED	Pushbutton 5 LED
PBLEDGGIO8	Ind06.stVal	PB6_LED	Pushbutton 6 LED
PBLEDGGIO8	Ind07.stVal	PB7_LED	Pushbutton 7 LED
PBLEDGGIO8	Ind08.stVal	PB8_LED	Pushbutton 8 LED
PBLEDGGIO8	Ind09.stVal	PB9_LED	Pushbutton 9 LED
PBLEDGGIO8	Ind10.stVal	PB10LED	Pushbutton 10 LED
PBLEDGGIO8	Ind11.stVal	PB11LED	Pushbutton 11 LED
PBLEDGGIO8	Ind12.stVal	PB12LED	Pushbutton 12 LED
PLTGGIO2	Ind01.stVal	PLT01	Protection Latch 1
PLTGGIO2	Ind02.stVal	PLT02	Protection Latch 2
PLTGGIO2	Ind03.stVal	PLT03	Protection Latch 3
• • •			
PLTGGIO2	Ind30.stVal	PLT30	Protection Latch 30
PLTGGIO2	Ind31.stVal	PLT31	Protection Latch 31
PLTGGIO2	Ind32.stVal	PLT32	Protection Latch 32
PSVGGIO1	Ind01.stVal	PSV01	Protection SELOGIC Variable 1
PSVGGIO1	Ind02.stVal	PSV02	Protection SELOGIC Variable 2
PSVGGIO1	Ind03.stVal	PSV03	Protection SELOGIC Variable 3
• • •			
PSVGGIO1	Ind62.stVal	PSV62	Protection SELOGIC Variable 62
PSVGGIO1	Ind63.stVal	PSV63	Protection SELOGIC Variable 63
PSVGGIO1	Ind64.stVal	PSV64	Protection SELOGIC Variable 64
RMBAGGIO9	Ind01.stVal	RMB1A	Channel A Receive Mirrored Bit 1
RMBAGGIO9	Ind02.stVal	RMB2A	Channel A Receive Mirrored Bit 2
RMBAGGIO9	Ind03.stVal	RMB3A	Channel A Receive Mirrored Bit 3
RMBAGGIO9	Ind04.stVal	RMB4A	Channel A Receive Mirrored Bit 4

NOTE: Not all relays support the RMBAGGIO9 and RMBBGGIO11 logical nodes.

NOTE: Not all relays support synchrophasor real time control (RTC) logical nodes.

NOTE: Not all relays support logical node RTDHGGIO1 for RTD inputs.

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 9 of 11)

Logical Node	Attribute	Data Source	Comment
RMBAGGIO9	Ind05.stVal	RMB5A	Channel A Receive Mirrored Bit 5
RMBAGGIO9	Ind06.stVal	RMB6A	Channel A Receive Mirrored Bit 6
RMBAGGIO9	Ind07.stVal	RMB7A	Channel A Receive Mirrored Bit 7
RMBAGGIO9	Ind08.stVal	RMB8A	Channel A Receive Mirrored Bit 8
RMBBGGIO11	Ind01.stVal	RMB1B	Channel B Receive Mirrored Bit 1
RMBBGGIO11	Ind02.stVal	RMB2B	Channel B Receive Mirrored Bit 2
RMBBGGIO11	Ind03.stVal	RMB3B	Channel B Receive Mirrored Bit 3
RMBBGGIO11	Ind04.stVal	RMB4B	Channel B Receive Mirrored Bit 4
RMBBGGIO11	Ind05.stVal	RMB5B	Channel B Receive Mirrored Bit 5
RMBBGGIO11	Ind06.stVal	RMB6B	Channel B Receive Mirrored Bit 6
RMBBGGIO11	Ind07.stVal	RMB7B	Channel B Receive Mirrored Bit 7
RMBBGGIO11	Ind08.stVal	RMB8B	Channel B Receive Mirrored Bit 8
RTCAGGIO1	Ind01.stVal	RTCAD01	RTC Remote Data Bits, Channel A, bit 1
RTCAGGIO1	Ind02.stVal	RTCAD02	RTC Remote Data Bits, Channel A, bit 2
RTCAGGIO1	Ind03.stVal	RTCAD03	RTC Remote Data Bits, Channel A, bit 3
• • •			
RTCAGGIO1	Ind14.stVal	RTCAD14	RTC Remote Data Bits, Channel A, bit 14
RTCAGGIO1	Ind15.stVal	RTCAD15	RTC Remote Data Bits, Channel A, bit 15
RTCAGGIO1	Ind16.stVal	RTCAD16	RTC Remote Data Bits, Channel A, bit 16
RTCBGGIO2	Ind01.stVal	RTCBD01	RTC Remote Data Bits, Channel B, bit 1
RTCBGGIO2	Ind02.stVal	RTCBD02	RTC Remote Data Bits, Channel B, bit 2
RTCBGGIO2	Ind03.stVal	RTCBD03	RTC Remote Data Bits, Channel B, bit 3
• • •			
RTCBGGIO2	Ind14.stVal	RTCBD14	RTC Remote Data Bits, Channel B, bit 14
RTCBGGIO2	Ind15.stVal	RTCBD15	RTC Remote Data Bits, Channel B, bit 15
RTCBGGIO2	Ind16.stVal	RTCBD16	RTC Remote Data Bits, Channel B, bit 16
RTDHGGIO1	Ind01.stVal	RTD01ST	RTD Status for Channel 1
RTDHGGIO1	Ind02.stVal	RTD02ST	RTD Status for Channel 2
RTDHGGIO1	Ind03.stVal	RTD03ST	RTD Status for Channel 3
RTDHGGIO1	Ind04.stVal	RTD04ST	RTD Status for Channel 4
RTDHGGIO1	Ind05.stVal	RTD05ST	RTD Status for Channel 5
RTDHGGIO1	Ind06.stVal	RTD06ST	RTD Status for Channel 6
RTDHGGIO1	Ind07.stVal	RTD07ST	RTD Status for Channel 7
RTDHGGIO1	Ind08.stVal	RTD08ST	RTD Status for Channel 8
RTDHGGIO1	Ind09.stVal	RTD09ST	RTD Status for Channel 9
RTDHGGIO1	Ind10.stVal	RTD10ST	RTD Status for Channel 10
RTDHGGIO1	Ind11.stVal	RTD11ST	RTD Status for Channel 11
RTDHGGIO1	Ind12.stVal	RTD12ST	RTD Status for Channel 12

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 10 of 11)

Logical Node	Attribute	Data Source	Comment
SGGGIO1	Ind01.stVal	SG1	Settings Group 1 active
SGGGIO1	Ind02.stVal	SG2	Settings Group 2 active
SGGGIO1	Ind03.stVal	SG3	Settings Group 3 active
SGGGIO1	Ind04.stVal	SG4	Settings Group 4 active
SGGGIO1	Ind05.stVal	SG5	Settings Group 5 active
SGGGIO1	Ind06.stVal	SG6	Settings Group 6 active
TLEDGGIO7	Ind01.stVal	EN	Relay Enabled
TLEDGGIO7	Ind02.stVal	TRIPLED	Trip LED
TLEDGGIO7	Ind03.stVal	TLED_1	Target LED 1
TLEDGGIO7	Ind04.stVal	TLED_2	Target LED 2
TLEDGGIO7	Ind05.stVal	TLED_3	Target LED 3
TLEDGGIO7	Ind06.stVal	TLED_4	Target LED 4
TLEDGGIO7	Ind07.stVal	TLED_5	Target LED 5
TLEDGGIO7	Ind08.stVal	TLED_6	Target LED 6
TLEDGGIO7	Ind09.stVal	TLED_7	Target LED 7
TLEDGGIO7	Ind10.stVal	TLED_8	Target LED 8
TLEDGGIO7	Ind11.stVal	TLED_9	Target LED 9
TLEDGGIO7	Ind12.stVal	TLED_10	Target LED 10
TLEDGGIO7	Ind13.stVal	TLED_11	Target LED 11
TLEDGGIO7	Ind14.stVal	TLED_12	Target LED 12
TLEDGGIO7	Ind15.stVal	TLED_13	Target LED 13
TLEDGGIO7	Ind16.stVal	TLED_14	Target LED 14
TLEDGGIO7	Ind17.stVal	TLED_15	Target LED 15
TLEDGGIO7	Ind18.stVal	TLED_16	Target LED 16
TLEDGGIO7	Ind19.stVal	TLED_17	Target LED 17
TLEDGGIO7	Ind20.stVal	TLED_18	Target LED 18
TLEDGGIO7	Ind21.stVal	TLED_19	Target LED 19
TLEDGGIO7	Ind22.stVal	TLED_20	Target LED 20
TLEDGGIO7	Ind23.stVal	TLED_21	Target LED 21
TLEDGGIO7	Ind24.stVal	TLED_22	Target LED 22
TLEDGGIO7	Ind25.stVal	TLED_23	Target LED 23
TLEDGGIO7	Ind26.stVal	TLED_24	Target LED 24
TMBAGGIO10	Ind01.stVal	TMB1A	Channel A Transmit Mirrored Bit 1
TMBAGGIO10	Ind02.stVal	TMB2A	Channel A Transmit Mirrored Bit 2
TMBAGGIO10	Ind03.stVal	TMB3A	Channel A Transmit Mirrored Bit 3
TMBAGGIO10	Ind04.stVal	TMB4A	Channel A Transmit Mirrored Bit 4
TMBAGGIO10	Ind05.stVal	TMB5A	Channel A Transmit Mirrored Bit 5
TMBAGGIO10	Ind06.stVal	TMB6A	Channel A Transmit Mirrored Bit 6
TMBAGGIO10	Ind07.stVal	TMB7A	Channel A Transmit Mirrored Bit 7
TMBAGGIO10	Ind08.stVal	TMB8A	Channel A Transmit Mirrored Bit 8

Table 17.12 Logical Device: ANN (Annunciation) (Sheet 11 of 11)

Logical Node	Attribute	Data Source	Comment
TMBBGGIO12	Ind01.stVal	TMB1B	Channel B Transmit Mirrored Bit 1
TMBBGGIO12	Ind02.stVal	TMB2B	Channel B Transmit Mirrored Bit 2
TMBBGGIO12	Ind03.stVal	TMB3B	Channel B Transmit Mirrored Bit 3
TMBBGGIO12	Ind04.stVal	TMB4B	Channel B Transmit Mirrored Bit 4
TMBBGGIO12	Ind05.stVal	TMB5B	Channel B Transmit Mirrored Bit 5
TMBBGGIO12	Ind06.stVal	TMB6B	Channel B Transmit Mirrored Bit 6
TMBBGGIO12	Ind07.stVal	TMB7B	Channel B Transmit Mirrored Bit 7
TMBBGGIO12	Ind08.stVal	TMB8B	Channel B Transmit Mirrored Bit 8
VBGGIO1	Ind001.stVal	VB001	Virtual Bit 001
VBGGIO1	Ind002.stVal	VB002	Virtual Bit 002
VBGGIO1	Ind003.stVal	VB003	Virtual Bit 003
• • •			
VBGGIO1	Ind126.stVal	VB126	Virtual Bit 126
VBGGIO1	Ind127.stVal	VB127	Virtual Bit 127
VBGGIO1	Ind128.stVal	VB128	Virtual Bit 128
VBGGIO2	Ind129.stVal	VB129	Virtual Bit 129
VBGGIO2	Ind130.stVal	VB130	Virtual Bit 130
VBGGIO2	Ind131.stVal	VB131	Virtual Bit 131
• • •			
VBGGIO2	Ind254.stVal	VB254	Virtual Bit 254
VBGGIO2	Ind255.stVal	VB255	Virtual Bit 255
VBGGIO2	Ind256.stVal	VB256	Virtual Bit 256

[a] Data attributes in the ST FC will provide high-speed GOOSE data if included in an outgoing GOOSE dataset.
[b] Not all SEL-400 series relays support main board inputs.
[c] Not all SEL-400 series relays support a third interface board.
[d] Not all SEL-400 series relays support four interface boards.
[e] Not all SEL-400 series relays support main board outputs.

SEL Nameplate Data

The CID file contains information that describes the physical device attributes according to IEC 61850 standards. The LN0 logical node of each logical device contains the Nameplate DOI (instantiated data object) with the following data.

Table 17.13 SEL Nameplate Data (Sheet 1 of 2)

Data Attribute	Value
vendor	“SEL”
swRev	Contents of FID string from **ID** command
d	Description of LD

Table 17.13 SEL Nameplate Data (Sheet 2 of 2)

Data Attribute	Value
configRev	Always 0
1dNs	IEC 61850-7-4:2007A

Protocol Implementation Conformance Statement

Table 17.14 and *Table 17.15* are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that because the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table 17.14 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table 17.15 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSSE
T4	GSSE	N	N	
T5	Time Sync	N	N	

Refer to the *ACSI Conformance Statements on page 17.50* for information on the supported services.

MMS Conformance

The manufacturing message specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table 17.16* defines the service support requirement and restrictions of the MMS services in the SEL-400 series devices. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 17.16 MMS Service Supported Conformance (Sheet 1 of 4)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
status		Y
getNameList		Y
identify		Y
rename		

Table 17.16 MMS Service Supported Conformance (Sheet 2 of 4)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		

Table 17.16 MMS Service Supported Conformance (Sheet 3 of 4)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
getProgramInvocationAttributes		
obtainFile		Y
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		Y
fileRead		Y
fileClose		Y
fileRename		
fileDelete		Y
fileDirectory		Y
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		

Table 17.16 MMS Service Supported Conformance (Sheet 4 of 4)

MMS Service Supported CBB	Client-CR	Server-CR
	Supported	Supported
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table 17.17 lists specific settings for the MMS parameter conformance building block (CBB).

Table 17.17 MMS Parameter CBB

MMS Parameter CBB	Client-CR	Server-CR
	Supported	Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following variable access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table 17.18 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR	Server-CR
	Supported	Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table 17.19 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR	Server-CR
	Supported	Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table 17.20 VariableSpecification Conformance Statement

VariableSpecification	Client-CR	Server-CR
	Supported	Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table 17.21 Read Conformance Statement

Read	Client-CR	Server-CR
	Supported	Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table 17.22 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table 17.23 DefineNamedVariableList Conformance Statement (Sheet 1 of 2)

DefineVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
variableListName		

Table 17.23 DefineNamedVariableList Conformance Statement (Sheet 2 of 2)

DefineVariableAccessAttributes	Client-CR	Server-CR
	Supported	Supported
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table 17.24 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR	Server-CR
	Supported	Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table 17.25 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table 17.26 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table 17.27 Basic Conformance Statement

Services		Client/ Subscriber[a]	Server/ Publisher[a]	Value/ Comments[a]
Client-Server Roles				
B11	Server side (of TWO-PARTY-APPLICATION-ASSOCIATION)		Y	
B12	Client side (of TWO-PARTY-APPLICATION-ASSOCIATION)			
SCSMs Supported				
B21	SCSM: IEC 6185-8-1 used		Y	
B22	SCSM: IEC 6185-9-1 used			Deprecated in Edition 2
B23	SCSM: IEC 6185-9-2 used			
B24	SCSM: other			
Generic Substation Event (GSE) Model				
B31	Publisher side		Y	
B32	Subscriber side	Y		
Transmission of Sampled Value Model (SVC)				
B41	Publisher side			
B42	Subscriber side	Y		

[a] Y = supported
N or blank = not supported

Table 17.28 ACSI Models Conformance Statement (Sheet 1 of 2)

		Client/Subscriber[a]	Server/Publisher[a]	Value/Comments
If Server Side (B11) and/or Client Side (B12) Supported				
M1	Logical device		Y	
M2	Logical node		Y	
M3	Data		Y	
M4	Data set		Y	
M5	Substitution			
M6	Setting group control		Y	
Reporting				
M7	Buffered report control		Y	
M7–1	sequence-number		Y	
M7–2	report-time-stamp		Y	
M7–3	reason-for-inclusion		Y	
M7–4	data-set-name		Y	
M7–5	data-reference		Y	
M7–6	buffer-overflow		Y	
M7–7	entryID		Y	
M7–8	BufTim		Y	
M7–9	IntgPd		Y	
M7–10	GI		Y	

Table 17.28 ACSI Models Conformance Statement (Sheet 2 of 2)

		Client/Subscriber[a]	Server/Publisher[a]	Value/Comments
M7–11	conf-revision		Y	
M8	Unbuffered report control		Y	
M8–1	sequence-number		Y	
M8–2	report-time-stamp		Y	
M8–3	reason-for-inclusion		Y	
M8–4	data-set-name		Y	
M8–5	data-reference		Y	
M8–6	BufTim		Y	
M8–7	IntgPd		Y	
M8–8	GI		Y	
M8–9	conf-revision		Y	
Logging				
M9	Log control			
M9–1	IntgPd			
M10	Log			
M11	Control		Y	
M17	File transfer		Y	
M18	Application association			
M19	GOOSE control block		Y	
M20	Sampled Value control block			
If GSE (B31/32) Is Supported				
M12	GOOSE		Y	
M13	GSSE			Deprecated in Edition 2
If SVC (B41/42) Is Supported				
M14	Multicast SVC			
M15	Unicast SVC			
For All IEDs				
M16	Time		Y	Time source with required accuracy shall be available. Only the time master is an SNTP (Mode 4 response) time server. All other client/server devices require SNTP (Mode 3 request) clients.

[a] Y = supported
N or blank = not supported

Table 17.29 ACSI Service Conformance Statement (Sheet 1 of 3)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Server						
S1	1, 2	GetServerDirectory (LOGICAL-DEVICE)	TP		Y	
Application Association						
S2	1, 2	Associate			Y	
S3	1, 2	Abort			Y	
S4	1, 2	Release			Y	
Logical Device						
S5	1, 2	GetLogicalDeviceDirectory	TP		Y	
Logical Node						
S6	1, 2	GetLogicalNodeDirectory	TP		Y	
S7	1, 2	GetAllDataValues	TP		Y	
Data						
S8	1, 2	GetDataValues	TP		Y	
S9	1, 2	SetDataValues	TP			
S10	1, 2	GetDataDirectory	TP		Y	
S11	1, 2	GetDataDefinition	TP		Y	
Data Set						
S12	1, 2	GetDataSetValues	TP		Y	
S13	1, 2	SetDataSetValues	TP			
S14	1, 2	CreateDataSet	TP			
S15	1, 2	DeleteDataSet	TP			
S16	1, 2	GetDataSetDirectory	TP		Y	
Substitution						
S17	1	SetDataValues	TP			
Setting Group Control						
S18	1, 2	SelectActiveSG	TP		Y	
S19	1, 2	SelectEditSG	TP			
S20	1, 2	SetEditSGValues	TP			
S21	1, 2	ConfirmEditSGValues	TP			
S22	1, 2	GetEditSGValues	TP			
S23	1, 2	GetSGCBValues	TP		Y	
Reporting						
Buffered Report Control Block (BRCB)						
S24	1, 2	Report	TP		Y	
S24–1	1, 2	data-change (dchg)			Y	
S24–2	1, 2	quality-change (qchg)			Y	
S24–3	1, 2	data-update (dupd)				
S25	1, 2	GetBRCBValues	TP		Y	
S26	1, 2	SetBRCBValues	TP		Y	

Table 17.29 ACSI Service Conformance Statement (Sheet 2 of 3)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Unbuffered Report Control Block (URCB)						
S27	1, 2	Report	TP		Y	
S27–1	1, 2	data-change (dchg)			Y	
S27–2	1, 2	quality-change (qchg)			Y	
S27–3	1, 2	data-update (dup)				
S28	1, 2	GetURCBValues	TP		Y	
S29	1, 2	SetURCBValues	TP		Y	
Logging						
Log Control Block						
S30	1, 2	GetLCBValues	TP			
S31	1, 2	SetLCBValues	TP			
Log						
S32	1, 2	QueryLogByTime	TP			
S33	1, 2	QueryLogAfter	TP			
S34	1, 2	GetLogStatusValues	TP			
Generic Substation Event Model (GSE)						
GOOSE						
S35	1, 2	SendGOOSEMessage	MC		Y	
GOOSE-CONTROL-BLOCK						
S36	1, 2	GetGoReference	TP			
S37	1, 2	GetGOOSEElementNumber	TP			
S38	1, 2	GetGoCBValues	TP		Y	
S39	1, 2	SetGoCBValues	TP			
GSSE						
S40	1	SendGSSEMessage	MC			Deprecated in Edition 2
GSSE-CONTROL-BLOCK						
S41	1	GetReference	TP			Deprecated in Edition 2
S42	1	GetGSSEElementNumber	TP			Deprecated in Edition 2
S43	1	GetGsCBValues	TP			Deprecated in Edition 2
S44	1	SetGsCBValues	TP			Deprecated in Edition 2
Transmission of Sampled Value Model (SVC)						
Multicast SV						
S45	1, 2	SendMSVMessage	MC			
Multicast Sampled Value Control Block						
S46	1, 2	GetMSVCBValues	TP			
S47	1, 2	SetMSVCBValues	TP			
Unicast SV						
S48	1, 2	SendUSVMessage	TP			
Unicast Sampled Value Control Block						
S49	1, 2	GetUSVCBValues	TP			
S50	1, 2	SetUSVCBValues	TP			

Table 17.29 ACSI Service Conformance Statement (Sheet 3 of 3)

Services			AA: TP/MC	Client (C)	Server (S)	Comments
Control						
S51	1, 2	Select				
S52	1, 2	SelectWithValue	TP		Y	
S53	1, 2	Cancel	TP		Y	
S54	1, 2	Operate	TP		Y	
S55	1, 2	CommandTermination	TP		Y	
S56	1, 2	TimeActivatedOperate	TP			
File Transfer						
S57	1, 2	GetFile	TP		Y	
S58	1, 2	SetFile	TP			
S59	1, 2	DeleteFile	TP			
S60	1, 2	GetFileAttributeValues	TP		Y	
S61	1, 2	GetServerDirectory (FILE SYSTEM)	TP		Y	
Time						
T1	1, 2	Time resolution of internal clock			20	Nearest negative power of 2 in seconds (Number 0 . . . 24)
T2	1, 2	Time accuracy of internal clock			IRIG-B T4 PTP T4 SNTP T0	TL (ms) (low accuracy), T3 < 7) (only Ed. 2) T0 (ms) (≤ 10 ms), 7 ≤ T3 < 10 T1 (µs) (≤ 1 ms), 10 ≤ T3 < 13 T2 (µs) (≤ 100 µS), 13 ≤ T3 < 15 T3 (µs) (≤ 25 µS), 15 ≤ T3 < 18 T4 (µs) (≤ 25 µS), 15 ≤ T3 < 18 T5 (µs) (≤ 1 µS), T3 ≥ 20
T3	1, 2	Supported TimeStamp resolution			IRIGB 18 PTP 18 SNTP 7	Nearest value of 2^n in seconds (Number 0 . . . 24)

Potential Client and Automation Application Issues With Edition 2 Upgrades

The following are issues that IEC 61850 Edition 1 (Ed1)-based client or automation applications may experience with IEC 61850 Edition 2 (Ed2) ICD and firmware changes. However, such issues may be resolved by reconfiguring the client or automation application or worked around by restoring the Ed1 (CID) configuration. None of these should prevent a client application from dynamically discovering the data in the IED as long as the application adheres to the specification of the standard. Note that upgrading to Ed2 firmware will not break existing Ed1 configurations (CID files) in the field, nor require loading an Ed2 version of the CID file.

Unexpected Error Messages

Some MMS and control errors have been changed in Ed2. Hence, the firmware now issues only the Ed2-compliant errors. Clients or automation applications that rely on the Ed1-compliant errors will not function correctly. You can resolve this by reconfiguring the client or automation application to accept Ed2-compliant errors.

Missing or Unknown Data Objects and Attributes

Ed2 has changed some data object and attribute names, as well as the data types of some attributes. Ed2 also prohibits the use of proprietary CDCs. See *Common Logical Nodes on page 17.30* and the logical nodes tables in each product-specific manual to determine the Ed2 names. This may cause the failure of clients or automation applications that rely on the Ed1 names. A workaround is to use the Ed1 version of the CID file, if available, to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 names.

Unable to Find Operate Time-Out

A proprietary method was used to specify the operate time-out of control objects in the CID files. A client or automation application that relies on this proprietary method will fail to find the operate time-out in the CID file. A workaround is to use the Ed1 CID file to configure the IED. You can also resolve this by reconfiguring the client or automation application to accept the Ed2 control object operate time-outs.

Unexpected Control Block Data Attribute Type

The string type data attributes in control blocks (RptID, DatSet, etc.) have been changed from a maximum length of 65 to 129 characters, i.e., VisString65 to VisString129. Some clients and automation applications might see this as an error when the type is reported in the MMS GetVariableAccessAttributes response. You can resolve this by reconfiguring the client or automation application.

Unexpected Reports

Ed2 requires report buffering to start when the device is turned on, unlike in the Ed1 implementation where report buffering started after the first report enable. If a client or automation application relies on the Ed1 behavior, it might fail or indicate an error if the IED sends buffered reports immediately after the first enable. You can resolve this by reconfiguring the client or automation application.

Failure to Reselect a Control Object Before the Timeout

In Ed1, if a client reselected a control object before the select-before-operate time-out expired, the reselection would succeed and cause the selected time-out to restart. According to Ed2, this reselection is supposed to fail. Ed1-based clients or automation applications that rely on successful reselection might operate incorrectly. You can resolve this by reconfiguring the client or automation application.

Test Control Commands Fail Immediately

In Ed1, if the test attribute was set in a control command structure, the relay would accept the command but perform no action on the target control object. With enhanced control models, the IED would eventually report an operate time-out error after the operate time-out expired. However, in Ed2, any such test commands will fail immediately with an error indicating that the command is blocked because the IED is not in the appropriate mode. Clients or automation applications that depend on the Ed1 behavior might fail. You can resolve this by reconfiguring the client or automation application.

No Reports

Ed2 specifies that no reports are to be generated for a dead-banded attribute if the dead band is set to 0. Previously in Ed1, a dead band of 0 would cause the relay to generate reports for any change in the instantaneous value. Ed1-based clients or automation applications might not operate correctly because of the lack of reports. You can resolve this by reconfiguring the client or automation application.

SECTION 18

Synchrophasors

Most SEL-400 series relays can be configured to function as a phasor measurement unit (PMU).

This section covers:

Introduction

The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other offline analysis functions.

The Global settings class contains the synchrophasor settings, including the choice of Synchrophasor Protocol and the synchrophasor data set the relay will transmit. The Port settings class selects which port(s) are configured for Synchrophasor Protocol use.

The high-accuracy timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables, and programmable digital trigger information (C37.118 protocol only) is also added to the Relay Word bits for synchrophasors (see Synchrophasor Relay Word Bits).

When synchrophasor measurement is enabled, the relay creates the synchrophasor data set at a rate of either 50 or 60 times per second, depending on the nominal system frequency (Global setting NFREQ). This dataset, including time-of-sample, is available in analog quantities in the relay (see Synchrophasor Analog Quantities). You can view synchrophasor data over the relay ASCII terminal interface (see *View Synchrophasors by Using the MET PM Command on page 18.21*).

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Two Synchrophasor Protocols are available in the relay that allow for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- ➤ Power-system state measurement
- ➤ Wide-area network protection and control schemes
- ➤ Small-signal analysis
- ➤ Power-system disturbance analysis

The SEL-5078-2 SYNCHROWAVE Central Software quickly translates power system data into visual information. It is a powerful yet easy-to-use solution for displaying and analyzing real-time streaming data, archived data, and relay event data, and provides a time-synchronized, wide-area view of your system. SYNCHROWAVE Central includes Event Viewer, providing engineers and operators the ability to view PMU data and perform event analysis by viewing relay event reports directly from SYNCHROWAVE Central.

The SEL-3378 synchrophasor vector processor (SVP) is a real-time synchrophasor programmable logic controller. Use the SVP to collect synchrophasor messages from relays and phasor measurement units (PMUs). The SVP time-aligns incoming messages, processes these messages with an internal logic engine, and sends control command to external devices to perform user-defined actions. Additionally, the SVP can send calculated or derived data to devices such as other SVPs, phasor data concentrators (PDCs), and monitoring systems.

In any installation, the relay can use only one of the synchrophasor message formats, SEL Fast Message Synchrophasor, or C37.118, as selected by Global setting MFRMT. The chosen format is available on multiple serial ports when port setting(s) PROTO := PMU. C37.118 is available over Ethernet when the Port 5 setting EPMIP = Y.

With either the SEL Fast Message or C37.118 synchrophasor format, the relay can receive control operation commands over the same channel used for synchrophasor data transmission. These commands are SEL Fast Operate messages, which are described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.

After enabling the data recording function with the Global EPMDR settings, record synchrophasor data using the PMTRIG setting. When PMTRIG asserts, the relay records synchrophasor data in binary format (IEEE C37.118 data format compliant) for the duration specified with the PMLER setting. The relay stores these files in the synchrophasor subdirectory in the relay.

You can configure the relay to receive C37.118 protocol synchrophasor data. The relay receives the data over a serial connection and stores these data in Analog Quantities. Time-alignment is automatic. Use the local phasor data and as many as two remote sets of phasor data in SELOGIC equations.

Synchrophasor Measurement

The PMU uses the signal processing shown in *Figure 18.1* to measure the synchrophasors. The input signal passes through a traditional anti-aliasing low-pass filter (LPF). This filter has a cutoff frequency of 250 Hz. The PMU decimates this 8 kHz filtered data by eight and then processes the resulting data at 1 kHz.

The PMU then modulates the 1 kHz data with two sinusoids, each 90 degrees apart to produce real and imaginary components of the synchrophasor. The modulating sinusoids are synchronized to absolute time to provide an absolute time reference for the synchrophasor. Also an angular compensation factor compensates for the phase shift introduced by the PMU hardware and software.

The modulated data are filtered using low-pass filters. The filter coefficients are based on NFREQ, PMAPP, and MRATE. The filtered data provides good attenuation for harmonics and interharmonics. For PMAPP = F and N the attenuation is 20 dB. For PMAPP = 1 the attenuation is 40 dB.

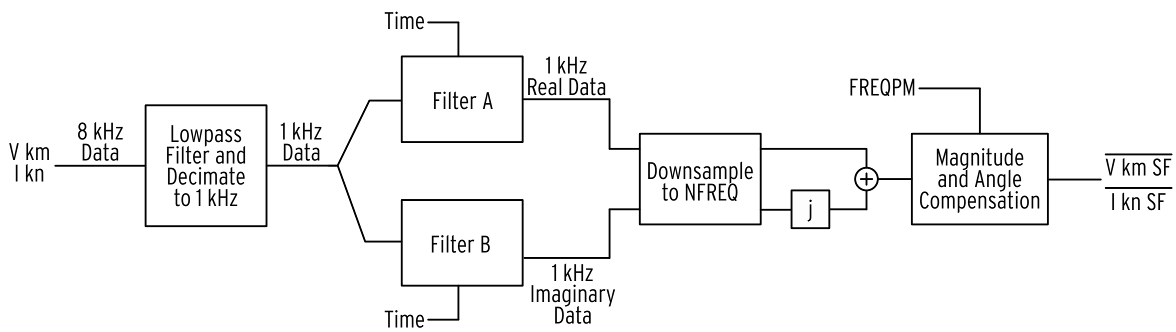


Figure 18.1 Synchrophasor Processing Block Diagram

Figure 18.2 shows the magnitude frequency response of the synchronized phasor measurement for PMAPP = F, N, and 1 for MRATE = 60.

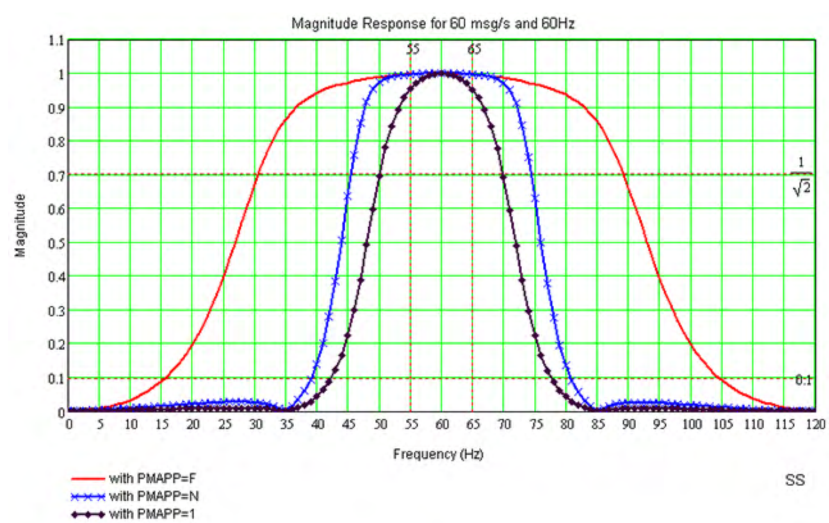


Figure 18.2 Magnitude Frequency Response

After low-pass filtering, the data are decimated to the nominal power system frequency (NFREQ).

If frequency-based phasor compensation is enabled (PHCOMP = Y), the relay calculates a compensation factor based on the measured synchrophasor frequency (FREQPM) and filter configuration (based on NFREQ, MRATE, and PMAPP). The PMU then corrects the measured synchrophasors by this factor.

Using the V*m*COMP and I*n*COMP settings, the PMU compensates the voltage and current synchrophasors for any externally introduced phase angle errors. The PMU adds the user-entered phase angle to the phase angle of the measured synchrophasor.

The PMU converts the synchrophasor data to primary units by multiplying them with the respective PT or CT ratios. Note that the resulting data Vk*m*SF and Ik*n*SF is in complex form (A + jB). The PMU calculates the positive-sequence synchrophasor with the three-phase synchrophasors.

The PMU then converts all synchrophasor data to polar and rectangular quantities. The data are available as analog quantities as well as for the synchrophasor data frames. The synchrophasor data are updated at the nominal power system frequency.

Accuracy

The following phasor measurement accuracy is valid when frequency-based phasor compensation is enabled (Global setting PHCOMP := Y), and when the phasor measurement application setting is in the narrow bandwidth mode (Global setting PMAPP := N).

NOTE: When the PMU is in the fast response mode (Global setting PMAPP := F), the TVE is within specified limits only when the out of band interfering signals influence quantity is not included.

TVE (total vector error) ≤1% for one or more of the following influence quantities.

- For PMAPP = N Signal Frequency Range: ±5 Hz of nominal (50 or 60 Hz)
- For PMAPP = 1 Signal Frequency Range: ±2 Hz of 60 Hz
- Voltage Magnitude Range: 30 V–150 V
- Current Magnitude Range: (0.1–2) • I_{NOM}, (I_{NOM} = 1 A or 5 A)
- Phase Angle Range: –179.99° to 180°
- Harmonic distortion ≤10 percent (any harmonic)
- Out of band interfering signals ≤10 percent

The out-of-band interfering signal frequency (f_i) must satisfy:

$| f_i - NFREQ | > MRATE/2$,

where NFREQ is nominal system frequency and MRATE is the message rate, as defined in IEEE C37.118.

It is important to note that the synchrophasors can only be correlated when the PMU is in HIRIG or HPTP timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the PMU timekeeping is synchronized to the high-accuracy IRIG-B signal or PTP time source, and the synchrophasor data are precisely time-stamped. See *Section 11: Time and Date Management* for details.

PMU Data Block Status

In a PMU data frame, each data block is headed by a two-byte STAT field. This field indicates the status of the PMU data block. Bit 15 of the STAT field indicates the validity of data. SEL-400 series relays assert bit 15 of the STAT when synchrophasor test mode indicator PMTEST asserts or SVBLK asserts in SEL-400 series Sampled Values (SV)-subscriber relays.

For SV-subscribing relays, configure Global setting SVBLK to assert on errors encountered in SV data acquisition. For example, set SVBLK := IAWBK OR IBWBK OR ICWBK. In this example, if SV data for any Terminal W current is lost, SVBLK asserts, which then asserts bit 15 in the STAT field, indicating current data have errors and, therefore, synchrophasor data are invalid.

For an explanation of other bits in the STAT field, refer to the IEEE C37.118 standard.

Synchrophasor Frequency

The PMU calculates frequency deviation and rate-of-change of frequency from the synchrophasor positive-sequence voltage angle (V1*n*PMA where *n* = PMFRQST) as follows.

First the PMU calculates the frequency deviation from nominal using the following formula.

$$f_k = \frac{(\theta_k - \theta_{k-1})}{\Delta t \bullet 360}$$

Equation 18.1

Where θ_k is the V1*n*PMA and θ_{k-1} is V1*n*PMA calculated 1 cycle previously. Δt is the time difference between the angle calculations (*k* increments once a nominal power system cycle).

Next, the PMU averages the frequency deviation as shown in *Equation 18.2* and *Equation 18.3*.

If the frequency application is smooth (PMFRQA = S)

$$favg_k = \frac{\left(\sum_{n=0}^{9} f_k - n\right) - f_{max1} - f_{max2} - f_{min1} - f_{min2}}{6}$$

Equation 18.2

If the frequency application is fast (PMFRQA = F)

$$favg_k = \frac{\left(\sum_{n=0}^{3} f_k - n\right) - f_{max} - f_{min}}{2}$$

Equation 18.3

The PMU then calculates rate-of-change of frequency, *dfdt* from the averaged frequencies deviations (*Equation 18.4*).

$$dfdt_k = \frac{(favg_k - favg_{k-1})}{\Delta t}$$

Equation 18.4

If the frequency value is equal to or within ±20 Hz and V1*n*MPM/PTR*n* (secondary) is larger than 0.1 • VNOM*n* then:

$FREQPM_k = favg_k + NFREQ$ <analog>
$DFDTPM_k = dfdt_k$ <analog>
After six consecutive cycles
$FROKPM_k = 1$ <digital>

If the frequency value exceeds ±20 Hz or the V1*n*MPM/PTR*n* (secondary) is below 0.1 • VNOM*n* then:

$FREQPM_k = FREQPM_{k-1}$ <analog>
$DFDTPM_k = 0$ <analog>
$FROKPM_k = 0$ <digital>

The frequency and rate-of-change of frequency are available as analog quantities as well as for the synchrophasor data frames. The data are updated at the nominal power system frequency.

Table 18.1 Synchrophasor Analog Quantities Frequency

Name	Description	Units
FREQPM	Measured system frequency	Hz
DFDTPM	Rate-of-change of frequency	Hz/s

Settings for Synchrophasors

Each SEL-400 series relay supports a variety of current and voltage terminals. See the product-specific instruction manuals to see which terminals are available to synchrophasors. Synchrophasors are primarily configured through the Global settings. There are also a few port settings necessary to enable synchrophasor communications.

Global Settings

The Global enable setting EPMU must be set to Y before the remaining synchrophasor settings are available. The PMU is disabled when EPMU := N.

Table 18.2 Global Settings for Configuring the PMU (Sheet 1 of 2)

Setting	Setting Prompt
EPMU	Synchronized Phasor Measurement (Y, N)
MFRMT	Message Format (C37.118, FM)
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)[a]
PMAPP	PMU Application (F, N, 1)
PMLEGCY	Synchrophasor Legacy Settings (Y, N, N1[b])

Table 18.2 Global Settings for Configuring the PMU (Sheet 2 of 2)

Setting	Setting Prompt
NUMPHDC	Number of Data Configurations (1–5)
PMSTN*q*[c]	Station Name (16 characters)
PMID*q*[c]	PMU Hardware ID (1–65534)
PHDV*q*[c]	Phasor Data Set, Voltages (V1, PH, ALL)
PHDI*q*[c]	Phasor Data Set, Currents (I1, PH, ALL)
PHNR*q*[c]	Phasor Num. Representation (I = Integer, F = Float)
PHFMT*q*[c]	Phasor Format (R = Rectangular, P = Polar)
FNR*q*[c]	Freq. Num. Representation (I = Integer, F = Float)
TREA[1–4]	Trigger Reason Bit [1–4] (SELOGIC Equation)
PMTRIG	Trigger (SELOGIC Equation)
PMTEST	PMU in Test Mode (SELOGIC Equation)
V*k*COMP[d]	Comp. Angle Terminal *k* (–179.99° to 180°)
I*n*COMP[e]	Comp. Angle Terminal *n* (–179.99° to 180°)
PMFRQST	PMU Primary Frequency Source Terminal
PMFRQA	PMU Frequency Application (F, S)
PHCOMP	Freq. Based Phasor Compensation (Y, N)

[a] If NFREQ = 50 then the range is 1, 2, 5, 10, 25, 50.
[b] PMLEGCY option of N1 only applies to the SEL-487E.
[c] *q* = 1–NUMPHDC.
[d] *k* = voltage terminal.
[e] *n* = current terminal.

Descriptions for some of the settings in *Table 18.2* are as follows.

MFRMT

Selects the message format for synchrophasor data.

SEL recommends the use of MFRMT := C37.118 for any new PMU applications because of increased setting flexibility and the expected availability of software for synchrophasor processors. The PMU still includes the MFRMT := FM setting choice to maintain compatibility in any systems presently using SEL Fast Message synchrophasors.

MRATE

Selects the message rate in messages per second for synchrophasor data.

Choose the MRATE setting that suits the needs of your PMU application. The PMU supports as many as 60 messages per second if NFREQ = 60 and as many as 50 messages per second if NFREQ = 50.

PMAPP

Selects the type of digital filters used in the synchrophasor measurement.

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately 1/4 of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.
- The Fast Response setting (F) represents filters with a higher cutoff frequency. The response in the frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracing system parameters.
- The Filter One setting (1) represents filters that have a response much narrower than the narrow bandwidth filters. This method has a better step response with overshoot within 7.5 percent. This filter is available only for MRATE = 60.

PMLEGCY

This setting is provided for supporting legacy synchrophasor settings. Set this to N to access the latest features. See *Legacy Settings on page 18.16* to see a description of the legacy settings. The remainder of this subsection describes the non-legacy settings.

NUMPHDC

Enables as many as five unique synchrophasor data configurations.

The four serial ports (Port 1, 2, 3, and F) and two Ethernet sessions (TCP/UDP sessions 1 and 2) can be mapped to any of these five data configurations. In other words each port can be configured to send unique synchrophasor data streams.

PMSTN*q* and PMID*q*

Defines the station name and number of the PMU for data configuration *q*.

The PMSTN*q* setting is an ASCII string with as many as 16 characters. The PMID*q* setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings. PMSTN*q* allows all printable characters.

Phasors Included in the Data *q*

Terminal Name, Relay Word Bit, Alternate Terminal Name

Specify the terminal for Synchrophasor measurement and transmission in the synchrophasor data stream *q*.

This is a freeform setting category for enabling the terminals for synchrophasor measurement and transmission. This freeform setting has three arguments. Specify the terminal name (any one of the valid terminals for the relay) for the first argument. Specify any Relay Word bit for the second argument. Specify the alternate terminal name (any one of the valid terminals for the relay) for the third argument.

The second and third arguments are optional unless switching between terminals is required. Whenever the Relay Word bit in the second argument is asserted the terminal synchrophasor data are replaced by the alternate terminal data.

PHDV*q*

Selects the type of voltages to be included in the synchrophasor data stream *q*.

This setting affects the synchrophasor data packet size.

- PHDV*q* := V1, sends only positive-sequence voltage synchrophasors of selected terminals.
- PHDV*q* := PH, sends only phase voltage synchrophasors of selected terminals.
- PHDV*q* := ALL, sends phase and positive-sequence voltage synchrophasors of selected terminals.

PHDI*q*

Selects the type of currents to be included in the synchrophasor data stream q.

This setting affects the synchrophasor data packet size.

- PHDI*q* := I1, sends only positive-sequence current synchrophasors of selected terminals.
- PHDI*q* := PH, sends only phase current synchrophasors of selected terminals.
- PHDI*q* := ALL, sends phase and positive-sequence current synchrophasors of selected terminals.

PHNR*q*

Selects the numeric representation, integer (I) or floating-point (F), of voltage and current phasor data in the synchrophasor data stream *q*. This setting affects the synchrophasor data packet size.

- PHNR*q* := I sends each voltage and/or current synchrophasor as 2 two-byte integer values. The PMU uses $((7 \cdot I_{NOM} \cdot \text{CT Ratio}) / 32768) \cdot 100000))$ for the current phasor scaling factor and uses $((150 \cdot \text{PTR}) / 32768) \cdot 100000))$ for the voltage phasor scaling factor. I_{NOM} is 1 A or 5 A.
- PHNR*q* := F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

PHFMT*q*

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream q.

- PHFMT*q* := R (rectangular) sends each voltage and/or current synchrophasor as a pair of signed real and imaginary values.
- PHFMT*q* := P (polar) sends each voltage and/or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR*q* := F, and in radians $\cdot 10^4$ when PHNR*q* := I. The range is $-\pi < \text{angle} \leq \pi$.

In both the rectangular and polar representations, the values are scaled in root mean square (rms) units. For example, a synchrophasor with a magnitude of 1.0 at an angle of –30 degrees will have a real component of 0.866, and an imaginary component of –0.500.

FNR*q*

Selects the numeric representation, integer (I) or floating-point (F), of the two frequency values in the synchrophasor data stream *q*.

This setting affects the synchrophasor data packet size.

- FNR*q* := I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula.

  (FREQPM – NFREQ) • 1000,

  represented as a signed, two-byte value. See *Synchrophasor Frequency on page 18.5* for details.
- FNR*q* := I also sends the rate-of-change of frequency data with scaling.

  DFDTPM • 100,

  represented as a signed, two-byte value. See *Synchrophasor Frequency on page 18.5* for details.
- FNR*q* := F sends the measured frequency data and rate-of-change-of-frequency as two four-byte, floating point values.

Phasor Aliases in Data Configuration *q*

Phasor Name, Alias Name

This is a freeform setting category with two arguments. Specify the phasor name and a 16 character descriptive name to be included in the synchrophasor data stream *q*. If a phasor is not assigned a descriptive name, it will be described using the phasor name.

Analog Quantities in Data Configuration *q*

Analog Quantity Name, Alias Name

This is a freeform setting category with two arguments. Specify the analog quantity name and an optional 16 character descriptive name to be included in the synchrophasor data stream *q*. See *Section 12: Analog Quantities* in the product-specific instruction manual for a list of analog quantities that the PMU supports. The PMU can be configured for as many as 16 unique analog quantities for each data configuration *q*. The analog quantities are floating point values, so each analog quantity the PMU includes will take four bytes.

Digitals in Data Configuration *q*

Relay Word Bit Name, Alias Name

This is a freeform setting category with two arguments. Specify the Relay Word bit name and an optional 16 character descriptive name that you need to include in the synchrophasor data stream *q*. See the Relay Word Bits section of the relay-specific instruction manual for a list of Relay Word bits that the PMU supports. You can configure the PMU for as many as 64 unique digitals for each data configuration.

TREA1, TREA2, TREA3, TREA4, and PMTRIG

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations. The PMU evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4 and PMTRIG.

NOTE: Select PMTRIG trigger conditions to assert PMTRIG no more frequently than once every four hours if EPMDR = Y (i.e., synchrophasor recording is enabled).

The Trigger Reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the Trigger Reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first 8 of 16 binary combinations of these trigger reason bits (Bits 0–3).

The remaining eight binary combinations are available for user definition.

The PMU does not automatically set the TREA1–TREA4 or PMTRIG Relay Word bits—these bits must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The PMU synchrophasor processing and protocol transmission are not affected by the status of these bits.

PMTEST

Program this SELOGIC setting to force the PMU to test mode. The SELOGIC evaluation of this setting, PMTEST is mapped to the data valid bit (i.e., bit 15) in the STAT field.

V*k*COMP

The V*k*COMP (*k* = voltage terminals) setting allows correction for any steady-state voltage phase errors (from the PTs or wiring characteristics). See *Synchrophasor Measurement on page 18.3* for details on this setting.

I*n*COMP

The I*n*COMP (*n* = current terminals) settings allow correction for any steady-state phase errors (from the CTs or wiring characteristics). See *Synchrophasor Measurement on page 18.3* for details on these settings.

PMFRQST

Selects the voltage terminal that will be the primary source of the system frequency for the PMU calculations. For example, if PMFRQST = Z, then the Z PT terminal is the source for frequency estimation.

PMFRQA

Selects the PMU frequency application. A setting of S sets a smooth frequency application. A setting of F selects a fast frequency application.

The frequency application is used in the calculation of the rate of change of frequency for a given analog signal. A smooth frequency application setting (PMFRQA = S) uses 9 cycles of data for the rate of change calculation. A fast frequency application setting (PMFRQA = F) uses 3 cycles of data for the rate of change calculation.

The fast frequency application will detect rapid changes in frequency faster, but will also contain more low-level oscillations. The slow frequency application will provide a rate of change profile that is smoother, but slower to respond to rapid frequency fluctuations.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

For most applications, set PHCOMP := Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal.

For PMAPP = F or N, the PMU only compensates if the estimated frequency is ±5 Hz of nominal frequency. For PMAPP = 1 the PMU compensates if the frequency is ±2 Hz of nominal frequency.

Serial Port Settings

The port settings found in *Table 18.3* are used for configuring synchrophasor data transmission over a serial port.

Table 18.3 Serial Port 1, 2, 3, F Settings for Synchrophasors

Setting	Description
PROTO	Protocol (SEL, DNP, MBA, MBB, PMU[a])
SPEED	Data Speed (300–57600)
STOPBIT	Stop Bits (1, 2)
RTSCTS	Enable Hardware Handshaking (Y, N)
FASTOP	Enable Fast Operate Messages (Y, N)
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)
PMODC	PMU Output Data Configuration (1–5)

[a] The specific protocol choices available depends on the relay.

Descriptions for some of the settings in *Table 18.3* are as follows.

PROTO

Setting this to PMU enables synchrophasor data transmission on the specific serial port. Once set to PMU that specific serial port cannot be used for accessing settings or issuing any ASCII commands.

If PROTO := PMU and MFRMT := C37.118, then the serial port will only respond to C37.118 commands.

- Stop synchrophasor data
- Start synchrophasor data
- Send header data
- Send Configuration 1 data
- Send Configuration 2 data
- Process extended frame data

If PROTO := PMU or SEL and MFRMT := FM, then the serial port will only respond to SEL Fast Message synchrophasor commands.

SPEED

Select the data rate (300–57600) for synchrophasor data transmission on the specific serial port. This setting affects the synchrophasor data packet size. See *Communications Bandwidth on page 18.24* for detailed information.

PMUMODE

Set PMUMODE := SERVER if the serial port is intended to send synchrophasor data. Client applications are described in *Real-Time Control on page 18.36*.

PMODC

NOTE: If PMODC is set to a number that exceeds the setting for NUMPHDC, the port sends the data for the first PMU configuration.

Select the data configuration (1-NUMPHDC) for synchrophasor data transmission on the specific serial port. This setting affects the synchrophasor data packet size. See *Communications Bandwidth on page 18.24* for detailed information. Through the use of this setting each serial port can be configured to stream unique synchrophasor data.

EPMU := N Supersedes Synchrophasor Port Settings

The PROTO := PMU settings choice can be made even when Global setting EPMU := N. However, in this situation, the serial port will not respond to any commands or requests. Either enable synchrophasors by setting EPMU to Y, or change the port PROTO setting to SEL.

If you use a computer terminal session or ACSELERATOR QuickSet SEL-5030 Software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands or virtual file interface commands. If this happens, either connect via another serial port (that has PROTO := SEL) or use the front-panel HMI SET/SHOW screen to change the disabled port PROTO setting back to SEL.

Ethernet Port Settings

The settings found in *Table 18.4* are used for configuring synchrophasor data transmission over an Ethernet port.

Table 18.4 Ethernet Port 5 Settings for Synchrophasors

Setting	Description	Default
EPMIP	Enable PMU Processing (Y, N)	N
PMOTS1	PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC1	PMU Output 1 Data Configuration (1–5)	1
PMOIPA1	PMU Output 1 Client IP (Remote) Address (www.xxx.yyy.zzz)	192.168.1.3
PMOTCP1	PMU Output 1TCP/IP (Local) Port Number (1–65534)	4712
PMOUDP1	PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMODC2	PMU Output 2 Data Configuration (1–5)	1
PMOIPA2	PMU Output 2 Client IP (Remote) Address (www.xxx.yyy.zzz)	192.168.1.4
PMOTCP2	PMU Output 2 TCP/IP (Local) Port Number (1–65534)	4722
PMOUDP2	PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534)	4714

Descriptions for some of the settings in *Table 18.4* are as follows.

EPMIP

Setting this to Y enables synchrophasor data transmission over Ethernet port. Setting this to N disables the synchrophasor data transmission over Ethernet port. The EPMIP := Y settings choice can be made when Global setting EPMU := N. This setting combination will result in the relay ignoring any incoming synchrophasor requests regardless of whether the Ethernet port settings are correct or not.

PMOTS[2]

Selects the PMU Output transport scheme for session 1 and 2, respectively.

➤ PMOTS[2] := TCP establishes a single, persistent TCP socket for transmitting and receiving synchrophasor messages (both commands and data), as illustrated in *Figure 18.3*.

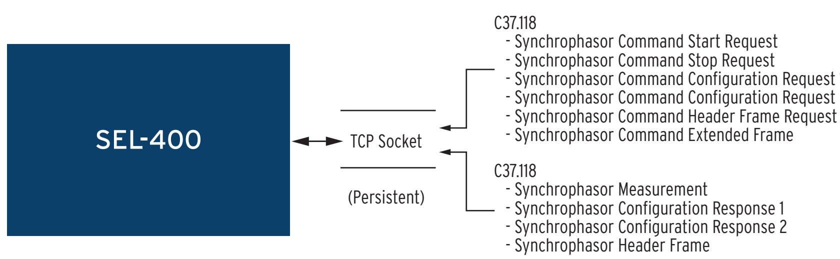


Figure 18.3 TCP Connection

- ➤ PMOTS[2] := UDP_T establishes two socket connections. A nonpersistent TCP connection is used for receiving synchrophasor command messages as well as synchrophasor configuration and header response messages. A persistent UDP connection is used to transmit synchrophasor data messages. *Figure 18.4* depicts the UDP_T connection.
- ➤ PMOTS[2] := UDP_U uses the same connection scheme as the UDP_T except the synchrophasor configuration and header response messages are sent over the UDP connection, as shown in *Figure 18.4*.

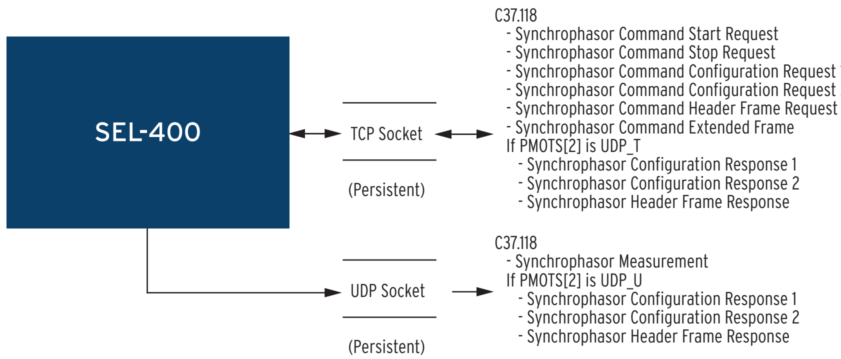


Figure 18.4 UDP_T and UDP_U Connections

- ➤ PMOTS[2] := UDP_S establishes a single persistent UDP socket to transmit synchrophasor messages. Synchrophasor data are transmitted whenever new data are read. With this communications scheme, the relay sends a "Synchrophasor Configuration Response 2" once every minute, as shown in *Figure 18.5*.

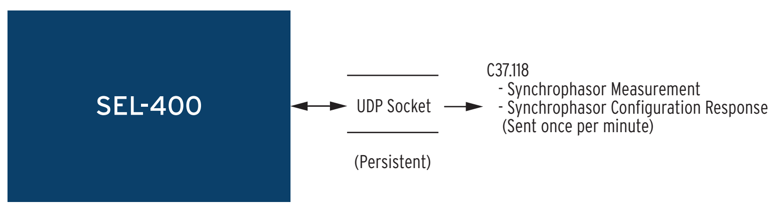


Figure 18.5 UDP_S Connection

PMODC[2]

NOTE: If PMODC is set to a number that exceeds the setting for NUMPHDC, the port sends the data for the first PMU configuration.

Select the data configuration (1-NUMPHDC) for synchrophasor data transmission on the specific session 1 and 2. Using this setting, each Ethernet session can be configured to stream unique synchrophasor data.

PMOIPA[2]

Defines the PMU Output Client IP address for session 1 and 2, respectively.

PMOTCP[2]

Defines the TCP/IP (Local) port number for session 1 and 2, respectively. These port numbers must all be unique.

PMOUDP[2]

Defines the UDP/IP (Remote) port number for session 1 and 2, respectively.

Legacy Settings

The PMU provides the following legacy synchrophasor settings that can be enabled by setting PMLEGCY = Y.

PMSTN and PMID

Defines the name and number of the PMU. The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value (1–65534). Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHVOLT and PHDATAV

PHDATAV and PHVOLT select which voltage synchrophasors to include in the data packet. If MFRMT = FM, the only options available are V1 and ALL.

- ➤ PHDATAV := V1 will transmit only positive-sequence voltage,V1
- ➤ PHDATAV = PH will transmit phase voltages only (VA, VB, VC)
- ➤ PHDATAV := ALL will transmit V1, VA, VB, and VC
- ➤ PHDATAV := NA will not transmit any voltages

PHVOLT selects the voltage sources for the synchrophasor data selected by PHDATAV.

Use the PHVOLT setting to select any combination of available voltage terminals.

PHCURR and PHDATAI

PHDATAI and PHCURR select which current synchrophasors to include in the data packet.

- ➤ PHDATAI := I1 will transmit only positive-sequence current, I1
- ➤ PHDATAI := PH transmits phase currents (IA, IB, IC)
- ➤ PHDATAI := ALL will transmit I1, IA, IB, and IC
- ➤ PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI.

Use the PHCURR setting to select any combination of available current terminals. If MFRMT = FM, only a single terminal can be selected.

PHNR

Selects the numerical representation of voltage and current phasor data in the synchrophasor data stream. If MFRMT = FM, this setting is forced to F, a floating point value.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream. If MFRMT = FM, this setting is forced to P, for polar phasor format. This setting is hidden if PHDATAV and PHDATAI = NA.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream. If MFRMT = FM, this setting is forced to F, a floating point value.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

- Setting NUMANA := 0 sends no user-definable analog values.
- Setting NUMANA := 1–16 sends the user-definable analog values, as listed in *Table 18.5*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes. If MFRMT = FM, this setting is forced to 0 and the relay does not send any user-definable analog values.

Table 18.5 User-Defined Analog Values Selected by NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	PMV64	4
2	Above, plus PMV63	8
3	Above, plus PMV62	12
4	Above, plus PMV61	16
5	Above, plus PMV60	20
6	Above, plus PMV59	24
7	Above, plus PMV58	28
8	Above, plus PMV57	32
9	Above, plus PMV56	36
10	Above, plus PMV55	40
11	Above, plus PMV54	44
12	Above, plus PMV53	48
13	Above, plus PMV52	52
14	Above, plus PMV51	56
15	Above, plus PMV50	60
16	Above, plus PMV49	64

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

Setting NUMDSW := 0 sends no user-definable binary status words.

Setting NUMDSW := 1, 2, 3, or 4 sends the user-definable binary status words, as listed in *Table 18.6*. If MFRMT = FM, this is forced to 1.

Table 18.6 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[PSV64, PSV63 … PSV49]	2
2	[PSV64, PSV63 … PSV49] [PSV48, PSV47 … PSV33]	4
3	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17]	6
4	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17] [PSV16,PSV15 … PSV01]	8

Synchrophasor Quantities

Relay Word Bits

This subsection describes the Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table 18.7* follow the state of the SELOGIC control equations of the same name. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table 18.6* for standard definitions for these settings.

Table 18.7 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC control equation)
TREA4	Trigger Reason Bit 4 (SELOGIC control equation)
TREA3	Trigger Reason Bit 3 (SELOGIC control equation)
TREA2	Trigger Reason Bit 2 (SELOGIC control equation)
TREA1	Trigger Reason Bit 1 (SELOGIC control equation)

The Time-Synchronization Relay Word bits in *Table 18.8* indicate the present status of the high-accuracy timekeeping function of the relay.

Table 18.8 Time-Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
PTP	Synchronized to a PTP source.
TSOK	Time synchronization OK. Asserts while time is based on high-accuracy IRIG-B or PTP time source (HIRIG or HPTP mode) of sufficient accuracy for synchrophasor measurement.
PTPSYNC	Asserts while the relay is synchronized to a high-quality PTP time source.
PMDOK	Phasor measurement data OK. Asserts when the relay is enabled and synchrophasors are enabled (Global setting EPMU := Y).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 18.9* indicate the state of the synchronization.

Table 18.9 Synchrophasor Client Status Bits for Real-Time Control

Name	Description
RTCENA	Asserts for one processing interval when a valid message is received on Channel A.
RTCENB	Asserts for one processing interval when a valid message is received on Channel B.
RTCROKA	Asserts for one processing interval when data are aligned for Channel A. Use this bit to condition usage of the Channel A data.
RTCROKB	Asserts for one processing interval when data are aligned for Channel B. Use this bit to condition usage of the Channel B data.
RTCROK	Asserts for one processing interval when data for all enabled channels are aligned. Use this bit to condition general usage of the aligned synchrophasor data.
RTCDLYA	This bit is asserted when the last received valid message on Channel A is older than MRTCDLY.
RTCDLYB	This bit is asserted when the last received valid message on Channel B is older than MRTCDLY.
RTCSEQA	This bit is asserted when the processed received message on Channel A is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel A data in applications where sequential data are required.
RTCSEQB	This bit is asserted when the processed received message on Channel B is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel B data in applications where sequential data are required.
RTCCFGA	Indicates Channel A is successfully configured.
RTCCFGB	Indicates Channel B is successfully configured.

When received, synchrophasor messages contain digital data. These data are stored in the Remote Synchrophasor Relay Word bits in *Table 18.10*.

Table 18.10 Remote Synchrophasor Data Bits for Real-Time Control

Name	Description
RTCAD01–RTCAD16	First sixteen digitals received in synchrophasor message on Channel A. Only valid when RTCROKA is asserted.
RTCBD01–RTCBD16	First sixteen digitals received in synchrophasor message on Channel B. Only valid when RTCROKB is asserted.

Analog Quantities

The synchrophasor measurements in *Table 18.11* are available whenever Global setting EPMU := Y. When EPMU := N, these analog quantities are set to 0.0000.

It is important to note that the synchrophasors are only valid when the relay is in HIRIG or HPTP timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the relay timekeeping is synchronized to the high-accuracy IRIG-B signal or PTP time source, and the synchrophasor data are precisely time-stamped.

NOTE: Sampled Values-subscribing relays experience a communication delay in their analog data. Time-stamping of synchrophasor data is adjusted by the Port 5 channel delay setting CH_DLY.

Table 18.11 Synchrophasor Analog Quantities

Name	Description	Units
Frequency		
FREQPM	Measured system frequency[a]	Hz
DFDTPM	Rate-of-change of frequency, df/dt[a]	Hz/s
Synchrophasor Measurements		
Vk*m*PMM, Vk*m*PMA, Vk*m*PMR, Vk*m*PMI[b, c]	Phase k synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
V1*m*PMM, V1*m*PMA, V1*m*PMR, V1*m*PMI	Positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
Ik*n*PMM, Ik*n*PMA, Ik*n*PMR, Ik*n*PMI[d]	Phase k synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
I1*n*PMM, I1*n*PMA, I1*n*PMR, I1*n*PMI	Positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
SODPM	Second of the day of the PM data	s
FOSPM	Fraction of the second of the PM data	s

[a] Measured value if the voltages are valid and EMPU = Y, otherwise FREQPM = nominal frequency setting NFREQ, and DFDT is zero.
[b] *k* = A, B, or C.
[c] *m* = voltage terminal.
[d] *n* = current terminal.

When using the relay for synchrophasor acquisition, the delayed and aligned analog quantities listed in *Table 18.11* are available. Be aware that these quantities are only valid when RTCROK is asserted and only for the enabled channels. The specific channel quantities are also valid whenever their respective RTCROK*c* Relay Word bit is set.

Table 18.12 Synchrophasor Aligned Analog Quantities for Real-Time Control (Sheet 1 of 2)

Name	Description	Units
RTCAP01–RTCAP32	Remote phasor pairs for Channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBP01–RTCBP32	Remote phasor pairs for Channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCAA01–RTCAA08	Remote analogs for Channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBA01–RTCBA08	Remote analogs for Channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCFA	Remote frequency for Channel A.	Hz
RTCFB	Remote frequency for Channel B.	Hz
RTCDFA	Remote frequency rate-of-change for Channel A.	Hz/s

Table 18.12 Synchrophasor Aligned Analog Quantities for Real-Time Control (Sheet 2 of 2)

Name	Description	Units
RTCDFB	Remote frequency rate-of-change for Channel B.	Hz/s
Vk*m*PMMD, Vk*m*PMAD, Vk*m*PMRD, Vk*m*PMID[a, b]	Aligned phase k synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*.	kV Primary, degrees, kV Primary, kV Primary
V1*m*PMMD, V1*m*PMAD, V1*m*PMRD, V1*m*PMID[b]	Aligned positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*.	kV Primary, degrees, kV Primary, kV Primary
Ik*n*PMMD, Ik*n*PMAD, Ik*n*PMRD, Ik*n*PMID[a, c]	Aligned phase *k* synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*.	A Primary, degrees, A Primary, A Primary
I1*n*PMMD, I1*n*PMAD, I1*n*PMRD, I1*n*PMID[c]	Aligned positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*.	A Primary, degrees, A Primary, A Primary
SODPMD	Second-of-day for all aligned data.	Seconds
FOSPMD	Fraction-of-second for all aligned data.	Seconds
FREQPMD	Aligned local system frequency.	Hz
DFDTPMD	Aligned local rate-of-change of frequency.	Hz/s

[a] *k* = A, B, or C.
[b] *m* = voltage terminal.
[c] *n* = current terminal.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the PMU synchrophasor measurements. See *METER on page 14.37* for general information on the **MET** command.

The **MET PM** command can be used as follows.

- ➤ As a test tool, to verify connections, phase rotation, and scaling.
- ➤ As an analytical tool, to capture synchrophasor data at an exact time, to compare it with similar data captured in other phasor measurement unit(s) at the same time.
- ➤ As a method of periodically gathering synchrophasor data through a communications processor.

Figure 18.6 shows a sample **MET PM** command response. The synchrophasor data are also available via the **HMI > Synchrophasor Metering** menu in QuickSet, and has a similar format to *Figure 18.6*.

The **MET PM** command can work even when no serial or Ethernet ports are configured for sending synchrophasor data.

The **MET PM** command will only operate when the relay is in the HIRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

The **MET PM** command shows if there is a serial port configuration error. If any of the SPCER*p* bits assert, then the command displays Y. Otherwise, it displays N.

The **MET PM** command checks for assertion of the PMTEST bit to show whether the PMU is in a test mode. If the bit is asserted then the command displays Y. Otherwise, it displays N.

The **MET PM** time command can be used to direct the PMU to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure 18.6* occurring just after 14:14:12, with the time stamp 14:14:12.000000.

If you are not connected to the PMU when the **MET PM** time command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue MET PM time to multiple PMUs at a certain point in time and then go back later to see the results from all the PMUs at that point in time.

See *MET PM on page 14.39* for complete command options, and error messages.

```
=>>MET PM <Enter>
Relay 1                                    Date: 04/20/2015 Time: 22:02:12.000
Station A                                  Serial Number: 1152490016

Time Quality   Maximum time synchronization error:  0.000 (ms)  TSOK = 1
Serial Port Configuration Error: N                     PMU in TEST MODE = N

Synchrophasors
                     VV Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)        127.266   126.972   127.148           127.128
ANG (DEG)        73.542   -46.400  -166.103            73.677


VZ Phase Voltages             Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)         76.383    76.103    76.277            76.254
ANG (DEG)        73.623   -46.319  -166.175            73.707


IS Phase Currents          IS Pos. Sequence Current
                 IA        IB        IC                 I1S
MAG (A)         221.707   221.851   221.661           221.740
ANG (DEG)        57.667   -62.223   177.875            57.767


T Phase Currents          IT Pos. Sequence Current
                 IA        IB        IC                 I1T
MAG (A)         440.487   441.507   440.698           440.897
ANG (DEG)      -122.055   118.057    -1.933          -121.983


I IU Phase Currents          IU Pos. Sequence Current
                 IA        IB        IC                 I1U
 I1U
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000


IW Phase Currents          IW Pos. Sequence Current
                 IA        IB        IC                 I1W
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000


IX Phase Currents          IX Pos. Sequence Current
                 IA        IB        IC                 I1X
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000


IY Phase Currents          IY Pos. Sequence Current
                 IA        IB        IC                 I1Y
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000
```

Figure 18.6 Sample SEL-487E MET PM Command Response

```
FREQ (Hz) 59.990          Frequency Tracking = Y
Rate-of-change of FREQ (Hz/s)    0.00

Digitals
PSV08  PSV07  PSV06  PSV05  PSV04  PSV03  PSV02  PSV01
  0      0      0      0      0      0      0      0
PSV16  PSV15  PSV14  PSV13  PSV12  PSV11  PSV10  PSV09
  0      0      0      0      0      0      0      0
PSV24  PSV23  PSV22  PSV21  PSV20  PSV19  PSV18  PSV17
  0      0      0      0      0      0      0      0
PSV32  PSV31  PSV30  PSV29  PSV28  PSV27  PSV26  PSV25
  0      0      0      0      0      0      0      0
PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  0      0      0      0      0      0      0      0


Analogs
PMV49      0.000  PMV50      0.000  PMV51      0.000  PMV52      0.000
PMV53      0.000  PMV54      0.000  PMV55      0.000  PMV56      0.000
PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63      0.000  PMV64      0.000
=>>
```

Figure 18.6 Sample SEL-487E MET PM Command Response (Continued)

C37.118 Synchrophasor Protocol

The relay complies with IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems, when Global setting MFRMT := C37.118. The protocol is available on Serial Ports 1, 2, 3, and F by setting the corresponding Port setting PROTO := PMU. The protocol is available on the Ethernet port when EPMIP := Y.

This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The relay allows several options for transmitting synchrophasor data. These are controlled by Global settings described in Settings for Synchrophasors. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit, which numeric representation to use, and which coordinate system to use.

The relay automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages. Global setting FNR*q* selects the numeric format to use for these two quantities.

The relay can include as many as sixteen user-programmable analog values in the synchrophasor message and 0, 16, 32, 48, or 64 digital status values.

The relay always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC control equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO := PMU is insufficient for the PMU Global settings, the relay or QuickSet will display an error message and fail to save settings until the error is corrected.

The C37.118 synchrophasor message format always includes 16 bytes for the message header and terminal ID, time information, and status bits. The selection of synchrophasor data, numeric format, programmable analog, and programmable digital data will add to the byte requirements. *Table 18.13* can be used to calculate the number of bytes in a synchrophasor message.

Table 18.13 Size of a C37.118 Synchrophasor Message

Item	Possible number of quantities	Bytes per quantity	Minimum number of bytes	Maximum number of bytes
Fixed			18	18
Synchrophasors[a]	0, 1, 2…32	4 (PHNR := I) 8 (PHNR := F)	0	256
Frequency	2 (fixed)	2 (FNR := I) 4 (FNR := F)	4	8
Analog Values	0 – 16	4	0	64
Digital Status Words	0 – 4	2	0	8
Total (Minimum and Maximum)			22	354

[a] Some SEL relays have a smaller number of possible synchrophasors.

Table 18.14 lists the bps settings available on any relay serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table 18.14 Serial Port Bandwidth for Synchrophasors (in Bytes) (Sheet 1 of 2)

Global Setting MRATE	Port Setting SPEED								
	300	600	1200	2400	4800	9600	19200	38400	57600
1	21	42	85	170	340	680	1360	2720	4080
2		21	42	85	170	340	680	1360	2040
4 (60 Hz only)			21	42	85	170	340	680	1020
5				34	68	136	272	544	816
10					34	68	136	272	408
12 (60 Hz only)					28	56	113	226	340
15 (60 Hz only)					21	45	90	181	272
20 (60 Hz only)						34	68	136	204
25 (50 Hz only)						27	54	108	163

Table 18.14 Serial Port Bandwidth for Synchrophasors (in Bytes) (Sheet 2 of 2)

Global Setting MRATE	Port Setting SPEED								
30 (60 Hz only)						22	45	90	136
50 (50 Hz only)							27	54	81
60 (60 Hz only)							22	45	68

Referring to *Table 18.13* and *Table 18.14*, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor and one digital status word, and this message would consume between 26 and 34 bytes, depending on the numeric format settings. This type of message could be sent at any message rate (MRATE) when SPEED := 38400 or 57600, as fast as MRATE := 50 or 30 when SPEED := 19200, and as fast as MRATE := 25 or 20 when SPEED := 9600.

Another example application has messages comprised of eight synchrophasors, one digital status word, and two analog values. This type of message would consume between 62 and 98 bytes, depending on the numeric format settings. The 62-byte version, using integer numeric representation, could be sent at any message rate (MRATE) when SPEED := 57600. The 98-byte version, using floating-point numeric representation, could be sent at as fast as MRATE := 30 when SPEED := 57600, as fast as MRATE := 25 when SPEED := 38400, and as fast as MRATE := 12 when SPEED := 19200.

Protocol Operation

The relay will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor. The synchrophasor processor controls the PMU functions of the relay, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The relay will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The relay can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The relay will only respond to configuration block request messages when it is in the nontransmitting mode.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO := PMU port will affect the maximum Global MRATE setting that can be used.

Ethernet Operation

C37.118 Synchrophasors may be used over Ethernet if an Ethernet card is installed in the relay. Four transport methods are supported: UDP_U, UDP_S, UDP_T, and TCP.

UDP_U, UDP_S, UDP_T

UDP stands for User Datagram Protocol and is a network protocol used for the Internet. UDP uses a simple transmission model without implicit handshaking interchanges for guaranteeing reliability, ordering, or data integrity. As such, UDP minimizes additional overhead needed to send messages. Time-sensitive applications often use UDP because dropping packets is preferable to waiting for delayed packets, which may not be an option in a real-time system. UDP_S is a version of UDP that only sends data; no reverse messaging is used, thus providing streaming data in one direction only. UDP_T uses a TCP socket to command and configure PMU measurements, and then uses a UDP socket for sending data out. A user may choose to use UDP to minimize the additional overhead bits added and thus minimize the communications bandwidth needed to send PMU information out of a substation. UDP_S uses the least amount of overhead (and provides some additional security as the PMU or PDC using this method is only sending data and ignores any messages coming in).

TCP

TCP stands for Transmission Control Protocol and is a connection-oriented protocol, which means that it requires handshaking to set up end-to-end communications. Once a connection is set up, user data may be sent bi-directionally over the connection. TCP manages message acknowledgment, retransmission, and timeouts. With TCP, there are no lost data; the server will request the lost portion to be resent. Additionally, TCP ensures that the messages are received in the order sent. TCP provides the most robust connection, but it also adds additional overhead bits to any message data.

PMU Setting Example

A power utility is upgrading the line protection on its 230 kV system to use the SEL-421 relay as main protection. The grid operator also wants the utility to install phasor measurement units (PMUs) in each 230 kV substation to collect data for a new remedial action scheme, and to eventually replace their present state-estimation system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- Frequency
- Positive-sequence voltage from the bus in each substation
- Three-phase and positive-sequence current for each line terminal
- Indication when the line breaker is open
- Indication when the voltage or frequency information is unusable
- Ambient temperature (one reading per station)

- Station battery voltage
- No relay control from the PMU communications port, for the initial stage of the project

The utility is able to meet the grid operator requirements with the relay, an SEL-2600A RTD Module, an SEL-2407 Satellite-Synchronized Clock, and an SEL-3373 Station Phasor Data Concentrator (PDC) in each substation.

This example will cover the PMU settings in one of the relays.

Some system details:

- The nominal frequency is 60 Hz.
- The line is protected by a breaker-and-a-half scheme.
- The station ambient temperature is collected by an SEL-2600A, Channel RTD01.
- The line pts and wiring have a phase error of 4.20 degrees (lagging) at 60 Hz.
- The Breaker 1 cts and wiring have a phase error of 3.50 degrees (lagging) at 60 Hz.
- The Breaker 2 cts and wiring have a phase error of 5.50 degrees (lagging) at 60 Hz.
- The synchrophasor data will be using Port 3, and the maximum bps allowed is 19200.
- The system designer specified floating point numeric representation for the synchrophasor data, and rectangular coordinates.
- The system designer specified integer numeric representation for the frequency data.
- The system designer specified fast synchrophasor response, because the data are being used for system monitoring.

The protection settings and RTD serial port settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table 18.13*, and determines the required message size. The system requirements, in order of appearance in *Table 18.13*, are as follows.

- 5 Synchrophasors, in floating point representation
- Integer representation for the frequency data
- 2 analog values
- 3 digital status bits, which require one status word

The message size is 16 + 5 • 8 + 2 • 2 + 2 • 4 + 1 • 2 = 70 bytes. Using *Table 18.14*, the engineer verifies that the port bps of 19200 is adequate for the message, at 10 messages per second.

Protection Math Variables PMV64 and PMV63 will be used to transmit the RTD01 ambient temperature data and the station battery voltage DC1, respectively.

The Protection SELOGIC Variables PSV64, PSV63, and PSV62 will be used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively.

The Port 3 FASTOP setting will be set to N, to disable any control attempts from the PMU port.

Make the Global settings as shown in *Table 18.15*.

Table 18.15 Example Synchrophasor Global Settings

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
NUMBK	Number of Breakers in Scheme (1, 2)	2
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth, 1 = Extra Narrow[a])	F
PMLEGCY	Synchrophasor Legacy Settings	N
NUMPHDC	Number of Phasor Data Configurations	1
PMFRQA	PMU Frequency Application (F = Fast, S = Slow)	S
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHVI111	Phasor 1 (S, W, X, Y, Z)	Y
PHVT112	Phasor 2 (S, W, X, Y, Z)	W
PHVI113	Phasor 3 (S, W, X, Y, Z)	X
PHDV1	Phasor Data Set, Voltages (I1, PH, ALL)	V1
VYCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
PHDI1	Phasor Data Set, Currents (I1, PH, ALL)	ALL
IWCOMP	IW Angle Compensation Factor (–179.99 to 180 degrees)	3.50
IXCOMP	IX Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR1	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT1	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR1	Frequency Numeric Representation (I = Integer, F = Float)	I
PMAQ11	Any Analog Quantity or alias	RTD01
PMAA11	Alias Name for the analog quantity	AmbientTemp
PMAQ12	Any Analog Quantity or alias	DC1
PMAA12	Alias Name for the analog quantity	StationBattery
PMDG11	Any Relay Word bit or alias	PSV64
PMDA11	Alias Name of Relay Word bit	LineBKStatus
PMDG12	Any Relay Word bit or alias	LOP
TREA1	Trigger Reason Bit 1 (SELOGIC Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Equation)	NA
PMTRIG	Trigger (SELOGIC Equation)	NA
EPMDR	Enable PMU Data Recording	N
PMTEST	PMU Test Mode Equation (SELOGIC Equation)	NA

[a] Option 1 is available only if MRATE = 60.

The line breaker status must be created with a protection SELOGIC variables. Make the Protection Freeform logic settings in *Table 18.16* in all six settings groups.

Table 18.16 Example Synchrophasor Protection Freeform Logic Settings

Setting	Value
PSV64	NOT (3PO OR SPO) # Line breaker status

Make the *Table 18.17* settings for Serial Port 3, using the **SET P 3** command.

Table 18.17 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, MBA, MBB, MBGA, MBGB, RTD, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N
PMU MODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
PMODC	PMU Output Data Configuration	1

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. The relay can send unsolicited write messages as fast as every 50 ms on a 60 Hz system, and 100 ms on a 50 Hz system. When MFRMT = FM, set PMLEGCY = Y to use Global settings PHDATAV, PHDATAI, PHVOLT, and PHCURR to select the voltage and current data to include in the Fast Message. Not all messages are supported at all data speeds. If the selected data rate is not sufficient for the given message length, the relay responds with an error message.

Table 18.18 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table 18.18 Fast Message Command Function Codes for Synchrophasor Fast Write

Function Code (Hex)	Function	Relay Action
00h	Fast message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80)
01h	Enable unsolicited transfer	Relay transmits Fast Message command acknowledged message (Function Code 81). Relay transmits Synchrophasor Measured Quantities (function to enable: Unsolicited Write broadcast, Function Code 20)
02h	Disable unsolicited transfer	Relay sends Fast Message command acknowledge message (Function Code 82) and discontinues transferring unsolicited synchrophasor messages (function to disable: Unsolicited Write broadcast, Function Code 20)
05h	Ping: determine if channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85)

See the SEL application guide “Using SEL-421 Relay Synchrophasors in Basic Applications” (AG2002-08) for more information on the SEL Fast Message Synchrophasor protocol.

Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table 18.19*. Many of these settings are identical to the settings for the C37.118 format (see *Settings for Synchrophasors on page 18.6*).

Table 18.19 PMU Settings in the Relay for SEL Fast Message Protocol (in Global Settings)

Setting	Description
EPMU	Enable Synchronized Phasor Measurement (Y, N)
MFRMT	Message Format (C37.118, FM)[a]
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth, 1 = Extra Narrow[b])
PMLEGCY[c]	Synchrophasor Legacy Settings (Y, N)
PHCOMP	Frequency-Based Phasor Compensation (Y, N)
PMID	PMU Hardware ID (0–4294967295)
PHVOLT	Include Voltage Terminal
PHDATAV	Phasor Data Set, Voltages (V1, ALL)
V*k*COMP[d]	V*k* Voltage Angle Compensation Factor (–179.99 to +180 degrees)
PHCURR[e]	Current Source
PHDATAI[f]	Phasor Data Set, Currents (ALL, NA)
I*n*COMP[g]	In Angle Compensation Factor (–179.99 to +180 degrees)

[a] C37.118 = IEEE Std C37.118. FM := SEL Fast Message. Set MFRMT := FM to enter the Fast Message settings.
[b] Option 1 is not available when MFRMT = FM.
[c] PMLEGCY must be set to Y to access the data configuration settings shown in this table.
[d] k = voltage terminal.
[e] Setting hidden when PHDATAI := NA.
[f] When PHDATAV:= V1, this setting is forced to NA and cannot be changed.
[g] n = current terminal.

Certain settings in *Table 18.19* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

The SEL Fast Message Synchrophasor Protocol always includes the frequency information in floating-point representation, and fourteen user-programmable SELOGIC variables PSV49–PSV64. There are no user-programmable analog quantities in the SEL Fast Message Synchrophasor Protocol.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors are added, or if the message rate is increased, some communications channel restrictions come into play.

In the SEL Fast Message Synchrophasor Protocol, the master device determines the message period (the time among successive synchrophasor message time-stamps) in the enable request. If the relay can support the requested message period on that serial port, the relay acknowledges the request (if an acknowledge was requested) and commences synchrophasor data transmission. If the relay cannot support the requested message period, the relay responds with a response code indicating bad data (if an acknowledge was requested).

The SPEED setting on any serial port set with PROTO := PMU should be set as high as possible, to allow for the largest number of possible message period requests to be successful.

The relay Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. *Table 18.20* can be used to calculate the number of bytes in a synchrophasor message.

Table 18.20 Size of an SEL Fast Message Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Median Number of Bytes	Maximum Number of Bytes
Fixed			32	32	32
Synchrophasors	1, 4, or 8	8	8	32	64
Total (Minimum, Median, and Maximum)			40	64	96

Table 18.21 lists the bps settings available on any relay serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 40 bytes.

Table 18.21 Serial Port Bandwidth for Synchrophasors (in Bytes)

Requested Message Period (ms)	Equivalent Message Rate (messages per second)	Port Setting SPEED								
		300	600	1200	2400	4800	9600	19200	38400	57600
1000	1		41	83	166	333	666	1332	2665	3998
500	2			41	83	166	333	666	1332	1999
250 (60 Hz only)	4				41	83	166	333	666	999
200	5					66	133	266	533	799
100	10						66	133	266	399
50 (60 Hz only)	20							66	133	199

Referring to *Table 18.20* and *Table 18.21*, it is clear that the lower SPEED settings are very restrictive.

Some observations from *Table 18.21* follow.

- ➤ A serial port set with SPEED := 38400 or 57600 can handle any size message at any data rate.
- ➤ A serial port set with SPEED := 19200 can handle a single-synchrophasor or four-synchrophasor message at any data rate, and any size message as fast as 10 messages per second.

- A serial port set with SPEED := 9600 can handle a single-synchrophasor message at any data rate, a four-synchrophasor message at as fast as 10 messages per second, and any size message at as fast as 5 messages per second.
- A serial port set with SPEED := 300 cannot be used for Fast Message synchrophasors.

Protocol Operation

The relay will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor. The synchrophasor processor controls the PMU functions of the relay, with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor determine the correct configuration for storing the synchrophasor data.

Transmit Mode Control

The relay will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission on a particular serial port when the disable command is received from the synchrophasor processor, or when the relay settings for that port are changed. The relay will stop synchrophasor transmission on all serial ports when any Global or Group settings change is made.

The relay will respond to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially-sent messages to be completely transmitted.

The relay will respond to a ping request immediately upon receipt, terminating any partially sent messages.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the SPEED setting on each PROTO := PMU port will affect the minimum synchrophasor message data period that can be used on that port.

Control Capabilities

Serial Port Fast Operate Operation

The PMU can be configured to process SEL Fast Operate commands received on serial ports that have the Port setting PROTO := PMU, when the Port setting FASTOP := Y, and Global Settings EPMU := Y and PMAPP := F.

This functionality can allow a remote device (client) to initiate control actions in a serially connected PMU without the need for a separate communications interface. The client should enable Fast Operate Transmit on the serial port connected to the PMU. This can be accomplished with Global Setting EPMU := Y, Port Settings PROTO := PMU, FASTOP := Y, and PMUMODE set to either CLIENTA or CLIENTB.

The client can request a Fast Operate Configuration Block when the relay is in the nontransmitting mode, and the relay will respond with a message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

Once the control points are identified, the Fast Operate Output (FOP) Control Bits can be assigned to SELOGIC equations in the client's SELOGIC freeform protection logic settings. FOP Control Bits take the form FOP*p_n*, where *p* is the serial port (F, 1, 2, or 3) and *n* is the bit number from 01–32. The bit number can correspond to a circuit breaker or remote bit control in the local relay, identified in the Fast Operate Configuration Block.

A change to any FOP*p_n* value will cause the client to transmit a Fast Operate remote bit control message on Port *p*. If the FOP control bit asserts, the message will contain the opcode to set the corresponding control bit in the PMU. If it deasserts, the message will contain the opcode to clear the control bit. The remote device will send a Fast Operate message no later than 20 ms after it detects a change in the FOP bit.

The PMU will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP := Y and PMUMODE is set to SERVER. When FASTOP := N, the relay will ignore Fast Operate commands. Use the FASTOP := N option to lock out any control actions from that serial port if required by your company operating practices.

SEL Fast Operate commands are discussed in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 15.28*.

The PMU can also process the Fast Operate commands embedded in the extended frame of the C37.118 command frame. This way you can accomplish both synchrophasor measurement and control using the same C37.118 protocol on both serial and Ethernet interfaces. This way is also independent of the FASTOP setting. The SEL-3378 is capable of sending the extended frame commands.

Ethernet Fast Operate Operation

Fast Operate commands can be issued from a host device to control the function of remote bits and breaker operation in the relay. When coupled with synchrophasor measurements, Fast Operate commands can provide control to system events when using an SEL-3378.

The implementation using the extended frame in the C37.118 synchrophasor packet makes it possible to send Fast Operate commands and synchrophasor data over the same Ethernet session. The Fast Operate command is embedded in the extended frame of the C37.118 command frame. See the following example for configuration and setup of the C37.118 extended frame implementation.

Example 18.1 Synchrophasor Control Application

Refer to *Table 18.15* for an example of a PMU communications network with a synchrophasor vector processor (SVP) collecting and analyzing synchrophasor data in the network, based on a programmed power flow and voltage regulation scheme. Each of the depicted PMU/IEDs are connected to a load, feeder line, or generation facility streaming synchrophasors to the SVP.

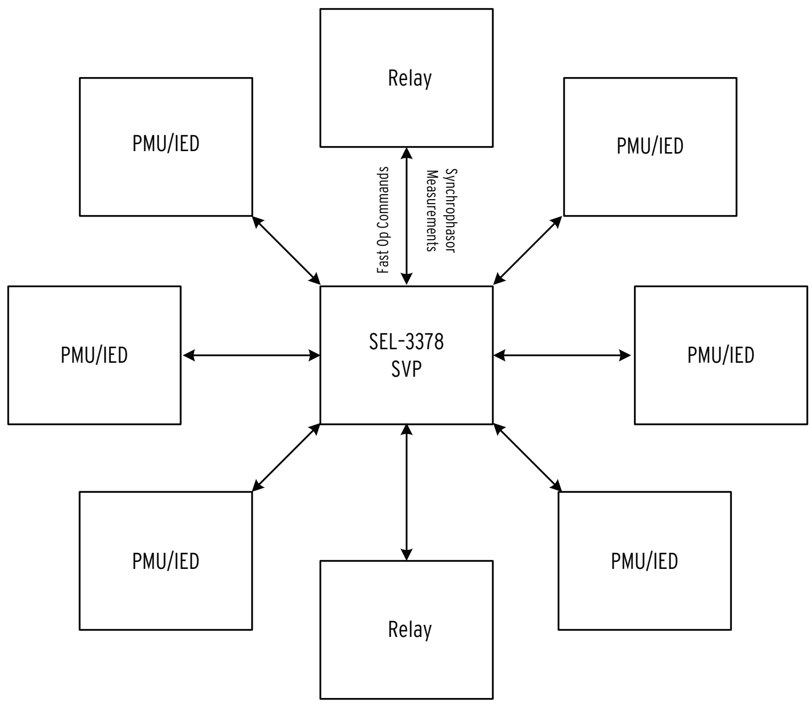


Figure 18.7 Synchrophasor Control Application

Should you need to change the relay protection scheme because of system configuration or to shed bus load to maintain voltage quality, you can use the SEL-3378 to send control commands to the relay according to a programmed algorithm. You can set a remote bit in the relay to change the group settings for an alternate protection scheme or send a **PULSE** command to the circuit breaker to disconnect load from the system.

To set the relay for such a control scenario, first configure synchrophasors for the C37.118 protocol. *Figure 18.8* depicts one way to configure synchrophasors for transport. In this SEL-487E example all of the S- and T-terminal phase currents and Z-terminal voltages along with the positive-sequence values are being transmitted in polar floating point format at a message rate of 60 messages per second. The filter settings are configured for a fast response with phase compensation.

```
Synchronized Phasor Configuration Settings

MFRMT   := C37.118  MRATE   := 60       PMAPP   := 1        PMLEGCY := N
NUMPHDC := 1


Synchrophasor Data Configuration 1

PMSTN1  := "PMU Control"
PMID1   := 1



Phasors Included in the Data 1

Terminal Name, Relay Word Bit, Alternate Terminal Name

1: Z
2: S
3: T


PHDV1   := ALL      PHDI1   := ALL      PHNR1   := F        PHFMT1  := P
FNR1    := F

Phasor Aliases in Data Configuration 1
 (Phasor Name, Alias Name)

Synchrophasor Analog Quantities in Data Configuration 1
 (Analog Quantity Name, Alias Name)


Synchrophasor Digitals in Data Configuration 1
 (Digital Name, Alias Name)

TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
PMTEST  := NA
VZCOMP  := 0.00     ISCOMP  := 0.00     ITCOMP  := 0.00     PMFRQA  := S
PHCOMP  := Y


Synchronized Phasor Recorder Settings

EPMDR   := N

Synchronized Phasor Real Time Control Settings

RTCRATE := 2        MRTCDLY := 500
```

Figure 18.8 PMU Global Settings

Next, configure the Ethernet port to transmit synchrophasor data and accept Fast Operate commands. To enable an Ethernet port to accept Fast Operate commands, simply set FASTOP := Y.

```
SEL Protocol Settings

AUTO    := Y        FASTOP  := Y        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0
```

Figure 18.9 Enabling Fast Operate Messages on Port 5

Using the C37.118 extended frame option to transport Fast Operate commands it is necessary to setup only one TCP/UDP session (see *Figure 18.10*).

```
Phasor Measurement Configuration

EPMIP   := Y        PMOTS1  := UDP_T
PMOIPA1 := "192.168.1.3"
PMOTCP1 := 4712     PMOUDP1 := 4713     PMOTS2  := OFF
```

Figure 18.10 Ethernet Port 5 Settings for Communications Using C37.118 Extended Fame

The relay is now ready to start transmitting synchrophasors and receive Fast Operate commands from the SVP.

Real-Time Control

The PMU can be configured to process C37.118 synchrophasor data received from two remote PMUs over serial ports. The PMU processes the remote PMU data, time aligns them with the local data, and makes them available as analogs and digitals. Use the local synchrophasor analogs and as many as two remote sets of synchrophasor analogs in SELOGIC equations to do real-time control (RTC) applications.

Table 18.22 shows the serial port settings that need to be configured for RTC applications.

Table 18.22 Serial Port Settings for RTC

Setting	Description	Default
PMUMODE[a]	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[b]	Remote PMU Hardware ID (1–65534)	1
PMODC[c]	PMU Output Data Configuration (1–5)	1

[a] Set PROTO := PMU to enable (on this port) the Synchrophasor Protocol selected by Global setting MFRMT.

[b] Setting hidden when PMUMODE := SERVER.

[c] Only available when PMUMODE := SERVER.

Descriptions for the settings in *Table 18.22* are as follows.

PMUMODE

Selects whether the port is operating as a synchrophasor server (source of data) or a client (consumer of data). When the port is intended to be a source of synchrophasor data, set this setting to SERVER. The Global setting MFRMT determines the format of the transmitted data. When using the port to receive synchrophasor data from another device, set this setting to either CLIENTA or CLIENTB. Only two ports may be configured as client ports and they must be uniquely configured for Channel A or Channel B. When a port is configured to receive synchrophasor data, the port will only receive data using the C37.118 format, regardless of the MFRMT setting.

RTCID

Expected synchrophasor ID from remote relay.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), it will only accept incoming messages that contain this ID. Make sure this ID matches the ID configured in the remote relay.

PMODC

Select the data configuration set to be sent out from that port. This setting is only available when the PMUMODE=SERVER.

Table 18.23 shows the Global settings that need to be configured for RTC applications.

NOTE: The maximum channel delay is available in the **COM RTC** command.

Table 18.23 Global Settings for RTC

Setting	Description	Default
RTCRATE	Remote Messages per Second (1, 2, 5, 10, or 50 when NFREQ := 50) (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60)	2
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–1000 ms)	500

Descriptions for the settings in *Table 18.23* are as follows.

RTCRATE

Rate at which to expect messages from the remote synchrophasor device.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), the relay will only accept incoming messages at this rate. Make sure the remote synchrophasor source(s) is configured to send messages at this same rate.

MRTCDLY

Selects the maximum acceptable delay for received synchrophasor messages.

When the PMU is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), the relay only accepts incoming messages that are not older than allowed by this setting. When determining an appropriate value for this setting, consider the channel delay, the transfer time at the selected baud rate, plus add some margin for internal delays in both the remote and local relay.

When you use the PMU for synchrophasor acquisition, the delayed and aligned analog quantities specific to that relay are available. Be aware that these quantities are only valid when RTCROK is asserted and only for the enabled channels. The specific channel quantities are also valid whenever their respective RTCROK*p* Relay Word bit is set (see *Table 18.11*).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 18.24* indicate the state of the synchronization.

Table 18.24 Synchrophasor Client Status Bits

Name	Description
RTCEN*p*[a]	Asserts for one processing interval when a valid message is received on Channel p.
RTCROK*p*[a]	Asserts for one processing interval when data are aligned for Channel p. Use this bit to condition usage of the Channel p data.
RTCROK	Asserts for one processing interval when data for all enabled channels are aligned. Use this bit to condition general usage of the aligned synchrophasor data.
RTCDLY*p*[a]	This bit is asserted when the last received valid message on Channel p is older than MRTCDLY.

Table 18.24 Synchrophasor Client Status Bits

Name	Description
RTCSEQ*p*[a]	This bit is asserted when the processed received message on Channel p is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of Channel p data in applications where sequential data are required.
RTCCFG*p*[a]	Indicates Channel *p* is successfully configured.

[a] *p* = A or B.

When received, synchrophasor messages contain digital data. These data are stored in the Remote Synchrophasor Relay Word bits in *Figure 18.25*.

Table 18.25 Remote Synchrophasor Data Bits

Name	Description
RTC*p*D[16][a]	First sixteen digitals received in synchrophasor message on Channel *p*. Only valid when RTCROK*p* is asserted.

[a] *p* = A or B.

Set MRTCDLY for the maximum expected communications channel delay in milliseconds. Any data arriving later than this time are rejected. The RTCDLY*p* Relay Word bit indicates this condition. Use the MRTCDLY to constrain the maximum longest operating time of the system. Set the RTCRATE to the rate of synchrophasor data being sent by remote relay. This is the MRATE setting on the remote relay.

Several Relay Word bits are useful for monitoring system status. Add RTCCFG*p* and RTCDLY*p* to the SER.

The RTCCFG*p* Relay Word bit is asserted after the two relays have communicated configuration data successfully. RTCCFG*p* deassertion indicates that the system has changed, perhaps because of a setting change in one of the relays.

If the RTCCFG*p* Relay Word bit indicates a new configuration, you can issue the **RTC** command to ensure that the data being received have not changed. The **RTC** command displays a description of the synchrophasor data being received. Use this command to ensure that the remote value that you chose for the SELOGIC equation is the correct value to compare with the local synchrophasor value.

The RTCDLYA bit asserts when synchrophasor data have not been received on Channel A within the window you set with the local MRTCDLY setting (100 ms in this example). If the RTCDLYA asserts, consider three options. First, the MRTCDLY setting can be increased. However, the MRTCDLY setting is your way of guaranteeing operation within a certain time. Increasing MRTCDLY allows for communications channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communications channel so that it operates within the required MRTCDLY setting time. A final option is available if the assertion of MRTCDLY results from a temporary communications channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 18.11* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communications channel delay. This information can help you choose an appropriate value for the MRTCDLY setting.

```
Summary for RTC channel A
Port:              2
ID:                8
Present Status:    Receiving
Max Packet Delay:  50 msec
Message Rate:      60 msgs/sec

Summary for RTC channel B
Port:              1
ID:                9
Present Status:    Receiving
Max Packet Delay:  40 msec
Message Rate:      60 msgs/sec
```

Figure 18.11 Example COM RTC Command Response

Real-Time Control Example

Figure 18.12 shows an application example using SEL-411L relays. In this example, Area 2 supplies power to Area 1 and Area 3. An important contingency is loss of both Link 1 and Link 2. In such a case, the generators in Area 2 accelerate. Alternate paths between Area 2 and Area 1 can also become stressed beyond their design limits. A simple solution is to measure the phase angle between Area 1 and Area 2. When the angle exceeds a predetermined limit, control the generation to avoid exceeding system limits.

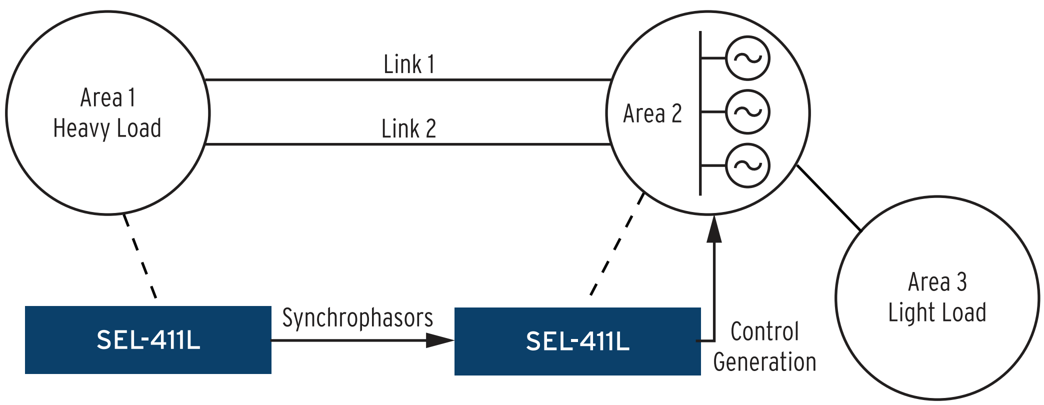


Figure 18.12 Real-Time Control Application

Figure 18.13 shows the SELOGIC for the relay controlling the generator (called the local relay in this example). Lines 1 and 2 store phasor data into PMV53 and PMV54 so they can be viewed through use of the **MET PMV** command. Line 3 computes the angle difference between the local and remote relays. RTCAP02 is the remote V1Y angle. Lines 4–10 unwrap the phase angle when the difference exceeds ±180 degrees.

RTCROKA pulses true whenever a good synchrophasor message is received. For purposes of this example, we need it to hold true until the next message is received. To achieve this, lines 11-13 implement a timer to extend this bit by 1.75 cycles. A message is expected every 1 cycle; the additional 0.75 cycles covers any jitter that may occur in the rate or message receipt. Line 14 calculates a qualification signal consisting of the local and remote quality indicators. RTCROKA is the local indicator which has been extended as PCT01. RTCAD16 is the remote quality indicator. *Figure 18.14* shows its construction at the remote relay.

Line 15 computes absolute value of the angle. Line 16 checks the angle against the reference value. In this case, the reference value is 10 degrees.

The final result, PSV03, asserts when the relay receives a synchrophasor message with an angle difference exceeding 10 degrees.

```
Protection 1
1: PMV53 := V1YPMAD
2: PMV54 := RTCAP02
3: PMV55 := V1YPMAD - RTCAP02
4: PSV01 := PMV55 >= 180.000000
5: PMV01 := -180.000000
6: PSV02 := PMV55 <= PMV01
7: PMV01 := PMV55 + 360.000000
8: PMV02 := PMV55 - 360.000000
9: PMV55 :=NOT PSV01*PMV55+PSV01*PMV02
10: PMV55 :=NOT PSV02*PMV55+PSV02*PMV01
11: PCT01PU := 0.000000
12: PCT01DO := 1.750000
13: PCT01N := R_TRIG RTCROKA
14: PSV01 := PCT01Q AND RTCAD16
15: PMV56 := ABS(PMV55)
16: PSV03 :=(PMV56 > 10.000000) AND PSV01
```

Figure 18.13 Local Relay SELOGIC Settings

Figure 18.14 shows the SELOGIC settings for the remote relay. Set PSV64 to indicate that the sending data are correct. These data are sent with the synchrophasor data in the C37.118 data packet and are received by the local relay as RTCAD16. The RTCAD16 qualification on line 11 of the local relay (see *Figure 18.13*) contains this remote data quality indicator. A local relay quality indicator also qualifies line 11.

```
1: PSV64 := TSOK AND PMDOK
```

Figure 18.14 Remote Relay SELOGIC Settings

Set the remote relay Global settings according to *Figure 18.15*. Set the number of digitals (NUMDSW) to one. In this case, the relay sends SELOGIC values PSV49–PSV64 in the C37.118 data packet. This is how the remote TSOK AND PMDOK qualification maps to the local RTCAD16 Relay Word bit. Set the PMU application (PMAPP) to fast, because this is a protection application. Therefore, you must choose a filter for faster response. Also set the synchrophasor enable Global setting to yes (EPMU = Y). The MRTCDLY and RTCRATE settings are set but not used by the remote relay.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 60      PMAPP   := F       PHCOMP  := Y
PMSTN   := "REMOTE RTC"
PMID    := 8
PHDATAV := V1       VCOMP   := 0.00    PHDATAI := NA      IWCOMP  := 0.00
IXCOMP  := 0.00     PHNR    := F       PHFMT   := P       FNR     := F
NUMANA  := 0        NUMDSW  := 1
TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
MRTCDLY := 100
RTCRATE := 60

Time and Date Management

IRIGC   := C37.118
```

Figure 18.15 Remote Relay Global Settings

Set the local relay Global settings according to *Figure 18.16*. It is important for synchrophasors to be enabled (EPMU = Y), the application to be fast (PMAPP = F), the compensation settings to be set correctly (VYCOMP, VZCOMP, IWCOMP, and IXCOMP), and for IRIGC = C37.118.

Set MRTCDLY for the maximum expected communications channel delay in milliseconds. Any data arriving later than this time are rejected. The RTCDLYA Relay Word bit indicates this condition. Use the MRTCDLY to constrain the maximum longest operating time of the system. Set the RTCRATE to the rate of synchrophasor data being sent by remote relay. This is the MRATE setting on the remote relay.

The other Global settings are not relevant to this application.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 60       PMAPP   := F        PHCOMP  := Y
PMSTN   := "LOCAL RTC"
PMID    := 4
PHDATAV := V1       VCOMP   := 0.00     PHDATAI := NA       IWCOMP  := 0.00
IXCOMP  := 0.00     PHNR    := F        PHFMT   := P        FNR     := F
NUMANA  := 0        NUMDSW  := 0

TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
MRTCDLY := 100
RTCRATE := 60

Time and Date Management

IRIGC   := C37.118
```

Figure 18.16 Local Relay Global Settings

Set the port settings for the port that sends the synchrophasor data on the remote relay, according to *Figure 18.17*.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1        RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := SERVER
```

Figure 18.17 Remote Relay Port Settings

Set the port settings for the port that receives the synchrophasor data on the local relay, according to *Figure 18.18*. Notice that the RTCID setting must match the PMID setting of the remote relay.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1        RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := CLIENTA
RTCID   := 8
```

Figure 18.18 Local Relay Port Settings

Several Relay Word bits are useful for monitoring system status. Add RTCCFGA and RTCDLYA to the SER.

The RTCCFGA Relay Word bit is asserted after the two relays have communicated configuration data successfully. RTCCFGA deassertion indicates that the system has changed, perhaps because of a setting change in one of the relays.

If the RTCCFGA Relay Word bit indicates a new configuration, you can issue the **RTC** command to ensure that the data being received have not changed. The **RTC** command displays a description of the synchrophasor data being received. Use this command to ensure that the remote value that you chose for the SELOGIC equation (for example, RTCAP02 in *Figure 18.13*) is the correct value to compare with the local synchrophasor value.

The RTCDLYA bit asserts when synchrophasor data have not been received within the window you set with the local MRTCDLY setting (100 ms in this example). If the RTCDLYA asserts, consider three options. First, the MRTCDLY setting can be increased. However, the MRTCDLY setting is your way of guaranteeing operation within a certain time. Increasing MRTCDLY allows for communications channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communications channel so that it operates within the required MRTCDLY setting time. A final option is available if the assertion of RTCDLY results from a temporary communications channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 18.19* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communications channel delay. This information can help you choose an appropriate value for the MRTCDLY setting.

```
Summary for RTC channel A
Port:              2
ID:                8
Present Status:    Receiving
Max Packet Delay:  50 msec
Message Rate:      60 msgs/sec

Summary for RTC channel B
Port:              1
ID:                9
Present Status:    Receiving
Max Packet Delay:  40 msec
Message Rate:      60 msgs/sec
```

Figure 18.19 Example COM RTC Command Response

PMU Recording Capabilities

The PMU can be configured to record synchrophasor data by setting EPMDR := Y. Select one of the data configuration q you want to record using SPMDR setting where q = 1–NUMPHDC. Create a recording trigger using PMTRIG SELOGIC setting. On the rising edge of PMTRIG, the PMU starts recording synchrophasor data. The duration and the pretrigger duration of the recording are user settable.

NOTE: Select PMTRIG trigger conditions to assert PMTRIG only once during a four-hour period if EPMDR = Y (i.e., synchrophasor recording is enabled).

The PMU stores these files in the SYNCHROPHASOR subdirectory with .PMU extension. Use FILE READ or FTP to retrieve these stored data files. The file is in binary format and IEEE C37.118 data format compliant.

The file starts with a Configuration 2 frame followed by the data frames as shown below.

<Configuration 2 Frame>

<Data Frame 1>

<Data Frame 2>

.

.

.

<Data Frame *t*>

<Data Frame *t*+1>

.

.

.

<Data Frame *n*>

where:

t = the number of pretrigger data frames, and is equal to PMPRE • MRATE.

n = the total number of data frames, and is equal to PMLER • MRATE.

<Data Frame *t*+1> is the first data frames with Bit 11 in the STAT field (PMTRIG) asserted.

The recorded file has the following file naming convention.

yymmdd,hhmmss,0,aaa,bbb,ccc.PMU

where,

yymmdd, hhmmss = the UTC time stamp of the first data frame in the file with bit 11 (PMTRIG) asserted

aaa = the last three characters of the PMSTN*q* setting (after removing characters “ / \ < > * | : ; [ ] $ % { } and the spaces)

bbb = the last three characters of the PMID*q*

ccc = the CONAM setting (after removing the spaces)

Additional PMTRIG assertions are ignored during recording.

Table 18.26 shows the setting name, description, and default value to help configure the data recording.

Table 18.26 PMU Recording Settings

Setting	Description
EPMDR[a]	Enable PMU Data Recording (Y, N)
SPMDR[b]	Select Data Configuration for PMU Recording (1–NUMPHDC)
CONAM[b]	Company Name (1–3 characters)
PMLER[b]	Length of PMU Triggered Data (2–120 s)
PMPRE[b]	Length of PMU Pretriggered Data (1–20 s)

[a] This setting is forced to N if MFRMT = FM.
[b] This setting is hidden if EPMRD = N.

Descriptions for the settings in *Table 18.26* are as follows.

EPMDR

Use the EPMDR setting to enable synchrophasor data recording. This setting is hidden when EPMU := N. When EPMDR = Y, phasor measurement data recording will begin on the rising edge of PMTRIG. Any subsequent PMTRIG assertions during the allotted recording period (PMLER) will not result in another PMU data recording being started. The relay will store synchrophasor measurement data as a C37.118 binary format file that can be retrieved from the relay using File Transfer Protocol. Synchrophasor data are recorded into a file with extension *.PMU.

SPMDR

The SPMDR setting provides a means for selecting any one of the enabled data configuration 1–NUMPHDC for synchrophasor data recording.

CONAM

The CONAM setting provides a means for inserting the company name into the recorded synchrophasor data file name. The CONAM setting is three characters long. The settings allows all printable characters except " / \ < > * | : ; [ ] $ % { }.

PMLER

PMLER sets the total length of the synchrophasor data recording, in seconds. The PMLER time includes the PMPRE time. For example, if PMLER is set for 30 seconds of PMU recorded data, and PMPRE is set for 10 seconds of pretrigger data, the final recording will contain 10 seconds of pretrigger data and 20 seconds of triggered data for a total report time of 30 seconds.

PMPRE

The PMPRE setting sets the length of the pretrigger data within the synchrophasor data recording. The PMPRE data begins at the PMTRIG point of the recording, and extends back in time (previous time to the trigger event) for the designated amount of time.

SECTION 19

Remote Data Acquisition

SEL-400 series relays can receive analog and binary inputs from remote data acquisition systems. This technology provides flexible solutions, reduces the cost of copper, and improves overall safety in the substation.

Time-Domain Link (TiDL)

Some SEL-400 series relays can receive remote analog and binary inputs from the SEL-2240 Axion. The Axion provides the remote analog and binary data over an IEC 61158 EtherCAT, TiDL network. This technology provides very low and deterministic latency over point-to-point architecture. Point-to-point architecture eliminates the need for time synchronization between the remote data acquisition units and the relay. In addition, it eliminates the complex communications network often associated with remote data acquisition and simplifies the programming and installation process.

Some of the benefits of a TiDL system include:

- Use ACSELERATOR QuickSet SEL-5030 Software to set the relay as you would conventional SEL-400 series relays. Firmware for the SEL-400 series relays was modified for the implementation of TiDL; however, the settings and protection algorithms were unchanged.
- Decrease costs through copper reduction.
- Simplify the installation process.
- Increase safety in the substation by removing high-energy cables from the control house. This also eliminates the concern of an open circuited CT when a relay is removed from service.

SEL-400 series relays with TiDL can receive as many as eight fiber links from as many as eight Axion remote data acquisition nodes. Not all nodes have to supply analog data—some can supply digital input and output (I/O) only. The firmware will recognize and validate the connected Axion modules and determine if they match a predefined supported topology. The supported topologies are balanced between copper reduction and the number of required remote Axion nodes. Refer to *Section 2: Installation* in the product-specific instruction manuals to review the supported TiDL topologies.

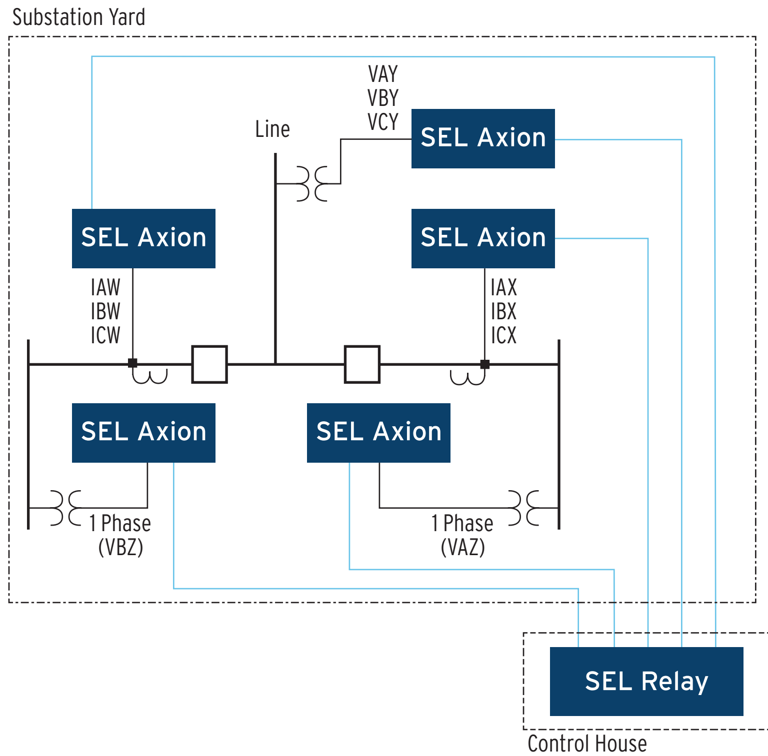


Figure 19.1 Sample TiDL System Topology

SEL-400 series relays that support TiDL are only available in a 4U chassis. These relays support an I/O board on the relay, and, when applicable, main board I/O. These I/Os will be mapped to the 100- and 200-level inputs and outputs. Axion remote modules provide additional I/O by using the internal digital Relay Word bits for the 300, 400, and 500 levels of the relays. Note that when the relay part number supports TiDL, all output settings for I/O are available. Correctly set these outputs for what is installed because all output settings will be available but all may not be physically installed in your system.

Relay Word bits IO300OK, IO400OK, and IO500OK indicate the status of installed I/O boards in standard relays or whether a remote module is commissioned, such as in a TiDL system. These bits can also identify whether a board is installed or when a remote I/O module fails.

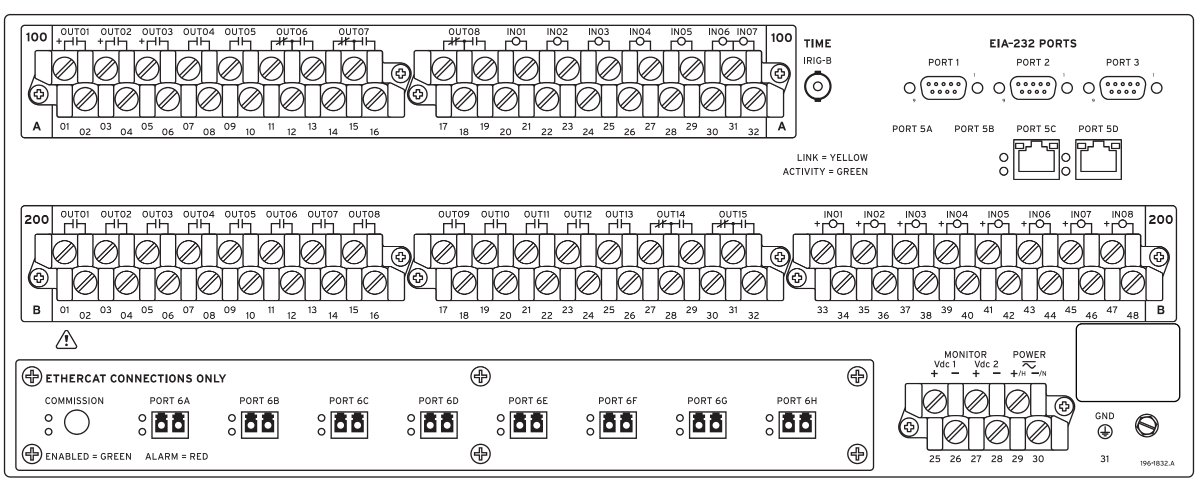


Figure 19.2 Rear Panel of Relays With TiDL

TiDL applications use the SEL-2240 Axion, which is a fully integrated analog and digital I/O control solution suitable for remote data acquisition. An Axion node consists of a 10-slot, 4-slot, or dual 4-slot chassis that is configurable to contain a power module and combinations of CT/PT, digital input (DI), or digital output (DO) modules.

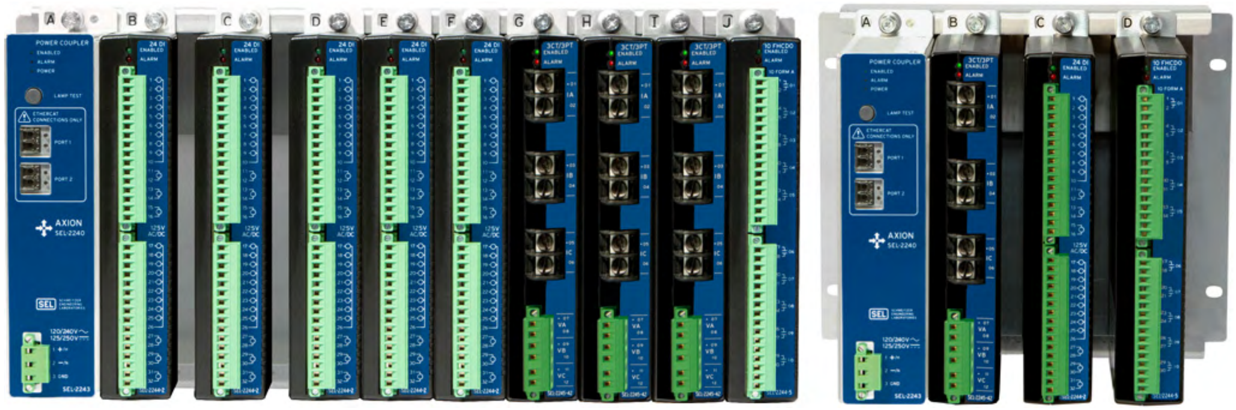


Figure 19.3 Axion Chassis

Each chassis requires a SEL-2243 Power Coupler (see *Figure 19.4*). This module supplies power to the rest of the node and transmits the data to the relay through fiber-optic communication. See the *SEL-2240 Axion Instruction Manual* for more information.

Figure 19.4 SEL-2243 Power Coupler

The SEL-2244-2 Digital Input Module (see *Figure 19.5*) consists of 24 optoisolated inputs that are not polarity-dependent. These inputs can be configured to respond to ac or dc control signals. The TiDL system maps as many as 72 DI points to the relay. For more information on DI mapping, refer to *Section 2: Installation* in the product-specific instruction manuals.

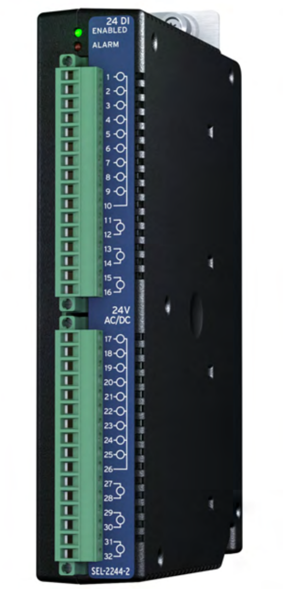


Figure 19.5 SEL-2244-2 Digital Input Module

The SEL-2244-5 Fast High-Current Digital Output Module (see *Figure 19.6*) consists of ten fast, high-current output contacts. The TiDL system can map as many as 48 DO points to the relay. For more information on DO mapping, refer to *Section 2: PC Software*.

Figure 19.6 SEL-2244-5 Fast High-Current Digital Output Module

The SEL-2245-42 AC Analog Input Module (see *Figure 19.7*) provides protection-class ac analog input (CT/PT) and can accept three voltage and three current inputs. The module samples at 24 kHz and is 1 A or 5 A software-selectable. Depending on the supported fixed topology, multiple CT/PT input modules can function in each node. Some topologies only support one CT/PT module per node. See the supported topologies in *Section 2: Installation* in the product-specific instruction manual for more information.

Figure 19.7 SEL-2245-42 AC Analog Input Module

A simple commissioning process identifies the connected TiDL system and verifies it matches one of the supported relay topologies. Once the commissioning process is complete, the topology is stored in memory. At each additional relay startup, the firmware validates that the connected modules match those of the stored configuration. It recognizes if any CT/PT modules within the node have changed. See *Section 2: PC Software* in the product-specific instruction manual for more information on commissioning.

Secondary injection testing takes place at each Axion node. Test sources are required to inject voltages and current to the Axion node to verify correct installation and mapping. Monitoring of the voltages and currents will remain in the control house at the relay location.

IEC 61850-9-2 Sampled Values (SV)

Some SEL-400 series relays are available with the capability to either publish or subscribe to remote analogs in accordance with the UCA International Users Group's "Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2," This type of remote data acquisition is a subset of IEC 61850-9-2 and specifies, among other things, logical devices, dataset contents, sampling rates, the time-synchronization method, and the message format. The 9-2LE guideline clarified ambiguities in the 9-2 standard, improving interoperability between SV devices from different manufacturers.

Architecture

9-2LE uses OSI Layer 2 multicast messages on standard Ethernet network architecture. Merging units such as the SEL-421-7 with SV publication capability enabled or the SEL-401 Merging Unit sample remote analog values, convert them to digital signals, and then publish them over the Ethernet network. Two key components of SV messages (besides the current and voltage data) are the destination MAC address and the application ID, or APPID. Relays, meters, DFRs, and other devices on the network can selectively subscribe to the SV streams they need for their application based on these attributes. Because SV streams only carry current and voltage measurements, to accommodate digital input and output data or controls, IEC 61850 GOOSE must also be configured on the network. This network, which carries data essential for the first level of basic substation processes, is known as the process bus. Another network commonly associated with IEC 61850 is known as the station bus, which carries station-level communications such as SCADA and engineering access.

The process bus allows a single merging unit to share its data with multiple devices and for a single device to receive remote data from multiple merging units. To align this data, 9-2LE requires time synchronization for all devices. This can also be accomplished over either the process bus or the station bus network via IEEE 1588 or Precision Time Protocol (PTP). Alternately, SEL SV devices can be synchronized via IRIG-B. Because of the bandwidth requirements and message types that can be present on the process bus, optimal SV performance requires a well-engineered process bus and station bus network.

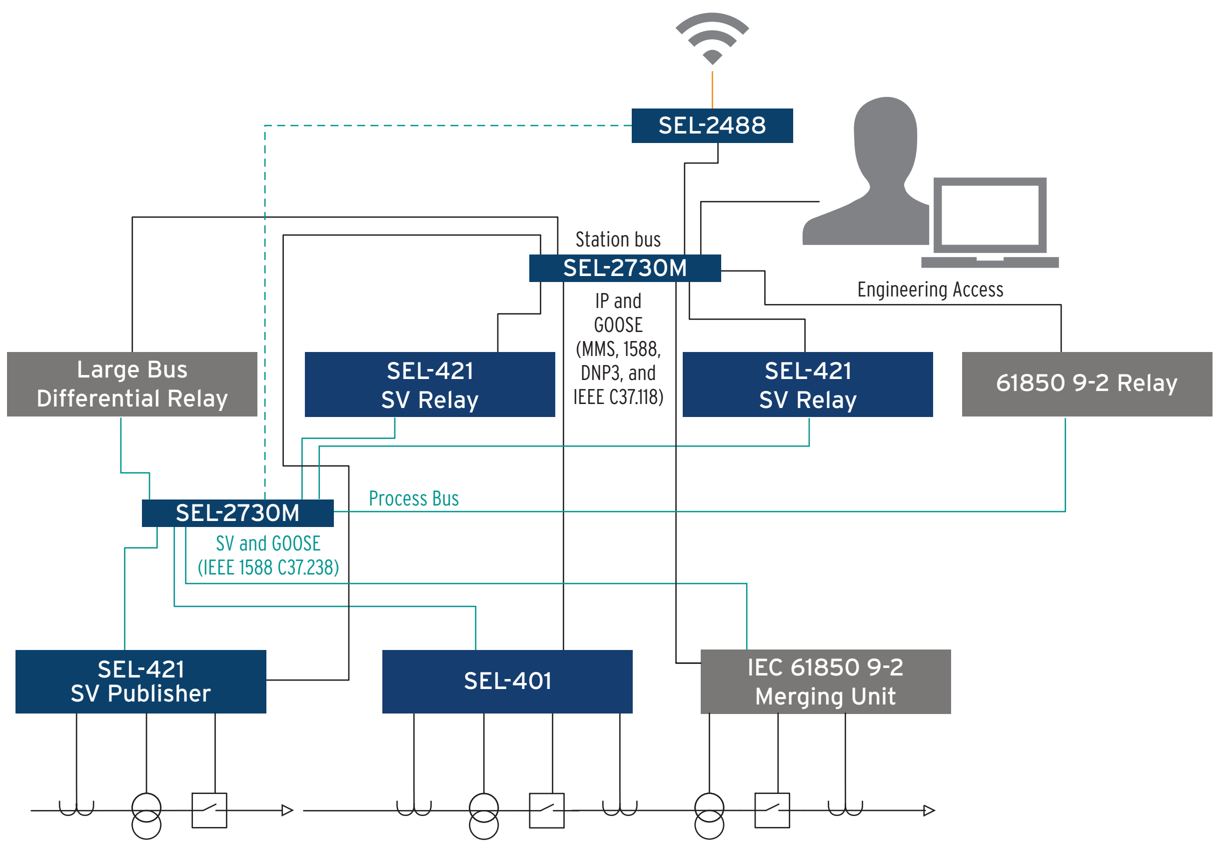


Figure 19.8 Example SV Network

SEL SV devices allow for flexible process bus and station bus configuration. The Port 5 setting, BUSMODE, can be used to change the default behavior of independent buses (BUSMODE := INDEPEND) and merge the two buses together (BUSMODE := MERGED). SEL does not recommend the use of the merged BUSMODE other than in a laboratory situation or for monitoring functions, as it disables Ethernet Ports 5C and 5D and places all network traffic on Ports 5A and 5B.

The Port 5 settings NETMODE and NETPORT determine and configure the Ethernet ports used for the station bus and the process bus. The NETMODE setting applies only to the station bus, and gives the user the ability to set the desired network redundancy mode in the device. The NETPORT setting determines which pair of Ethernet ports the SV device will use for its station bus. The SV device will use the other pair of Ethernet ports for the process bus. For example, if NETPORT = A or B, the station bus will be on Ethernet Ports 5A and 5B with the process bus on Ports 5C and 5D. SV process bus ports only operate in FAILOVER mode. Refer to *Ethernet Communications on page 15.6* for more information on Ethernet network operation and using redundant Ethernet ports.

Benefits of a 9-2LE SV System

Some of the benefits of a 9-2LE SV system include:

- Set the relay as you would conventional SEL-400 series relays through use of QuickSet and ACSELERATOR Architect SEL-5032 Software.
- Decrease costs through copper reduction and data sharing.
- Increase safety in the substation by removing high-energy cables from the control house. This also eliminates the concern of an open circuited CT when a relay is removed from service.

SV Publication

SV Publication Capability

Some SEL-400 series relays are available with the capability for SV publication. Enabling SV publication through settings (Port 5 setting SVTXEN > 0 or via CID file) enables the merging unit functionality of the device. The SV publication capability of each SEL SV publishing devices is identical, so throughout this section, SEL devices with SV publication enabled are referred to as SV publishers.

The SV publisher digitizes the data from its voltage and current inputs, records its current state of time synchronization, scales these values to primary units by using the CT and PT ratio settings, and then transmits these values in accordance with the 9-2LE guideline. SEL SV publishers support the “MSVCB01” model of the multicast SV control block described in the guideline, which includes a single application service data unit (ASDU). The transmission rate is 80 samples per nominal frequency cycle. If the nominal frequency setting of the SV publisher NFREQ = 50 Hz or 60 Hz, the SV transmission rate is 4000 or 4800 samples per second, respectively.

The SV publisher can publish as many as seven SV streams simultaneously. SV publication is independent of the protection elements, so protection functionality remains secure even when the SV publisher is publishing the maximum number of SV streams.

Because multiple SV streams may be received by a single subscriber, all streams usually require time-alignment to a time source with an accuracy of <1 µs. SV messages indicate the synchronization state of the SV publisher at the time the sample was taken. This value, smpSynch in the SV message, will be 0, 1, or 2, to indicate whether the merging unit was synchronized with a global time source (2), a local time source (1), or an internal clock (0). If the SV publisher is synchronized with an IEEE 1588 Precision Time Protocol (PTP) time source that uses the PTP Power Profile (C37.238), the smpSynch value is equal to the ID of the grandmaster clock, usually a value between 5 and 254.

Though SV messages do not contain an actual time stamp, they do include a value, smpcnt (sample count), that the publisher increments for each message that it transmits, which represents the time at which the sample was taken. For every SV message that the SV publisher transmits, smpcnt increments until it reaches a value of 4799 on a 60 Hz system, or 3999 on a 50 Hz system. At the top of the second, smpcnt resets to 0. Smpcnt can be used to calculate the time stamp of the message in relation to the most recent top of a second by multiplying it by the transmission interval (208.33 µs for a 60 Hz system or 250 µs for a 50 Hz system). For example, a message with smpcnt=699 on a 50 Hz system was taken 699 • 250 µs = 174.75 ms after the top of the second.

SV Publisher Configuration

Architect provides support for the configuration of the SEL SV publisher via a GUI. This interface provides the most flexible configuration of SV publications, including the creation of customized SV datasets. This mechanism is very similar to the configuration of GOOSE publications. For more information, see *IEC 61850 Configuration on page 17.22*.

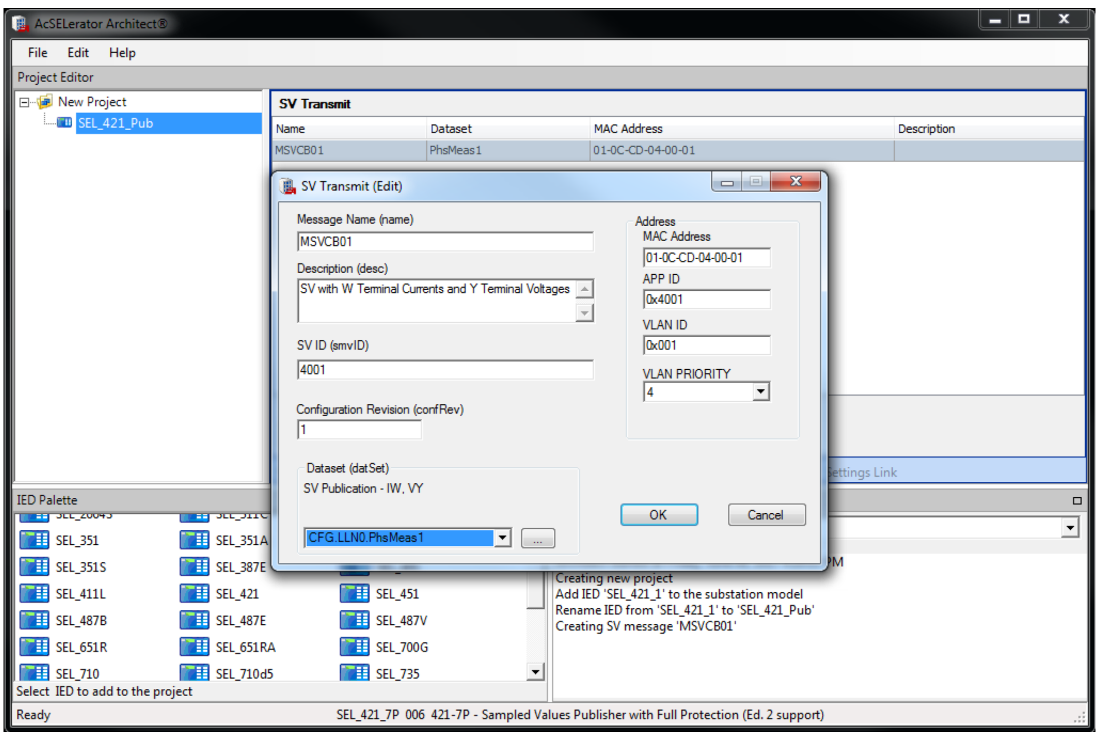


Figure 19.9 Example Architect SV Publication Configuration

Architect includes an ICD file for the SEL-401 and an ICD file for the SEL-421 with SV publication capability. ICD files of both SV publishers contain default SV datasets, which contain combinations of the current and voltage terminals available on the publisher, i.e. W and Y, W and Z, X and Y, or X and Z. You can choose to publish any of these preconfigured datasets or create and publish a custom dataset that conforms to the 9-2LE guideline. This feature is useful if you need the SV publisher to send anything other than all phases (A, B, C, and neutral) of a current or voltage terminal in an SV stream.

SV publications may also be configured via Port 5 settings through QuickSet or an ASCII terminal window. You can use Port 5 settings to quickly configure SV streams that do not require much customization. All phases (A, B, C, and neutral) of a current or voltage terminal must be mapped to an SV stream, and each stream must contain at least one set of voltage or current terminal phase quantities.

SV Publisher Startup

When initially turned on, the SV publisher ENABLED LED illuminates as soon as protection functionality is enabled, typically within 10 seconds, but there can be an additional delay of approximately 6 seconds before the initial SV publication is transmitted. Once the SV publisher has begun transmitting SV streams, they can be temporarily disabled for the following conditions:

- Port 5 settings are modified
- A new CID file configuration is enabled
- Power is cycled

SV publications stop if the SV publisher is disabled (EN Relay Word bit = False), the Port 5 setting EPORT is set to "N", or the processor fails. SV publications will not resume unless the disabling condition is addressed.

SV Publisher Diagnostics and Testing

Once SV publication is configured and enabled, new commands are available to verify configuration, diagnose and troubleshoot SV communications, and aid in commissioning and testing: **COM SV** and **TEST SV**.

The **COM SV** command displays information about the SV streams that the unit is configured to publish. The data includes the SV destination MAC address, Application ID, message name, dataset name, VLAN ID, and priority if the SV publisher is configured via CID file. If the publisher is configured via Port 5 settings, the dataset name remains blank because it is not used in Port 5 settings, and therefore unavailable. For more information on the **COM SV** command, see *Section 9: ASCII Command Reference* in the product-specific manual.

The **TEST SV** command places the SV publisher into TEST SV mode. In this mode, it replaces the current and voltage data of all SV configured streams with predefined signals for a period of 15 minutes. Also, the SV publisher asserts the test bit in the quality attribute of each current and voltage to identify it as test data. Note that the SV publisher remains in normal mode, and does not enter IEC 61850 Test mode. This does not affect metering or protection functions on the SV publisher. The **COM SV** command indicates whether the SV publisher is in TEST SV mode by displaying the information at the top of the response. Refer to the **TEST SV** command description in *Section 9: ASCII Command Reference* in the product-specific manual for more information.

SV Subscriber

SV Subscriber Functionality

SEL SV subscriber relays do not have current or voltage input terminals like conventional relays. SV subscriber relays also do not have internal instrument transformers. Conventional relays are typically ordered from the factory with either 1 A or 5 A nominal CTs, which provide the full range of measured values for the current input terminals. Before or during installation, SEL SV subscriber relays must be configured with the same nominal current value of the merging unit for proper operation. The ASCII command **CFG CTNOM *n***, where *n* is 1 or 5, must be used to configure the SV subscriber with the nominal current value of the subscribed merging unit. Refer to the *Section 9: ASCII Command Reference in the SEL-421-7 Instruction Manual* for more information on the **CFG CTNOM** command.

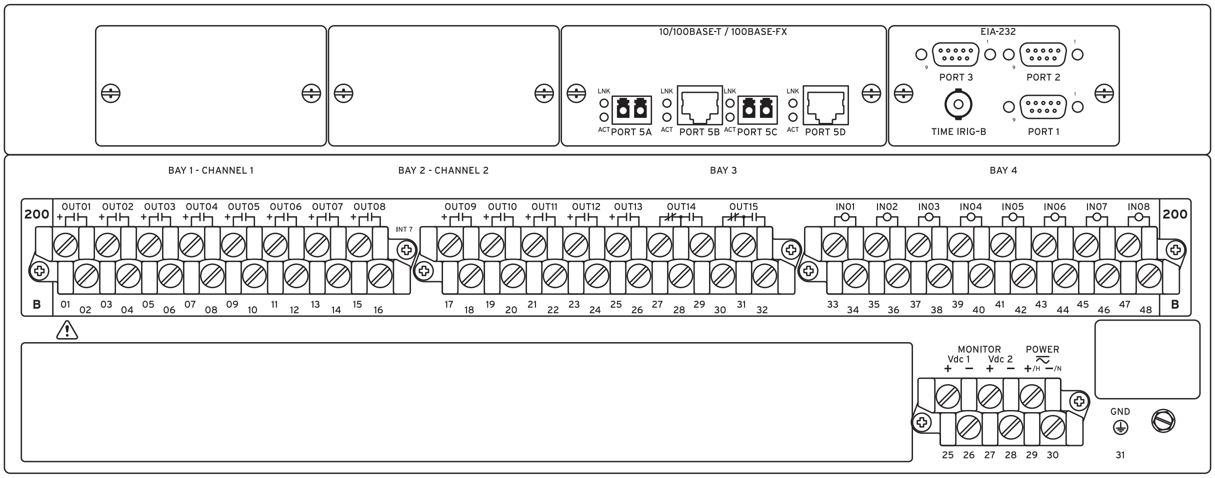


Figure 19.10 SEL-421-7 SV Subscriber Relay, 4U Rear Panel

SV Subscribers, such as the SEL 421-7 SV Subscriber Relay, must be configured to subscribe to 9-2LE-compliant SV streams to enable any protection functions. When configured via Port 5 settings, all phases (A, B, and C) of a current or voltage terminal must come from an SV stream, and terminals cannot be mapped more than once. Because of this, SEL SV relays that use Port 5 SV configuration can subscribe to as many as four SV streams from one or more merging units. When configured via Architect, which allows the selection of individual phases from each SV stream, SEL SV relays can subscribe to as many as seven SV streams.

Once SV subscriptions are configured and are being received, the SV subscriber relay provides a suite of protection functionality. Please refer to the specific product instruction manual for a list of available protection functions.

Note that IEC 61850-9-2LE only covers the publication and subscription of remote analog data. To communicate digital input and output data or controls, IEC 61850 GOOSE must be configured and optimized on either the process bus or the station bus.

SV Subscriber Configuration

Architect provides support for the configuration of the SEL SV subscriber via a GUI. This interface provides the most flexible configuration of SV publications, including the creation of customized SV datasets. This mechanism is very similar to the configuration of GOOSE publications. For more detailed information, see *IEC 61850 Configuration on page 17.22*.

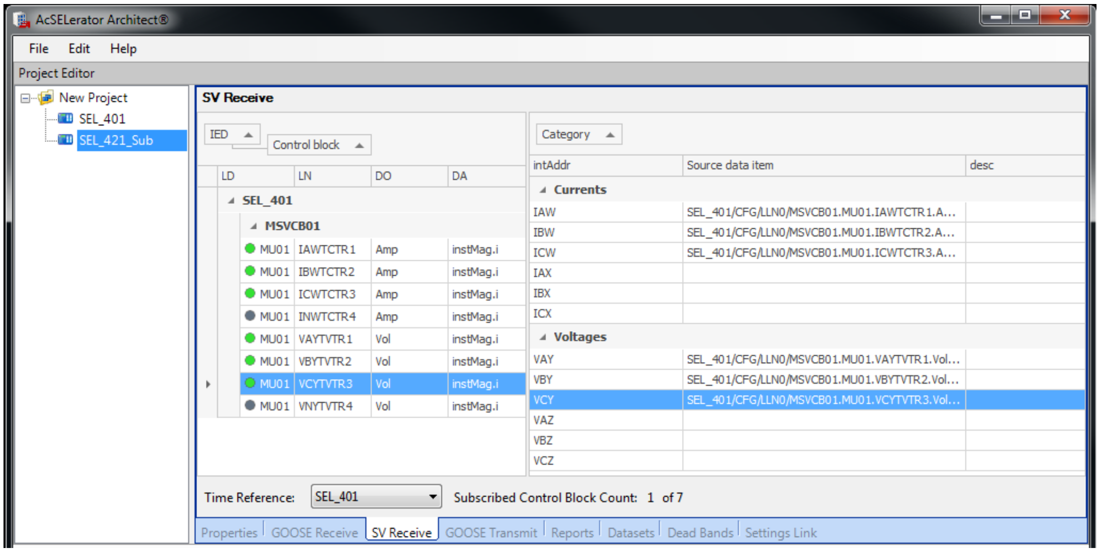


Figure 19.11 Example Architect SV Subscription Configuration

When configuring the SV subscriber, SV subscriptions are accomplished in the same manner as GOOSE subscriptions. Simply drag a published current into an appropriate current slot, or a published voltage into a voltage slot in the SV subscriber **SV Receive** tab. Note that even though a publisher may have a neutral current or voltage value in its publication, the SEL subscriber does not have a neutral current or voltage slot to map it into. Finally, configure the time reference of the subscriber (which selects the device whose smpSynch value all other subscribed messages must match) by selecting the device name from the drop-down menu labeled **Time Reference**. See *Subscription Reference Stream on page 17.19* for more information about the reference stream.

SV subscriptions may also be configured via Port 5 settings through QuickSet or an ASCII terminal window. Port 5 settings can be used to quickly configure SV subscriptions that do not require much customization. All phases (A, B, C) of a current or voltage terminal must be mapped to an SV subscription. Please note that regardless of the configuration method, you cannot map a current or voltage phase value into more than one subscriber slot.

SV Subscriber Startup

When initially turned on, the SV subscriber **ENABLED** LED illuminates as soon as protection functionality is enabled, which can take as long as 17 seconds but will typically be within 10 seconds. Once the SV subscriber has begun accepting SV streams, SV processing can be temporarily disabled for the following conditions:

- Port 5 settings are modified
- A new CID file configuration is enabled
- Power is cycled

SV subscriptions are disabled if the SV subscriber is disabled (EN Relay Word bit = False), the Port 5 setting EPORT is set to “N”, or the processor fails. SV subscriptions do not resume unless the disabling condition is addressed. When SV subscriptions are disabled, so is the primary means of data acquisition for the relay. Take care to recognize when such a condition occurs, generate appropriate warnings or alarms, and resolve any issues.

SV Subscriber Diagnostics and Testing

Once SV subscriptions are configured and enabled, new commands are available to verify configuration, diagnose and troubleshoot SV communications, and aid in commissioning and testing: **COM SV** and **TEST SV**.

The **COM SV** command displays information about the SV streams to which the unit has been configured to subscribe. The data includes the SV destination MAC address, Application ID, message name, dataset name, VLAN ID, and priority if the information is available. If information is not available, the field remains blank. The **COM SV** command also provides statistics for individual subscribed SV streams and any error conditions that are currently present or were present during the previous 30 seconds. For more information on the **COM SV** command, see *Section 9: ASCII Command Reference* in the product-specific manual.

As the SV subscriber receives subscribed SV messages, it places them into a buffer that has a capacity of about 3 ms for each subscribed stream. The Port 5 CH_DLY SV channel setting determines how long the subscriber waits to receive data from all subscribed streams and will use the channel data from its buffer that corresponds to this instant in its past. If a subscribed message arrives so late (> 3 ms) that the SV subscriber does not have a place for it in its buffer, or it never arrives, the message is considered lost. If SV messages are delayed by more than CH_DLY but arrive in time to be received into the buffer of the subscriber, these messages are not considered lost, but their data are not used. The **COM SV** command uses the warning **CH_DLY EXCEEDED** to indicate this condition. If one to three consecutive messages are delayed or lost, the SEL SV subscriber interpolates the missing data. The **COM SV** command uses the INTERPOLATED warning code to indicate when it has had to interpolate for missing or lost data. If more than three consecutive SV packets are delayed or missing, the **COM SV** command uses the error message **SV STREAM LOST** to indicate any subscriptions in this condition.

If any subscribed SV streams are lost, the SV subscriber can still be able to provide some subset of metering and protection functionality, depending on what data are in the missing stream(s). For example, consider an SV subscriber that has two active subscriptions with the first one providing one set of terminal currents and voltages, and the other providing another set of currents. If the second subscription is lost, the SV subscriber can still provide metering data and some degree of overcurrent and LOP protection with the data available from the first stream. Refer to the product-specific instruction manual for available protection features.

The **TEST SV** command places the SV subscriber into TEST SV mode. In this mode, it accepts any subscribed messages with or without the test bit of the quality attribute set. The data that the SV subscriber receives while in TEST SV mode are processed as valid data, so take care to ensure that outputs are blocked to prevent any undesired operations. The **MET** command reflects the received data as actual data, even with the test bit asserted. The **COM SV** command indicates whether the SV subscriber is in TEST SV mode by displaying the information at the top of the response. Refer to the TEST SV command description in *Section 9: ASCII Command Reference* of the product-specific manual for more information.

The health of the incoming SV subscription data channels can be monitored with the SV subscription Relay Word bits SVSALM, SVS*mm*OK, and SVCC, and the SVND*mm* (where *mm* is the SV stream number 01–07) analog quantities. The SVS*mm*OK Relay Word bits are asserted when subscription *mm* is configured and data conforming with the 9-2LE guideline is being actively received from it. The SVCC (SV coupled clocks mode) Relay Word bit is asserted when the SV subscriber is synchronized with the same smpSynch value as the subscription reference stream. The SVND*mm* analog quantities indicate the measured channel delay of each subscription and are compared with the Port 5 CH_DLY setting to generate an alarm condition as described in the following.

The SVSALM Relay Word bit is a general purpose alarm that will assert for the following conditions:

- The SV subscriber has lost sync with the device providing its reference stream
- One or more subscribed SV streams network delays exceed the CH_DLY setting
- One or more subscribed SV streams are no longer being received (lost)
- One or more subscribed SV streams have a subscription status SVS*mm*OK bit that is not set.

The SV subscriber also provides analog channel status Relay Word bits, which are useful for supervising protection based on the state of SV communications for each current and voltage channel. These bits include *nnn*OK and *nnn*BK bits, where *nnn* is the product-specific current or voltage channel that can potentially be mapped to data from an incoming SV stream, for example, IAW, IBW, ICW, VAY, VBY, VCY, etc. in the SEL-421 SV Subscriber Relay. The *nnn*OK bits asserts for all data channels that are mapped to a subscribed SV stream and have data actively being received from it. The *nnn*BK bits are the inverse of the *nnn*OK bits.

See *Section 5: Protection Functions* of the product-specific manual for more information on SV status logic.

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APPENDIX A

Manual Versions

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.1 lists the firmware versions, revision descriptions, and corresponding instruction manual date codes.

Table A.1 Instruction Manual Revision History (Sheet 1 of 3)

Date Code	Summary of Revisions
20171006	Section 16 ➤ Updated *Table 16.8: Relay DNP3 Object List*. Section 17 ➤ Updated for IEC 61850 configuration. Appendix B ➤ Updated to help preserve IEC 61850 configuration during a firmware upgrade.
20170714	Section 2 ➤ Updated *Table 2.2: QuickSet HMI Tree View Functions*. ➤ Updated *Figure 2.20: Retrieving an Event History* and *Figure 2.22: Sample Event Oscillogram*. Section 9 ➤ Updated *Figure 9.1: Input Processing* to include Sampled Values data acquisition. ➤ Added *Figure 9.2: Input Processing of SEL-400 Series Relays With SV Remote Data Acquisition*. ➤ Updated *Generating Raw Data Oscillograms*, and added *Figure 9.7: An Overcurrent Application Via Remote Data Acquisition* through *Figure 9.9: Filtered Event Reports From SEL-401 and SEL-421*. Section 10 ➤ Added Sequence of Events Recorder to *Table 10.6: Troubleshooting Procedures*. ➤ Added *Table 10.7: Troubleshooting for Relay Self-Test Warnings and Failures.* Section 11 ➤ Added *PTP Over PRP Networks*. ➤ Added *Global Time Source vs Local Time Source*. Section 12 ➤ Added a footnote to *Table 12.5: Protocol Selection* for the EPORT setting. ➤ Added *Table 12.14: SV Receiver Configuration* and *Table 12.15: SV Transmitter Configuration*. ➤ Added a footnote to *Table 12.23: PTP Settings* for setting PTPPRO. ➤ Removed note that PTP is not supported in PRP mode. Section 14 ➤ Added references to IEC Sampled Values. ➤ Added a note that the CFG NFREQ command is not available in IEC Sampled Values relays. ➤ Updated *Figure 14.2: Sample ETH Command Response*. ➤ Updated *Figure 14.11: Sample VER Command Response*. Section 15 ➤ Updated *Figure 15.6: Using Internal Ethernet Switch to Add Networked Devices*. Section 16 ➤ Updated *Table 16.8: Relay DNP Object List*.

Table A.1 Instruction Manual Revision History (Sheet 2 of 3)

Date Code	Summary of Revisions
	Section 17 ➤ Added text for IEC Sampled Values. ➤ Updated *Table 17.3: Relay Logical Devices*. ➤ Added *Sampled Values*. ➤ Added *Simulation Mode*. ➤ Added *Example 17.1: SV Application*. ➤ Updated *Table 17.27: Basic Conformance Statement.* ➤ Updated *Table 17.28: ACSI Models Conformance Statement*. ➤ Updated *Table 17.29: ACSI Service Conformance Statement*. Section 18 ➤ Added a note regarding Sampled Values-subscribing relays. Section 19 ➤ Added *IEC 61850-9-2 Sampled Values (SV)*. Appendix C ➤ Updated text for LNKFAIL and LNKFL2. Glossary ➤ Added terms for IEC Sampled Values, Parallel Redundancy Protocol, and real-time control.
20170428	Section 19 ➤ Updated *Figure 19.4: SEL-2243 Power Coupler.*
20170326	Section 15 ➤ Updated Ethernet Communications for information on MMS inactivity. Appendix B ➤ Updated *TiDL Firmware Upgrade*.
20161215	Preface ➤ Updated to describe the new section, *Section19: Remote Data Acquisition*. Section 1 ➤ Updated to introduce TiDL technology. Section 3 ➤ Added information on TiDL system input and output handling. Section 7 ➤ Added information about leading and lagging power factor Relay Word bits. Section 9 ➤ Described the impact of the ERDIG setting on event report handling. ➤ Added a note about SER storage limitations. Section 10 ➤ Added information on TiDL system commissioning. ➤ Described additional diagnostics. ➤ Described module replacement in Axion nodes for the TiDL system. Section 11 ➤ Improved the description of the TSOK Relay Word bit. Section 12 ➤ Added the ERDIG report setting. Section 14 ➤ Added **CFG CTNOM** and **CFG NFREQ** commands. ➤ Clarified the **TEST DB2 A** operation. Section 15 ➤ Updated SNTP accuracy.

Table A.1 Instruction Manual Revision History (Sheet 3 of 3)

Date Code	Summary of Revisions
	Section 18 ➤ Updated typographical information in *Figure 18.5: UDP_S Connection*. Section 19 ➤ Added as a new section. Appendix B ➤ Updated to describe firmware upgrades to the TiDL system. Appendix C ➤ Updated to describe cybersecurity aspects of EtherCAT ports. Glossary ➤ Added terms related to TiDL systems.
20160518	➤ Initial version.

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APPENDIX B

Firmware Upgrade Instructions

These instructions guide you through the process of upgrading the firmware in the device. Note that these instructions are only intended for upgrading firmware from an older revision to a newer revision. Downgrading firmware—going from a newer to an older revision—should not be attempted. It will result in the loss of relay calibration, MAC addresses, and other device configuration information. Please contact SEL if you need to downgrade the firmware in a relay.

The firmware upgrade will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device firmware identification (FID) string.

Existing firmware:

FID=SEL-411L-**R100**-V0-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-**R100**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-411L-**R101**-V0-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-**R101**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID string.

Existing firmware:

FID=SEL-411L-R100-**V0**-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-R100-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-411L-R100-**V1**-Z001001-Dxxxxxxxx, or

FID=SEL-411L-1-R100-**V1**-Z001001-Dxxxxxxxx

Required Equipment

You will need the following items before beginning the firmware upgrade process:

- Personal computer (PC)
- Terminal emulation software that supports Xmodem/CRC protocol
- SEL-C234A cable, SEL-C662 USB to EIA-232, or equivalent
- Disc containing the firmware upgrade file(s)
  - .z19 or .s19 firmware upgrade file (.z19 requires SELBOOT R205 or newer)
  - SELBOOT firmware upgrade file (if necessary; based on the existing SELBOOT revision of the relay)
  - EtherCAT communications board firmware file (SEL-ECB-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx.zds)
  - Remote SEL Axion firmware file (SEL-2245-42-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx.zds)
- Relay Firmware Upgrade Instructions
- SD Card with Time-Domain Link (TiDL) interface firmware if upgrading a relay that uses remote data acquisition through TiDL technology.

Optional Equipment

These items help you manage relay settings and understand procedures in the relay upgrade process:

- ACSELERATOR QuickSet SEL-5030 Software (contains a firmware upload tool that helps to automate this process)
- ACSELERATOR Architect SEL-5032 Software (manages IEC 61850 GOOSE, MMS, and SV CID files)
- Appropriate SEL-400 series relay manual

Important Considerations

If upgrading an SEL-451-5, SEL-421-4, or SEL-421-5 relay from firmware revision R309 or earlier to firmware revision R312 and later, make sure you save all relay settings (including IEC 61850 CID configurations, if applicable) prior to the firmware upgrade, as indicated in *Save Settings and Other Data on page B.4* and *Save Settings and Other Data on page B.9*. Upon completion of the upgrade process, the relay settings will reset to default values and the IEC 61850 CID file may be removed. These files will need to be reloaded.

If you are upgrading an SEL-451-5, SEL-421-4, or SEL-421-5 relay from firmware revision R309 or earlier to firmware revision R311, you must first upgrade the relay firmware to R310 before upgrading to R311. This requirement is only needed if upgrading specifically to R311. Failure to do so will result in the reset of all relay MAC address settings back to factory defaults.

In some unusual cases, such as loss of relay power during the firmware file transfer process, it is possible for data, including relay settings and the IEC 61850 CID file to be lost. Before beginning the firmware upgrade process, save relay settings and, if applicable, the IEC 68150 CID file that has been configured for the relay.

Upgrade Procedure

The upgrade kit you received contains the firmware needed to upgrade the SEL-400 series relay. The kit may also contain firmware needed to upgrade the SELBOOT program. See *Table B.1* to identify which firmware files you received in the upgrade kit.

NOTE: The .z19 files are compressed versions of the .s19 files. These will load into the relay much faster than the .s19 files, but you must have relay SELBOOT version R205 or newer to use these files.

Table B.1 Firmware Upgrade Files

Product	File Name[a]	File Type
SEL-400 series relays SELBOOT	S*nnn*4*xx*.s19	SEL-400 series SELBOOT firmware
SEL-400 series relays	R*nnn*4*xx*.s19 or R*nnn*4*xx*.z19	SEL-400 series relay firmware
SEL-400 series relays following the start of point releases	R*nnn*-V*y*4*xx*.s19 or R*nnn*-V*y*4*xx*.z19	SEL-400 series relay firmware

[a] *nnn* in the file name will always represent the device firmware revision number.
y represents that point release version number.
4*xx* represents the product name.

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the PC to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

The firmware upgrade can be performed in one of two ways:

➤ Method One: Use the Firmware Loader provided within QuickSet. The Firmware Loader automates the firmware upgrade process and is the preferred method. The Firmware Loader can be used to upgrade only relay firmware (R*nnn*4*xx* files or R*nnn*-V*y*-4*xx*). If upgrading SELBOOT (S*nnn*4*xx*) firmware is required, use Method Two.
➤ Method Two: Connect to the relay in a terminal session and upgrade the firmware using the steps documented in *Method Two: Using a Terminal Emulator on page B.8*.

Method One: Using QuickSet Firmware Loader

To use the QuickSet Firmware Loader, you must have QuickSet. See *Section 2: PC Software* for instructions on how to obtain and install the software. Once the software is installed, perform the firmware upgrade as follows.

A Obtain Firmware File

NOTE: The Firmware Loader can be used to load only relay firmware (R*nnn*4*xx* or R*nnn*-V*y*4*xx*). If you need to upgrade relay SELBOOT firmware, use Method Two.

The firmware file is usually provided on a CD-ROM. Locate the firmware file on the disc. The file name is of the form R*nnn*4*xx* or *Rnnn*-V*y*4*xx*, where R*nnn* is the firmware revision number, V*y* indicates the point release number, 4*xx* indicates the relay type, and .s19 or .z19 is the firmware file extension. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Remove Relay From Service

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

Step 2. Apply power to the relay.

Step 3. Connect a communications cable and determine the port speed.

If using the EIA-232 front port to upgrade firmware, determine the port speed as follows:

a. From the relay front panel, press the **ENT** pushbutton.

b. Use the arrow pushbuttons to navigate to `SET/SHOW`.

c. Press the **ENT** pushbutton.

d. Use the arrow pushbuttons to navigate to `PORT`.

e. Press the **ENT** pushbutton.

f. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port, Port F).

g. Press the **ENT** pushbutton.

h. Use the arrow pushbuttons to navigate to **Communication Settings**.

i. Press the **ENT** pushbutton to view the selected port communications settings. Write down the value for each setting.

j. Once the port settings have been recorded, press the **ESC** pushbutton four times to return to the `MAIN MENU`.

k. Connect an SEL-C234A EIA-232 serial cable, SEL-C662 USB to EIA-232 converter, or equivalent communications cable to the relay serial port and to the PC.

C Establish Communications With the Relay

NOTE: Once serial port communication is established, it is recommended to set the SELBOOT Max Baud setting to the highest possible port speed available (typically 115200 bps). This will reduce the time needed to read settings and events from the relay.

Use the **Communications > Parameters** menu of QuickSet to establish a connection using the communications settings determined in *Step 3* under *B Remove Relay From Service on page B.3*. See *Section 2: PC Software* for additional information.

D Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Step 1. For SEL-400 series relays with optional IEC 61850 protocol configured, follow the steps in section *Verify IEC 61850 Operation (Optional) on page B.13* to save the CID file and send it back to the relay after the firmware upgrade.

Step 2. Select **Tools > Firmware Loader** and follow the onscreen prompts.

Step 3. In the Step 1 of 4 window of the Firmware Loader (as shown in *Figure B.1*), click the ellipsis button and browse to the location of the firmware file. Select the file and click **Open**.

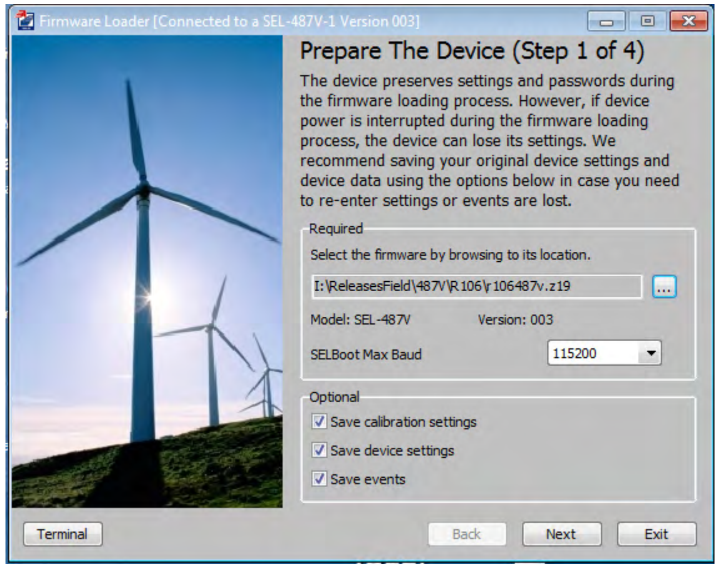

Figure B.1 Prepare the Device (Step 1 of 4)

Step 4. Select the **Save calibration settings** check box in the Step 1 of 4 window of the Firmware Loader. These factory settings are required for proper operation of the relay and must be reentered in the unlikely event they are erased during the firmware upgrade process. The Firmware Loader saves the settings in a text file on the PC.

Step 5. Select the **Save device settings** check box if you do not have a copy of the relay settings. It is possible for relay settings to be lost during the upgrade process.

Step 6. Select the **Save events** check box if there are any event reports that have not been previously saved. The event history is cleared during the upgrade process.

Step 7. Click **Next**.

The Firmware Loader reads the calibration settings and saves them in a text file on the PC. Make note of the file name and the location.

If **Save device settings** was selected, the Firmware Loader reads all of the settings from the relay. The software may ask if you want to merge the settings read from the relay with existing design templates on the PC. Click **No, do not merge settings with Design Template**. The Firmware Loader will suggest a name for the settings, but the suggested name can be modified as desired.

If **Save events** was selected, the **Event History** window will open to allow the events to be saved. See *Section 2: PC Software* for more information.

Step 8. If you use the Breaker Wear Monitor, click the **Terminal** button in the lower left portion of the Firmware Loader to open the terminal window. From the Access Level 1 prompt, issue the **BRE** command and record the internal and external trip counters, internal and external trip currents for each phase, and breaker wear percentages for each phase.

Step 9. Enable Terminal Logging capture (see *Section 2: PC Software*) and issue the following commands to save stored data. It is possible for these data to be lost during the firmware upgrade process.

a. **MET E**—accumulated energy metering

b. **MET D**—demand and peak demand

c. **MET M**—maximum/minimum metering

d. **COMM A** and **COMM B**—MIRRORED BITS communications logs

e. **PROFILE**—Load Profile

f. **SER**—Sequential Events Records

E Start SELBOOT

In the Step 2 of 4 window of the Firmware Loader, click **Next** to disable the relay and enter SELBOOT (see *Figure B.2*).

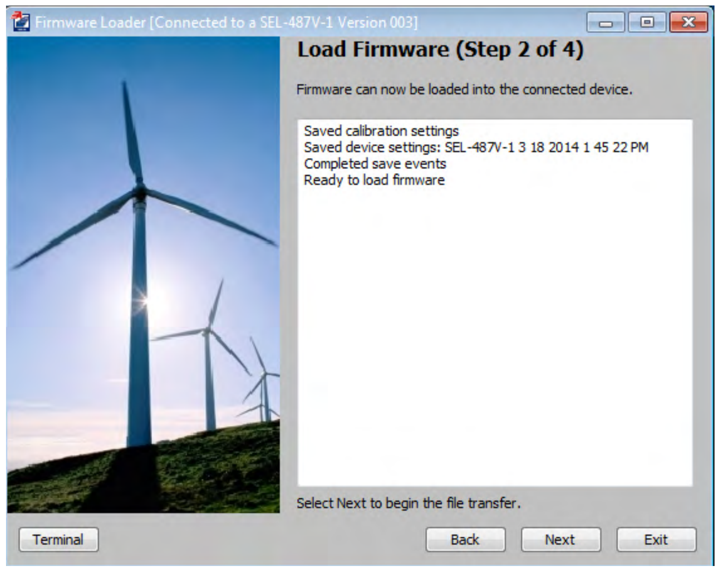

Figure B.2 Load Firmware (Step 2 of 4)

F Maximize Port Data Rate

This step is performed automatically by the software.

G Upload New Relay Firmware

This step is performed automatically by the software. The software will erase the existing firmware and start the file transfer to upload the new firmware. Upload progress will be shown in the **Transfer Status** window. The entire firmware upload process can take longer than 10 minutes to complete.

When the firmware upload is complete, the relay will restart. The Firmware Loader automatically re-establishes communications and issues an **STA** command to the relay.

In cases where the relay does not restart within two minutes of the firmware upload completion (as indicated by the PC application), and no error messages appear on the relay HMI, turn the relay off and back on again. The firmware loader application should then resume. Answer **Yes** if the Firmware Loader prompts you to continue.

H Verify Relay Self-Tests

The Step 3 of 4 window of the Firmware Loader will indicate that it is checking the device status and when the check is complete (see *Figure B.3*).

The software will notify you if any problems are detected. You can view the relay status by opening the terminal using the Terminal button in the lower left portion of the Firmware Loader. If status failures are shown, open the terminal and see *Troubleshooting on page B.17*.

Click **Next** to go to the completion step.

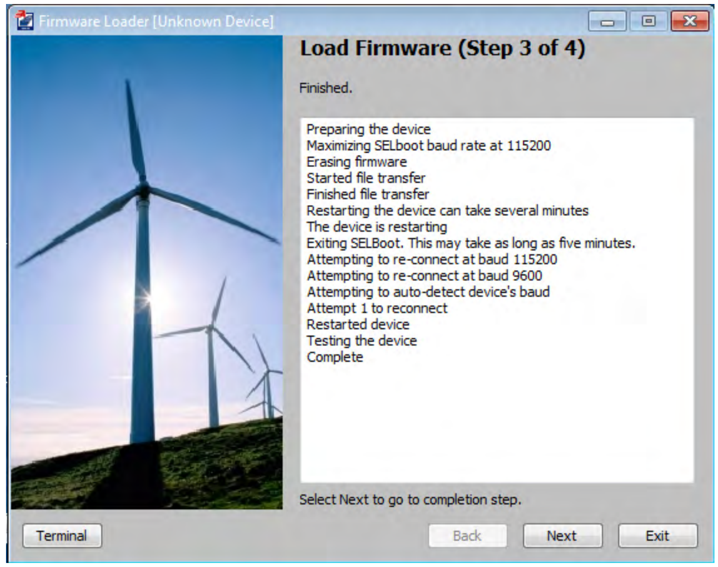

Figure B.3 Load Firmware (Step 3 of 4)

Verify Relay Settings

If there are no failures, the relay will enable. In the Step 4 of 4 window (see *Figure B.4*), the Firmware Loader will give you the option to compare the device settings. If any differences are found, the software will provide the opportunity to restore the settings.

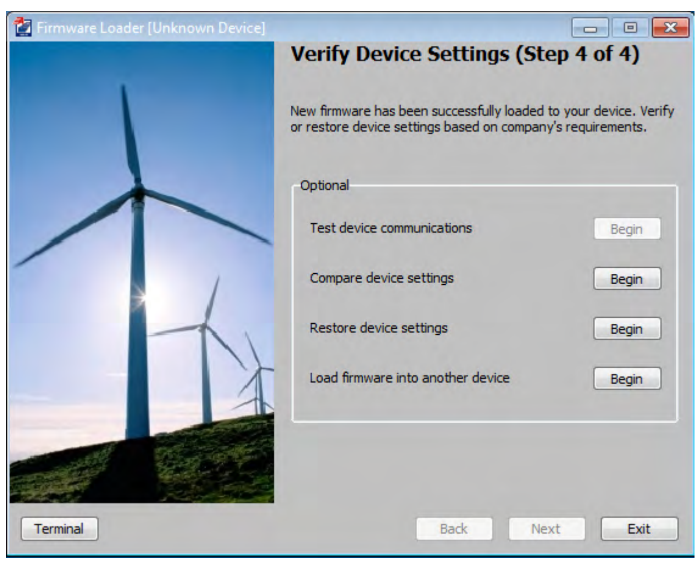

Figure B.4 Verify Device Settings (Step 4 of 4)

J Return Relay to Service

Step 1. Open the terminal window using the **Terminal** button in the lower left portion of the Firmware Loader.

Step 2. Use the **ACC** command with the associated password to enter Access Level 1.

Step 3. Issue the **ID** command and compare the firmware revision (R*nnn* or R*nnn*-V*y*) displayed in the FID string against the number from the firmware envelope label. If the numbers match, proceed to *Step 5*.

Step 4. For a mismatch between a displayed FID and the firmware envelope label, re-attempt the upgrade or contact SEL for assistance.

Step 5. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data to see if the relay retained breaker wear data through the upgrade procedure. If the relay did not retain these data, use the **BRE W** command to reload the percent contact wear values recorded in *D Save Settings and Other Data on page B.4*.

Step 6. Apply current and voltage signals to the relay.

Step 7. Type **MET <Enter>** or use the QuickSet HMI to verify that the current and voltage signals are correct.

Step 8. Use the **TRI** and **EVE/CEV** commands or **Tools > Events > Get Events** menu in QuickSet to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report. If these values do not match, check the relay settings and wiring.

Step 9. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay. This step re-establishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

Step 10. Follow your company procedures for returning a relay to service.

Method Two: Using a Terminal Emulator

These instructions assume you have a working knowledge of your PC terminal emulation software. In particular, you must be able to modify the serial communications parameters (data speed, data bits, parity, and similar parameters), disable any hardware or software flow control in the computer terminal emulation software, select a transfer protocol (1K Xmodem, for example), and transfer files (send and receive binary files).

The programs (firmware) that run in the SEL-400 series relays reside in Flash memory. To load new firmware versions, follow these instructions. SEL-400 series relays have two programs that you may need to upgrade: the regular, or “executable” program and the SELBOOT program.

A Obtain Firmware File

The firmware file is usually provided on a CD-ROM. Locate the firmware file on the disc. The file name is of the form R*nnn*4*xx* or R*nnn*-*Vy*4*xx*, where R*nnn* is the firmware revision number, *Vy* indicates the point release number, 4*xx* indicates the relay type, and .s19 or .z19 is the firmware file extension. Copy the firmware file to an easily accessible location on the PC.

Firmware is designed to be used with specific relays. A list of relay serial numbers is provided as part of the firmware upgrade package. The firmware provided is for use with the listed relays only. Attempts to upgrade relays not listed might not be successful and can result in relay failure.

B Prepare the Relay

If the relay is in service, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

C Save Settings and Other Data

It is possible for data to be lost during the firmware upgrade process. Follow the steps in this section carefully to ensure that important data are saved.

Enter Access Level 2

NOTE: Once serial port communication is established, it is recommended to set the port SPEED setting to the highest possible port speed available (typically 57600 bps in Access Level 2). This will reduce the time needed to read settings and events from the relay.

Step 1. Using the communications terminal, at Access Level 0, type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**, and then type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

For more information, see *Making an EIA-232 Serial Port Connection on page 3.4*.

Backup Relay Settings

The relay preserves the settings and passwords during the firmware upgrade process. However, if relay power is interrupted during the firmware upgrade process, the relay can lose the settings. Make a copy of the original relay settings in case you need to reenter settings.

NOTE: In addition to all of the normal settings classes, log in to Access Level C and save the SET_CM.TXT file.

Use one of the following methods to backup relay settings.

- ➤ If you have not already saved copies of the relay settings, use QuickSet to read and save the relay settings.

  See *Create and Manage Relay Settings on page 2.9*.
- ➤ Alternatively, you can use the terminal to download all the relay settings.

  See the **FILE READ** command under *FILE on page 14.27*.

  For file retrieval procedures see *Reading Oscillograms, Event Reports, and SER on page 3.48*.
- ➤ If you have IEC 61850 configurations and you have not already saved copies of the CID file, use Architect to read and save the CID file. See *Verify IEC 61850 Operation (Optional) on page B.13* for details.

D Start SELBOOT

Step 1. Establish/confirm binary transfer terminal communication.

Use a terminal program that supports 1K Xmodem transfer protocol to communicate with the relay.

Step 2. Prepare to control the relay at Access Level 2. If the relay is not already at Access Level 2, use the procedure in *Enter Access Level 2 on page B.9*.

Step 3. Start the relay SELBOOT program.

a. Type **L_D <Enter>**.

The relay responds with the following message:

`Disable relay to send or receive firmware (Y/N)?`

b. Type **Y <Enter>**.

The relay responds with the following message:

`Are you sure (Y/N)?`

c. Type **Y <Enter>**.

The relay responds with the following message:

`Relay Disabled`

Step 4. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT R*yyy* firmware number (e.g., `SELBOOT R100`). R*yyy* is the SELBOOT revision number and is a different revision number from the relay firmware revision number. The LCD also displays the present relay firmware (e.g., `SEL-451-R102`), and `INITIALIZING`.

When finished loading the SELBOOT program, the relay responds to the terminal with the SELBOOT !> prompt; the LCD shows the SELBOOT and relay firmware revision numbers.

Step 5. Press **<Enter>** to confirm that the relay is in SELBOOT; you will see another SELBOOT !> prompt.

Establish a High-Speed Serial Connection

Step 1. At the SELBOOT prompt, type **BAU 115200 <Enter>** (see *Figure B.5*).

Step 2. Set your terminal program for a data speed of 115200 bps.

Step 3. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication at 115200 bps is successful.

E Upload New SELBOOT Firmware to the Relay

NOTE: Loading the incorrect SELBOOT firmware to the relay may cause the relay to malfunction, requiring factory repair.

NOTE: Do not cycle power to the relay during the SELBOOT firmware upgrade process. Doing so may cause the relay to malfunction, requiring factory repair.

Upgrading SELBOOT firmware in SEL-400 series relays is typically not required as part of a normal relay firmware upgrade process. However, core functions of the relay are occasionally enhanced, and the SELBOOT firmware must be upgraded to enable the enhanced functions. If a SELBOOT upgrade for the relay is not indicated in your upgrade kit, skip this step and continue on to *G Upload New Relay Firmware on page B.6*. See *Table B.1* for file names.

To begin the relay SELBOOT upgrade, start at the SELBOOT !> prompt.

Step 1. Type **REC BOOT** command at the SELBOOT prompt, and answer **Y** when prompted to erase the existing SELBOOT firmware.

```
!>REC BOOT <Enter>
Caution! -  This command erases the SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N)
```

Step 2. The relay will prompt you to begin the file transfer. Press any key to begin the file transfer to the relay.

Step 3. Using an Xmodem file transfer protocol, point the sending software tool to the relay SELBOOT file (S*nnn*4xx.s19) that is to be uploaded to the relay.

Upon successful negotiation of the new SELBOOT firmware file, the old SELBOOT software will be erased, and the new SELBOOT firmware will be written to the Flash memory of the relay. SELBOOT will then automatically restart using the new SELBOOT firmware.

```
Erasing old SELboot

Writing new SELboot to flash

Press any key to begin transfer, then start transfer at the PCC
Restarting SELboot
```

Step 4. Once the relay has restarted in SELBOOT, the SELBOOT !> prompt will appear in the terminal window. Remain in SELBOOT and continue to *G Upload New Relay Firmware on page B.6* of this procedure.

F Upload New Relay Firmware

If you are only upgrading SELboot, you can skip this step and continue to *G Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT on page B.12*.

Step 1. From the SELBOOT !> prompt, type **REC <Enter>**.

The relay responds with the prompt shown in *Figure B.5*. The end of the relay response is:

`Are you sure you want to erase the existing firmware? (Y/N)`

Step 2. Type **Y <Enter>**.

The relay responds, `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay responds, `Erase successful`, and prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>BAU 115200 <Enter>
!><Enter>


!>REC <Enter>
Caution! - This command erases the device firmware.
If you erase the firmware, new firmware must be loaded into the device
before it can be put back into service.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing


Erase successful
Press any key to begin transfer, then start transfer at the PCCC <Enter>
```

Figure B.5 Transferring New Firmware

Step 3. Press **<Enter>** to begin uploading the new firmware.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19 or .z19).

NOTE: The relay displays one or more "C" characters while waiting for your PC terminal emulation program to send the new firmware. If you do not start the transfer quickly (within about 18 seconds), the relay times out and responds `Remote system is not responding`. If this happens, begin again at *F Upload New Relay Firmware on page B.11*.

Step 6. Begin the file transfer.

The typical transfer time at 115200 bps with 1K Xmodem is 10 to 20 minutes. The LCD screen shows `SELBOOT Ryyy LOADING CODE` while the relay loads the new firmware.

Step 7. Wait for firmware load completion.

If the relay responds with the message `Transfer failed — Model mismatch`, please refer to *Troubleshooting on page B.17*.

When finished loading the new firmware, the relay responds, `Transfer completed successfully` and displays the SELBOOT !> prompt. The LCD screen displays `SELBOOT Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, 4*xx* is the particular model of the SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-421-R105.

G Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT

Step 1. Type **<Enter>** to confirm relay communication.

The terminal displays the SELBOOT !> prompt.

Step 2. Type **BAU 9600 <Enter>** to reduce the data speed to your nominal serial communications speed (9600 bps in this example).

Step 3. Set your terminal emulation program to match the nominal data speed.

Step 4. Type **<Enter>** to confirm that you have reestablished communication with the relay.

The relay responds with the SELBOOT !> prompt.

Step 5. Type **EXI <Enter>** to exit the SELBOOT program.

After a slight delay, the relay responds with the following message:

```
CAUTION: Initial relay restart. DO NOT cycle power during
this time. Please wait 3 minutes for restart completion.
```

H Verify Relay Self-Tests

Step 1. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on your terminal screen.

Step 2. Remove input power to the relay.

a. Allow at least 10 seconds during the removal of relay power to ensure that the power supply has shut down.

b. Reapply input power to the relay.

c. Wait 10 minutes after startup of the relay to allow the relay to detect any hardware changes made during the upgrade process.

Step 3. Enter Access Level 1 using the **ACC** command and Access Level 1 password.

Step 4. Enter Access Level 2 using the **2AC** command and Access Level 2 password.

Step 5. Type **STA <Enter>** to check the relay status and accept new hardware changes if needed.

Step 6. Verify that all relay self-test parameters are within tolerance. (The relay compares the settings before and after the upgrade process and displays an upgrade warning if settings are dissimilar. You can find details in the upgrade report file.)

Step 7. View the front-panel **ENABLED** LED and confirm that the LED is illuminated.

Unless there is a serious problem, the **ENABLED** LED illuminates without any intervention, and the relay retains all settings.

If the relay does not enable within five minutes of the `Initial relay restart` message, contact your Technical Service Center or the SEL factory for assistance (see *Technical Support on page B.18*).

I Verify Relay Settings

Step 1. Prepare to control the relay at Access Level 2; use the procedure in *Enter Access Level 2 on page B.9*.

Step 2. Type **VER <Enter>** to confirm the new firmware.

Step 3. Match the firmware revision number with the FID number on the screen.

Step 4. Use one of the following methods to review your settings.

- ➢ Use the QuickSet **Read** menu.

  If the settings do not match the settings that you recorded in *Backup Relay Settings on page B.9*, use QuickSet to restore relay settings.

- ➢ Type **SHOW <Enter>**.

  You can reissue the settings with the **SET** commands (see *Section 9: ASCII Command Reference* of the product-specific instruction manual for information on the **SHOW** and **SET** commands).

Step 5. Type **STA <Enter>** to check relay status.

Step 6. Verify that all relay self-test parameters are within tolerance.

J Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Type **MET <Enter>** to view power system metering.

Step 3. Verify that the current and voltage signals are correct.

Step 4. Type **TRI <Enter>** and then type **EVE <Enter>** to view the event report for the event just triggered.

Step 5. Verify that the current and voltage signals are correct in the event report.

Step 6. Autoconfigure the communications processor port if an SEL communications processor is connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the SEL-400 series relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

Verify IEC 61850 Operation (Optional)

SEL-400 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or restore the relay CID file after a firmware upgrade in which the CID file is removed. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol because it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational and if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the firmware upgrade. If the IEC 61850 protocol was not configured prior to the upgrade, skip to *J Return Relay to Service on page B.8*. Refer to the *Section 17: IEC 61850 Communication* for help with IEC 61850 configuration.

Step 1. Issue the **STA**, **ID**, and **GOO** commands.

Step 2. Verify that there are no error messages regarding IEC 61850 or CID file parsing.

If the responses to the **STA**, **ID**, or **GOO** commands contain IEC 61850 or CID error messages, continue with the following steps to re-enable the IEC 61850 protocol. Otherwise, skip to *J Return Relay to Service on page B.8*.

If the IEC 61850 protocol has been disabled because of an upgrade-induced CID file incompatibility, you can use Architect to convert the existing CID file and make it compatible again.

a. Install the Architect upgrade that supports your required CID file version.

b. Run Architect, and open the project that contains the existing CID file for the relay. Use Architect to download the CID from the relay, and select **File > Download CID** in the menu bar to save the CID file.

c. If using embedded settings, create an updated .rdb file with the settings read in *I Verify Relay Settings on page B.7*. Update the reference in the **Settings Link** tab and save the new CID file.

d. In the **Project Editor** in Architect, select and right-click the CID file. Click **Send CID** to download the CID file to the relay. Download the CID file to the relay.

Upon connecting to the relay, Architect will detect the upgraded Ethernet port firmware and prompt you before converting the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to re-enable the IEC 61850 protocol.

Step 3. In the Telnet session, issue the **STA**, **ID**, and **GOO** commands.

Step 4. Verify that no IEC 61850 error messages are in the **STA** or **ID** command responses.

Step 5. Verify the GOOSE transmitted and received messages are as expected.

Relays being upgraded from firmware that did not support a local-time UTC offset setting (UTCOFF) to firmware that does support the UTCOFF setting may show incorrect time stamps in Demand Metering and Breaker Monitor report data that was recorded by the relay prior to the firmware upgrade.

The time stamps shown for the Demand Metering and Breaker Monitor data recorded prior to the firmware upgrade will show UTC time plus an eight-hour local time offset, along with any applicable daylight-saving time adjustment.

This only affects time stamps recorded and stored by the relay prior to the firmware upgrade. All time stamps in Demand Metering and Breaker Monitoring following the firmware upgrade will be UTC time with the local time offset setting (UTCOFF) and daylight-saving time applied.

No other reports (Event History, Event Summary, SER, etc.) are affected.

Time-Domain Link (TiDL) Firmware Upgrade

The relay firmware will be upgraded through the standard upgrade process shown above. The TiDL interface board has its own firmware upgrade process, and the firmware for the TiDL interface board is stored on an SD card. This procedure will upgrade the TiDL interface board as well as the connected Axion modules. The firmware for the TiDL interface board can be determined by issuing the **VERSION** command in the relay (see *Figure B.6*).

```
=>>VER <ENTER>
FID=SEL-451-5-R317-V0-Z022012-D20160728
CID=FFE8
Part Number:  0451543RRC4X4H60X0XXX
Serial Number:  0000000000
SELboot:
    BFID= SLBT-4XX-R209-V0-Z001002-D20150130
    Checksum:  0000
ECB FID= R100
Mainboard:
    Code FLASH Size:   12 MB
    Data FLASH Size:   52 MB
    RAM Size:          64 MB
    EEPROM Size:      128 kB
Front Panel: not installed
Analog Inputs (provided by remote Axion Nodes):
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y:  Voltage:   67 Volts
    Z:  Voltage:   67 Volts
Interface Boards:
    Board 1:  not installed
    Remote I/O:  72 inputs  48 outputs
E4 Configuration: 4
Extended Relay Features:
    IEC 61850
```

Figure B.6 EtherCAT Cal Board (ECB) FID

To upgrade the firmware, perform the following steps.

Remove From Service

Step 1. Remove the unit from service.

Step 2. Turn the unit off.

Step 3. Remove the front panel.

Upgrade

Step 1. Copy the ECB and SEL-2245 firmware .zds files from the upgrade CD to an SD card.

Step 2. Install the SD card in the SD card slot indicated in *Figure B.7*.

Step 3. Turn the unit on.

Step 4. Wait for the upgrade to complete. (See the accompanying note.)

Step 5. The LEDs located next to the SD card slot will indicate the status of the upgrade.

⚠CAUTION
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

Note: During the upgrade of the TiDL interface board, the eight LEDs will toggle sequentially from left to right. During the remote module upgrade, the eight LEDs correspond to each port, **6A** is the left-most LED and **6H** is the right-most LED. As each module is updated, its corresponding LED blinks four times per second.

The upgrade process usually completes in less than 10 minutes. (If remote Axion modules are being upgraded and there is more than one Axion module connected to a port, the upgrade may take longer.)

The upgrade has successfully completed when all of the LEDs are either on or off (not blinking). The left four LEDs are on if the interface board upgrade succeeded; they are off if the upgrade was not necessary. The right four LEDs are on if the module upgrade succeeded; they are off if the upgrade was not necessary. If the interface board upgrade failed, the left four LEDs blink twice per second. If the module upgrade failed, the right four LEDs blink twice per second.

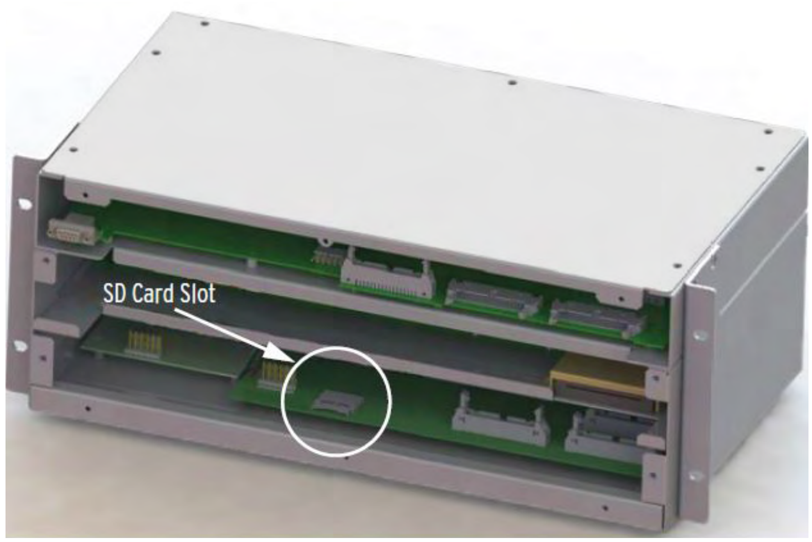

Figure B.7 TiDL Interface Board SD Card Slot

Recommission

Step 1. Turn the unit off.

Step 2. Remove the SD card (recommended but not required).

Step 3. Replace the front panel.

Step 4. Turn the unit on.

Step 5. Perform the TiDL commissioning process and return the unit to service.

Troubleshooting

Resolving Model Mismatch

When uploading a new firmware file to the relay, SELBOOT checks the relay model number (for example, 451, 421, 487) to ensure that the firmware being loaded into the relay is correct for the relay model. If the relay responds with `Transfer failed — Model mismatch` when a firmware download is attempted, it is because the relay model number does not match. This may be because the firmware file is not correct, or the relay model number stored in the relay memory was corrupted by an interruption of the file download.

To remedy this problem, first ensure you are sending the correct file to the relay. *Table B.1* shows the file names used for the firmware files. Verify that the model number in the firmware file matches the model of the relay being upgraded. After confirming that the file is correct, restart the relay into SELBOOT. Do this by turning the relay off and back on while holding down the front-panel left and right arrow navigation keys. The LCD will display `SELBOOT Ryyy` once the power cycle is complete. The data rate will reset to 9600 during this process. To increase the data rate to the highest speed possible on the port, type **BAU 115200 <Enter>** at the SELBOOT !> prompt (see *Figure B.5*). Switch the port communications parameters data rate to 115200 and verify the SELBOOT prompt in the terminal screen. At the SELBOOT prompt, issue a **REC OVERRIDE** command to the relay. This tells the relay to bypass the model number check at the start of the firmware upload process. Once the **REC OVERRIDE** command is issued, the firmware upload process can be continued following the procedures in *F Upload New Relay Firmware on page B.11*, starting with *Step 2 on page B.11*.

Resolving Status Failure Message Response to STA Command

If a status failure message is returned in response to the **STA** command, perform the following steps.

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Type **STA C <Enter>**. Answer **Y <Enter>** to the `Reboot the relay and clear status` prompt. The relay will respond with `Rebooting the relay`. Wait for about 30 seconds, then press **<Enter>** until you see the Access Level 0 = prompt.

Step 3. Use the **ACC** command with the associated password to enter Access Level 1.

Step 4. Type **STA <Enter>**.

If there are no fail messages and you are using Method One, click **Next** in Step 3 of 4 of the Firmware Loader and go to *I Verify Relay Settings on page B.13*.

If there are no fail messages and you are using Method Two, go to *I Verify Relay Settings on page B.13*.

If there are fail messages, continue with *Step 5*.

NOTE: Step 6 will cause the loss of settings and other important data. Be sure to retain relay settings and other data downloaded from the relay at the start of the firmware upgrade process. Relay calibration level settings will not be lost.

Step 5. Use the **2AC** command with the associated password to enter Access Level 2.

Step 6. Type **R_S <Enter>** to restore factory default settings in the relay.

The relay asks whether to restore default settings. If the relay does not accept the **R_S** command, contact SEL for assistance.

Step 7. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the ENABLED LED illuminates. This LED is labeled either EN or ENABLED, depending on the relay model.

Step 8. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 9. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 10. Use the **CAL** command and type the corresponding password to enter the relay Calibration settings level.

Step 11. Type **SHO C <Enter>** to verify the relay calibration settings.

If using Method One and the settings do not match the settings contained in the text file you recorded in *C Save Settings and Other Data on page B.9*, contact SEL for assistance.

If using Method Two and the settings do not match the settings contained in the text file you recorded in *B Prepare the Relay on page B.9*, contact SEL for assistance.

Step 12. Use the **PAS *n*** (*n* = 0, 1, 2, B, P, A, O, C) command to set the relay passwords.

Step 13. Restore the relay settings:

a. If you have SEL-5010 Relay Assistant software or QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or QuickSet, restore the original settings by issuing the necessary **SET *n*** commands.

Step 14. If any failure status messages still appear on the relay display, see the Testing and Troubleshooting section in your relay instruction manual or contact SEL for assistance.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

APPENDIX C

Cybersecurity Features

The SEL-400 series relays have a number of security features to assist users with meeting their cybersecurity design requirements.

Ports and Services

Physical Ports

SEL-400 series relays include four serial ports and as many as four Ethernet ports. Each physical serial port and Ethernet port can be individually disabled using the EPORT setting. By default, all of the ports are enabled.

SEL recommends that unused communications ports be disabled.

SEL-400 series relays with a TiDL configuration also have eight EtherCAT ports. These are always enabled, but they have a very limited functionality, as described below.

IP Ports

When using Ethernet, there are a number of possible IP ports available within the relay. Many of these IP port numbers are configurable. All IP ports can be disabled and are disabled by default. *Table C.1* describes each of these.

Table C.1 IP Port Numbers

IP Port Default	Port Selection Setting	Network Protocol	Default Port State	Port Enable Setting	Purpose
21	--	TCP	Disabled	FTPSERV	FTP protocol access for file transfer of settings and reports
23	TPORT	TCP	Disabled	ETELNET	Telnet access for general engineering terminal access
80	HTTPPOR	TCP	Disabled	EHTTP	Web server access to read various relay information
102	--	TCP	Disabled	E61850	IEC 61850 MMS for SCADA functionality
123	SNTPPOR	UDP	Disabled	ESNTP	SNTP time synchronization
319/320	--	UDP	Disabled	EPTP	PTP time synchronization
4712/ 4713	PMOTCP1/ PMOUDP1	TCP/UDP	Disabled	PMOTS1	Synchrophasor data output, session 1
4712/ 4713	PMOTCP2/ PMOUDP2	TCP/UDP	Disabled	PMOTS2	Synchrophasor data output, session 2
20000	DNPPNUM	TCP/UDP	Disabled	EDNP	DNP3 for SCADA functionality

Note that IP traffic is only supported on station bus ports, so process bus ports have no open IP ports. See *Ethernet Communications on page 15.6* for more information on these settings.

Segregating Ethernet Ports

In most modes, the enabled Ethernet ports support both IP traffic and layer 2 protocols (i.e. IEC 61850 GOOSE). If NETMODE = ISOLATEIP, then one port only permits GOOSE traffic. This allows this port to be routed outside of a security perimeter while retaining the ability to perform basic monitoring and control. See *Using Redundant Ethernet Ports on page 15.10* for more information on this mode.

EtherCAT Ports

SEL-400 series relays with a TiDL configuration have eight EtherCAT ports. These communicate with remote Axion nodes. The ports are used exclusively for exchanging analog and digital data with Axions; they will not recognize any other types of communication.

Once the system is configured and commissioned, the relay will only communicate with recognized Axions. Any other traffic on these ports will be ignored. After commissioning, the loss of communications to any configured Axion or Axion module will cause the relay to disable.

Authentication and Authorization Controls

Local Accounts

SEL-400 series relays support eight levels of access, as described in the *Access Levels and Passwords on page 3.7*. Refer to this section to learn how each level is accessed and what the default passwords are. It is good security practice to change the default passwords of each access level and to use a unique password for each level.

Relays have the capability to limit the level of access on a port basis. The MAXACC setting may be used on each port to restrict these authorization levels. This permits you to operate under the principle of "least privilege," restricting ports to the levels needed for the functions performed on those ports.

Each relay supports strong passwords of as many as 12 characters including any printable character, allowing users to select complex passwords if they so choose. SEL recommends that passwords contain a minimum of eight characters containing at least one of each of the following: lowercase letter, uppercase letter, number, and special character.

Authentication Failures

When three successive login attempts fail as a result of an incorrect password entry, the relay locks out login attempts on that port for 30 seconds. It also pulses the BADPASS Relay Word bit.

Malware Protection Features

Firmware Hash Verification

SEL provides firmware hashes as an additional tool to verify the integrity of SEL firmware upgrade files. This helps ensure that the firmware received from the factory is complete and unaltered prior to sending the firmware to the SEL device. Verify that the firmware file in your possession is a known good SEL firmware release by comparing the calculated hash value of the firmware in your possession with the hash value provided at selinc.com/products/firmware/.

Operating System/Firmware

SEL-400 series relays are embedded devices that do not allow additional software to be installed. SEL-400 series relays include a self-test that continually checks running code against the known good baseline version of code in nonvolatile memory. This process is outlined in more detail in the document titled *The SEL Process for Mitigating Malware Risk to Embedded Devices* located at selinc.com/mitigating_malware/.

SEL-400 series relays run in an embedded environment for which there is no commercial anti-virus software available.

Software/Firmware Verification

SEL-400 series relays have the ability to install firmware updates in the field. Authenticity and integrity of firmware updates can be verified by using the Firmware Hash page at selinc.com/products/firmware/.

Logging Features

Internal Log Storage

The Sequential Event Recorder (SER) log is a useful tool for capturing a variety of relay events. In addition to capturing state changes of user selected Relay Word bits, it captures all startups, settings changes, and group switches. See *Sequential Events Recorder (SER) on page 9.28* for more information about SER.

Alarm Reporting

The relay provides the following Relay Word bits that are useful for monitoring relay access:

- BADPASS—Pulses for one second if a user enters three successive bad passwords.
- ACCESS—Set while any user is logged into Access Level B or higher.
- ACCESSP—Pulses for one second whenever a user gains access to an Access Level of B or higher.
- PASSDIS—Set if the password disable jumper is installed.
- BRKENAB—Set if the breaker control enable jumper is installed.

- LINK5A, LINK5B, LINK5C, LINK5D—Set while the link is active on the respective Ethernet port. Loss-of-link can be an indication that an Ethernet cable has been disconnected.

NOTE: The relay can take as long as 6 ms to detect and report the loss of link on an active port (assert LNKFAIL or LNKFL2).

- LNKFAIL—Set if link is lost on any active station bus port. For relays with only two Ethernet ports, LNKFAIL asserts if link is lost on either port.
- LNKFL2—Set if link is lost on the active process bus port (Ethernet 87L ports or Sampled Values (SV) ports in devices with those capabilities). Once detected, the loss of the active port on the process bus causes immediate failover if the backup port has a good data link. If this is the case, failover may occur too quickly for the SER scanner to register the assertion and deassertion of LNKFL2.

These bits can be mapped for SCADA monitoring via DNP3, IEC 61850, or SEL Fast Message. They can also be added to the SER log for later analysis and assigned to output contacts for alarm purposes.

Physical Access Security

Physical security of cybersecurity assets is a common concern. Typically, relays are installed within a control enclosure that provides physical security. Other times, they are installed in boxes within the switch yard. The relay provides some tools that may be useful to help manage physical security, especially when the unit is installed in the switch yard.

You can monitor physical ingress by wiring a door sensor to one of the relay contact inputs. This input can then be mapped for SCADA monitoring or added to the SER log so that you can detect when physical access to the relay occurs.

It is also possible to wire an electronic latch to a relay contact output. You could then map this input for SCADA control.

Configuration Control Support

Product Version Information

The SEL-400 series relay firmware revision number (FID) provides the current firmware version/patch level. The FID can be obtained using the **STATUS** command.

Settings Version Information

All settings changes are logged to the SER log. Analysis of this log will let you determine if any unauthorized settings changes occurred.

The relay also stores a hash code for each settings class in the CFG.txt file. After configuring the device, you can read the CFG.txt file and store it for future reference. You can then periodically read this file from the relay and compare it to the stored reference. If any of the hash codes have changed, then you know that a settings class has been modified.

Backup and Restore

SEL-400 series relays support the export and import of settings and configuration using ACSELERATOR QuickSet SEL-5030 Software and ACSELERATOR Architect SEL-5032 Software. Settings can also be imported and exported as files using any file transfer mechanism.

Decommissioning

NOTE: Do not do this when sending in the relay for service at the factory. SEL needs to be able to see how the relay was configured in order to properly diagnose any problems.

It is often desirable to erase the settings from the relay when it is removed from service. You can completely erase all the configuration settings from the relay using the following procedure.

Step 1. Go to Access Level 2.

Step 2. Execute the **R_S** command to restore the device to factory-default settings.

Step 3. Allow the relay to restart.

Step 4. Go to Access Level 2.

Step 5. Execute the **R_S** command again to set the backup copy of settings to factory default.

Step 6. Allow the relay to restart.

Once this procedure is complete, all internal instances of all user settings and passwords will be erased.

Vulnerability Notification Process

Security Vulnerability Process

SEL provides security disclosure alerts to customers, and SEL instruction manuals document all releases. SEL security vulnerability disclosures are described in *The SEL Process for Disclosing Security Vulnerabilities* located at selinc.com.

Emailed Security Notification

You can sign up to receive email notifications when SEL releases security vulnerability notices and service bulletins at selinc.com/support/security-notifications/.

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Glossary

a Contact A breaker auxiliary contact (ANSI Standard Device Number 52A) that closes when the breaker is closed and opens when the breaker is open.

a Output A relay control output that closes when the output relay asserts.

b Contact A breaker auxiliary contact (ANSI Standard Device Number 52B) that opens when the breaker is closed and closes when the breaker is open.

b Output A relay control output that opens when the output relay asserts.

c Contact A breaker auxiliary contact that can be set to serve either as an a contact or as a b contact.

c Output An output with both an a output and b output sharing a common post.

3U, 4U, 5U, 6U, 7U, 9U The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 inches or 44.45 mm.

A Abbreviation for amps or amperes—a unit of electrical current flow.

ABS Operator An operator in math SELOGIC control equations that provides absolute value.

AC Ripple The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

Acceptance Testing Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. Such testing involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.

Access Level A relay command level with a specified set of relay information and commands. Except for Access Level 0, you must have the correct password to enter an access level.

Access Level 0 The least secure and most limited access level. No password protects this level. From this level, you must enter a password to go to a higher level.

Access Level 1 A relay command level you use to monitor (view) relay information. The default access level for the relay front panel.

Access Level 2 The most secure access level where you have total relay functionality and control of all settings types.

Access Level A A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Automation, Alias, Global, Front Panel, Report, Port, and DNP3 settings.

Access Level B A relay command level you use for Access Level 1 functions plus circuit breaker control and data.

Access Level O A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Output, Alias, Global, Front Panel, Report, Port, and DNP3 settings.

Access Level P A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Protection, SELOGIC, Alias, Global, Group, Breaker Monitor, Front Panel, Report, Port, and DNP3 settings.

ACSELERATOR Architect SEL-5032 Software ACSELERATOR Architect is an add-on to the ACSELERATOR QuickSet Suite that uses the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet SEL-5030 Software A Windows-based program that simplifies settings and provides analysis support.

ACSI Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group The settings group that the relay is presently using from among six settings groups available in the relay.

ADC Analog to Digital Converter. A device that converts analog signals into digital signals.

Admittance The reciprocal of impedance, I/V.

Advanced Settings Settings for customizing protection functions; these settings are hidden unless you set EADVS := Y and EGADVS := Y.

Alias An alternative name assigned to Relay Word bits, analog quantities, default terminals, and bus-zone names.

Analog Quantities Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

21	Distance element
24	Volts/Hertz Element
25	Synchronism-check element
27	Undervoltage Element
32	Directional Elements
49	Thermal Element
50	Overcurrent Element
51	Inverse-Time Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
67	Definite-Time Overcurrent
79	Recloser
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
G	Residual/Ground Element
N	Neutral/Ground Element
Q	Negative-Sequence (3I2) Element

Anti-Aliasing Filter A low-pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

Apparent Power, S Complex power expressed in units of volt-amperes (VA), kilovolt-amperes (kVA), or megavolt-amperes (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: $S = P + jQ$. This is power at the fundamental frequency only; no harmonics are included in this quantity.

Arcing Resistance The resistance in the arc resulting from a power line fault.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The relay uses ASCII text characters to communicate using front-panel and rear-panel EIA-232 serial ports on the relay and through virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to a relay input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control autodial modems from an ASCII terminal (usually EIA-232 connected) or a PC containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, data rate, passwords, relay elements, and other information that an IED (an SEL-2020/2030 communications processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automatic Reclose Automatic closing of a circuit breaker after a breaker trip by a protective relay.

Automation Variables Variables that you include in automation SELOGIC control equations.

Autoreclose-Drive-to-Lockout A logical condition that drives the autoreclose function out of service with respect to a specific circuit breaker.

Autotransformer A transformer with at least two common windings.

AX-S4 MMS “Access for MMS” is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4 MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850/UCA2 and MMS device objects.

Axion Another term for the SEL-2240. The Axion is an integrated, modular input/output and control solution suited for utility and industrial applications. In TiDL systems, it is used for remote data acquisition and control.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Bay Primary plant including disconnects, circuit breaker, CTs, PTs, power transformer, etc.

Bay Control Front-panel control (open and close) of the transformer circuit breakers and disconnects (isolators).

Best Choice Ground Directional Element Logic An SEL logic that determines the directional element that the relay uses for ground faults.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Block Trip Extension Continuing the blocking signal at the receiving relay by delaying the dropout of Relay Word bit BT.

Blocking Signal Extension The blocking signal for the DCB (directional comparison blocking) trip scheme is extended by a time delay on dropout timer to prevent unwanted tripping following current reversals.

Bolted Fault A fault with essentially zero impedance or resistance between the shorted conductors.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A Form A breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A Form B breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Breaker Differential Differential zone of protection configured exclusively across the tie breaker; the breaker differential protects only the area between the two tie-breaker CTs.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost because of transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

Busbar Electrical junction of two or more primary circuits. For a single busbar, there could be multiple bus-zones; there can be more bus-zones than busbars, but not more busbars than bus-zones.

Bus Coupler (see also Tie Breaker)
Equipment with at least a CT and circuit breaker, connecting two busbars when the circuit breaker is closed. Disconnects of other terminals at the station (feeders, lines, etc.) are normally arranged in parallel with the bus coupler. Closing two or more disconnects of the other terminals bypasses the bus coupler, forming a connection without a circuit breaker between two or more busbars.

Busbar Protection Element
Each busbar protection elements comprise a differential element, a directional element, and a fault detection logic.

Bus Sectionalizer (see also Buscoupler)
Equipment with at least a CT and circuit breaker, connecting two busbars when the circuit breaker is closed.

Bus-Zone-to-Bus-Zone Connection Variable
SELOGIC variable stating the conditions when the relay merges two zones to form a single protection zone.

Bus-Zone (see also Protection Zone)
Area of protection formed by a minimum of two terminals.

C37.118
IEEE C37.118, Standard for Synchrophasor Measurements for Power Systems.

C37.238
IEEE C37.238, Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications.

Capacitor Bank
Assembly of a number of capacitor units.

Capacitor Element
Device consisting of two electrodes separated by a dielectric.

Capacitor Unit
Assembly of a number of capacitor elements.

Category
A collection of similar relay settings.

CCVT
Coupling-capacitor voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CVT.

Checksum
A method for checking the accuracy of data transmission involving summation of a group of digits and comparison of this sum to a previously calculated value.

Check Zone
Protection zone formed by two or more terminals where the differential calculation is independent of the status of the disconnect auxiliary contacts.

CID
Checksum identification of the firmware.

CID File
IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic
This logic within the relay detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Circuit Breaker History Report
A concise circuit breaker event history that contains as many as 128 events. This breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and dc battery monitor voltages.

Circuit Breaker Report
A full report of breaker parameters for the most recent operation. These parameters include interrupted currents, number of operations, and mechanical and electrical operating times among many parameters.

Class The first level of the relay settings structure including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP3 settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Cold Start Turning a system on without carryover of previous system activities.

Combined Winding Mathematical combination (in the SEL-400) of currents from two separate sets of CT on the same voltage level, typical of breaker-and-a-half busbar configurations.

Commissioning Assistant Software used during transformer commissioning that checks for typical (single-contingency) wiring errors; The software uses load current to calculate the correct matrix combinations for as many as five windings.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Class Components Composite data objects that contain instances of UCA standard data types.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Common Time Delay Both ground- and phase-distance protection follow a common time delay on pickup.

Common Zone Timing Both ground- and phase-distance protection follow a common time delay on pickup.

Communications Protocol A language for communication between devices.

Communications-Assisted Tripping Circuit breaker tripping resulting from the transmission of a control signal over a communications medium.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values such as currents, total counts, and other measured and calculated quantities.

Computer Terminal Emulation Software Software such as Microsoft HyperTerminal or ProComm Plus that can be used to send and receive ASCII text messages and files via a computer serial port.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The relay supports the IEEE Std C37.111–1999, Common Format for Transient Data Exchange (COMTRADE) for Power Systems.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control Input.

Contact Output See Control Output.

Control Input Relay inputs for monitoring the state of external circuits. Connect auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay outputs that affect the state of other equipment. Connect control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

Cross-country fault A cross-country fault consists of simultaneous separate single phase-to-ground faults on parallel lines.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Compensation Adjustment of the current signals to nullify any standing unbalance current.

Current Reversal Guard Logic Under this logic, the relay does not key the transmitter and ignores reception of a permissive signal from the remote terminal when a reverse-looking element detects an external fault.

Current Transformer Saturation The point of maximum current input to a CT; any change of input beyond the saturation point fails to produce any appreciable change in output.

CVT Capacitive voltage transformer that uses a capacitive voltage divider to reduce transmission voltage to a level safe for metering and relaying devices. See CCVT.

CVT Transient Blocking Logic that prevents transient errors on capacitive voltage transformers from causing false operation of Zone 1 mho elements.

CVT Transient Detection Logic Logic that detects transient errors on capacitive voltage transformers.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated.

Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

DCB (Directional Comparison Blocking) A communications-assisted protection scheme. A fault occurring behind a sending relay causes the sending relay to transmit a blocking signal to a remote relay; the blocking signal interrupts the tripping circuit of the remote relay and prevents tripping of the protected line.

DCE Devices Data communications equipment devices (modems).

DCUB (Directional Comparison Unblocking) A communications-assisted tripping scheme with logic added to a POTT scheme that allows high-speed tripping of overreaching elements for a brief time during a loss of channel. The logic then blocks trip permission until the communications channel guard returns for a set time.

Dead Band The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across a relay input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the relay uses in DNP3 protocol.

Delta A phase-to-phase series connection of circuit elements, particularly voltage transformers or loads.

Demand Meter A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

Differential Element The differential element calculates current differences across a zone of protection.

Direct Tripping Local or remote protection elements provide tripping without any additional supervision.

Directional Element The directional element determines the direction of power flow at a point in the power system.

Directional Start A blocking signal provided by reverse reaching elements to a remote terminal used in DCB communications-assisted tripping schemes. If the fault is internal (on the protected line), the directional start elements do not see the fault and do not send a blocking signal. If the fault is external (not on the protected line), the directional start elements start sending the block signal.

Directional Supervision The relay uses directional elements to determine whether protective elements operate based on the direction of a fault relative to the relay.

Disabling Time Delay A DCUB scheme timer (UBDURD) that prevents high-speed tripping following a loss-of-channel condition.

Disconnect (Isolator) Mechanical switch that isolates primary equipment such as circuit breakers from the electrical system.

Distance Calculation Smoothness A relay algorithm that determines whether the distance-to-fault calculation varies significantly or is constant.

Distance Protection Zone The area of a power system where a fault or other application-specific abnormal condition should cause operation of a protective relay.

DMTC Period The time of the demand meter time constant in demand metering.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

DTT (Direct Transfer Trip) A communications-assisted tripping scheme. A relay at one end of a line sends a tripping signal to the relay at the opposite end of the line.

Dumb Terminal See ASCII terminal.

DUTT (Direct Underreaching Transfer Trip) A communications-assisted tripping scheme. Detection of a Zone 1 fault at either end of a line causes tripping of the local circuit breaker as well as simultaneous transmission of a tripping signal to the relay at the opposite end of the line. The scheme is said to be underreaching because the Zone 1 relays at both ends of the line reach only 80 percent (typically) of the entire line length.

Dynamic Zone Selection The process by which the currents from the CTs are assigned to or removed from the differential calculations as a function of the Boolean value (logical 0 or logical 1) of a particular SELOGIC equation.

ECB (EtherCAT Communications Board) A circuit board mounted within the relay that has eight EtherCAT fiber connections for creating a TiDL system.

Echo The action of a local relay returning (echoing) the remote terminal permissive signal to the remote terminal when the local breaker is open or a weak infeed condition exists.

Echo Block Time Delay A time delay that blocks the echo logic after dropout of local permissive elements.

Echo Duration Time Delay A time delay that limits the duration of the echoed permissive signal.

ECTT (Echo Conversion to Trip) An element that allows a weak terminal, after satisfaction of specific conditions, to trip by converting an echoed permissive signal to a trip signal.

EEPROM Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV Extra high voltage. Voltages greater than 230 kV.

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time Time between trip or close initiation and an open-phase status change.

Electromechanical Reset Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

End-Zone Fault A fault at the farthest end of a zone that a relay is required to protect.

Energy Metering Energy metering provides a look at imported power, exported power, and net usage over time; measured in MWh (megawatt hours).

Equalize Mode A procedure where substation batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

EtherCAT (Ethernet for Control Automation Technology) An Ethernet-based network protocol for high-speed control networks that require real-time performance and ease of network configuration.

Ethernet A network physical and data link layer defined by IEEE 802.2 and IEEE 802.3.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault location, time source, recloser shot counter, prefault and fault voltages, currents, and sequence current, and MIRRORED BITS communications channel status (if enabled).

The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

External Fuse Fuse external to a capacitor unit (usually mounted on the unit).

EXP Operator Math SELOGIC control equation operator that provides exponentiation.

F_TRIG Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Fail-Safe Refers to an output that is open during normal relay operation and closed when relay power is removed or if the relay fails. Configure alarm outputs for fail-safe operation.

Falling Edge Transition from logical 1 to logical 0.

Fast Hybrid Control Output A control output similar to, but faster than, the hybrid control output. The fast hybrid output uses an insulated-gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity sensitive—reversed polarity causes no misoperations.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Fast Message SEL binary serial port protocol used for Fast SER, Fast Message Synchrophasors, and RTD communications.

Fault Detection Logic Logic that distinguishes between internal and external faults.

Fault Type Identification Selection Logic the relay uses to identify balanced and unbalanced faults (FIDS).

FID Relay firmware identification string. Lists the relay model, firmware version and date code, and other information that uniquely identifies the firmware installed in a particular relay.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Flashover A disruptive discharge over the surface of a solid dielectric in a gas or liquid.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELogic Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File Transfer Protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Portion of a UCA GOMSFE brick dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Power Power calculated with components of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz.

Fuse Device that opens the circuit in which it is connected to provide overcurrent protection.

Fuseless Capacitor Bank A capacitor bank without internal or external fuses.

Global Settings General settings including those for relay and station identifiers, number of breakers, date format, phase rotation, nominal system frequency, enables, station dc monitoring, control inputs, settings group selection, data reset controls, frequency tracking, time and date management, and current and voltage source selection.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

Ground Directional Element Priority The order the relay uses to select directional elements to provide ground directional decisions (relay setting ORDER).

Ground-Distance Element A mho or quadrilateral distance element the relay uses to detect faults involving ground along a transmission line.

Ground Fault Loop Impedance The impedance in a fault-caused electric circuit connecting two or more points through ground conduction paths.

Ground Overcurrent Elements Elements that operate by comparing a residual ground calculation of the three-phase inputs with the residual overcurrent threshold setting. The relay asserts ground overcurrent elements when a relay residual current calculation exceeds ground current setting thresholds.

Ground Quadrilateral Distance Protection Ground-distance protection consisting of a four-sided characteristic on an R-X diagram.

Ground Return Resistance Fault resistance that can consist of ground path resistance typically in tower footing resistance and tree resistance.

Grounded Capacitor Bank Capacitor bank with a solid connection to ground.

Guard-Present Delay A timer that determines the minimum time before the relay reinstates permissive tripping following a loss-of-channel condition in the DCUB communications-assisted tripping scheme (relay setting GARD1D).

GUI Graphical user interface.

Harmonics Frequencies that are multiples of the frequency of the power system; 100 Hz is the second harmonic of a 50 Hz power system.

Harmonic Restraint Method by which harmonics are used to desensitize differential elements, thereby avoiding misoperations during inrush conditions.

Harmonic Blocking Method by which harmonics are used to block differential elements thereby avoiding misoperations during inrush conditions.

Hexadecimal Address A register address consisting of a numeral with an "h" suffix or a "0x" prefix.

High-Resolution Data Capture Reporting of 3 kHz low-pass analog filtered data from the power system at each event trigger or trip at high sample rates of 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second.

High-Speed, High-Current Interrupting Control Output A control output similar to, but faster than, the hybrid control output. The high-speed, high-current interrupting output uses an insulated-gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity sensitive—reversed polarity causes no misoperations.

HMI Human-machine interface.

Homogeneous System A power system with nearly the same angle (less than ∠5° difference) for the impedance angles of the local source, the protected line, and the remote source.

HV High voltage. System voltage greater than or equal to 100 kV and less than 230 kV.

Hybrid Control Output Contacts that use an insulated-gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) high inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. These contacts are polarity-dependent and cannot be used to switch ac control signals.

IA, IB, IC Measured A-Phase, B-Phase, and C-Phase currents.

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IEC 61850-9-2 IEC 61850 standard that defines mapping of Sampled Values data onto ISO 8802-3.

IED Intelligent electronic device.

IEEE Institute of Electrical and Electronics Engineers, Inc.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero.

IGBT Insulated-gate bipolar junction transistor.

Inboard CT (bushing CT) Current transformer physically positioned in such a way that the CT is bypassed when the feeder is on transfer.

Independent Zone Timing The provision of separate zone timers for phase and ground-distance elements.

Infinite Bus A constant-voltage bus.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

Instantaneous Meter Type of meter data presented by the relay that includes the present values measured at the relay ac inputs. The word "Instantaneous" is used to differentiate these values from the measurements presented by the demand, thermal, energy, and other meter types.

Internal Fuse Fuse inside a capacitor unit.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

ISO 8802-3 Defines Ethernet for local area and metropolitan area networks.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

LAN Local Area Network. A network of IEDs interconnected in a relatively small area, such as a room, building, or group of buildings.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LMD SEL distributed port switch protocol.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Load Encroachment The load-encroachment feature allows setting of phase overcurrent elements and phase-distance elements independent of load levels.

Local Bits The Relay Word bit outputs of local control switches that you access through the front panel of the relay. Local control switches replace traditional panel-mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or by hand.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Loss of Channel Loss of guard and no permissive signal from communications gear in a DCUB (directional comparison unblocking scheme) for either two or three terminal lines.

Loss of Guard No guard signal from communications gear.

Loss of Potential Loss of one or more phase voltage inputs to the relay secondary inputs.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values and provide a numerical base-10 result.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Maximum/Minimum Meter Type of meter data presented by the relay that includes a record of the maximum and minimum of each value, along with the date and time that each maximum and minimum occurred.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

Merging Unit A device that converts analog signals to digital signals and transmits them as IEC 61850-9-2 data.

Mho Characteristic A directional distance relay characteristic that plots a circle for the basic relay operation characteristic on an R-X diagram.

MIRRORED BITS Communications Patented relay-to-relay communications technique that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing messaging specification, a data exchange protocol used by UCA.

MOD Motor-operated disconnect.

Model Model of device (or component of a device) including the data, control access, and other features in UCA protocol.

Motor Running Time The circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressor motor.

MOV Metal-oxide varistor.

MVA Mega Volt-Ampere. Typical unit for expressing the capacity of a power transformer, e.g., 100MVA.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°, and have clockwise phase rotation with current and voltage maxima that occur differently from that for positive-sequence configuration. If positive-sequence maxima occur as ABC, negative-sequence maxima occur as ACB.

Negative-Sequence Current Supervision Pickup An element allowed to operate only when a negative-sequence current exceeds a threshold.

Negative-Sequence Directional Element An element that provides directivity by the sign, plus or minus, of the measured negative-sequence impedance.

Negative-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced negative-sequence set of voltage sources.

Negative-Sequence Overcurrent Elements Elements that operate by comparing a negative-sequence calculation of the three-phase secondary inputs with negative-sequence overcurrent setting thresholds. The relay asserts these elements when a relay negative-sequence calculation exceeds negative-sequence current setting thresholds.

Negative-Sequence Voltage-Polarized Directional Element These directional elements are 32QG and 32Q. 32QG supervises the ground-distance elements and residual directional overcurrent elements; 32Q supervises the phase-distance elements.

NEMA National Electrical Manufacturers' Association.

Neutral Impedance An impedance from neutral to ground on a device such as a generator or transformer.

No Current/Residual Current Circuit Breaker Failure Protection Logic Logic for detecting and initiating circuit breaker failure protection with a logic transition, or when a weak source drives the fault or a high-resistance ground fault occurs.

Nondirectional Start A blocking signal provided by nondirectional overcurrent elements to a remote terminal used in DCB communications-assisted tripping schemes. The nondirectional start elements start sending the block signal.

Nonhomogeneous System A power system with a large angle difference (>5° difference) for the impedance angles of the local source, the protected line, and the remote source.

Nonvolatile Memory Relay memory that persists over time to maintain the contained data even when the relay is de-energized.

NOT Operator A logical operator that produces the inverse value.

Operate Current Differential current (vector sum) between current(s) that enter a point, and current(s) that leave that point.

OR Operator Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Out-of-Step Blocking Blocks the operation of phase-distance elements during power swings.

Out-of-Step Tripping Trips the circuit breaker(s) during power swings.

Outboard CT Current transformer physically positioned in such a way that the CT remains in circuit when the feeder is on transfer.

Over/Underpower Elements Elements that calculate the forward and reverse power flow and compare the result against settable thresholds.

Over/Undervoltage Elements Elements that calculate the system voltage and compare the result against settable thresholds.

Over/Underfrequency Elements Elements that calculate the power system frequency and compare the result against settable thresholds.

Overlap Configuration Configuration of the tie-breaker protection whereby the area between the tie-breaker CTs are part of two bus-zones, i.e., a fault between the tie-breaker CTs is common to two bus-zones.

Override Values Test values you enter in Fast Meter, DNP3, and communications card database storage.

Parentheses Operator Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The relay stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

Phase-Distance Element A mho distance element the relay uses to detect phase-to-phase and three-phase faults at a set reach along a transmission line.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-Phase voltage lags the A-Phase voltage by 120°, and the C-Phase voltage lags B-Phase voltage by 120°. In an ACB phase rotation system, the C-Phase voltage lags the A-Phase voltage by 120°, and the B-Phase voltage lags the C-Phase voltage by 120°.

Phase Selection Ability of the relay to determine the faulted phase or phases.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

PMU Phasor measurement unit. A device that measures and publishes synchrophasor data.

Polarizing Memory A circuit that provides a polarizing source for a period after the polarizing quantity has changed or gone to zero.

Pole Discrepancy A difference in the open/closed status of circuit breaker poles. The relay continuously monitors the status of each circuit breaker pole to detect open or close conditions among the three poles.

Pole-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

Pole Scatter Deviation in operating time between pairs of circuit breaker poles.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°. With conventional rotation in the counter-clockwise direction, the positive-sequence current and voltage maxima occur in ABC order.

Positive-Sequence Current Restraint Factor, a2 This factor compensates for highly unbalanced systems with many untransposed lines and helps prevent misoperation during CT saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current (I2/I1).

Positive-Sequence Current Supervision Pickup An element that operates only when a positive-sequence current exceeds a threshold.

Positive-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced positive-sequence set of voltage sources.

POTT (Permissive Overreaching Transfer Trip) A communications-assisted line protection scheme. At least two overreaching protective relays must receive a permissive signal from the other terminal(s) before all relays trip and isolate the protected line.

Power Factor The cosine of the angle by which phase current lags or leads phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a pure resistive load.

PPS Pulse per second from a GPS receiver. Previous relays had a TIME 1k PPS input.

Primitive Name The predefined name of a quantity within the relay.

Process Bus Network bus for IED communication at the bay level.

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group Individual scheme settings for as many as six different schemes (or instances).

Protection-Disabled State Suspension of relay protection element and trip/close logic processing and de-energization of all control outputs.

Protection Zone (also see Bus-Zone) Area of protection formed by a minimum of one bus-zone. A protection zone can include more than one bus-zone. For example, merging two bus-zones results in a single protection zone. When no bus-zones are merged, a protection zone and a bus-zone have the same meanings.

PRP Parallel Redundancy Protocol, as defined in IEC 62439-3 for network redundancy and seamless failover.

PT Potential transformer. Also referred to as a voltage transformer or VT.

PTP Precision Time Protocol, as defined in IEEE 1588 for high-accuracy clock synchronization.

PTR Potential transformer ratio.

Quadrilateral Characteristic A distance relay characteristic on an R-X diagram consisting of a directional measurement, reactance measurement, and two resistive measurements.

Qualifier Code Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP3 master devices can compose the shortest, most concise messages.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

RAM Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.

Reactance Reach The reach of a distance element in the reactive (X) direction in the R-X plane.

Real Power Power that produces actual work. The portion of apparent power that is real, not imaginary.

Reclose The act of automatically closing breaker contacts after a protective relay trip has opened the circuit breaker contacts and interrupted current through the breaker.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

Remapping The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.

Remote Bit A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP3 binary output operation, or a UCA control operation.

Report Settings Event report and Sequential Events Recorder (SER) settings.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero.

Residual Directional Overcurrent Element A residual overcurrent element allowed to operate in only the forward or reverse direction.

Residual Overcurrent Protection Overcurrent protection that operates at conditions exceeding a threshold of system unbalance ($3I_0 = I_A + I_B + I_C$).

Resistance Blinder An operate boundary in the resistive direction of a ground quadrilateral distance element.

Resistive Reach The reach of a distance element in the resistive (R) direction in the R-X plane.

Restraint Current Sum of the absolute values of current(s) entering a point, and leaving that point. Used as basis to calculate the reference (setting) value for differential elements.

Restricted Earth Fault Differential element that augments the phase differential element by providing sensitive protection against ground faults close to the neutral of a grounded-wye transformer. The element compares the phase angle of zero-sequence quantities from the transformer neutral with zero-sequence quantities from as many as five line CTs.

Retrip A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.

Reverse Fault A fault operation behind a relay terminal.

Rising Edge Transition from logical 0 to logical 1, or the beginning of an operation.

RMS Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher-order harmonics in the signal.

Rolling Demand A sliding time-window arithmetic average in demand metering.

RTC Real Time Control. A method for exchanging synchrophasor control data.

RTD Resistance Temperature Detector.

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

SCD File IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

SDN Software-defined networking.

Self-Description A feature of GOMSFE in the UCA2 protocol. A master device can request a description of all of the GOMSFE models and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The relay has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. A Sequential Events Recorder (SER) provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Series-Compensated Line A power line on which the addition of series capacitance compensates for excessive inductive line impedance.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

Shot Counter A counter that records the number of times a recloser attempts to close a circuit breaker.

Shunt Admittance The admittance resulting from the presence of a device in parallel across other devices or apparatus that diverts some current away from these devices or apparatus.

Shunt Capacitance The capacitance between a network connection and any existing ground.

Shunt Current The current that a parallel-connected high-resistance or high-impedance device diverts away from devices or apparatus.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

Single-CT Application Tie breaker with only one CT available for busbar protection.

Single-Pole Trip A circuit breaker trip operation that occurs when one pole of the three poles of a circuit breaker opens independently of the other poles.

Single Relay Application (Bus Protection) Stations with as many as 21 per-phase CTs require only one SEL-487B. Stations with more than 21 and as many as 54 per-phase CTs require three SEL-487B relays.

SIR Source-to-line impedance ratio.

SNTP Simple Network Time Protocol. A network protocol for time synchronization.

SOTF (Switch-Onto-Fault Protection Logic) Logic that provides tripping if a circuit breaker closes into a zero voltage bolted fault, such as would happen if protective grounds remained on the line following maintenance.

Source Impedance The impedance of an energy source at the input terminals of a device or network.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Stable Power Swing A change in the electrical angle between power systems. A control action can return the angular separation between systems to less than the critical angle.

Station Bus Network bus for IED communication between the bay and station levels.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Strong Password A mix of valid password characters in a six-character combination that does not spell common words in any portion of the password. Valid password characters are numbers, upper- and lowercase alphabetic characters, "." (period), and "-" (hyphen).

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

SV Sampled Values, as defined in Part 9-2 of IEC 61850.

SV Channel A single-phase voltage or current transmitted as an integer value containing its magnitude and phase angle.

SV Stream Multicast packets containing a fixed dataset transmitted periodically. In the case of 9-2LE, SV streams contain four currents and four voltages and are transmitted at a rate of 80 samples per cycle.

Synch Reference A phasor the relay uses as a polarizing quantity for synchronism-check calculations.

Synchronism-Check Verification by the relay that system components operate within a preset frequency difference and within a preset phase angle displacement between voltages.

Synchronized Phasor A phasor calculated from data samples using an absolute time signal as the reference for the sampling process. The phasors from remote sites have a defined common phase relationship. Also known as Synchrophasor.

TAP Full-load secondary current that the relay uses to convert Ampere values to dimensionless per-unit values.

TAP Tappings on some power transformer windings, used for voltage/reactive power flow control.

TAP (Point) Point in each phase that divides the capacitor bank into two parts.

Telnet An IP for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal-to-Bus-Zone Connection Variable SELOGIC variable stating the conditions when the relay considers the current input from a particular terminal in the differential calculations of a particular bus-zone.

Terminal Emulation Software Software that can be used to send and receive ASCII text messages and files via a computer serial port.

Thermal Demand Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities (used in demand metering).

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Three-Relay Application Stations with more than 21 and as many as 54 per-phase CTs require three SEL-487B relays. Stations with as many as 21 per-phase CTs require only one SEL-487B.

Tie Breaker See Bus Coupler and Bus Sectionalizer.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a predetermined time.

Time-Domain Link (TiDL) A technology that uses remote Axion units to provide CT and PT inputs that are communicated to the relay by using direct fiber EtherCAT connections.

Time Error A measurement of how much time an ac powered clock would be ahead or behind a reference clock, as determined from system frequency measurements.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Time Quality An indication from a GPS clock receiver that specifies the maximum error in the time information. Defined in IEEE C37.118.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

Tower Footing Resistance The resistance between true ground and the grounding system of a tower.

Transformer Impedance The resistive and reactive parameters of a transformer looking in to the transformer primary or secondary windings. Use industry accepted open-circuit and short-circuit tests to determine these transformer equivalent circuit parameters.

Tree Resistance Resistance resulting from a tree in contact with a power line.

TVE Total Vector Error. A measurement of accuracy for phasor quantities that combines magnitude and angle errors into one quantity. Defined in IEEE C37.118.

TXD Transmitted data.

UCA2 Utility Communications Architecture. A network-independent protocol suite that serves as an interface for individual IEDs.

UCA 61850-9-2LE Guideline for implementation of IEC 61850-9-2 created by the UCAIug to facilitate interoperability. The guideline can be considered a subset, or profile, of the IEC 61850-9-2 standard, which defines requirements for certain parts of the standard, including data mode implementation, data set descriptions, time synchronization, transfer rates, and sampling rates. Also referred to as 9-2LE.

UCAIug Utility Communications Architecture International Users Group.

Unbalanced Current Element Element that calculates the percentage difference between the three phase currents.

Unbalanced Fault All faults that do not include all three phases of a system.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a "best efforts" basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

Unconditional Tripping Protection element tripping that occurs apart from conditions such as those involving communication, switch-onto-fault logic, etc.

Ungrounded Capacitor Bank Capacitor bank with no intentional connection to ground. (A bank with a PT connected between the bank's neutral point and ground is considered ungrounded.)

Unstable Power Swing A change in the electrical angle between power systems for which a control action cannot return the angular separation between systems to an angle less than the critical angle.

Untransposed Line A transmission line with phase conductors that are not regularly transposed. The result is an unbalance in the mutual impedances between phases.

User ST Region in GOOSE for user-specified applications.

VA, VB, VC Measured A-Phase-to-neutral, B-Phase-to-neutral, and C-Phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

VG Residual voltage calculated from the sum of the three phase-to-neutral voltages, if connected.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

Volatile Storage A storage device that cannot retain data following removal of relay power.

Voltage Compensation Adjustment of the voltage signals to nullify any standing unbalance voltage.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Weak Infeed Logic Logic that permits rapid tripping for internal faults when a line terminal has insufficient fault current to operate protective elements.

Winding Transformer winding, synonymous with "terminal."

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase to neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-Phase-, B-Phase-, and C-Phase-to-neutral voltages. This connection is frequently called 'four-wire wye,' alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero-Sequence A configuration of three-phase currents and voltages with currents and voltages that occur simultaneously, are always in phase, and have equal magnitude ($3I_0 = I_A + I_B + I_C$).

Zero-Sequence Compensation Factor A factor based on the zero-sequence and positive-sequence impedance of a line that modifies a ground-distance element to have the same reach as a phase-distance element.

Zero-Sequence Impedance Impedance of a device or circuit resulting in current flow when a single voltage source is applied to all phases.

Zero-Sequence Mutual Coupling Zero-sequence current in an unbalanced circuit in close proximity to a second circuit induces voltage into the second circuit. When not controlled by protection system design and relay settings, this situation can cause improper operation of relays in both systems.

Zero-Sequence Overcurrent Element Overcurrent protection that operates at conditions exceeding a threshold of system unbalance.

Zero-Sequence Voltage-Polarized Directional Element An element that provides directionality by the sign, plus or minus, of the measured zero-sequence impedance.

Z-Number That portion of the relay FID string that identifies the proper ACSELERATOR QuickSet software relay driver version and HMI driver version when creating or editing relay settings files.

Zone Time Delay Time delay associated with the forward or reverse step distance and zone protection.

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