SECTION 14. CURRENT DIFFERENTIAL RELAY

14.1 OVERVIEW

The GARD 8000 Current Differential Module provides a comprehensive set of primary protection algorithms. An additional set of backup protection algorithms are available when inter-relay communications are lost for any reason.
The GARD 8000 Current Differential Module can be configured for optional single-pole tripping. The standard ordering version is for three-pole tripping only. Three terminal configuration is also available as an option.
Other GARD 8000 Current Differential Module features include sequence of events recorder (SOE) and oscillography.

14.1.1 PROTECTION FUNCTIONS

The primary protection functions included in the GARD 8000 Current Differential Module include:

- Current Differential
- Close Into Fault
- High Set Trip
- Open Conductor
- Dual Breaker

The current differential protection is the heart of the relay. The algorithm includes a secure communications protocol and a robust current measurement that reduces the impact of momentary measurement transients.

The communications channel delay is removed as part of the normal data processing. The design of the algorithm will tolerate fairly modest errors in the channel delay measurement or changes in the delay due to network conditions.

The current differential protection can easily be configured to accommodate any specific installation.

Line charging currents and system resonances create particular concerns immediately following a breaker closing. Proper system configuration allows the relay to ride-through these normal transient events while allowing a trip if the system closes into a faulted line.

The high set trip routines provide an extremely fast response under very high fault currents.

The open conductor routines allow the system to respond to system imbalances when the fault condition results in a phase open circuiting rather than shorting to another phase or ground.

Dual breaker operation allows a second CT input to be used for breaker and half schemes.

14.1.1.1 BACKUP PROTECTION

The protection algorithms just described are the "primary" protection routines and are intended to provide protection with relays at both ends of the line being protected and a communications link between the relays. There will be unavoidable failures in the communications link and the relay provides some backup protection algorithms to maintain protection even without a functioning communications channel.

- Overcurrent
- Time Overcurrent
- Close Into Fault
- Loss of Load

The relay also has a stub bus protection feature. When an 89 disconnect is used to disconnect a line from the remote end it may leave a bus stub energized and requiring protection. The 89B contact can be fed into the relay to enable the stub bus feature.
The stub bus function basically isolates the local and remote relays. The local relay will operate using only overcurrent and time overcurrent routines that are similar to the backup routines but have independently programmable settings. The remote relay will then continue to operate in primary protection mode but will be told that the local (stub-bus side) relay is receiving zero current through the line.

14.1.2 ADDITIONAL FUNCTIONS

The current differential relay also provides several additional functions:

- Transferred Status Bits
- Sequence of Events
- Oscillography
- Recloser Block

14.2 CONFIGURATION

14.2.1 SYSTEM CONFIGURATION OVERVIEW

The GARD 8000 System differs from most conventional multifunctional differential relays in that rather than supplied with very complex generic default logic, the GARD 8000 can be easily customized to meet your specific application requirements.

For most applications, the factory default logic may be suitable but RFL will modify it free-of-charge when required.

The advantage with custom logic is that the user interface is greatly simplified as the web pages for logic settings are automatically created to correspond to the actual logic.

While the logic is custom made, a considerable amount of settings and field flexibility can be built-in to cover a large number of application needs. For instance, mapping of inputs and outputs, inverters for inputs and outputs, timers, communications channel selections, etc. can all be made on web pages as settings.

The current diff. module in itself is highly programmable but the interaction in the system has been kept to a minimum in order to simplify the system user interface.

NOTE

While most of the GARD 8000 Modules can be installed and removed while powered, it is not recommended to do so **while Tripping Circuits are enabled** as unintended operations may result.

14.2.1.1 HARDWARE CONFIGURATION

A GARD 8000 System can be built up with Functional Modules as required for a specific application, with a selectable number of inputs, outputs and communications interfaces. The following overview describes a factory default configuration of a 3U chassis built up of:

- Single Power Supply
- Single Main Controller
- Display Board with base Teleprotection System
- RS 449 communications port on the rear of the PS module (included in Base System)
- C37.94 communications module in rear Slot 1
- Distance Protection module in front and rear Slot 4
- Current Differential Module in Slot 3
- 6 input module in rear Slot 2
- 6 output module in rear Slot 2

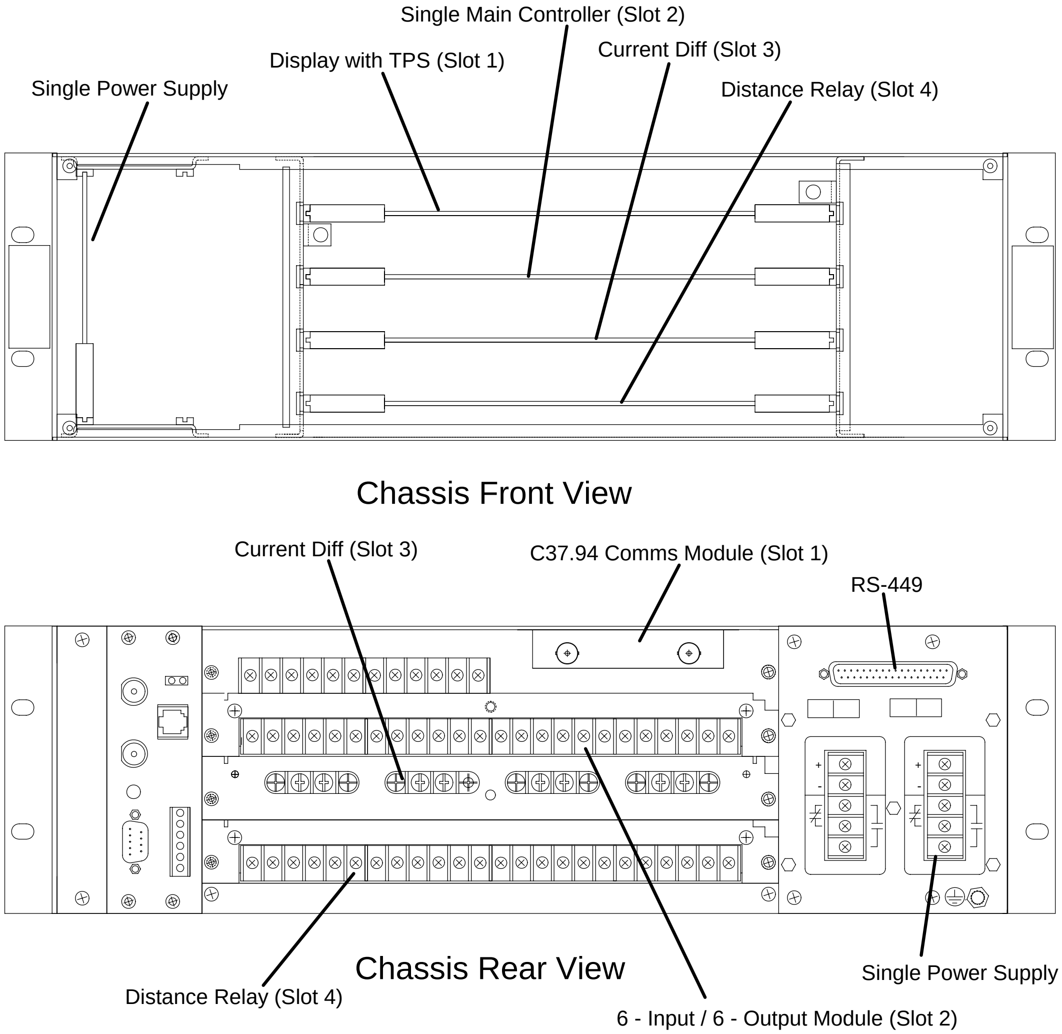

Figure 14-1 Front and Rear view of 3U chassis with Current Diff Module (Typical)

Connections are made to the Current Diff. Module on the rear of the GARD chassis as shown below. The terminal assignments are the same for the 3U and 6U chassis. These connections are fixed.

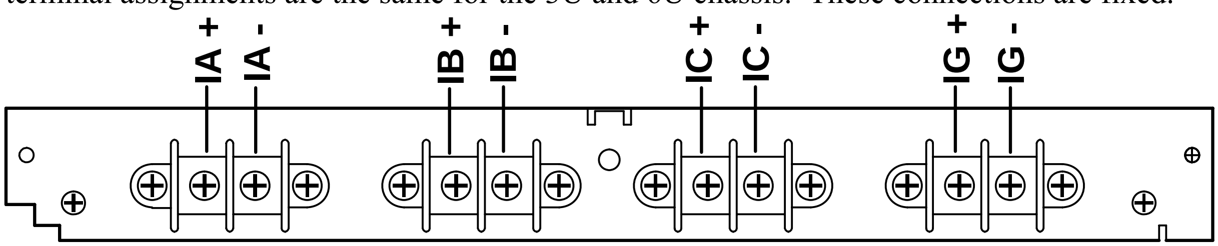

Figure 14-2. Current Differential Rear Connections

Shown below is a typical AC/DC Schematic for the GARD 3U Chassis with a Distance Relay Module in slot 3 and a Current Diff Module in slot 4.

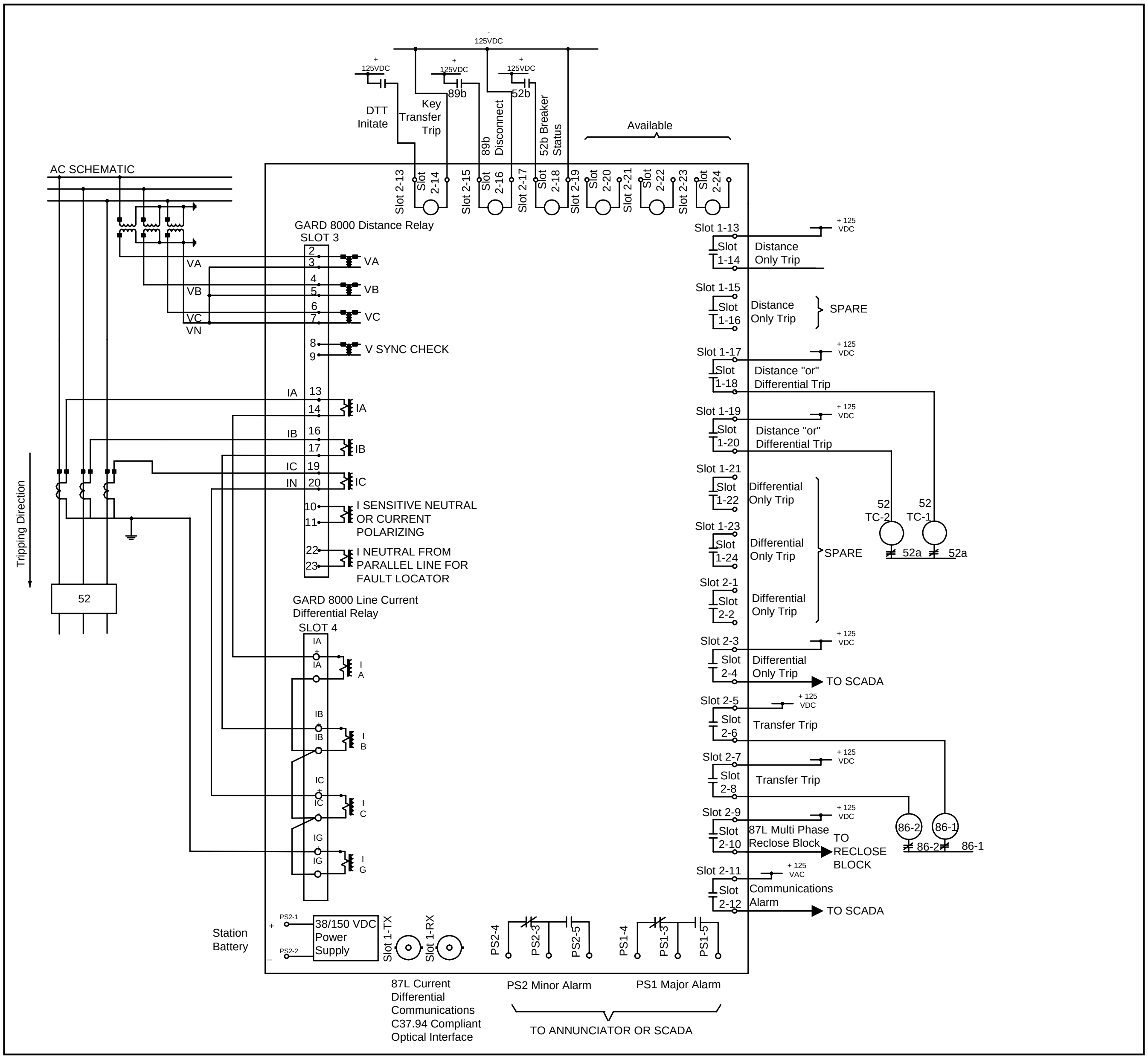

Figure 14-3. AC/DC Schematic for GARD 8000 Differential Relay (Typical)

In many cases the system logic for the current diff relay application is pre-configured (mapped) at the factory. The following pages will give the user a brief introduction to the mapping options available when the current diff module is installed. **For a more detailed discussion of system logic configuration see Section 8 in this manual.** As every chassis logic configuration is unique the logic files have to be sent to the GARD.

From the home page "Settings" pull down menu click "File Operations," the following web page will appear.

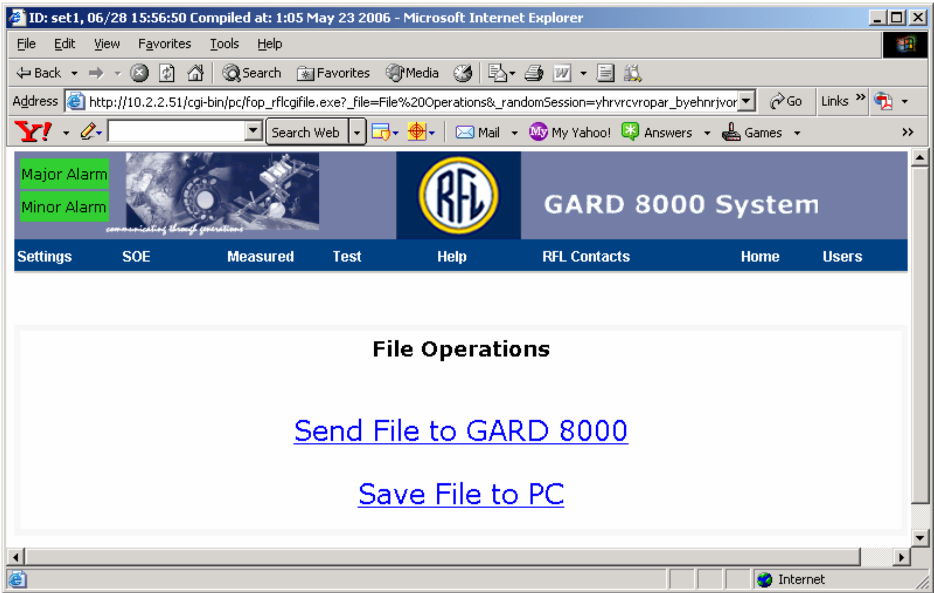

Figure 14-4 File Operations, Current Diff

Click "Send File to GARD 8000," select and SEND the 4 System Logic files.

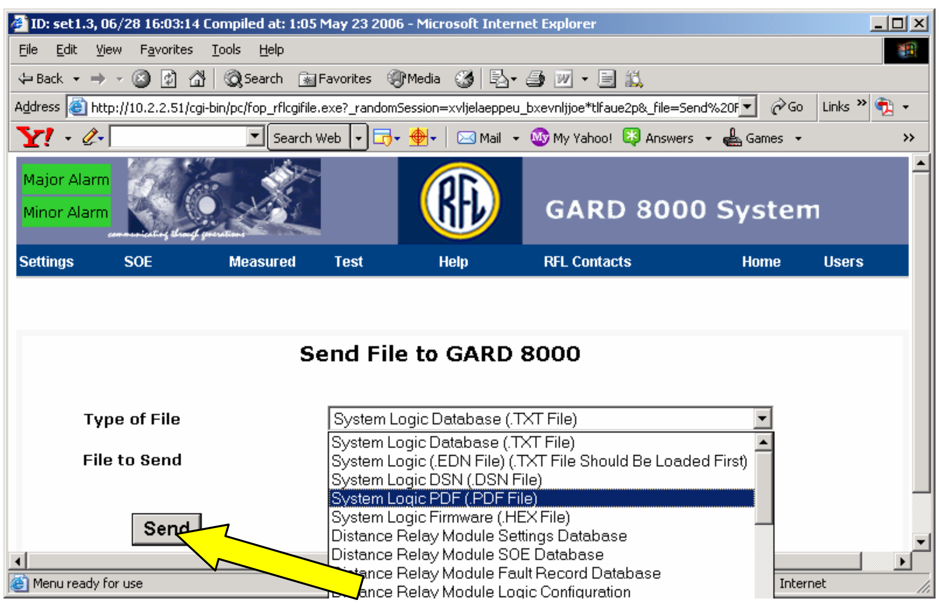

Figure 14-5 Send File to GARD 8000, Current Diff

Return to the home page and from the "Settings" pull down menu click "System Logic Configuration" as shown below.

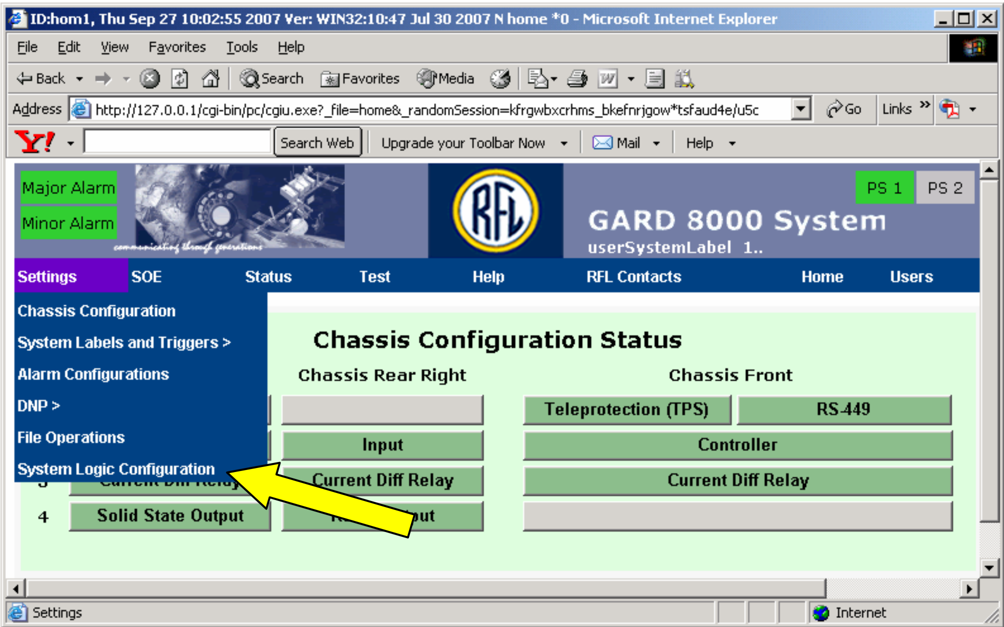

Figure 14-6. Home Page

The following web page will appear.

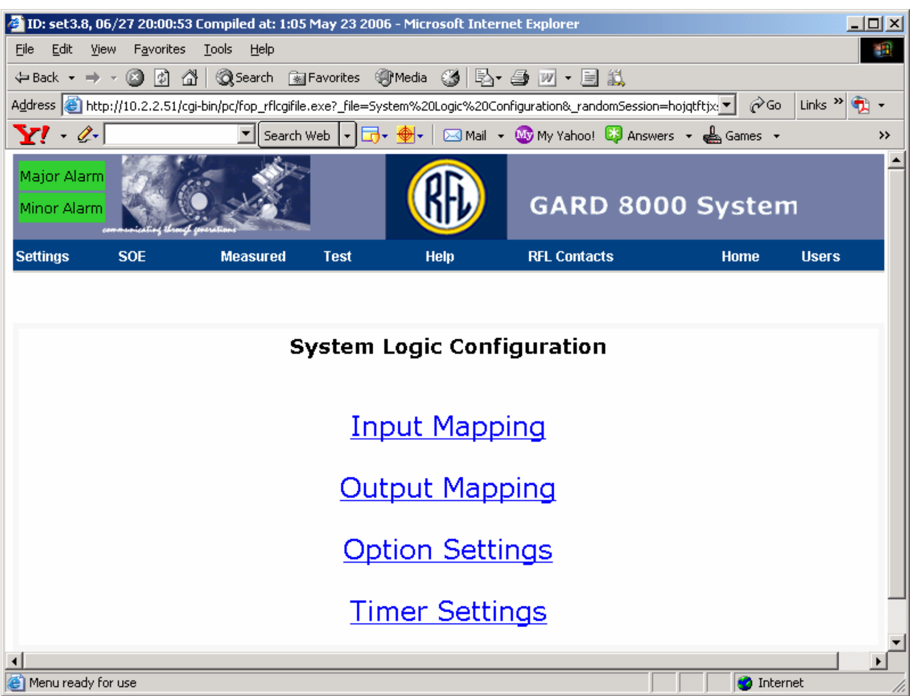

Figure 14-7 System Logic Configuration

Click “Input Mapping” the following web page will appear.

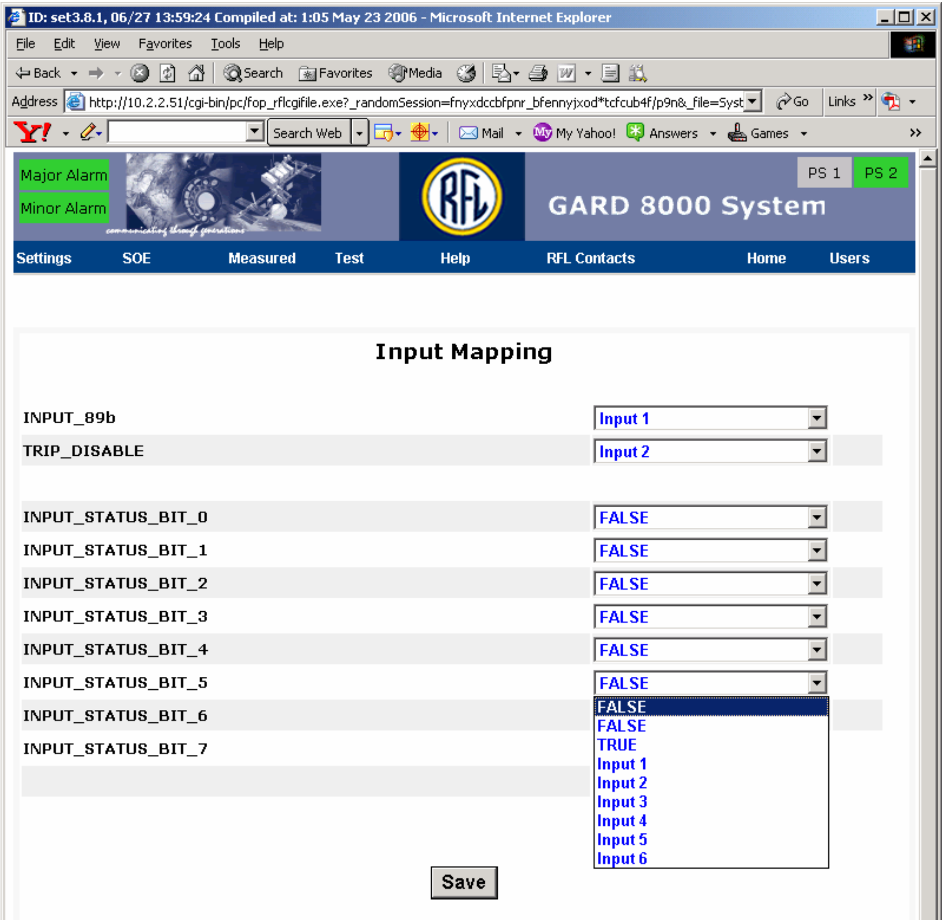

Figure 14-8. Input Mapping Webpage

The number of physical inputs depends on how many input modules were ordered. The logic inputs (shown on the left on the input mapping page) are determined in the OrCAD logic, and can be customized for your application.

Outputs are configured in a similar way. Again, the number of physical outputs depends on how many output modules were ordered. The logic outputs (shown on the left on the output mapping page as ‘source’) are determined in the OrCAD logic, and can be customized for your application.

When changes are made click the “Save” button to save your configuration, a conformation page will appear.

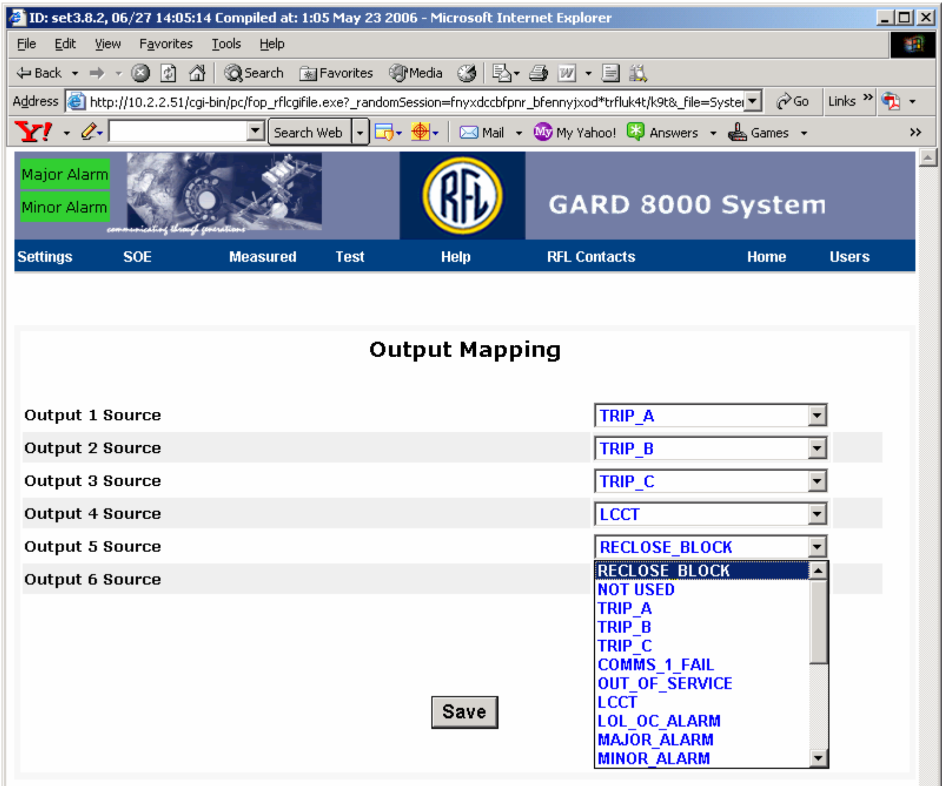

Figure 14-9. Output Mapping Webpage

To fully understand what the inputs and outputs are doing in the system logic, the actual System Logic Diagram should be consulted. This is supplied in a separate section at the rear of the instruction manual.

For example, the current diff. inputs are shown as follows:

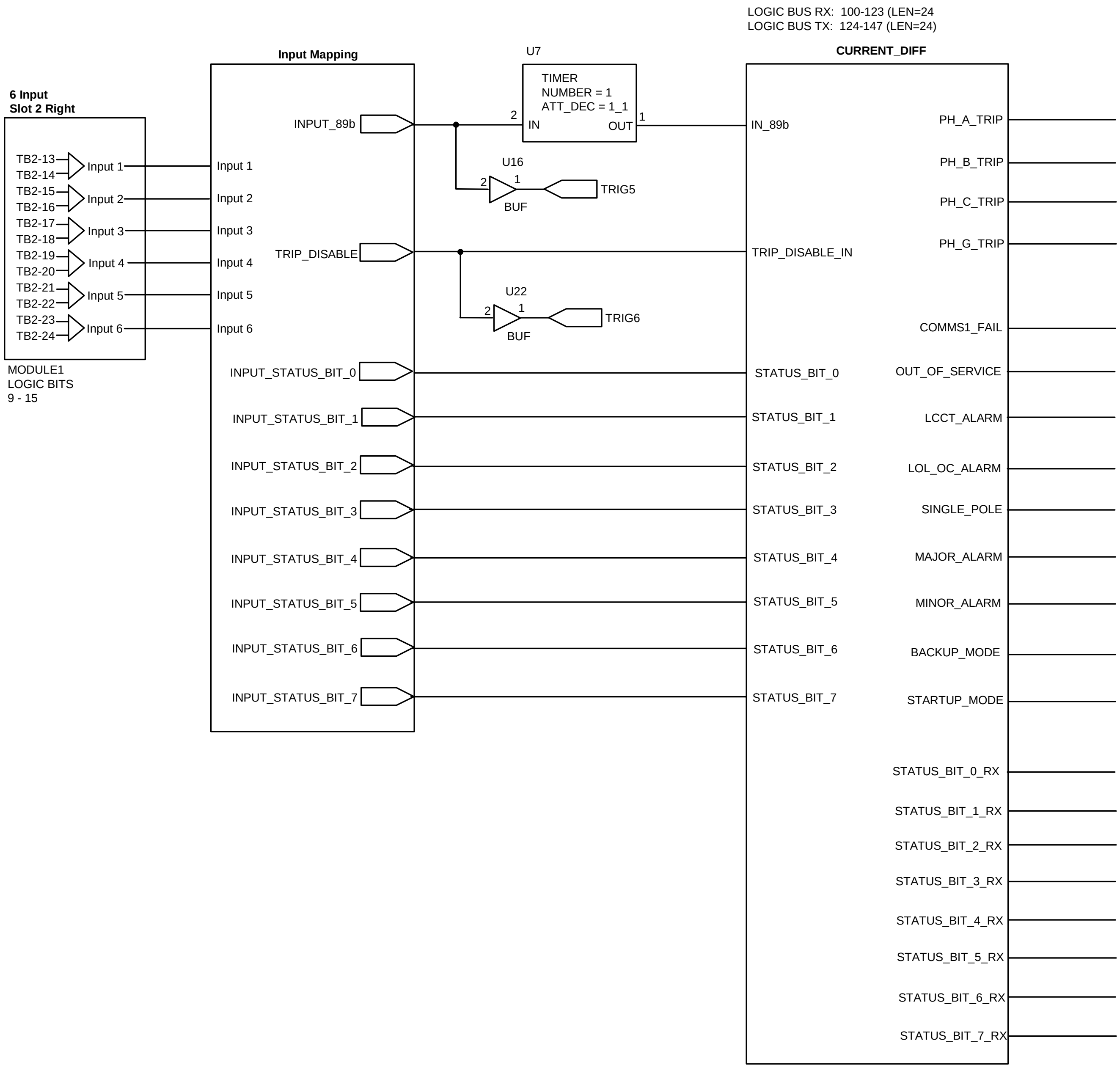

Figure 14-10. Current Differential Inputs, Schematic Diagram

The logic inside the ‘current diff’ block on the schematic is fixed as delivered from the factory but can be custom ordered for your application. While the proven logic in the current diff relay is not changed, the input and output signals of the current diff block can be customized to provide different functionality for different applications. A complete list of available signals is provided at the end of this section.

The physical inputs (in this example Inputs 1 – 6) are mapped on the webpage to logic inputs. Any physical input can be freely assigned to any number of logical inputs.

The outputs are mapped in a similar way.

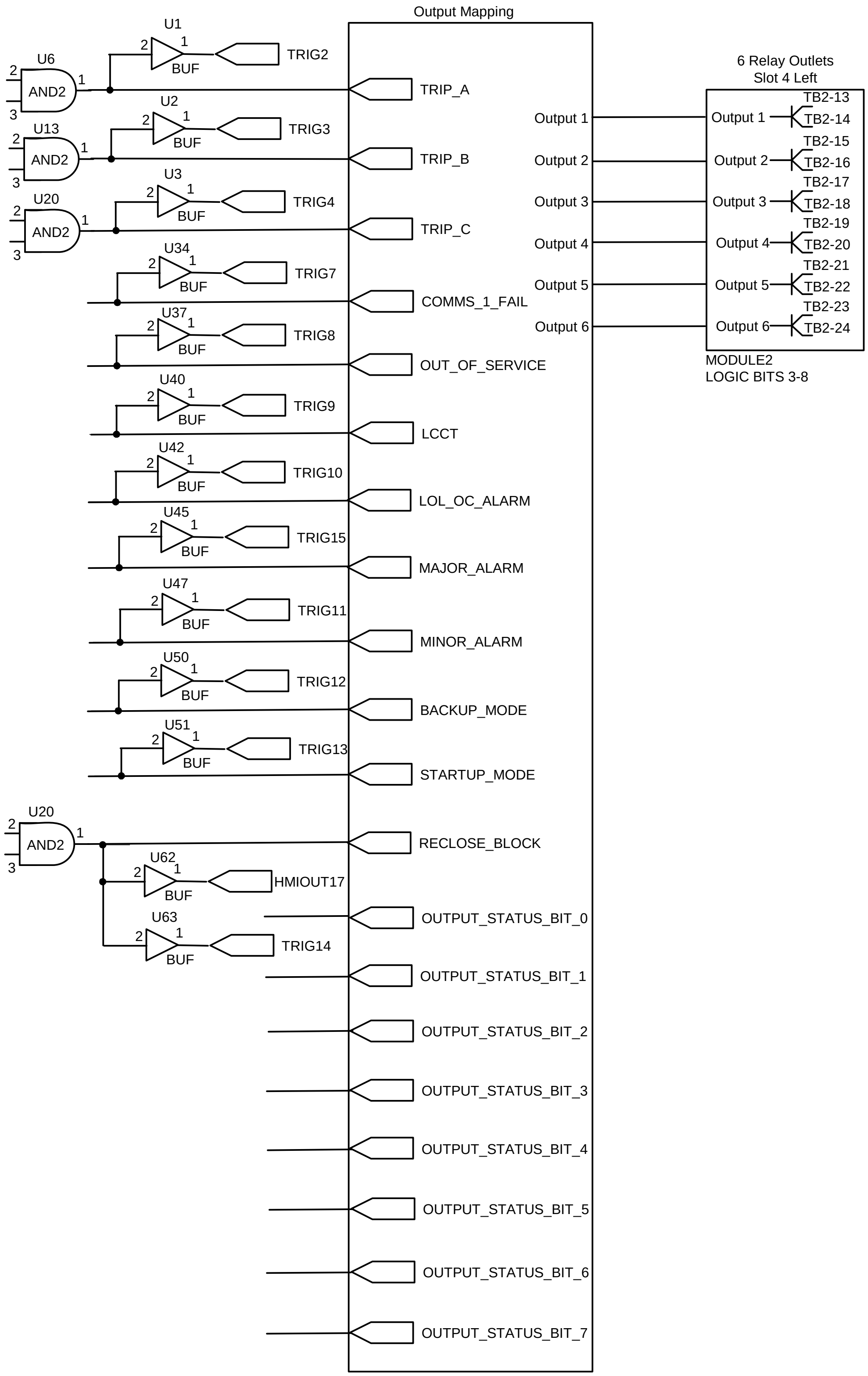

Figure 14-11. Current Differential Outputs, Schematic Diagram

The logical outputs available are defined in the OrCAD logic and can be customized for your application. A logic output can be mapped to a single physical output only, this is why some logic signals are duplicated in the logic. If there is a need for more than two alarm or trip contacts, it can be simply provided by a custom made logic for your needs.

The GARD 8000 System provides 20 user configurable LED’s. Each LED is tri-colored; red, yellow, and green. Each color can individually represent a logic function. In case more than one color is active, red will override yellow and green and yellow will override green.

The current diff relay logic also includes a block named ‘LED MAPPING SIGNALS’. These signals are created for simple mapping to the front panel LED’s. Again, custom made logic can provide other and/or more signals as required.

Each LED function can be given a label. The front panel label can also be custom made by a print-out of the supplied template. While there is limited space for text on the front, the web page user labels can contain up to 32 characters.

14.2.1.2 LOGIC SIGNALS AVAILABLE FROM THE CURRENT DIFFERENTIAL MODULE

The Current Differential Module creates a number of logic signals from its measuring element and protection logic. The GARD 8000 System logic uses these signals to perform trip and pilot scheme operations. The default logic is bringing out some of the available signals, but all of the signals shown in the logic diagrams are available for custom logic.

14.3 RELAY SETTINGS

From the Home Page pull down menu click Settings > Chassis Configuration.

Clicking on the Current Diff. Module will bring up the Current Differential Relay Settings Group web page as shown below.

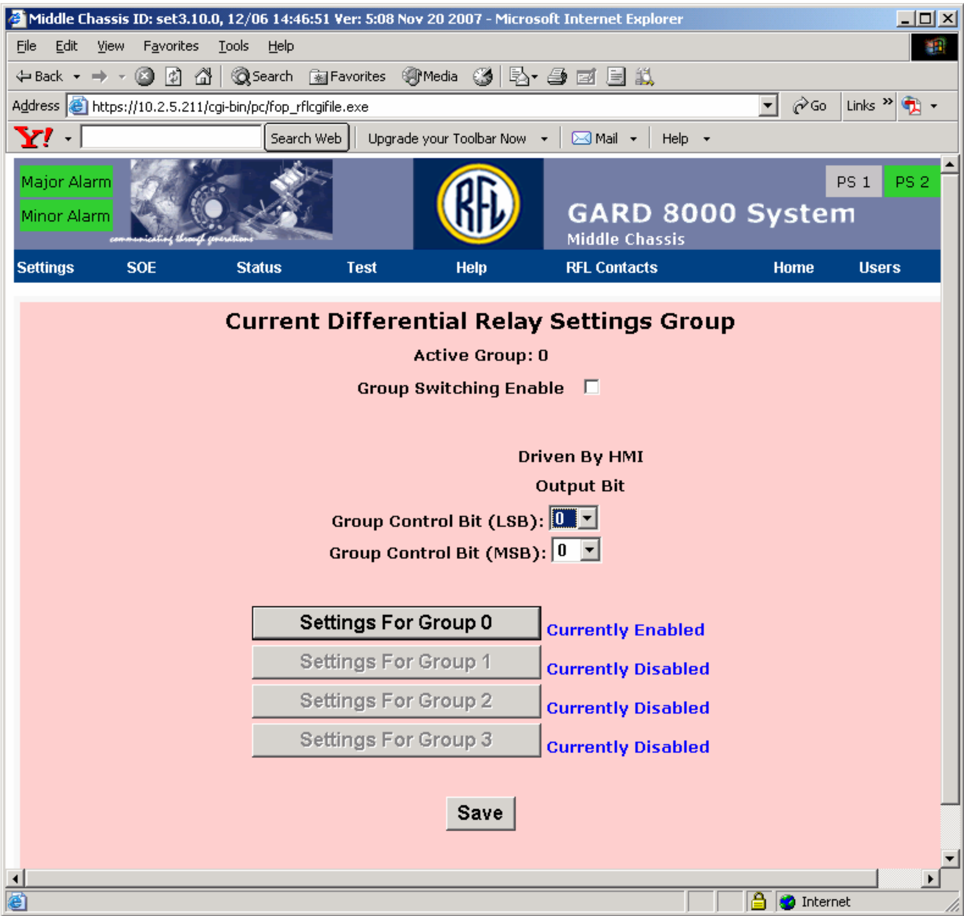

Figure 14-12. Current Differential Relay Settings Group web page

The above web page will allow the user to save up to four different sets of Current Differential settings (Groups 0 thru 3). Once set, these groups can be changed "on the fly" to react to various operating conditions removing the need to change web pages. Check "Group Switching Enable" to enter the group switching mode. By default Group Switching is disabled and settings for Group 0 is enabled, if necessary consult RFL before making any changes.

The separate groups of settings are stored on the Control Module and driven from the HMI logic output based on the value of the HMI output bits selected. Values from 1 to 63 are available in the drop down menus for the most and least significant bit.

MSB	LSB	Group
0	0	0
0	1	1
1	0	2
1	1	3

Clicking on "Settings for Group 0" will bring up the following web page, click "Save" after each group is configured.

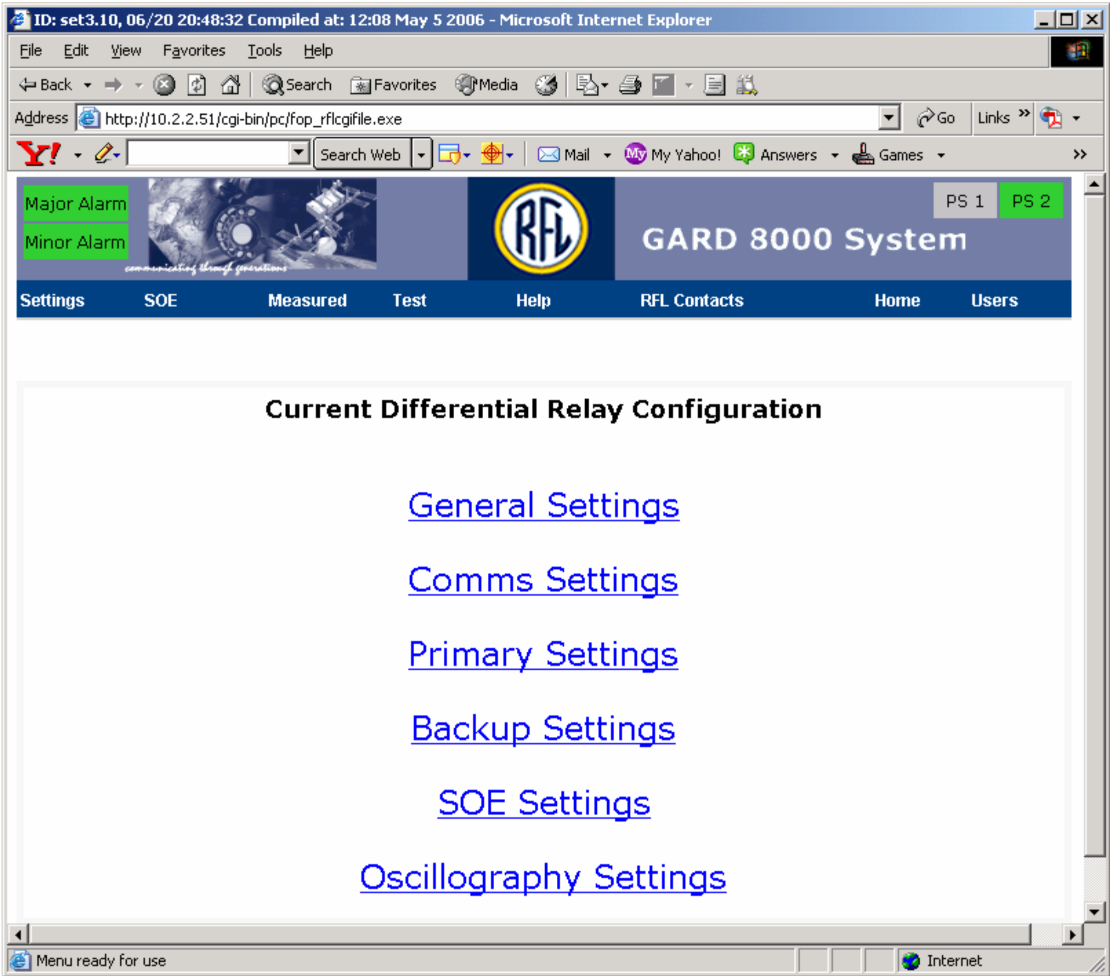

Figure 14-13. Current Differential Relay Configuration

Each of the above web pages can be configured by the end user. In many cases the Current Differential Module comes pre-configured from the factory. RFL recommends that the Supervising Engineer carefully review the following information and if necessary consult RFL before making any changes.

14.3.1 GENERAL SETTINGS

The following pages list the various settings with their definitions. **If changes are made click the "Save" button to save your configuration, a conformation page will appear.**

The General Settings web page is shown below.

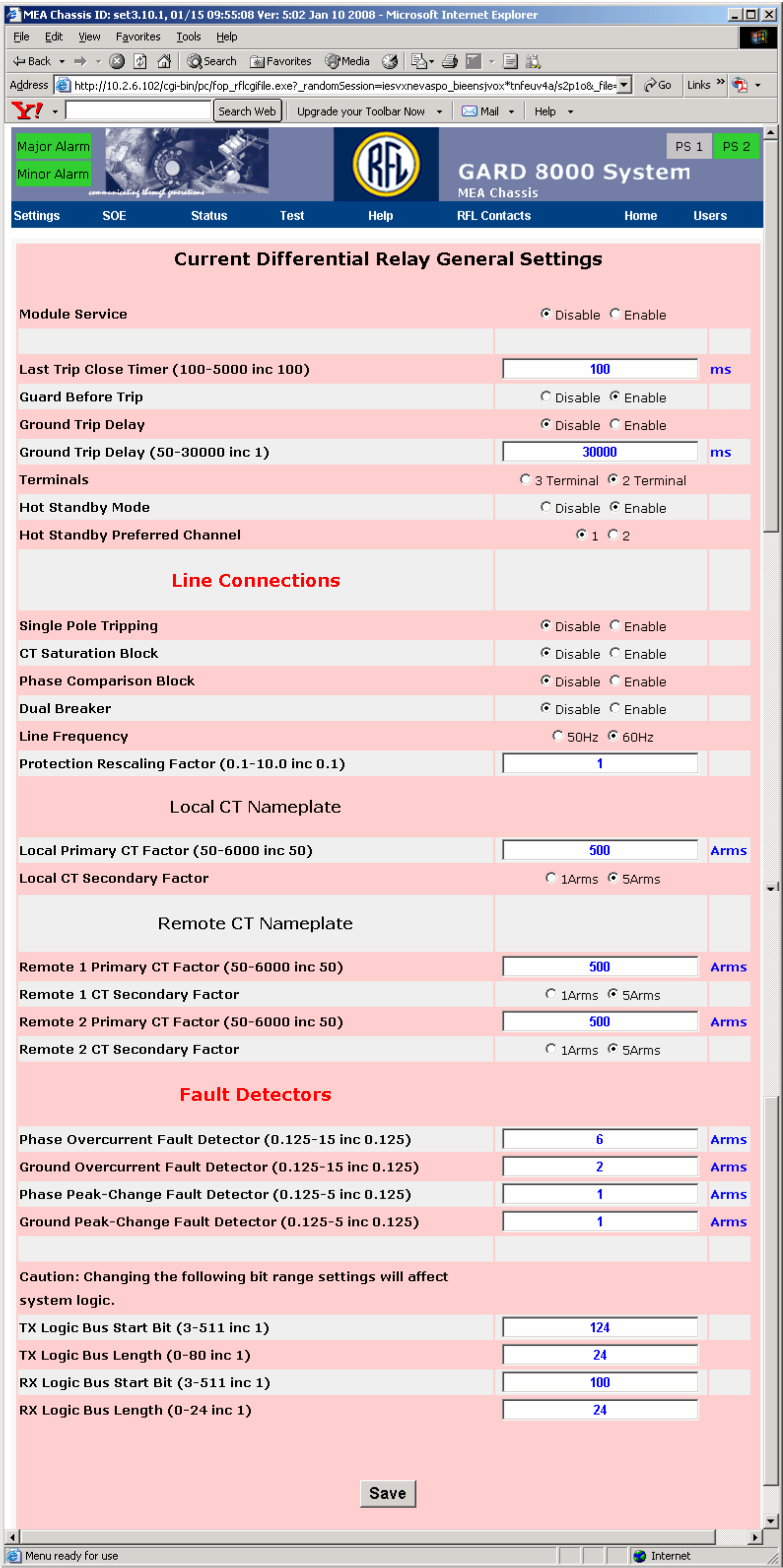

Figure 14-14. Current Differential Relay General Settings

General Settings Definitions:

Module Service

This enables or disables the module. When disabled it is removed from the logic and communications busses.

Last Trip Close Timer (100-5000 inc 100)

This timer is used for the last trip function (section 14.4.6). This sets the time the relay must be in a non-tripped condition in order to close a trip event and make the information available in the last trip status page.
The setting must be between 100ms and 5s (inclusive) in increments of 100ms.

Guard Before Trip

This enables or disables the guard before trip function. The guard before trip function adds an extra level of security to the permissive trip functions of the relay by requiring a clean and stable communications channel prior to allowing any trip messages through. This function may be disabled if the speed of reestablishing protection is more important than the added security the feature provides.

Ground Trip Delay

This enables or disables the ground trip delay function (see below).

Ground Trip Delay (1-30000 inc 1)

This sets the delay for the ground tripping function when enabled (see above). This delay prevents a ground trip just after the breaker closes. When the ground phase calculates a trip the issuing of the trip command may be delayed in order to allow other elements to clear the fault.
The delay may be set between 1ms and 30s (inclusive) in increments of 1ms.

Terminals

This enables or disables terminal 2 or 3.

Hot Standby Mode

This enables a backup Comms Channel.

Hot Standby Preferred Channel

Check to select channel 1 or 2 for Hot Standby Mode. Note that hot standby will communicate on the selected channel until that channel fails and then switch to the unselected channel.

Line Connections

Single Pole Tripping

For relays purchased with the single pole option this is used to enable or disable the single pole features. Disabling single pole makes the relay function as a three pole relay.
Note: Minor Alarm on Trip Disabled.
If tripping is disabled this enable will cause a minor alarm.

CT Saturation Block

When enabled this function will detect CT errors during external faults. When such an error is detected, outfeed operation in blocked for 250ms in 60Hz mode and 300ms in 50Hz mode.

Phase Comparison Block

Check to enable blocking of trips when the remote and local currents remain 180 degrees out of phase.

Dual Breaker

Check to enable dual breaker option. This only has effect when a second relay I/O is installed. When enabled, tripping will be blocked when an external dual breaker fault is detected.

Line Frequency

The user must select either 50Hz or 60Hz line frequency.

Protection Rescaling Factor (0.1-10.0 inc 0.1)

The current measurements used for the protection algorithms are internally adjusted to a normalized scale based upon the CTs; however, in rare occasions the automatic normalization factors need to be adjusted. The protection current measurements are divided by the protection rescaling factor prior to being processed by the algorithms. In most applications this parameter should be left at 1.0 and should only be changed following consultation with RFL.
The protection rescaling factor must be between 0.1 and 10 (inclusive) in increments of 0.1. The protection rescaling factor must be set to the same value in both relays.

Local CT Nameplate

Local Primary CT Factor (50-6000 inc 50)

The user must set the primary CT factor from the nameplate rating. The acceptable range is 50 to 6000 (inclusive) in increments of 50.

Local CT Secondary Factor

The user must select the secondary factor for the CT. The available options are $1A_{RMS}$ and $5A_{RMS}$.

Remote CT Nameplate

Remote 1 and 2 Primary CT Factor (50-6000 inc 50)

The user must set the primary CT factor from the nameplate rating. The acceptable range is 50 to 6000 (inclusive) in increments of 50.

Remote 1 and 2 CT Secondary Factor

The user must select the secondary factor for the CT. The available options are $1A_{RMS}$ and $5A_{RMS}$.

Fault Detectors

Phase Overcurrent Fault Detector (0.125-15 inc 0.125)

This is used to set the threshold for the overcurrent fault detectors for phase A, B, and C. The setting must be between $0.125A_{RMS}$ and $20A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
See section 14.5.1.1.1 for further information.

Ground Overcurrent Fault Detector (0.125-15 inc 0.125)

This is used to set the threshold for the overcurrent fault detector for ground. The setting must be between $0.125A_{RMS}$ and $20A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
See section 14.5.1.1.1 for further information.

Phase Peak-Change Fault Detector (0.125-5 inc 0.125)

This is used to set the threshold for the peak-change fault detectors for phase A, B, and C. The setting must be between 0.125A_{RMS} and 20A_{RMS} (inclusive) in increments of 0.125A_{RMS}.
See section 14.5.1.1.2 for further information.

Ground Peak-Change Fault Detector (0.125-5 inc 0.125)

This is used to set the threshold for the peak-change fault detector for phase A, B, and C. The setting must be between 0.125A_{RMS} and 20A_{RMS} (inclusive) in increments of 0.125A_{RMS}.

TX Logic Bus Start Bit (3-511 inc 1)

Sets the beginning position of the TX logic bus time-slot. Allowed values are between 3 and 511 in increments of 1. TX logic bus time-slot refers to data driven onto the logic bus by the current diff module. This value is detected by the logic.

TX Logic Bus Length (0-80 inc 1)

Sets the length of the TX logic bus time-slot.

RX Logic Bus Start Bit (3-511 inc 1)

Sets the beginning position of the RX logic bus time-slot. RX logic bus time-slot refers to data retrieved from the logic bus by the current diff module. This value is detected by the logic.

RX Logic Bus Length (0-24 inc 1)

Sets the length of the TX logic bus time-slot.
See section 14.5.1.1.2 for further information.

After all the settings have been entered click the "Save" button to save your configuration, a conformation page will appear.

14.3.2 COMMUNICATIONS SETTINGS

The Comms Settings web page is shown below.

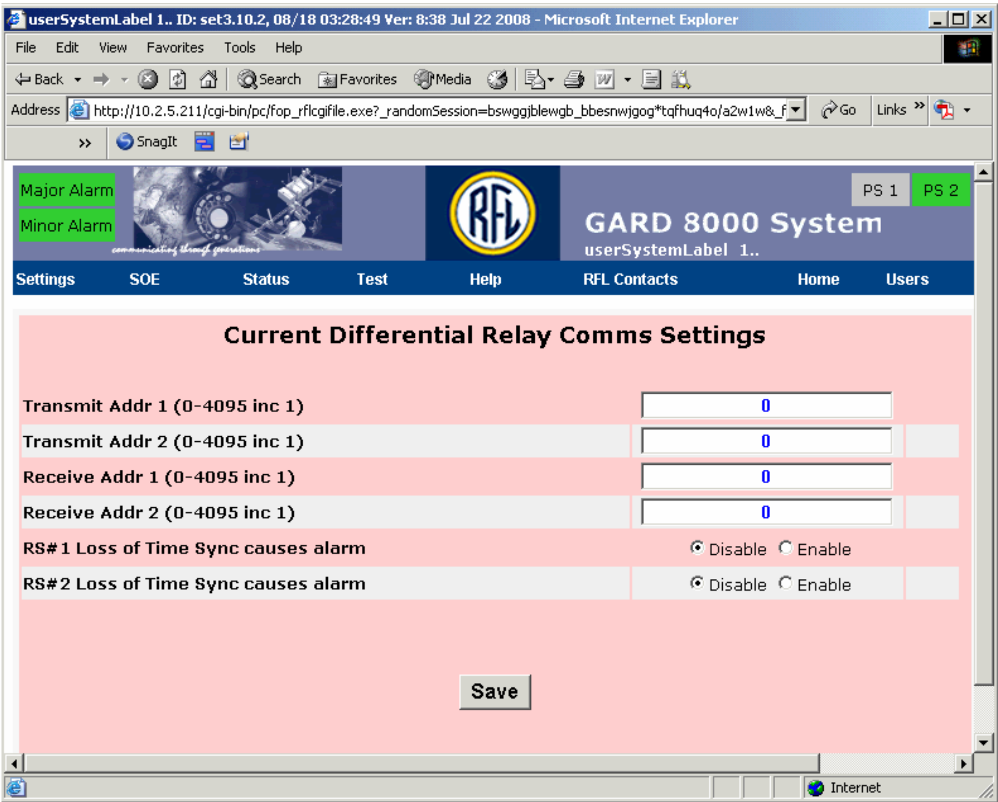

Figure 14-15. Current Differential Relay Comms Settings

Comms Settings Definitions:

Transmit Addr 1 or 2 (0-4095 inc 1)

This sets the transmit address for communications channel 1 and/or 2. It may be from 0 to 4095 in increments of 1. The transmit address setting at the local relay must match the receive address setting at the remote relay for communications to take place.
This prevents inadvertent communications network cross-connects from creating incorrect relay links.

Receive Addr 1 or 2 (0-4095 inc 1)

This sets the receive address for communications channel 1 and/or 2. It may be from 0 to 4095 in increments of 1. The transmit address setting at the local relay must match the receive address setting at the remote relay for communications to take place.
This prevents inadvertent communications network cross-connects from creating incorrect relay links.

RS# 1 or 2 Loss of Time Sync causes alarm

Enable to give a minor alarm if the remote station and local real-time clocks are not synchronized. The default is disabled.

14.3.3 PRIMARY SETTINGS

The Primary Settings web page is shown below.

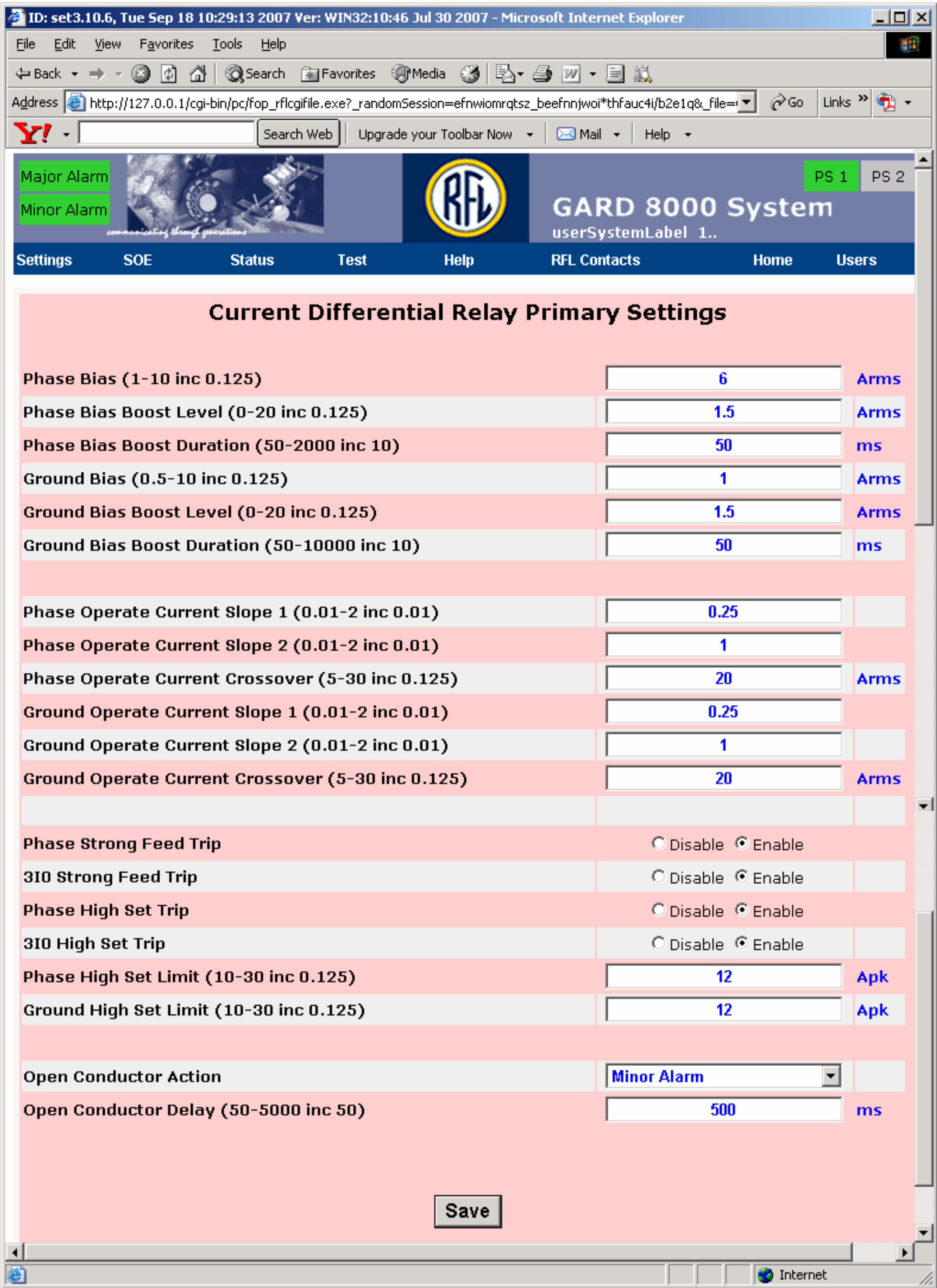

Figure 14-16. Current Differential Relay Primary Settings

Primary Settings Definitions:

Phase Bias (1-10 inc 0.125)

This sets the bias for phase A, B, and C. The setting must be between $0.5A_{RMS}$ and $10A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The bias is the minimum operate level for the current differential algorithms. The operate level can increase for a period following breaker closing (bias boost, section 14.5.1.2.7) or based upon the measured currents in the system (slope characteristic, section 14.5.1.2.8).

Phase Bias Boost Level (0-20 inc 0.125)

This sets the bias boost for phase A, B, and C. The setting must be between $0A_{RMS}$ and $20A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The bias boost increases the operate level for the current differential algorithms for a user programmable duration following breaker closing (see bias boost duration below). Setting this parameter to zero effectively disables it.
For further information see section 14.5.1.2.7.

Phase Bias Boost Duration (50-2000 inc 10)

This sets the duration of bias boost for phase A, B, and C. The setting must be between 50ms and 2s (inclusive) in 10ms increments. Following a breaker closing the operate level for the current differential algorithms is increased by the bias boost setting (see above) for the duration set with this parameter.
For further information see section 14.5.1.2.7.

Ground Bias (0.5-10 inc 0.125)

This sets the bias for ground. The setting must be between $0.5A_{RMS}$ and $10A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The bias is the minimum operate level for the current differential algorithms. The operate level can increase for a period following breaker closing (bias boost, section 14.5.1.2.7) or based upon the measured currents in the system (slope characteristic, section 14.5.1.2.8).

Ground Bias Boost Level (0-20 inc 0.125)

This sets the bias boost for ground. The setting must be between $0A_{RMS}$ and $20A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The bias boost increases the operate level for the current differential algorithms for a user programmable duration following breaker closing (see bias boost duration below). Setting this parameter to zero effectively disables it.
For further information see section 14.5.1.2.7.

Ground Bias Boost Duration (50-10000 inc 10)

This sets the duration of bias boost for ground. The setting must be between 50ms and 2s (inclusive) in 10ms increments. Following a breaker closing the operate level for the current differential algorithms is increased by the bias boost setting (see above) for the duration set with this parameter.
For further information see section 14.5.1.2.7.

Phase Operate Current Slope 1 (0.01-2 inc 0.01)

This sets the slop for the first segment of the operate level slope characteristic for phase A, B, and C. The setting must be between 0 and 2 (inclusive) in increments of 0.01. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Phase Operate Current Slope 2 (0.01-2 inc 0.01)

This sets the slop for the second segment of the operate level slope characteristic for phase A, B, and C. The setting must be between 0 and 2 (inclusive) in increments of 0.01. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Phase Operate Current Crossover (5-30 inc 0.125)

This sets the transition point between the first and second slope segments of the operate level slope characteristic for phase A, B, and C. The setting must be between $5A_{RMS}$ and $30A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Ground Operate Current Slope 1 (0.01-2 inc 0.01)

This sets the slop for the first segment of the operate level slope characteristic for ground. The setting must be between 0 and 2 (inclusive) in increments of 0.01. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Ground Operate Current Slope 2 (0.01-2 inc 0.01)

This sets the slop for the second segment of the operate level slope characteristic for ground. The setting must be between 0 and 2 (inclusive) in increments of 0.01. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Ground Operate Current Crossover (5-30 inc 0.125)

This sets the transition point between the first and second slope segments of the operate level slope characteristic for ground. The setting must be between $5A_{RMS}$ and $30A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$. The operate level slope characteristic increases the operate level based upon the currents measured by both relays. This is used to desensitize the relay with increasing current to allow for cumulative system errors such as CT nonlinearities.
For further information see section 14.5.1.2.8.

Phase Strong Feed Trip

This is used to enable or disable the strong feed trip (SFT) function in the relay see section xxx.

3I0 Strong Feed Trip

This is a separate enable for 3I0 strong feed trips.

Phase High Set Trip

This is used to enable or disable the high set trip function in the relay.

3I0 High Set Trip

This is a separate enable for the 3I0 high set trips.

Phase High Set Limit (5-30 inc 0.125)

This sets the threshold for the HST routines for phase A, B and C. The setting must be between $5A_{PEAK}$ and $30A_{PEAK}$ (inclusive) in increments of $0.125A_{PEAK}$. The HST routines provide a very quick tripping mechanism for high internal fault currents.
For further information see section 14.5.1.4.

Ground High Set Limit (5-30 inc 0.125)

This sets the threshold for the HST routine for ground. The setting must be between $5A_{PEAK}$ and $30A_{PEAK}$ (inclusive) in increments of $0.125A_{PEAK}$. The HST routines provide a very quick tripping mechanism for high internal fault currents.
For further information see section 14.5.1.4.

Open Conductor Action

This sets the action to take when an open conductor fault is detected. The user may set the relay to go into minor or major alarm, or to disable the function. This function is automatically disabled in single-pole / selective-pole relays.
For further information see section 14.5.1.5.

Open Conductor Delay (50-5000 inc 50)

This sets the delay for the open conductor algorithm. The setting must be between 50ms and 5s (inclusive) in increments of 50ms.
For further information see section 14.5.1.5.

14.3.4 BACKUP PROTECTION SETTINGS

The Backup Settings web page is shown below.

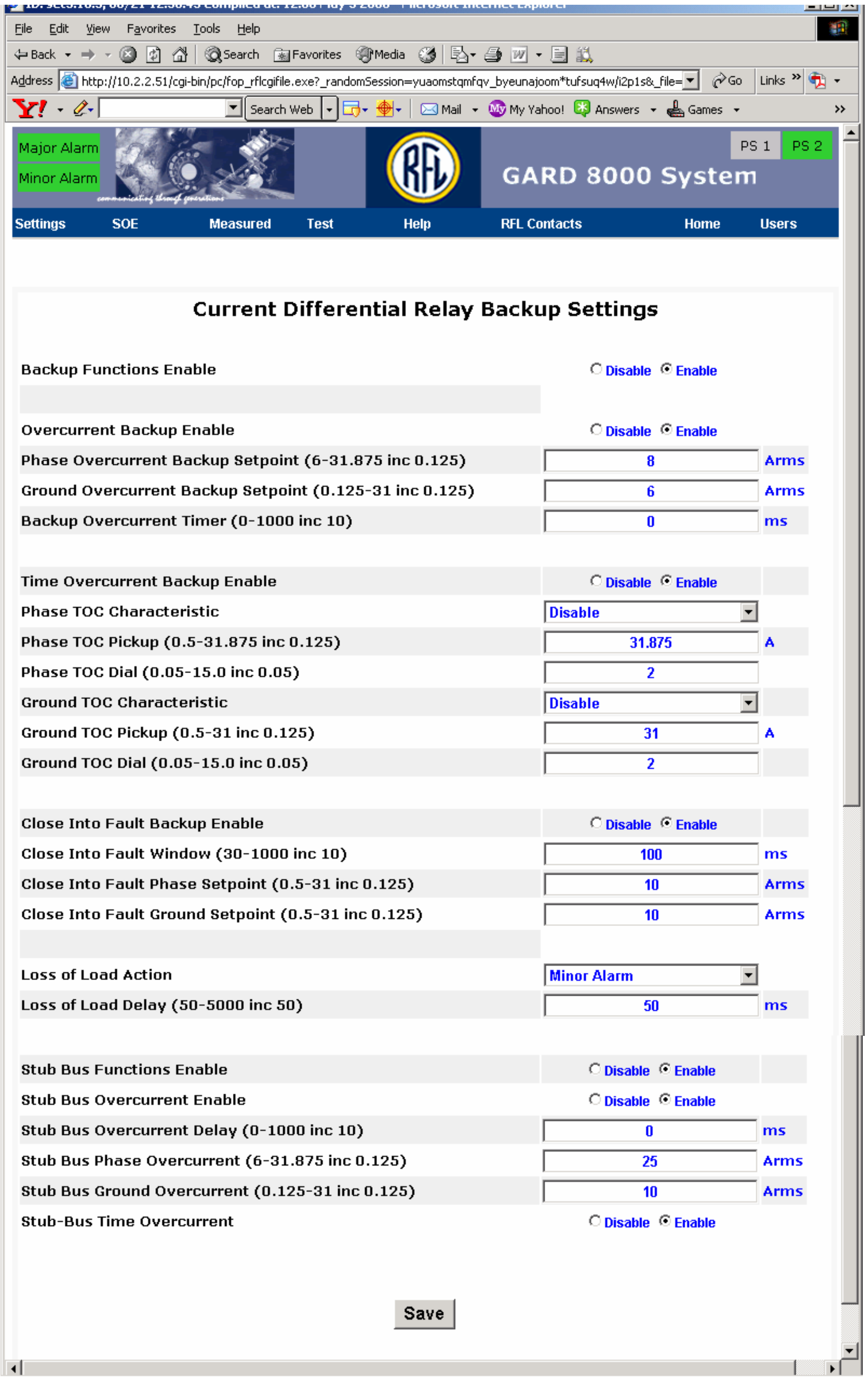

Figure 14-17. Current Differential Relay Backup Settings

Backup Settings Definitions:

Backup Functions Enable

This is used to enable or disable all backup functions in the relay (see section 14.5.1.6).

Overcurrent Backup Enable

This is used to enable or disable the overcurrent backup function in the relay (see section 14.5.1.6).

Phase Overcurrent Backup Setpoint (6-31.875 inc 0.125)

This sets the threshold for the overcurrent backup algorithm for phase A, B, and C. The setting must be between $6A_{RMS}$ and $31.875A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
For further information see section 14.5.1.6.

Ground Overcurrent Backup Setpoint (0.125-31 inc 0.125)

This sets the threshold for the overcurrent backup algorithm for ground. The setting must be between $0.125A_{RMS}$ and $31A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
For further information see section 14.5.1.6.

Backup Overcurrent Timer (0-1000 inc 10)

This sets the timer for the overcurrent backup algorithm for both the three phases and ground. The setting must be between 0ms and 1s (inclusive) in increments of 10ms.
For further information see section 14.5.1.6.

Time Overcurrent Backup Enable

This enables or disables the TOC functions for both the three phases and ground.
For further information see section 14.5.1.6.2.

Phase TOC Characteristic

This selects which TOC characteristic curve to use for phase A, B, and C. There are four USA curves and three IEC curves supported.
For further information see section 14.5.1.6.2.

Phase TOC Pickup (0.5-31.875 inc 0.125)

This selects the TOC pickup current for phase A, B, and C. The setting must be between $0.5A_{RMS}$ and $31.875A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
For further information see section 14.5.1.6.2.

Phase TOC Dial (0.05-15.0 inc 0.05)

This selects the TOC time dial for phase A, B, and C. The setting must be between 0.05 and 15 (inclusive) in increments of 0.05.
For further information see section 14.5.1.6.2.

Ground TOC Characteristic

This selects which TOC characteristic curve to use for ground. There are four USA curves and three IEC curves supported.
For further information see section 14.5.1.6.2.

Ground TOC Pickup (0.5-31 inc 0.125)

This selects the TOC pickup current for ground. The setting must be between 0.5A_{RMS} and 31.875A_{RMS} (inclusive) in increments of 0.125A_{RMS}.
For further information see section 14.5.1.6.2.

Ground TOC Dial (0.05-15.0 inc 0.05)

This selects the TOC time dial for ground. The setting must be between 0.05 and 15 (inclusive) in increments of 0.05.
For further information see section 14.5.1.6.2.

Close Into Fault Backup Enable

This is used to enable or disable the Close Into Fault (CIF) backup function in the relay (see section 14.5.1.6.3).

Close Into Fault Window (30-1000 inc 10)

This sets the CIF window for both the three phases and ground. The setting must be between 30ms and 1s (inclusive) in increments of 10ms. The current must exceed the setpoint (see below) within this specified time window in order for the relay to trip. If tripped the relay output will deactivate when the timer window is exceeded.
For further information see section 14.5.1.6.3.

Close Into Fault Phase Setpoint (0.5-31 inc 0.125)

This sets the CIF setpoint for phase A, B, and C. The setting must be between 0.5A_{RMS} and 31A_{RMS} (inclusive) in increments of 0.125A_{RMS}. The current must exceed the setpoint for approximately one full cycle within the specified time window (see above) in order for the relay to trip. If tripped the relay output will deactivate when the timer window is exceeded.
For further information see section 14.5.1.6.3.

Close Into Fault Ground Setpoint (0.5-31 inc 0.125)

This sets the CIF setpoint for ground. The setting must be between 0.5A_{RMS} and 31A_{RMS} (inclusive) in increments of 0.125A_{RMS}. The current must exceed the setpoint for approximately one full cycle within the specified time window (see above) in order for the relay to trip. If tripped the relay output will deactivate when the timer window is exceeded.
For further information see section 14.5.1.6.3.

Loss of Load Action

This sets the action to take when a Loss of Load (LOL) fault is detected. The user may set the relay to go into minor or major alarm, or to disable the function. This function is automatically disabled in single-pole / selective-pole relays.
For further information see section 14.5.1.6.4.

Loss of Load Delay (50-5000 inc 50)

This sets the delay for the LOL algorithm. The setting must be between 50ms and 5s (inclusive) in increments of 50ms.
For further information see section 14.5.1.6.4.

Stub Bus Functions Enable

This enables or disables all of the stub bus features of the relay (see section 14.5.1.6.5).

Stub Bus Overcurrent Enable

This is used to enable or disable the stub bus overcurrent function in the relay (see section 14.5.1.6.5).

Stub Bus Overcurrent Delay (0-1000 inc 10)

This sets the timer for the stub bus overcurrent algorithm for both the three phases and ground. The setting must be between 0ms and 1s (inclusive) in increments of 10ms.
For further information see section 14.5.1.6.5.

Stub Bus Phase Overcurrent (6-31.875 inc 0.125)

This sets the threshold for the overcurrent backup algorithm for phase A, B, and C. The setting must be between $6A_{RMS}$ and $31.875A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
For further information see section 14.5.1.6.5.

Stub Bus Ground Overcurrent (0.125-31 inc 0.125)

This sets the threshold for the overcurrent backup algorithm for ground. The setting must be between $0.125A_{RMS}$ and $31A_{RMS}$ (inclusive) in increments of $0.125A_{RMS}$.
For further information see section 14.5.1.6.5.

Stub Bus Time Overcurrent

This is used to enable or disable the stub bus TOC functions in the relay. When enabled they use the same TOC configuration settings as the backup TOC routines (see section 14.5.1.6.2).

14.3.5 SEQUENCE OF EVENTS (SOE) SETTINGS

The following 2 web pages are used for reporting data; the triggers can be toggled on or off.

The SOE Settings web page is shown below.

Figure 14-18. Current Differential Relay SOE Settings

SOE Settings Definitions:

Fault Detectors

Setting this to "Yes" will allow the fault detectors to trigger a SOE recording. A change of state (becoming active or inactive) in any of the fault detectors for any phase or ground will initiate an SOE recording.

External Dual Breaker Fault

Setting this to "Yes" will allow detection of an external dual breaker fault to initiate an SOE recording. See section 14.5.1.1.7

Major Alarm

Setting this to "Yes" will allow the major alarm to trigger a SOE recording. A change of state (becoming active or inactive) in the major alarm will initiate an SOE recording. See section 14.5.2.4 for further information.

Minor Alarm

Setting this to "Yes" will allow the minor alarm to trigger a SOE recording. A change of state (becoming active or inactive) in the minor alarm will initiate an SOE recording. See section 14.5.2.5 for further information.

Curr Diff Alarm

Setting this to "Yes" will allow the current differential alarm to trigger a SOE recording. A change of state (becoming active or inactive) in the current differential alarm will initiate an SOE recording. See section 14.5.1.2.11 for further information.

Comms Enable

Setting this to "Yes" will allow a change in state in the comms to trigger an SOE record (becoming inactive).

Ping-Pong Alarm

Setting this to "Yes" will allow the ping-pong alarm to trigger a SOE recording. A change of state (becoming active or inactive) in the ping-pong alarm will initiate an SOE recording. See section 14.5.2.6.4 for further information.

Address Failure

The relay verifies communications with the proper remote relay using an addressing scheme (see section 14.5.2.6.1). Setting this to "Yes" will allow an address failure (or recovery from an address failure) to trigger an SOE recording.

Comms Failure

Setting this to "Yes" will allow the communications failure flag to trigger a SOE recording. A change of state (becoming active or inactive) in the communications failure flag will initiate an SOE recording. See section 14.5.2.6.3 for further information.

Remote # 1 Fault Detector

Setting this to "Yes" will allow a change in the status of the remote # 1 relays fault detector, triggering an SOE recording.

Remote # 2 Fault Detector

Setting this to "Yes" will allow a change in the status of the remote # 2 relay fault detector, triggering an SOE recording.

Remote # 1 TCTD

Setting this to "Yes" will allow the receipt of a TCDT message from the remote # 1 relay triggering an SOE recording.

Remote # 2 TCTD

Setting this to "Yes" will allow the receipt of a TCDT message from the remote # 2 relay triggering an SOE recording.

Remote # 1 HST

Setting this to "Yes" will allow the receipt of a HST message from the remote # 1 relay to triggering an SOE recording.

Remote # 2 HST

Setting this to "Yes" will allow the receipt of a HST message from the remote # 2 relay to triggering an SOE recording.

Transmit HST

Setting this to "Yes" will allow the transmitted HST message to trigger an SOE recording.

Input - 89B

Setting this to "Yes" will allow the Logic Bus signal representing the 89B input to trigger a SOE recording. A change of state (becoming active or inactive) in the 89B input (after being qualified by the timer in the controller's logic processing) will initiate an SOE recording.

Input - Trip Disable

Setting this to "Yes" will allow the Logic Bus signal representing the Trip Disable to trigger a SOE recording. A change of state of the Trip Disable input will initiate an SOE recording.

Input – DTT to Remote 1

Setting this to "Yes" will allow the logic bus signal representing the DTT to remote terminal 1 to trigger an SOE recording. A change of state of the DTT to remote 1 input will also initiate an SOE recording.

Input – DTT to Remote 2

Setting this to "Yes" will allow the logic bus signal representing the DTT to remote terminal 2 to trigger an SOE recording. A change of state of the DTT to remote 2 input will also initiate an SOE recording.

Input - Transferred Status # 0 through # 7

Setting this to "Yes" will allow the Logic Bus signals representing the Tx Transferred Status input bits to trigger a SOE recording. A change of state of the logic bus bit will initiate an SOE recording. Note that these bits are inputs to the relay, the relay will transmit the information to the remote relay (hence "Tx" bits).
See section 14.5.2.7 for more information.

Output - Out of Service

Setting this to “Yes” will allow the Logic Bus signals representing the out of service flag output bit to trigger a SOE recording. A change of state of the bit will initiate an SOE recording. The relay may be out of service if it has been disabled by the user, is in the process of initializing, or has taken itself out of service due to a detected problem.

Output - Phase Loss

Setting this to “Yes” will allow the Logic Bus signals representing the phase loss output bit to trigger a SOE recording. A change of state of the bit will initiate an SOE recording.

Output – DTT from Remote 1

Setting this to “Yes” will allow the logic bus signal representing the DTT from remote terminal 1 to trigger an SOE recording. A change of state of the DTT from remote 1 output will also initiate an SOE recording.

Output – DTT from Remote 2

Setting this to “Yes” will allow the logic bus signal representing the DTT from remote terminal 2 to trigger an SOE recording. A change of state of the DTT from remote 2 output will also initiate an SOE recording.

Output - Transferred Status # 0 through #7

Setting this to “Yes” will allow the Logic Bus signals representing the Rx Transferred Status output bits to trigger a SOE recording. A change of state of the logic bus bit will initiate an SOE recording. Note that these bits are outputs from the relay, the relay has received the information from the remote relay (hence “Rx” bits).

See section 14.5.2.7 for more information.

14.3.6 OSCILLOGRAPHY SETTINGS

The Oscillography Settings web page is shown below.

Figure 14-19. Current Differential Relay Oscillography Settings

Oscillography Settings Definitions – Configuration:

Oscillography Duration (10-180 inc 1)

This sets the length of each oscillography recording in units of cycles. The setting must be between 10 cycles and 600 cycles (inclusive) in increments of 1. The length selected for each oscillography recording will impact the total number of recordings that can be saved in the system. Changing this parameter will cause all previously recorded oscillography records to be erased.
See section 14.6.2.1 for further information.

Oscillography Pre-Trigger (0-180 inc 1)

This sets the length of pre-trigger data to be recorded for each oscillography recording. The setting must be between 0 cycles and 300 cycles (inclusive) in increments of 1. If the setting exceeds the oscillography duration setting (see above) the relay will save the entire recording as pre-trigger data. Changing this parameter will cause all previously recorded oscillography records to be erased.
For further information see section 14.6.2.2.

Oscillography Settings Definitions – Triggers:

The user may configure which signals within the relay will cause an oscillography recording to be initiated.
In addition to the user selectable triggers the design of the relay sets all trips as valid oscillography triggers. Thus, a change of state (becoming active or inactive) in any primary tripping element (see sections 14.5.1.2 through 14.5.1.5) or backup element (see sections 14.5.1.6 through 14.5.1.6.5) for any phase or ground that will initiate an oscillography recording.

14.4 CURRENT DIFFERENTIAL RELAY STATUS

From the Home page select Current Differential; a webpage similar to the one shown below will appear.

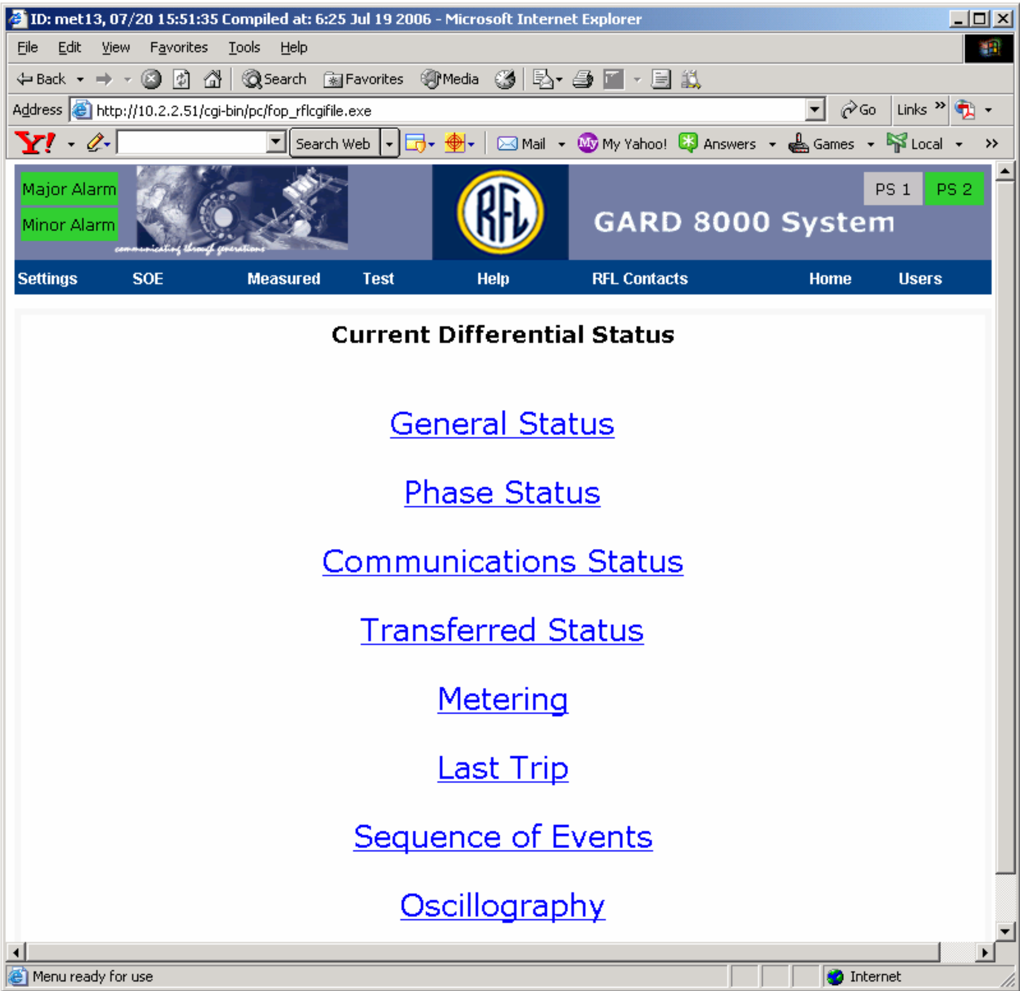

Figure 14-20. Current Differential Relay Status

14.4.1 GENERAL STATUS

The General Status web page is shown below.

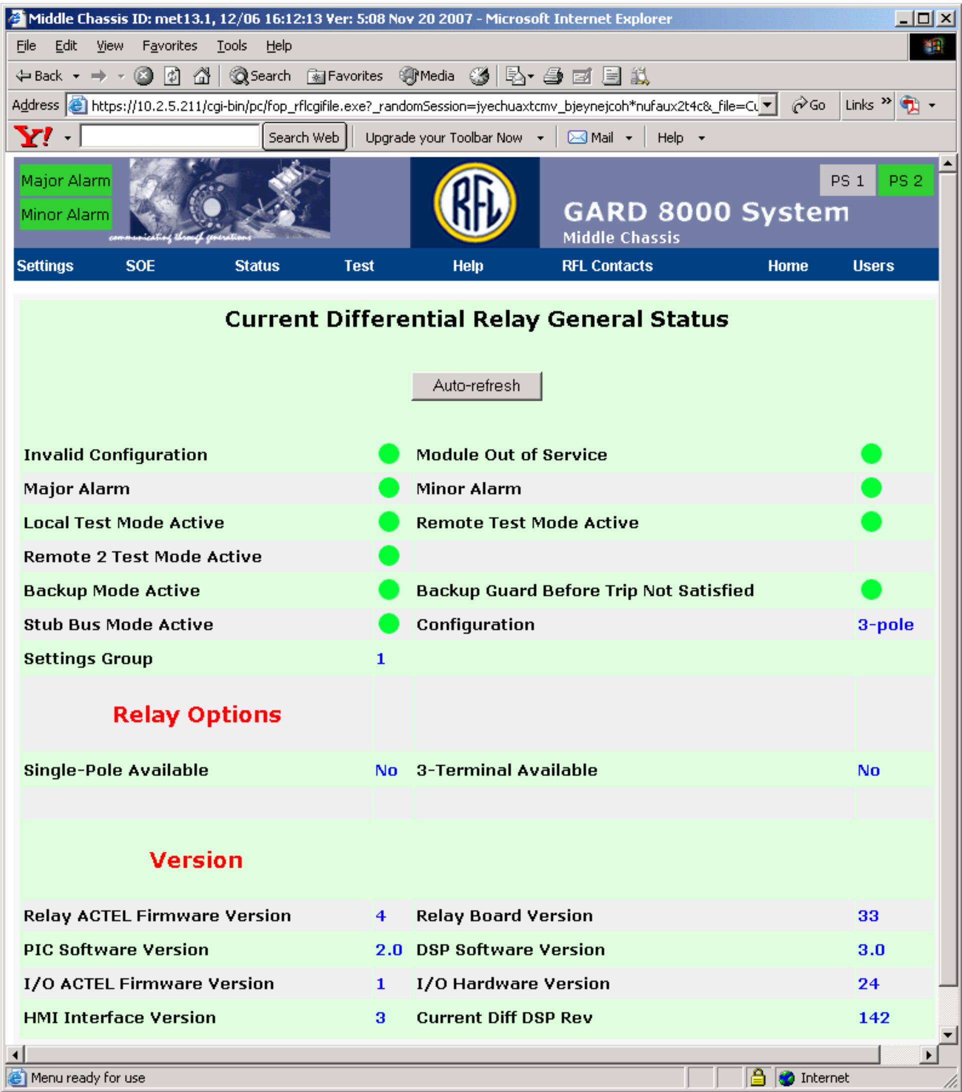

Figure 14-21. Current Differential Relay General Status webpage

General Status Definitions:

Invalid Configuration

When red this indicates that the module has received an invalid configuration message from the controller and rejected it. If the module had previously received a valid configuration it will continue to use the previous configuration.
Green indicates the last configuration was valid.

Module Out of Service

When red this indicates the module is not in service. This could be because the module has been disabled by the user, the module is in the process of initializing, it has not received a valid configuration, or it has detected a hardware problem and taken itself out of service. Green indicates the module is in service.

When a module is out of service it does not provide any protection functions and does not drive either the communications or logic busses in the GARD system.

Major Alarm

When red this indicates that the module has an active major alarm (see section 14.5.2.4). Green indicates the absence of a major alarm.

Minor Alarm

When red this indicates that the module has an active minor alarm (see section 14.5.2.5). Green indicates the absence of a minor alarm.

Local Test Mode Active

When red this indicates that the local relay is in test mode (see section 14.5.2.1). Green indicates that the local relay is not in test mode.

Remote Test Mode Active

When red this indicates that the remote relay #1 is in test mode (see section 14.5.2.1). Green indicates that the remote relay #1 is not in test mode.

Remote 2 Test Mode Active

When red this indicates that the remote relay # 2 is in test mode (see section 14.5.2.1). Green indicates that the remote relay #2 is not in test mode.

Backup Mode Active

When red this indicates that the relay is in backup mode (see section 14.5.1.6). Green indicates that the relay is not in backup mode.

Backup Guard Before Trip Not Satisfied

When red this indicates that the backup guard before trip criteria has not been satisfied and the relay will not trip in backup mode. Green indicates that either the criteria have been satisfied or guard before trip has been disabled by the user.

Stub Bus Mode Active

When red this indicates that the relay is in stub bus mode (see section 14.5.1.6.5). Green indicates that the relay is not in stub bus mode.

Configuration

This will indicate if the relay is configured for single pole (“1-pole”) or three pole (“3-pole”) operation.

Settings Group

This will indicate which settings group status is being displayed.

Relay Options

Single-pole Available

This indicates if the relay was purchased with the single pole option (“yes” or “no”).

Version

As well as informing the user on the health of the Current Diff module this web page will give the installed version of the following components.

Relay ACTEL Firmware Version

Relay Board Version

PIC Software Version

DSP Software Version

I/O ACTEL Firmware Version

I/O Hardware Version

HMI Interface Version

Current Diff DSP Rev

14.4.2 PHASE STATUS

The Phase Status web page is shown below.

Figure 14-22. Current Differential Relay Phase Status webpage

Relay Phase Status Definitions:

Local and Remote Trips

Phase A, B, C, and Ground Active Trip

When red this indicates that the corresponding phase has an active trip. Green indicates the absence of an active trip.

Fault Detectors

Phase A, B, C, Ground, and Remote Fault Detectors

When red this indicates that the corresponding phase has an active fault detector. Green indicates the absence of active fault detectors.

Current Differential Alarms

Current Diff Alarm Phase A, B, C, and Ground

When red this indicates that the corresponding phase has an active current differential alarm (see section 14.5.1.2.11). Green indicates the absence of a current differential alarm.

Phase Loss Alarms

Phase Loss Alarms Phase A, B, and C

Red indicates that the relay has calculated a loss of current in the corresponding phase per the open conductor or loss of load algorithms. Note that if the open conductor or loss of load algorithm is configured by the user to cause a trip the condition will be transient and would not be expected to be seen on the web page. Green indicates the algorithms have not calculated a phase loss condition.

Local and Remote Phase Sequence (deg)

Phase A, B, C, and Ground

The system provides an indication of the relative phasing of the phase currents. The phasing is reported relative to the phase A current (no voltages are applied to the relay, only currents). The data is only valid when the system is in steady-state and there are currents applied to the relay.
The local currents will be displayed as 0º, 120º, 240º or “Error” (not available). The remote currents will be displayed as 180º, 300º, 60º or “Error”.

14.4.3 COMMUNICATIONS STATUS

The Communications Status web page is shown below.

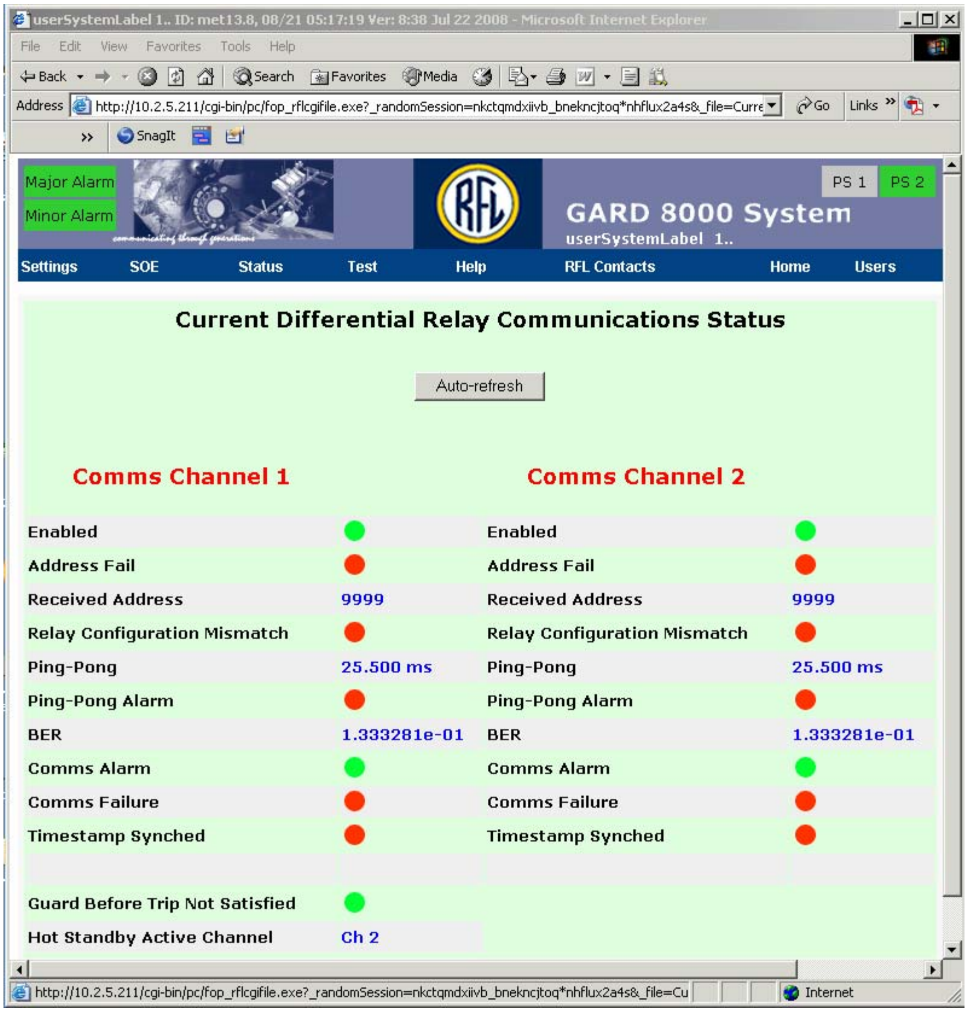

Figure 14-23. Current Differential Relay Communications Status webpage

Relay Communications Status Definitions:

Comms Channel 1 - 2

Enabled

Red will indicate that the channel is not enabled; green indicates that the channel is enabled.

Address Fail

When red this indicates that the address received from the remote relay (set via the transmit address setting on the remote relay) does not match the setting for the received address at the local relay. **No protection messages are passed between relays unless the addresses match.** Green indicates the addresses are correct.

Received Address

This displays the received address from the remote relay (which must match the local settings for receive address). It is displayed to help diagnose addressing problems, which may be caused by network misconnections.

Relay Configuration Mismatch

There are a number of key setup and configuration parameters that need to be the same on both ends of the line being protected. The current diff relay compares these parameters and if they do not match this indicator is set to red. When they match the indicator is set to green.
The parameters that must match include:

- 50 Hz /60 Hz line
- Two-terminal / three terminal relay configuration
- Single-pole / three-pole configuration
- The local and remote CT factor settings in both relays must agree

Pong-Pong

This is the unidirectional channel delay (in ms) as measured by the ping-pong tests. The ping-pong is calculated based on a bidirectional measurement; the displayed result is half of the bidirectional measurement.

Pong-Pong Alarm

When red this indicates that the ping-pong measurements made by the local and remote relays do not match. The ping-pong is a bidirectional measurement and should provide the same result when either relay initiates the test. If the two measurements differ by more than 3 ms the error flag is set.
Green indicates the ping-pong tests are the same.

BER

This is an approximation of the communications channel bit error rate (BER). It is most accurate for modest BER's (between 2E-5 and 8E-3).

Comms Alarm

When red this indicates an alarm condition in the communications channel. Green indicates the absence of an alarm condition.

Comms Failure

When red this indicates a failure in the communications channel. Green indicates the absence of a failure condition.

Timestamp Synched

Red indicates that the real-time clock on the remote system is not synchronized with the local clock. Green indicates that the two clocks are synchronized.

Guard Before Trip Not Satisfied

When red this indicates that the guard before trip criteria has not been satisfied and the relay will not trip in primary protection mode. Green indicates that either the criteria have been satisfied or guard before trip has been disabled by the user.

Hot Standby Active Channel

When red this indicates that the hot standby channel is inactive, green indicates that the channel is active.

14.4.4 TRANSFERRED STATUS

The Transferred Status Bits web page is shown below.

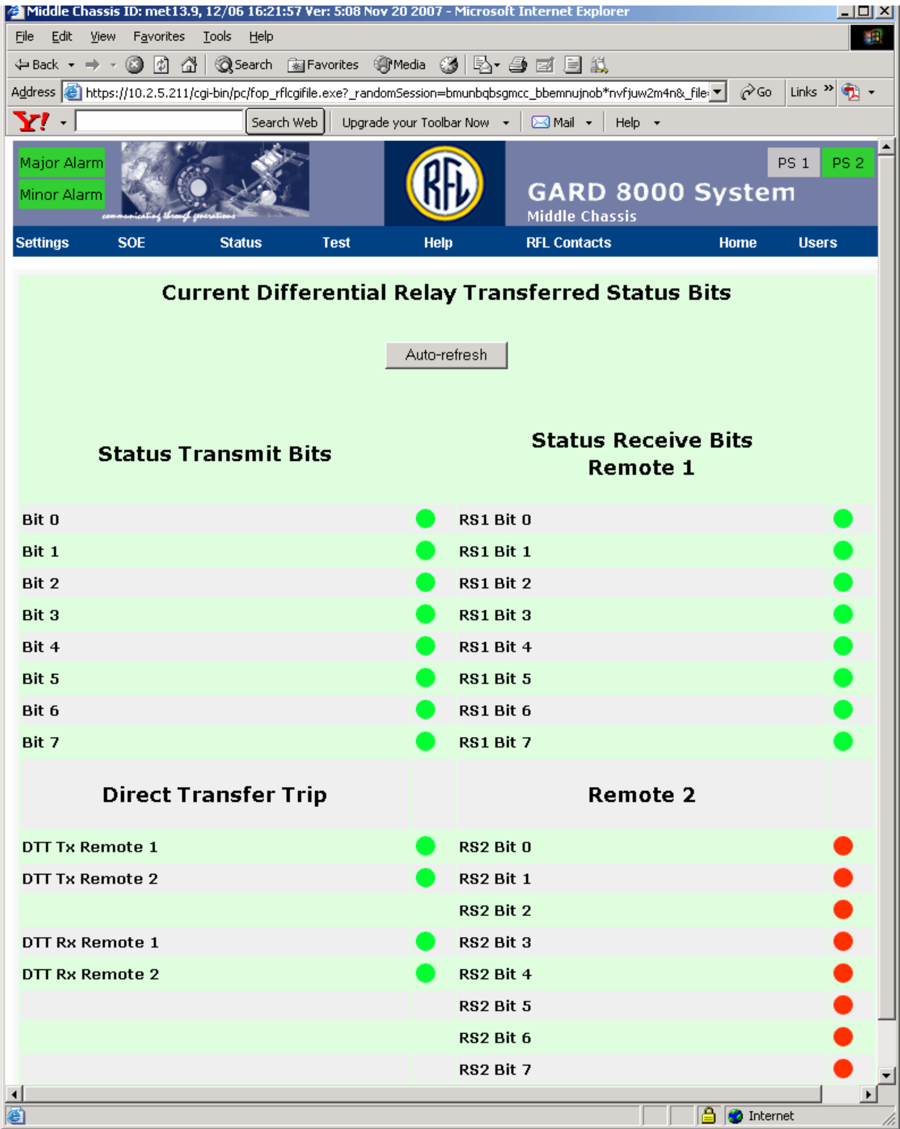

Figure 14-24. Current Differential Relay Transferred Status Bits webpage

The status of eight bits received by the logic bus in the chassis is shown above. Green indicates an active state while red indicates an inactive state.

Direct Transfer Trip

The Current Differential relay provides a bidirectional high priority transfer trip message to one or both remote stations in three terminal line applications. The transfer trip function is independent of the differential protection, and is initiated externally via one of the optical isolated inputs. It is available at the remote station via one of the programmable outputs.

The transfer trip message is the highest priority message in the relay, and provides a back to back channel time of 3ms, as measured to a solid state output.

14.4.5 METERING AND STATUS

The Metering and Status webpage is shown below.

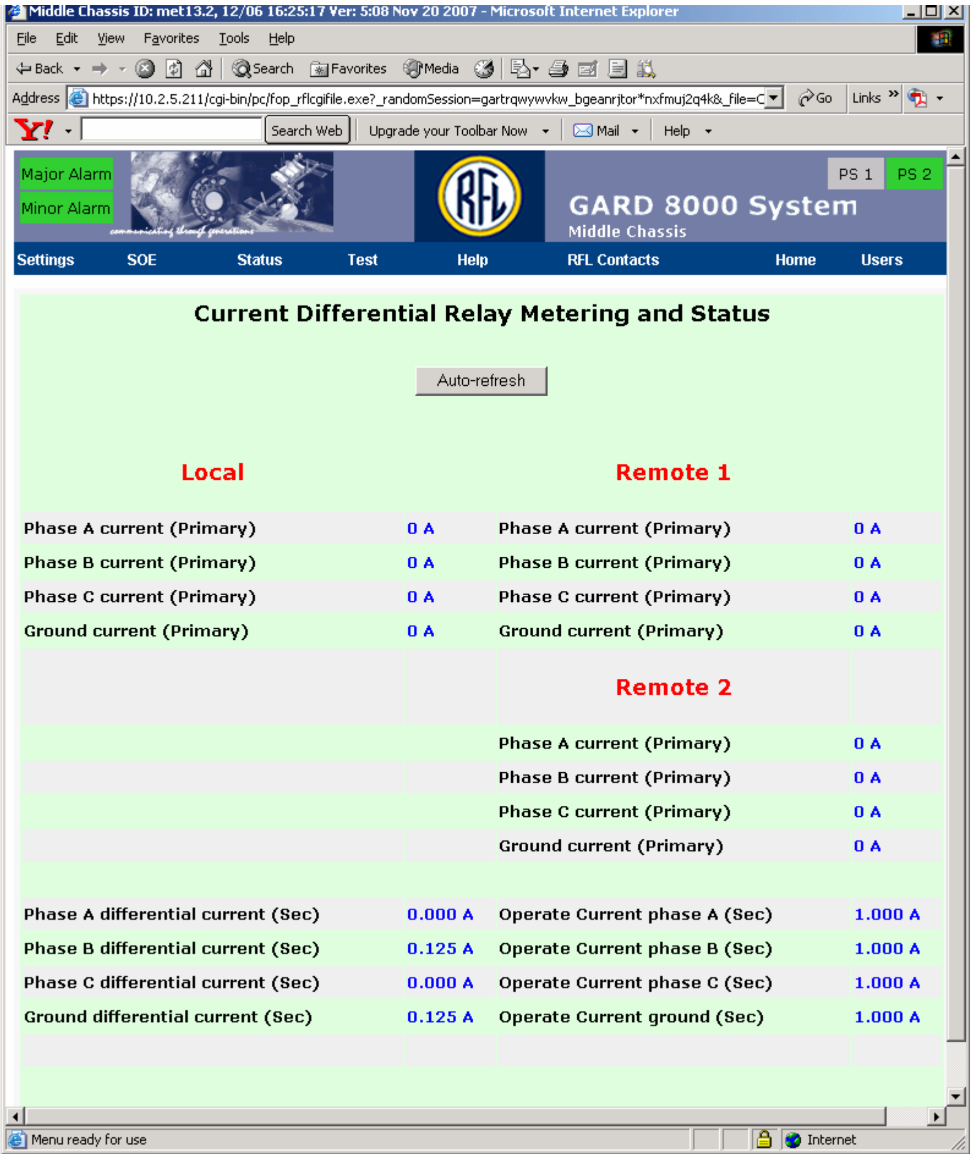

Figure 14-25. Current Differential Metering and Status webpage

Local

Phase A, B, C, and Ground current (Primary)

These indicate the current measured locally for each of the relay inputs. The measurements are in A_{RMS} and are referenced to the primary side of the CT.

Remote 1

Phase A, B, C, and Ground current (Primary)

These indicate the current measured at the remote 1 relay for each of the relay inputs. The measurements are in A_{RMS} and are referenced to the primary side of the CT.

Remote 2

Phase A, B, C, and Ground current (Primary)

These indicate the current measured at the remote 2 relay for each of the relay inputs. The measurements are in A_{RMS} and are referenced to the primary side of the CT.

Phase A, B, C, and Ground differential current (Sec)

These indicate the differential current calculated at the local relay for each phase. The measurements are in A_{RMS} and are referenced to the secondary side of the CT.

Phase A, B, C, and Ground operate current (Sec)

These indicate the relay operate current calculated at the local relay for each phase. The measurements are in A_{RMS} and are referenced to the secondary side of the CT.

14.4.6 LAST TRIP INFORMATION

The Relay Last Trip status webpage is shown below.

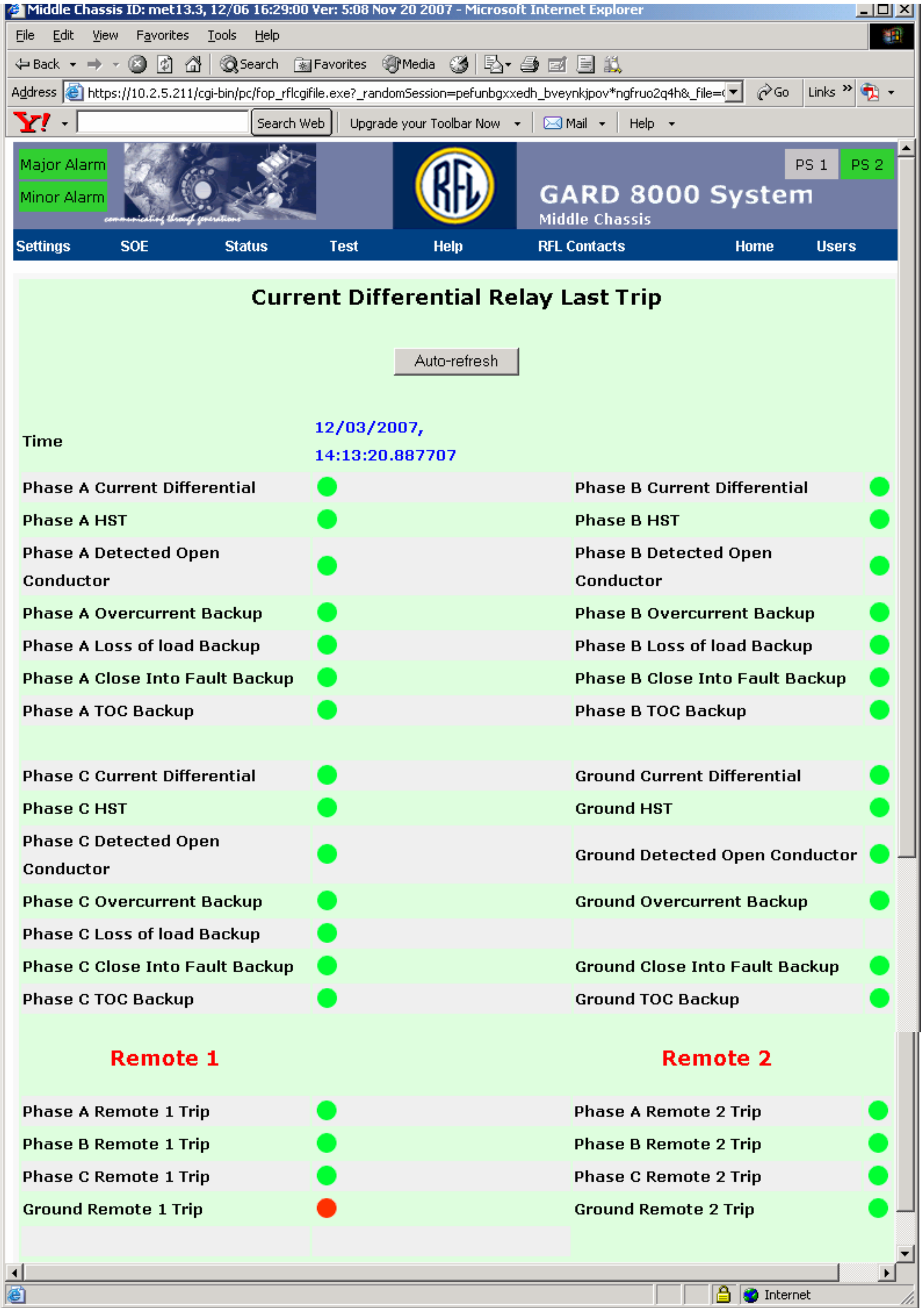

Figure 14-26. Current Differential Relay Last Trip webpage

The last trip web page provides a very broad overview of the last trip processed by the relay. It is a summary only, it is anticipated that the user will review the SOE and oscillography records for more detailed information.

The relay's last trip web page displays all of the tripping elements that were active during the last trip event. A 'trip event' in this context includes the time period between the first tripping element becoming active and all tripping elements being inactive for a user programmable period of time (see section 14.3.1).

For example, if the last trip event close timer is set for 1 second. A trip will start the event window and all trips that become active (even momentarily) are recorded. If the trips are all cleared and a reclose occurs two seconds later, which causes another trip, a new last trip event would be saved—it would include only the trips detected as a result of the reclosing. If the last trip event close timer was set for three seconds the trips detected during the initial fault and the reclosing would be included in the same last trip display.

14.4.7 SEQUENCE OF EVENTS

The Sequence of Events status webpage is shown below.

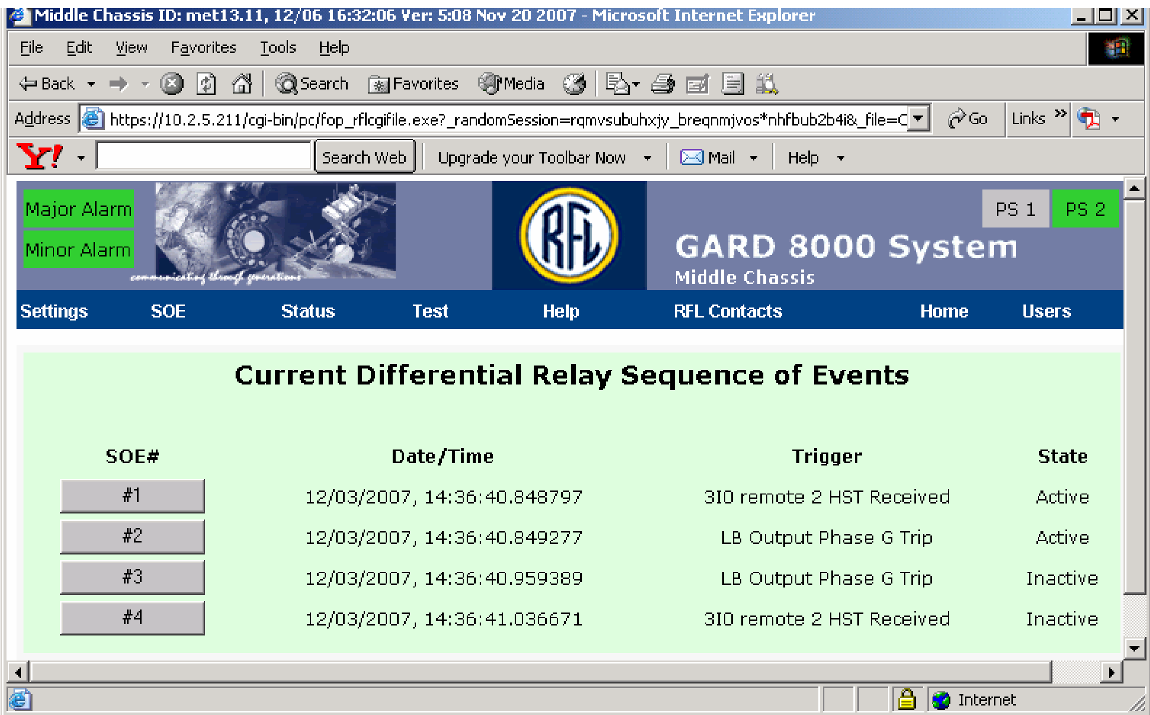

Figure 14-27. Current Differential Relay Last Trip webpage

The above web page shows SOE records with #1 being the oldest. Clicking a button will display the data for that button. The web page displayed is an instantaneous "snapshot" of the conditions when the trigger event occurred.

To reset this webpage do the following:

From the pull down menu select Test > System Test, and check the Current Diff Relay Module. In the web page that appears check the "Reset SOE" box. Click Run Test.

14.4.8 OSCILLOGRAPHY

The Oscillography Records webpage is shown below.

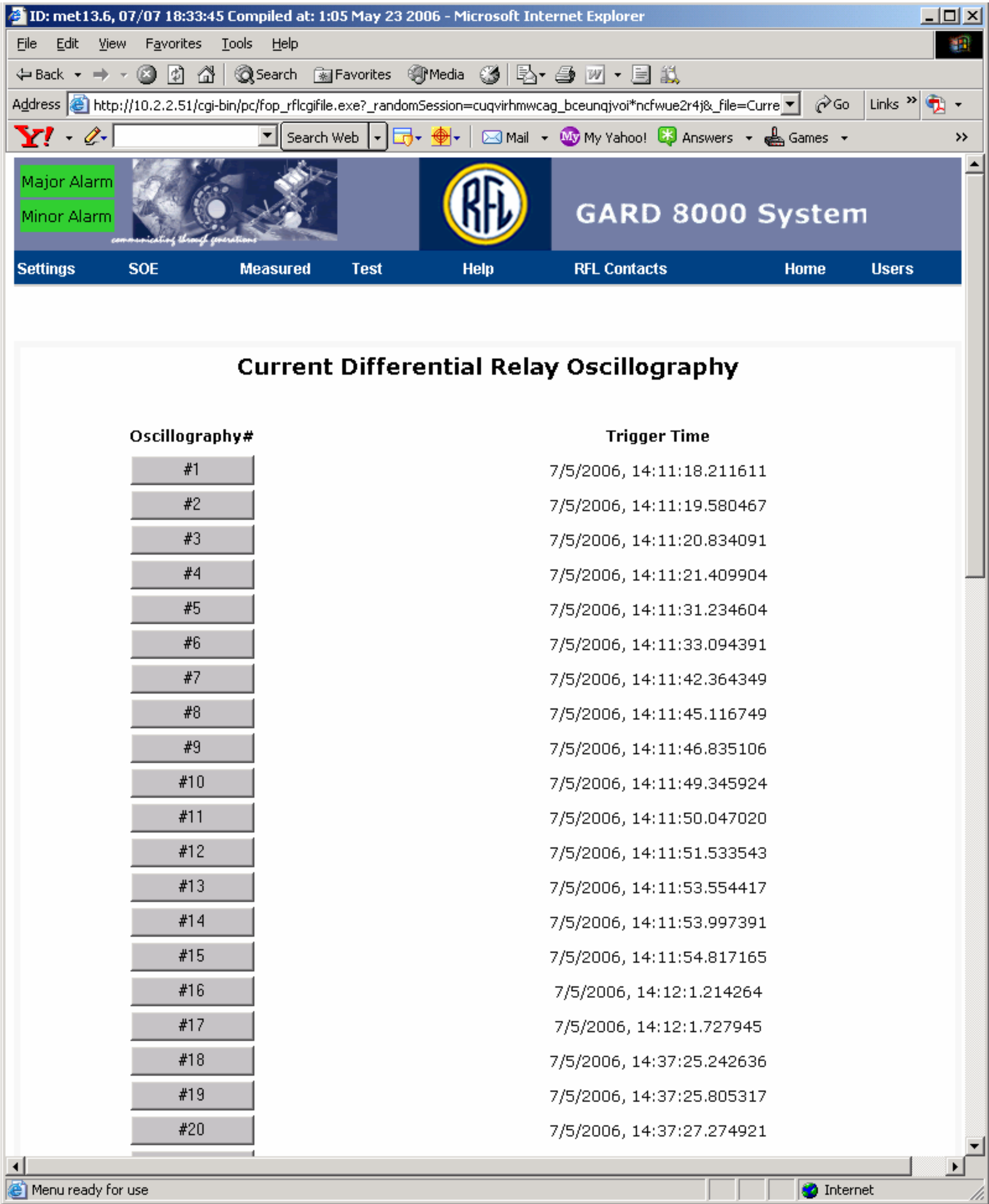

Figure 14-28. Retrieving Oscillography Records webpage

The above web page shows oscillography records with #1 being the oldest. Clicking a button will transfer the oscillography record to a customer directory.

To reset this webpage do the following:

From the pull down menu select Test > System Test, and check the Current Diff Relay Module. In the web page that appears check the "Reset Oscillography" box. Click Run Test.

14.5 APPLICATIONS

14.5.1 PROTECTION FUNCTIONS

14.5.1.1 FAULT DETECTORS

14.5.1.1.1 Overcurrent Fault Detector

When the measured current exceeds the user selected threshold the detector is tripped. The measurement used is the floating measurement, so it does not depend upon zero crossings. The detector is based upon the magnitude of the current and will thus trip on both positive and negative current.

There are separate setpoints for the three phases and ground. A small amount of hysteresis is added to ensure the detection is stable.

14.5.1.1.2 Peak Change Fault Detector

This routine uses the half-cycle current measurements. Each positive half-cycle measurement is compared to the previous positive half-cycle measurement and each negative half-cycle measurement is compared to the previous negative half-cycle measurement. Any change that exceeds the user selected setpoint will trip the detector.

14.5.1.1.3 Pulse-Width Fault Detector

The pulse-width fault detector looks for half-cycles that are significantly too narrow or wide. The detector is only active if the current is greater than approximately $1.5A_{RMS}$. Both the positive and negative half-cycles are checked.

If the half-cycle is completed in less than 14 sample-periods or the half-cycle does not complete within 28 sample-periods the detector is tripped.

14.5.1.1.4 Slope Change Fault Detector

The slope change FD processes the magnitude of the current and works on both positive and negative half-cycles. A normal sinusoidal half-cycle will have an increasing current (positive slope) for the first ¼-cycle followed by decreasing current (a change in slope to a negative slope) in the second ¼-cycle. Thus a single slope change is expected in a half-cycle.

The slope-change FD looks for two slope changes in a given half-cycle. It also requires the current to be greater than approximately $1.5A_{RMS}$. If both of these conditions are met the FD is tripped.

14.5.1.1.5 Polarity Change Fault Detector

The polarity change FD is based upon expecting the current to continue to cross-through zero and change polarity. The detector notes when the current reaches zero and then checks the instantaneous current measurement four sample-periods later. There should be current of the opposite polarity compared to that preceding the zero-cross.

This FD requires that the pre-zero-cross current be greater than approximately $1.5A_{RMS}$. If both of these conditions are met the FD is tripped. Note that this detector will trip if the current remains at zero or inverts phase at or near the zero crossing.

14.5.1.1.6 Breaker Closing Fault Detector

In order to account for charging currents and other transient conditions that occur when a breaker is closed the relay is typically desensitized for a period after the breaker is closed. This is accomplished using the bias boost as described in section 14.5.1.2.7. While this prevents the transient condition from causing a trip some low-level fault conditions, however, may be masked by the bias boost.

When the boost is removed the normal protection algorithms will calculate a trip. A problem can arise if the fault detectors are no longer active, as may be the case with boost durations of greater than 100ms. To work around this issue the breaker closing FD has been incorporated.

The breaker closing FD does not actually detect any fault; rather, it simulates a fault when the boost timer expires. This allows the protection algorithms to generate a trip even if there are no active FDs when the timer expires.

14.5.1.1.7 Dual Breaker

Dual breakers are commonly used in protection where the current into that end of the line is the sum of the currents in each CT. A problem arises when there is a fault that causes a large current to flow through both CT's without going onto the line. Differences between the CT's will appear to be a current flowing into the line. The dual breaker system has two sets of CT inputs. The operation of the system is that the current for each phase from the two inputs is added and used as the current input on that relay. In addition, a calculation for an external dual breaker fault is done. If this is detected, tripping on both ends is blocked.

An external dual breaker fault is detected by subtracting the arithmetic sum of the two inputs from the sum of the absolute value of the two inputs. If the absolute value of the difference is above a preset bias, an External Dual Breaker Fault is declared. This function can be enabled or disabled.

14.5.1.2 CURRENT DIFFERENTIAL PROTECTION

Each relay measures the local current, stores the locally measured value, and transmits the measurement to the remote relay.
When a relay receives a message regarding the current measured at the remote relay it compares it to the current measured locally for the same phase at the same instant in time.
The differential current calculated for that half-cycle is compared to a calculated operate level. If the differential current exceeds the operate level a trip is issued.

14.5.1.2.1 Current measurements

The basic current measurement used for the current differential algorithm takes the currents measured between zero crossings. All of the individual samples (normally sixteen of them) are added together. This essentially calculates the integral of the current during that half-cycle (or "area under the curve") multiplied by a scale factor.

This is related directly to the charge being transferred over the line and in the case of sinusoidal currents the RMS value of the current during the half-cycle. Using this "equivalent RMS" value provides an increased level of security and robustness when compared to peak measurements etc.

14.5.1.2.2 Measurement Qualifiers

The purpose of the half-cycle current measurements is to provide a standardized and consistent basis for relays at both ends of the line so that meaningful comparisons can be made. As such certain qualifiers are added to the measurements to ensure the validity of the data.

14.5.1.2.3 Communicating Current Measurements to Remote Relay

Each valid half-cycle current measurement is saved locally for the current differential processing routines. Phase A, B, and C transmit their current measurements only for the positive half-cycle and the ground transmits only the negative half-cycle measurements. The messages used to transmit the measured current are called CCD messages.

When a current measurement is transmitted to the remote relay two additional pieces of information are included in the message. The message includes a flag to indicate the status of the local fault detectors. The message also includes information regarding the delay between when the current measurement was taken and when the message was transmitted to the remote end.

14.5.1.2.4 Nesting

When a relay receives a CCD message from the remote relay it must compute how long ago the actual current measurement was made. As stated above the message itself includes information indicating how long the data was held in queue at the remote end prior to transmission. Two additional pieces of timing information are also required to determine how old the data is.
The relay keeps track of the channel delay in the system (how long it takes between transmitting a message and receiving it at the other end. The last piece of timing information required is the delay at the local end between when a message is received and the data is actually processed.

These three delay times (remote queuing time, channel time, and local queuing time) are added to determine how long ago the remote relay made the current measurement that is being processed. This is used to determine which of the locally calculated half-cycle currents was measured at the same time. This process is called nesting.

The fact that the comparisons are made based upon half-cycle measurements results in some notable characteristics of the algorithm. First, the channel delay is canceled by the algorithm so it does not compromise the integrity of the protection (although longer channel delays will result in delayed trip times). The system can tolerate greater than 27ms of channel delay and still provide protection.

The other benefit is that exact delay compensation is not required. Modest errors in the calculated delays can be tolerated while still allowing the received CCD message to nest with the correct local half-cycle. Delay compensation errors on the order of ± 4ms will not cause a nesting error.

14.5.1.2.5 Operate Level Calculation

The differential current that will cause the relay to operate is the operate level. The operate level is based upon several user settings and the dynamic conditions of the line.

14.5.1.2.6 Bias Setting

The user selects the bias level depending upon the system application. There is one setting for the phases and one for ground.

14.5.1.2.7 Bias Boost

The user may chose to boost the bias level following a breaker closing. This reduces the relay's sensitivity and accommodates line charging currents. Phase and ground have independent settings for both the boost level and the duration of the boost. The boost function may be disabled by setting the boost level to zero.

14.5.1.2.8 Operate Level Slope Characteristic

The bias level sets the baseline operate level. As line currents increase the relay must be further desensitized to accommodate normal system variances and errors, such as CT errors. This is accomplished by increasing the operate level as the line currents increase.
The parameter that is used as the driving factor for this compensation is the scalar sum of the line currents. The magnitudes of the current measured at each relay are added and the compensation is based upon this sum. The compensation is a two-segment piecewise linear function as shown in the following Figure.

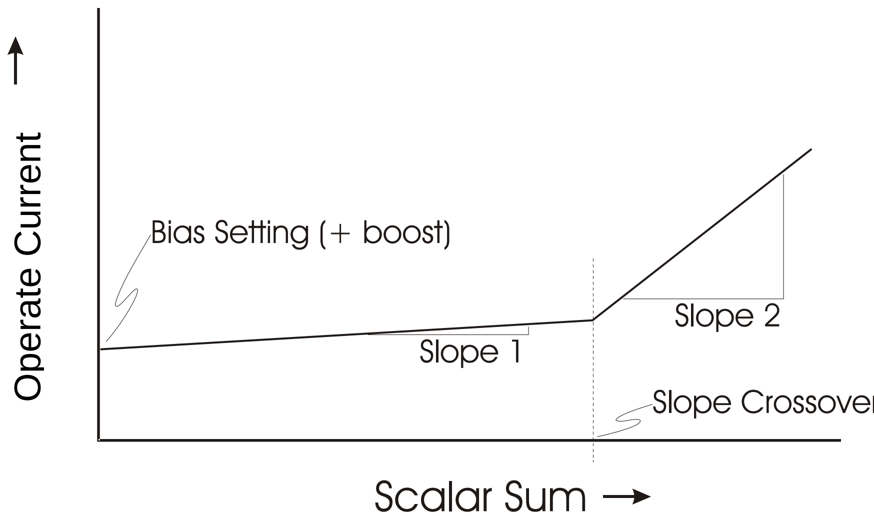

Figure 14-29 Operate Level Slope Characteristic

As show in the figure above with zero current at both ends the operate level is equal to the bias setting (plus boost following a breaker close). As the current increases from zero the operate increases as specified by "slope 1". Thus continues until the scalar sum reaches the user specified slope crossover current point at which it will increase as prescribed by "slope 2".
The phase and ground have independent settings for both slopes and the crossover point.

14.5.1.2.9 Trip Calculation

The calculated differential current is compared to the operate level computed above. If the current exceeds the operate level a trip is issued locally and a Transferred Current Differential Trip (TCDT) message is sent to the remote end to force it to trip.

14.5.1.2.10 Fault Detector Qualification

The phase calculating the trip must have an active fault detector and there must be at least one additional (local or remote) fault detector active.

14.5.1.2.11 Current Differential Alarm

If the phase calculates a trip but it is not processed into a qualified trip due to a lack of fault detectors the relay issues a current differential alarm to alert the user of the condition.

14.5.1.3 CLOSE INTO FAULT PROTECTION

The bias boost function described in section 14.5.1.2.7 allows the current differential protection routines to provide the required CIF protection.

14.5.1.4 HIGH-SET TRIP PROTECTION

As described in section 14.5.1.2 the current differential routines work entirely upon half-cycle current measurements which, by definition, cannot be completed until the half cycle is completed. In cases of extremely high fault currents it is desirable to provide a mechanism that does not require the half-cycle measurement. This is for two reasons; first, it provides faster tripping and, second, the fault may cause an extended delay in the zero-crossing of the current (which is used to determine the bounds of the half-cycle measurement). The relay includes a high set trip (HST) routine for this purpose.
The HST algorithm is a two stage process. First, if a relay measures inordinately high current it sends a message to the remote relay. The remote relay then checks it's measured current and blocks the trip if it is an external fault. If the remote relay does not determine it to be an external fault it will trip and send a trip signal back to the originating relay.

14.5.1.4.1 Generation of the HST message

As with the current differential routines the HST routines are processed for the positive half-cycle for the phases and negative half-cycle for the ground. If the relay measures four consecutive samples (instantaneous current measurements) that exceed the HST setpoint a HST message is sent.
As with the CCD message the HST message includes data indicating how long the delay was between determining the current exceeded the HST setpoint and the message was actually transmitted.

14.5.1.4.2 Processing received HST messages

When the HST message is received the local currents are compared to a blocking current to avoid tripping on through faults.

14.5.1.4.3 Calculating the Blocking Current

The HST is essentially a degenerate form of the current differential algorithm that has been tailored for quick response. Given the HST process begins with the remote relay detecting a high current, the local (receiving) relay must block if it also measures current equal to the HST setpoint (which would make the differential current zero).
As with the current differential routines the bias setting is used to desensitize the element. Given the bias setting is an RMS value and the HST routines process instantaneous values the bias setting must be converted to an equivalent peak value. An additional 1A of desensitization is included to account for the high currents (as the slope characteristic does for the current differential algorithm) and limitations of the speed-optimized routine.
The blocking current is further limited to a maximum value of $7.5A_{PEAK}$. The calculation of the blocking current is thus:

$$block\_current = \min\begin{cases} high\_set\_limit - bias * 1.414 - 1\text{A} \\ 7.5\text{A} \end{cases}$$

14.5.1.4.4 Calculating the Trip

When a relay receives a HST message it determines how long ago the HST message was calculated at the remote end. This process is very similar to the nesting performed by the current differential routine (section 14.5.1.2.4), however, as mentioned above rather than computing a differential current the local current is compared to a blocking level.

The normal nesting routines deal only with half-cycle blocks and can thus accommodate modest nesting errors without any impact. The HST routines work on instantaneous measurements and must allow for some uncertainties and system errors. As such, the local current is checked over a 12-sample window—if the local current exceeds the blocking level at any time during this window the unit will not trip.

If there is insufficient blocking current the local end will trip and send a TCDT message to the remote relay.

14.5.1.5 OPEN CONDUCTOR (PHASE UNBALANCE) UNIT (46)

The open conductor algorithm is a multi-step algorithm that works only with the three phases. The only potential involvement of the ground is that it can contribute a FD.

14.5.1.5.1 Prefault Condition

The system must start in a stable condition with all three phases seeing currents of at least $1.5A_{RMS}$ (5A CTs).

14.5.1.5.2 pHASE Loss Detector

A phase is considered lost when there is a phase imbalance and at least two fault detectors while having been in a valid prefault condition within the past two cycles.

Phase imbalance is defined as at least one phase having greater than or equal to $3A_{RMS}$ (5A CTs) and at least one phase having less than $0.5A_{RMS}$ (5A CTs).

14.5.1.5.3 Delay TImer and Action

Once the phase loss is detected the phase imbalance must continue for a user specified duration in order to satisfy the algorithm (at which point the FDs will most likely be inactive as will the prefault condition).

The user can specify if they want the open conductor algorithm to cause a trip, an alarm, or be ignored.

14.5.1.6 BACKUP PROTECTION

If enabled the relay will enter the backup protection mode when the communications channel has failed (section 14.5.2.6.3) or the communications channel is OK but the primary guard before trip criteria has not been satisfied (and it is enabled).

14.5.1.6.1 Instantaneous and Definite Time Overcurrent elements (50)

The overcurrent elements work on the measured RMS values of the measured currents. The measurement must exceed the user setpoint for a time period exceeding the user specified duration for the element to become active, there must also be an active FD in the phase calculating the trip and at least one additional FD.

14.5.1.6.2 Time Overcurrent elements (51)

The relay allows for independent configuration of the phase and ground time overcurrent elements. Each has four configuration settings: enable/disable, type of characteristic curve to use, pickup level, and time dial setting.
The relay supports several operate characteristic curves. All curves have an instantaneous reset characteristic—if the current drops below the pickup level the integrator is reset and the algorithm will restart.

14.5.1.6.2.1 Functional Overview

The general form of the operate function is:

$$operate\_time = td\left(\frac{A}{M^{p}-1}+B\right)$$

Where td is the time dial setting and M is the multiple of the pickup current.

14.5.1.6.2.2 Multiple of Pickup Current

The multiple of pickup current is defined as:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The algorithm is fully specified within the range 1.5 < M < 20. Additionally there are practical limitations due to the current measurement itself—the measurement will start to clip if the peak current exceeds the range of the equipment.

The calculations are based upon the half-cycle equivalent RMS value measurements. The individual half-cycle contributions to the algorithm are integrated to account for time-varying currents. When the integrated signal exceeds the operate time the output is asserted. As previously mentioned the integration is reset if the measured current drops below the pickup current.

14.5.1.6.2.3 Time Dial Setting

The time dial setting for all the curves is from 0.05 to 15 with a step size of 0.05. However, the following restrictions apply:

- The USA curves have an effective range of 0.1 to 15 (if the user specifies 0.05 it will be rounded up to 0.1 for the calculations).
- The IEC curves have a range of 0.05 to 1. If set to a value above 1, the relay will use 1 for the calculations.

14.5.1.6.2.4 Characteristic Curves

Time overcurrent units include seven characteristic curves:

- USA Moderately Inverse
- USA Inverse
- USA Very Inverse
- USA Extremely Inverse
- IEC Standard Type A (Inverse)
- IEC Standard Type B (Very Inverse)
- IEC Standard Type C (Extremely Inverse)

14.5.1.6.2.4.1 USA Moderately Inverse TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{0.0104}{M^{0.02}-1}+0.0226\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically as follows.

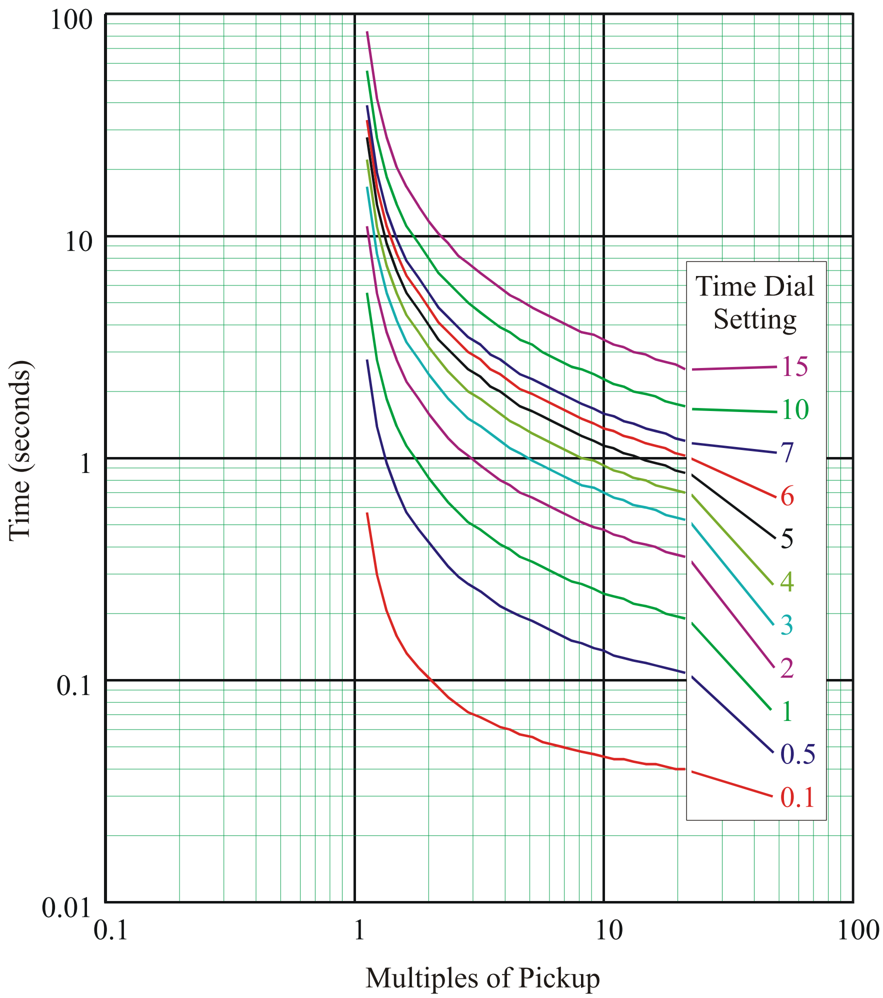

Figure 14-30 USA Moderately Inverse TOC Characteristic

14.5.1.6.2.4.2 USA Inverse TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{5.95}{M^2 - 1} + 0.180\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below

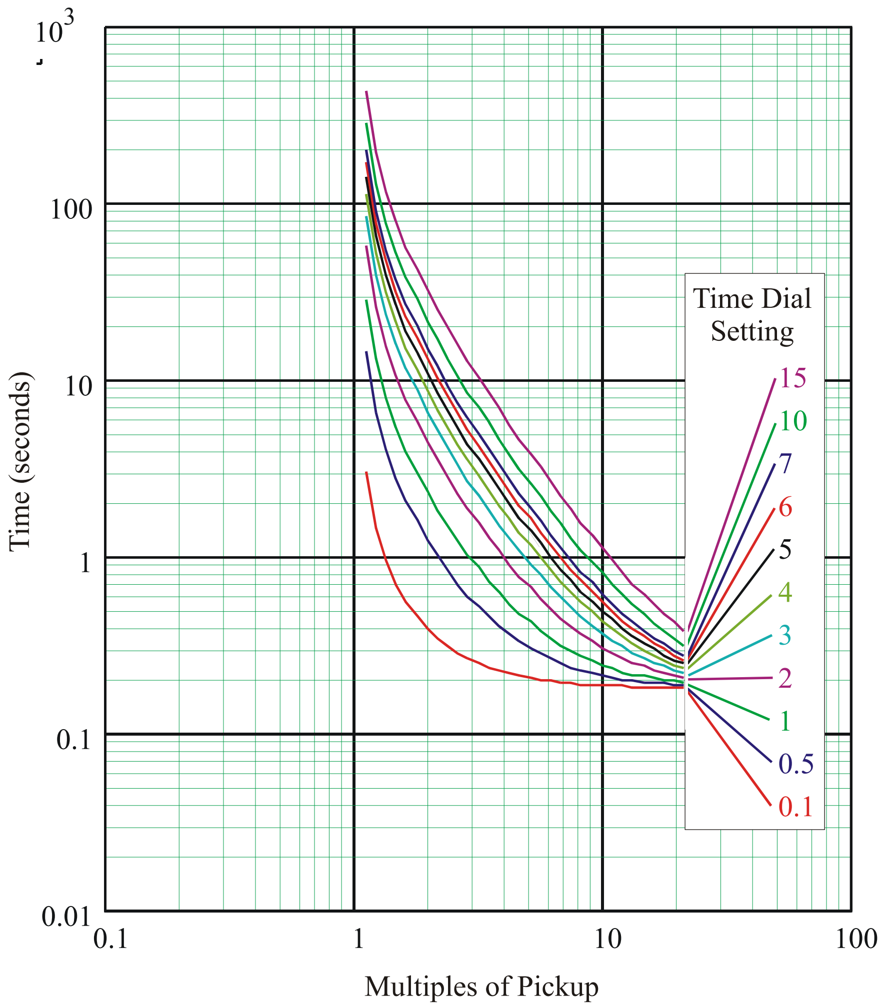

Figure 14-31 USA Inverse TOC Characteristic

14.5.1.6.2.4.3 USA Very Inverse TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{3.88}{M^2 - 1} + 0.0963\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below.

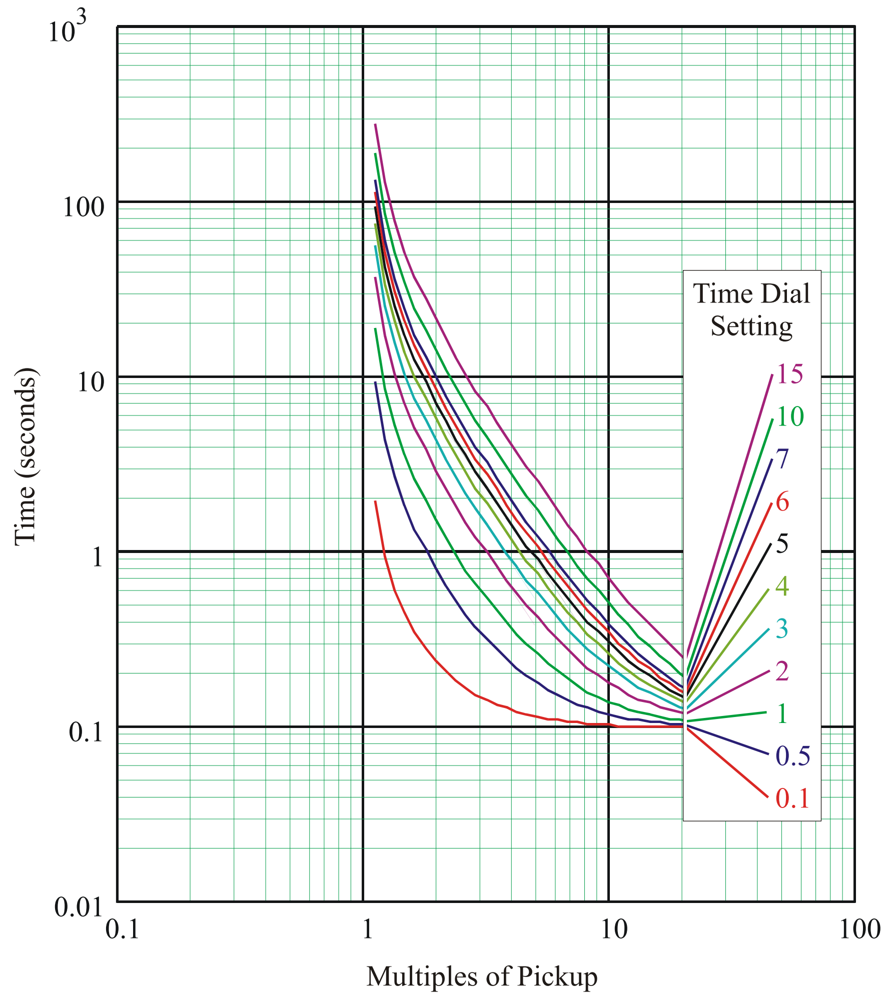

Figure 14-32 USA Very Inverse TOC Characteristic

14.5.1.6.2.4.4 USA Extremely Inverse TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{5.67}{M^2 - 1} + 0.0352\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below.

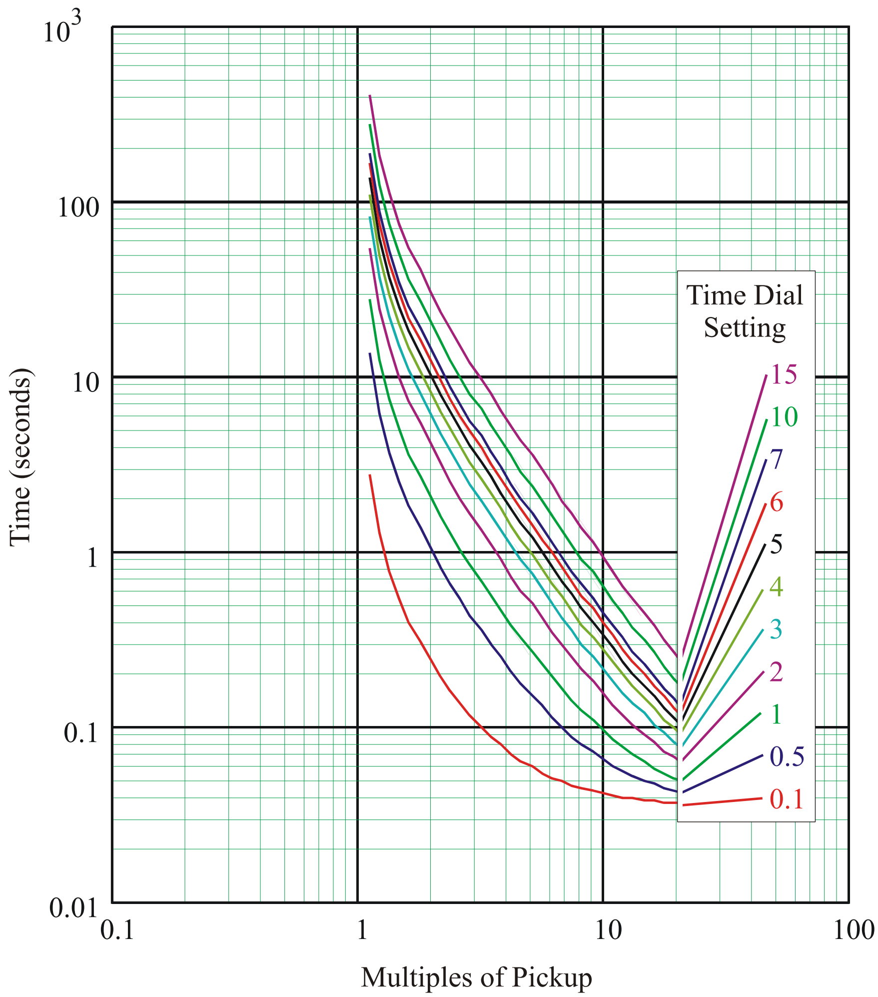

Figure 14-33 USA Extremely Inverse TOC Characteristic

14.5.1.6.2.4.5 IEC Standard Type A TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{0.14}{M^{0.02} - 1}\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below.

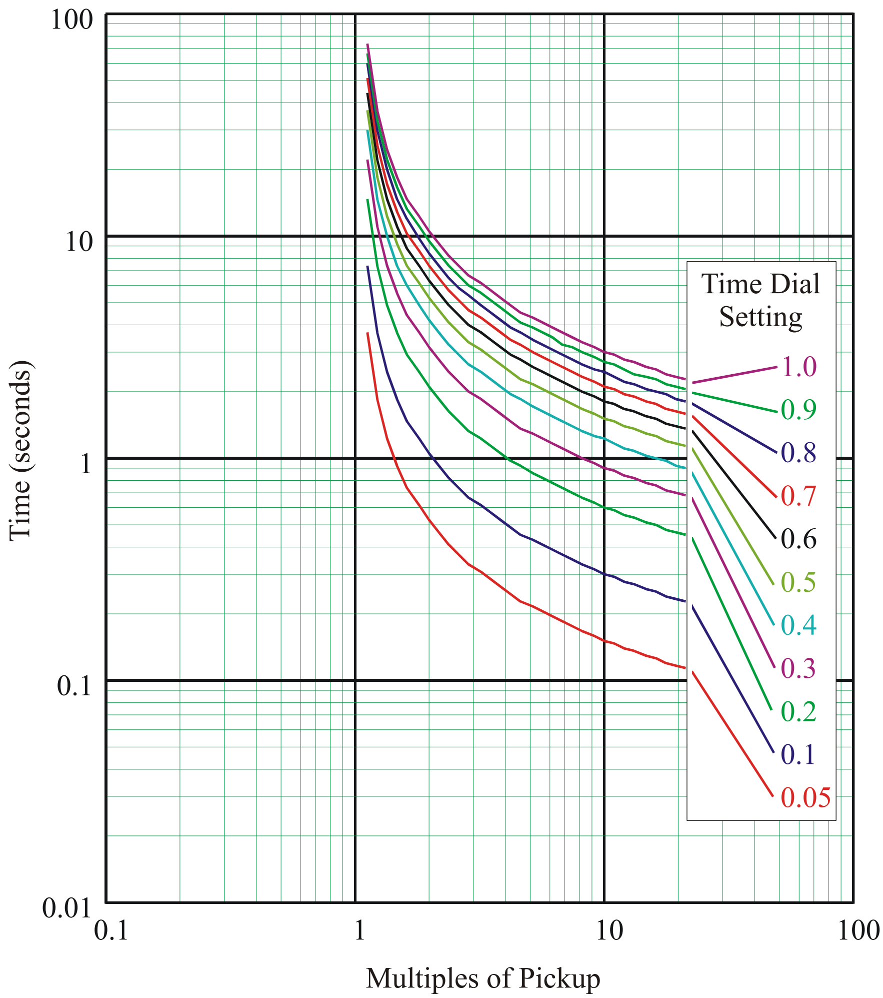

Figure 14-34 IEC Standard Type A TOC Characteristic

14.5.1.6.2.4.6 IEC Standard Type B TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{13.5}{M^{1}-1}\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below.

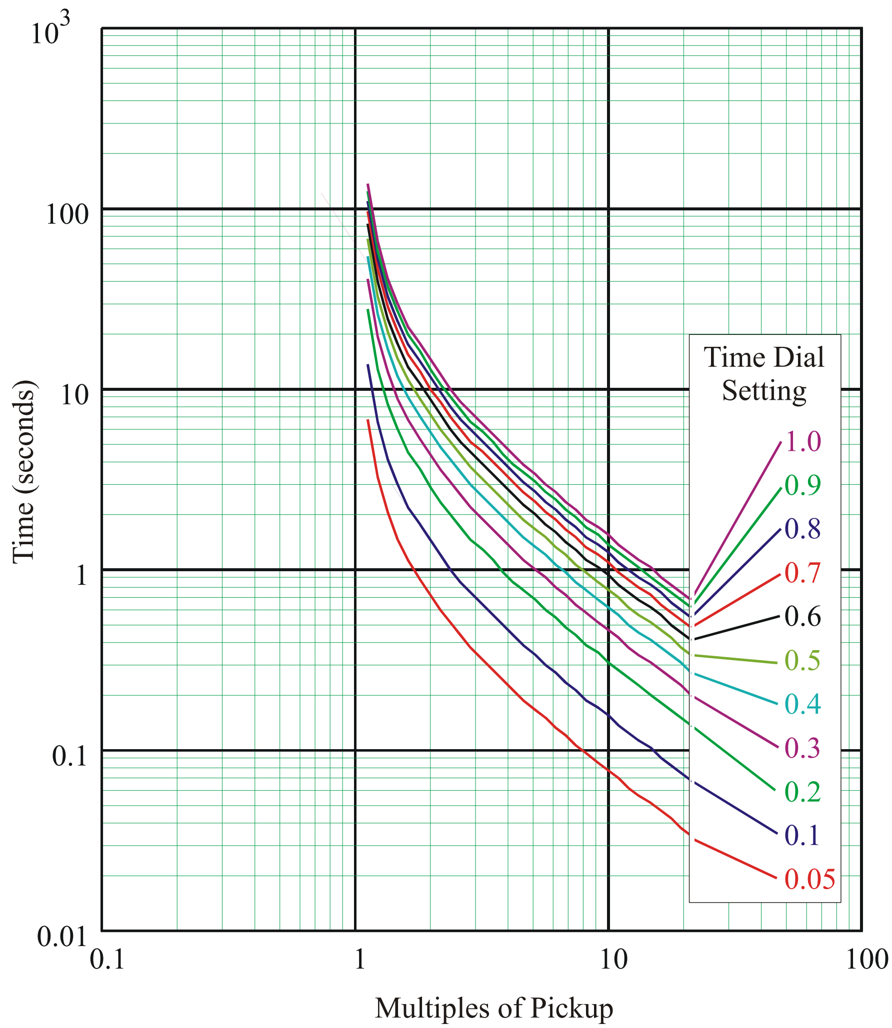

Figure 14-35 IEC Standard Type B TOC Characteristic

14.5.1.6.2.4.7 IEC Standard Type B TOC Characteristic

The relay operate characteristic is defined as:

$$operate\_time = td\left(\frac{80}{M^2 - 1}\right)$$

Where td is the time dial setting and M is the multiple of the pickup current:

$$M = \frac{\text{measured current}}{\text{pickup setting}}$$

The characteristic is shown graphically below.

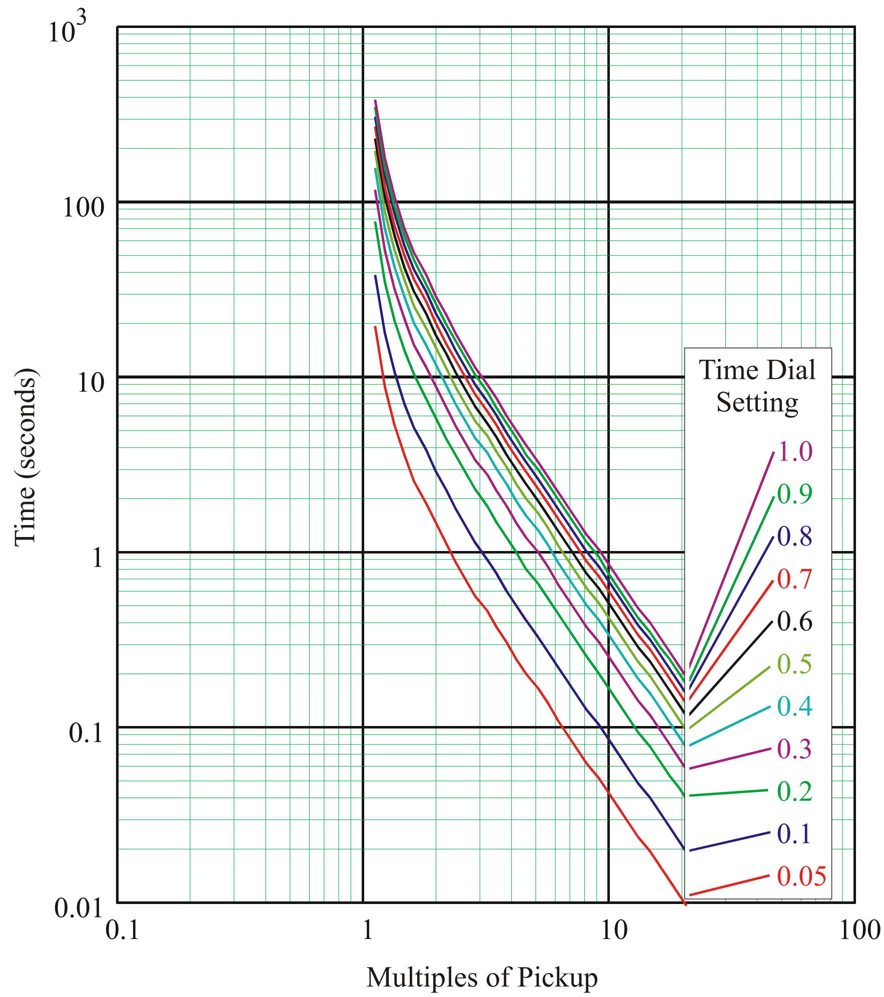

Figure 14-36 IEC Standard Type C TOC Character

14.5.1.6.3 Close into fault (cif)

The backup close into fault elements are only active during a user specified period following the breaker closing. The measured RMS current must exceed the user setpoint for one full cycle period for the element to become active and there must also be an active FD in the phase calculating the trip and at least one additional FD.

Once tripped the CIF element will become inactive when the user specified time period has expired (if the fault persists other elements should pick up).

14.5.1.6.4 Loss of load (LOL)

The loss of load algorithm is a multi-step algorithm that works only with the three phases. The only potential involvement of the ground is that it can contribute a FD. The loss of load algorithm is automatically disabled in single-pole configuration.

14.5.1.6.4.1 Prefault Condition

The system must start in a stable condition with all three phases seeing currents of at least $1.5A_{RMS}$ (5A CTs).

14.5.1.6.4.2 Loss Detector

A phase is considered lost when there is a phase imbalance and at least two fault detectors while having been in a valid prefault condition within the past two cycles.
Phase imbalance is defined as at least one phase having greater than or equal to $3A_{RMS}$ (5A CTs) and at least one phase having less than $0.5A_{RMS}$ (5A CTs).

14.5.1.6.4.3 Delay TImer and Action

Once the phase loss is detected the phase imbalance must continue for a user specified duration in order to satisfy the algorithm (at which point the FDs will most likely be inactive as will the prefault condition).

The user can specify if they want the open conductor algorithm to cause a trip, an alarm, or be ignored.

14.5.1.6.5 Stub bus protection

When the bus is configured with an 89 disconnect that may leave a bus stub energized and requiring protection the 89B contact can be fed into the relay to enable the stub bus feature. The stub bus functions may be disabled by the user.

The stub bus function basically isolates the local and remote relays. The local relay is switched into a modified backup mode that provides only overcurrent and time overcurrent routines. The stub bus overcurrent routines are identical to the backup overcurrent routines (section 14.5.1.6.2) but allow independent configuration of the delay and phase and ground overcurrent thresholds.

The stub bus time overcurrent (TOC) routines use the same configuration settings as the backup TOC routines (section 14.5.1.6.2) but have an independent enable/disable control.

14.5.2 ADDITIONAL FUNCTIONS

14.5.2.1 TEST MODE

The test mode is a relay function that blocks local tripping allowing commissioning and other diagnostic tests to be run without actually tripping breakers. Given the test mode disables breaker tripping it should be used with extreme caution. RFL recommends that the relay trip outputs be manually bypassed during testing when possible.
While in test mode virtually all of the relay functions continue to operate as normal—currents are measured, messages are passed between relays, trips are calculated, and SOE and oscillography data is recorded. The trips are blocked from being sent to the breakers by the logic in the GARD controller. This allows all of the functions of the relay to be stimulated and tested.
When the relay is in test mode a minor alarm will be issued.

14.5.2.2 PHASE SEQUENCE REPORTING

The relay checks the relative phase sequencing of the current inputs. All measurements are made with respect to (local) phase A current. The measurements are status indicators only, not intended as measurements of actual phase angles. The readings are expected to be used in a steady-state condition with nominal currents applied to the relay (a minimum of 0.5A for 5A CTs, 0.1A for 1A CTs).

The test checks each phase to see if they are at 0, 120, or 240 degrees (relative to phase A). A measurement within about ±11° will be accepted, if the measurement is outside this range or the currents are too low "Error" will be displayed. Given the measurements are relative to phase A, phase A will either be 0° or "Error".

Each relay will perform the same measurement and report the result to the remote relay. Under normal steady-state conditions the local and remote phase A currents will be 180° out of phase and each relay will be taking measurements with phase A defined as 0°. In order to make the display of results more useful, the relay uses the channel delay time and relay to relay current measurements to confirm the two ends are out of phase and flips the remote measurement by 180°.

Thus the remote phase A current will be displayed as 180° (or "Error" if the remote end did not make a measurement or the local and remote are not out of phase). The remaining phases will be displayed as 180° (remotely measured as 0°), 300° (remotely measured as 120°), or 60° (remotely measured as 240°), or "Error". This provides an approximation of both the local and remote phasing and can readily identify miswires or gross system abnormalities.

14.5.2.2.1 Entering Test Mode

When the user commands the relay to enter test mode the relay must not be tripped and there cannot be any fault detectors (local or remote) active. The relay will then enter test mode, block the local trip outputs, and issue a minor alarm. It will also send a message to the remote relay to place it in test mode (this is sent repeatedly as a configuration).
The remote relay will also verify that there are no trips or fault detectors and then enter test mode. The remote relay will send a return message confirming it has entered test mode, block the local trip outputs, and issue a minor alarm. The user should confirm, using the status web pages, that both the local and remote relays have entered test mode prior to performing any testing.

14.5.2.2.2 Exiting Test Mode

In order to exit test mode the user must turn off the test mode in the relay where it was originally set. This local relay will then change the configuration message sent to the remote relay to indicate that it should no longer be in test mode and the remote relay will also exit test mode.
If communications are lost while in test mode the remote relay will remain in test mode. If it is desired to exit test mode while comms are down, the user may do so using the web pages, however, when comms are restored the relay will again be commanded to enter test mode if the "local" relay is still configured for test mode.
Note that the test mode is a volatile setting: it is cleared when power is removed. Thus, if power is cycled at the remote relay the relay will power-up normally and return to test mode once it receives the appropriate messages from the local relay. If the local relay (the one that the user initiated test mode at) loses power it will power-up normally (not in test mode). This was done to prevent relays from potentially powering-up (after an indeterminate period of time or even in different chassis) in test mode.

14.5.2.3 PRIMARY GUARD BEFORE TRIP

Upon establishing communications (or reestablishing if comms had failed) the relay will require 100ms of communications with the remote relay without calculating or receiving any trips to satisfy the GB4T criteria. While this provides a secure method of enabling protection under normal conditions, it will prevent the relay from coming up with a faulted line.
To work around this the relay will also satisfy the GB4T criteria if a clear channel is detected. A clear channel is defined as approximately 250ms without any detected communications errors.

14.5.2.4 MAJOR ALARM

The relay will go into major alarm when it detects a problem that prevents it from providing protection. The alarm bit is sent out on the logic bus and is used in the system logic (in the GARD controller module) to prevent trip signals from being issued.

14.5.2.5 MINOR ALARM

The minor alarm is a user alerting function that goes out as a bit on the logic bus. The system logic in the GARD controller module has a timer that monitors the minor alarm signal. If this signal is continuously active for a prolonged period (e.g. 10 seconds) they user can be notified.

The module minor alarm has no direct impact the protection functions of the relay; it is intended strictly to alert the user to possible trouble conditions.

- Current Differential Alarm
  The current differential alarm is an indicator that the relay has calculated a current differential trip; however, the trip has not been fully processed because there were not sufficient fault detectors. See section 14.5.1.2.11 for further information.

- Loss of Load / Open Conductor
  The loss of load (section 14.5.1.6.4) and open conductor (section 14.5.1.5) algorithms may be configured by the user to place the module in minor alarm.

- Communications Alarm
  When the communications alarm (section 14.5.2.6.2) is active the relay will be in minor alarm.

- Ping-Pong Alarm
  When the ping-pong alarm (section 14.5.2.6.4) is active the relay will be in minor alarm.

- Communications Failure
  When the relay is in communications failure (section 14.5.2.6.3) the relay will be in minor alarm.

14.5.2.6 COMMUNICATIONS FUNCTIONS

All communications channels suffer from occasional bit errors and message corruption. Each message contains a data integrity check and any messages that are corrupted are discarded. Each message is transmitted three times and the receiver performs a two-out-of-three voting logic. Thus, even if a single instance of a message is corrupted in the communications link the message will be correctly received by the relay.

If the errors are infrequent the relay will simply ride through them without any degradation in performance. More frequent errors will cause individual messages to be dropped which will result in degraded performance. Low to modest errors rates that continue for a prolonged period of time are generally a sign of problems with the communications channel and should be investigated. When relay detects these prolonged periods of errors, even if the relay is able to continue to function, it alarms the user.

If high error rates are detected the relay will go into a comms failure condition.

14.5.2.6.1 Addressing

The relay implements an addressing scheme to ensure that the relay is communicating with the proper remote relay prior to opening the communications channel. The user must set a receive (Rx) and transmit (Tx) address in the relay.

The local Rx setting must match the Tx setting of the remote relay (and likewise in the opposite direction).

14.5.2.6.2 Communications Alarm

The relay constantly monitors the communications channel. Minor, low-level communications problems can be accepted by the relay without any degradation in performance. Modest communications problems may result in slightly degraded performance and severely degraded comms will result in the relay declaring a comms failure (see below), however, while the relay can work-through minor or modest communications channel problems they should not go unreported. The relay identifies these problems by setting a communications alarm which is displayed on a status web page.

The communications alarm also causes the module to go into minor alarm which goes out as a bit on the logic bus. The system logic in the GARD controller module has a timer that monitors the minor alarm signal. If this signal is continuously active for a prolonged period (e.g. 10 seconds) they user can be notified.

Neither the communications alarm or module minor alarm has any direct impact the protection functions of the relay in any way; they are intended strictly to alert the user.

14.5.2.6.3 Communications Failure

A communications failure is declared whenever the communications channel is determined to be unusable. The following conditions will generate a comms failure.

- Detection of a comms hardware failure within the GARD chassis (or the bus not configured).
- Address mismatch.
- Failing six successive ping-pong tests.
- Severely degraded comms.

When the communications channel fails the relay will go into backup mode (if enabled).

14.5.2.6.4 Ping-Pong and Ping-Pong Alarm

The relay constantly monitors the communications channel delay using a ping-pong measurement. The measurement is calculated by generating a message at the local end, the remote end responds to the message with a reply—included in the reply is the amount of time between the remote end receiving the message and sending out the reply. The local end knows when the first message was transmitted and when the reply was received, after compensating for the delay at the remote relay the round-trip communications time is calculated. The reported ping-pong delay is ½ of the calculated round-trip time.

The contributors to the ping-pong alarm include:

- Failure of one or more ping-pong tests.
- If the measured ping-pong exceeds 28ms.
- If the ping-pong measured at the local and remote relay do not match.
- If the ping-pong changes by more than 3ms.

These criteria are deliberately made sensitive and are required to remain active for a prolonged period prior to being reported to avoid nuisance errors.

The ping-pong alarm also causes the module to go into minor alarm which goes out as a bit on the logic bus. The system logic in the GARD controller module has a timer that monitors the minor alarm signal. If this signal is continuously active for a prolonged period (e.g. 10 seconds) the user can be notified.

Neither the ping-pong alarm or module minor alarm has any direct impact the protection functions of the relay in any way; they are intended strictly to alert the user.

14.5.2.7 TRANSFERRED STATUS BITS

The relays are constantly communicating with each other passing data regarding the measured currents, addressing, ping-pong, etc. Messages are also included that communicate the status of eight bits received from the logic bus in the chassis. The data is transferred to the remote relay and then placed onto the logic bus in the remote chassis.

Under normal steady-state conditions the bits are updated approximately 30 times per second. During trip conditions, however, the status bit messages may be preempted by higher priority protection messages, resulting in lengthened transfer times.

Note: The status bit transmission time ranges between 6 and 24 ms with an average of 16 ms. The status bits are CRC protected for security.

14.5.2.8 RECLOSER BLOCKING FUNCTION

The GARD 8000 provides a recloser blocking output. The logic is shown in Figure 14-37. This logic is implemented in the programmable logic processing of the controller module.
The recloser block function is enabled for a period of 3 seconds after the first trip signal is generated by one of the phases. The user can select if they want to initiate a block for a 2-phase trip or 3-phase trip condition. The trip output is held for 50ms and then released.

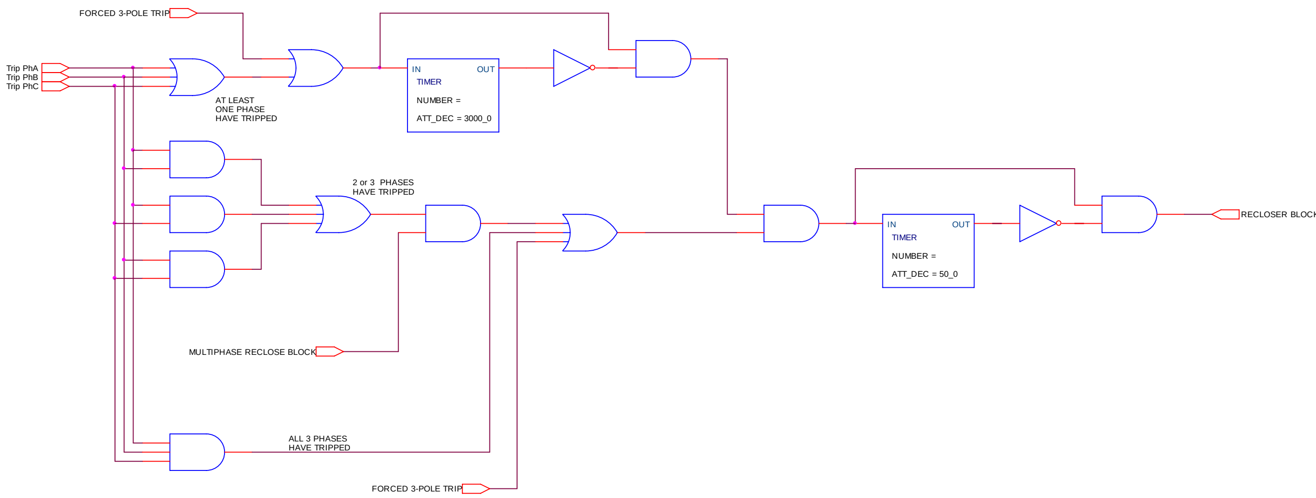

Figure 14-37 Recloser Block Logic

The 'FORCED 3-POLE TRIP signal is generated by the tripping logic and may be configured to allow tripping when only the ground generates a trip.

14.5.3 TRIP LOGIC

The GARD 8000 Distance Relay trip logic combines all measuring elements set to produce tripping into one main TRIP signal.

14.5.3.1 THREE POLE TRIPPING LOGIC

The three pole tripping logic is implemented in the GARD controller's logic processing and is shown in Figure 14-38. Each of the phase and ground processing routines has independent outputs to the logic bus. These signals are latched and then routed to front panel LED indicators. A target reset function is implemented using the front panel pushbutton.
These individual trip signals are combined and fed into a timer which holds the output active for a period after the trip stops being calculated. Following the trip timer the trip output will be blocked if the relay is out of service, is in test mode (see section 14.5.2.1), or the relay is in major alarm (see section 14.5.2.4).

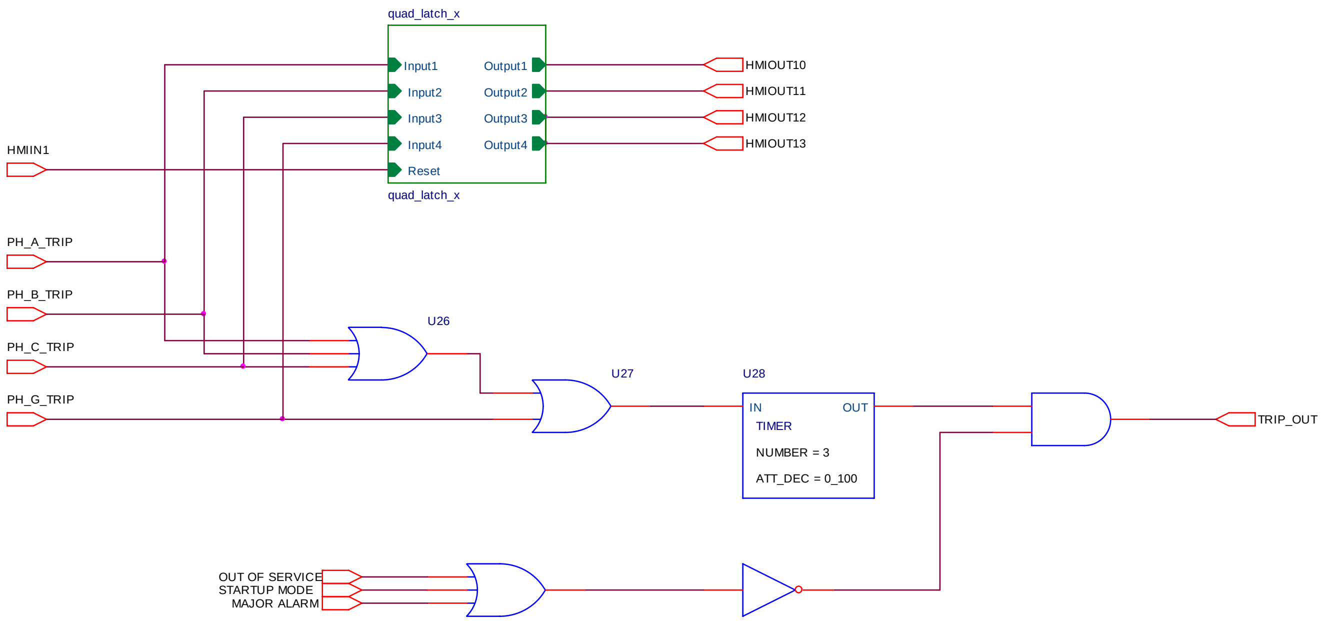

Figure 14-38 Three Pole Tripping Logic

14.5.3.2 SINGLE POLE TRIPPING LOGIC

The single pole tripping logic is implemented in the GARD controller's logic processing and is shown in Figure 14-39. As with the three pole logic each of the phase and ground processing routines have independent outputs to the logic bus. The generation of these per-phase trip signals is somewhat more complicated than for the three phase relay. A single-pole relay may be configured to operate as with single-pole, multiphase, or three-pole tripping.

As with the three pole logic the phase trip signals are latched and then routed to front panel LED indicators. A target reset function is implemented using the front panel pushbutton.

Each phase has an independent trip output with a trip release timer which holds the output active for a period after the trip stops being calculated. Depending upon configuration a phase may be forced to trip even if no fault was calculated for that particular phase (as described below). Following the trip timer each trip output will be blocked if the relay is out of service, is in startup mode, or the relay is in major alarm.

If the relay is configured for 3-pole tripping only a trip on any phase or ground will force a 3-pole trip (any of the trip outputs may be used). If the relay is operating in backup mode the logic will automatically operate in 3-pole tripping mode regardless of the user selection.

If the user has enable the single-pole ground tripping feature a trip calculated by ground can cause all three poles to trip. A trip calculated by ground is delayed to allow the trip to be cleared normally.

If the trip has not been cleared when the timer expires and no phase has calculated a trip, all phases will be forced to trip.

If two or more phases calculate a trip and the relay is configured for single-pole tripping (rather than multiphase) all phases will be forced to trip.

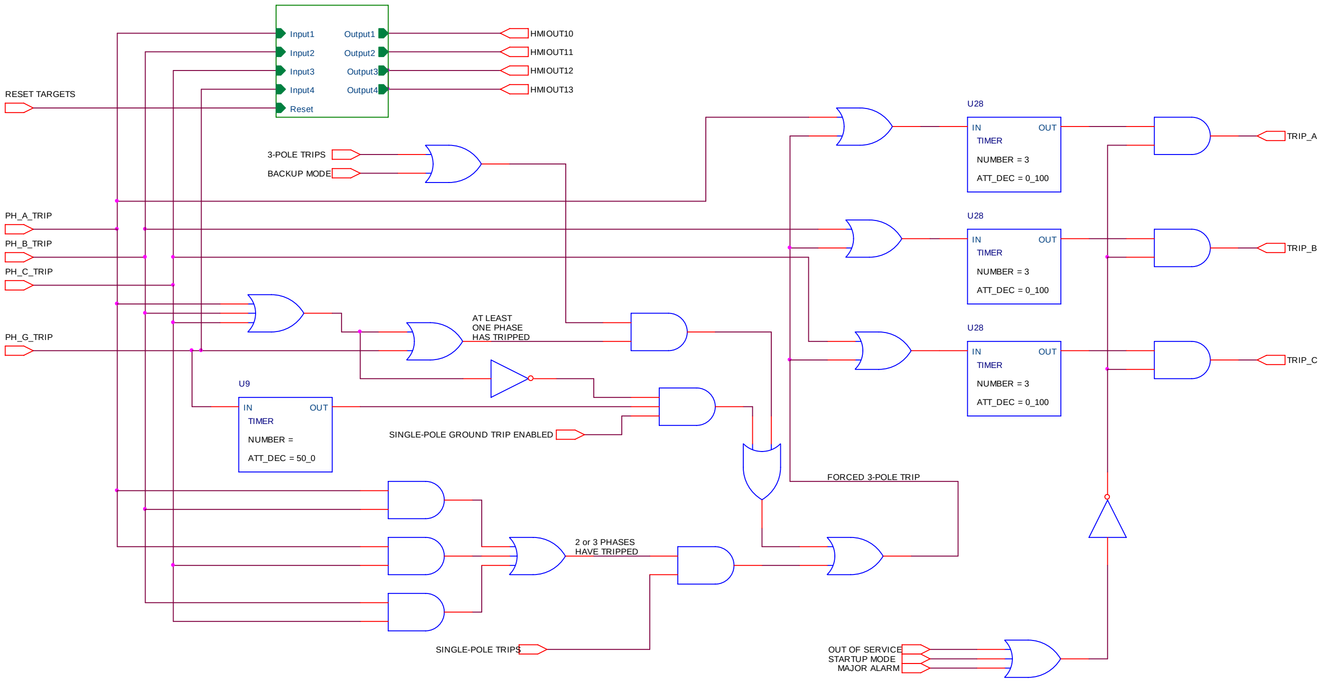

Figure 14-39 Single Pole Tripping Logic

14.6 SEQUENCE OF EVENTS AND OSCILLOGRAPHY

14.6.1 SOE

The relay has a sequence of events recorder (SOE) which can be configured to store information based upon user selectable triggers. The data saved is an instantaneous "snapshot" of the conditions when the trigger event occurred. This differs from the oscillography records which records the data over a period of time around the trigger event.

The user can select various parameters to trigger (initiate) an SOE recording. Any change of a trigger (becoming active or inactive) will initiate a recording. Trip outputs are automatically enabled as triggers and cannot be disabled by the user.

14.6.2 OSCILLOGRAPHY

The relay includes an oscillography recording function that allows the conditions surrounding a trip to be captured for later review. The recording includes the measured currents and a large amount of status information regarding the system conditions and relay calculations.

14.6.2.1 LENGTH OF OSCILLOGRAPHIC RECORD

The user can select the length of the oscillography recordings between 10 and 180 cycles. The length selected for each recording can impact the maximum number of recordings the relay can store due to the finite memory available. All of the oscillography recordings saved in the relay must have the same configuration, therefore, if the user changes the oscillography length setting all previously recorded oscillography records will be erased.

14.6.2.2 PRE-TRIGGER LENGTH

The user can select the amount of pre-trigger information retained in the oscillography recordings between 0 and 180 cycles. If the length selected exceeds the user setting for the total recording length (section 14.6.2.1) the relay will use the selected recording length setting and set the entire recording as pre-trigger data. All of the oscillography recordings saved in the relay must have the same configuration, therefore, if the user changes the pre-trigger length setting all previously recorded oscillography records will be erased.

14.6.2.3 NUMBER OF OSCILLOGRAPHY RECORDINGS

A maximum of approximately 2300 cycles can be recorded in the memory. The number of fault records depends on the length selected for the recording. Maximum number of records is 64, if more than 36 cycles are recorded per record the maximum number of records will be less than 64. Table 14-1 shows the rough correspondence between record length and number of records.

Table 14-1 Maximum Number of Oscillography Records

Set Record Length (cycles)	Approximate number of records
10 to 36	64
37 to 45	63
46 to 57	50
57 to 75	40
76 to 111	30
112 to 180	20

14.6.2.4 TRIGGER CONDITIONS

The user may configure which signals within the relay will cause an oscillography recording to be initiated. In addition to the user selected triggers the relay sets all trips as valid oscillography triggers. Any change of state (becoming active or inactive) of any trigger will initiate an oscillography recording.

The selection of triggers does not impact what data is recorded in the oscillography.

14.6.2.5 RECORDED DATA

The oscillography records record 33 samples per cycle. Each sample includes all of the measured currents (as analog measurements), all of the selectable trigger items, and a number of additional status items (as digital measurements).

Major Alarm

A logical “1” indicates the relay has an active major alarm.

Minor Alarm

A logical “1” indicates the relay has an active minor alarm.

Curr Diff Alarms Phase, A, B, C, and Ground

A logical “1” indicates the phase in question has an active current differential alarm.

Breaker Open

There has been no current measured in any of the four inputs for a period of time.

External Dual Breaker Fault Detector

A logical “1” indicates that an external dual breaker fault has been detected. (See section 14.5.1.1.7)

Remote1 Fault Detector

A logical “1” indicates the remote relay has an active fault detector.

Comms1 Relay Configuration Mismatch

A logical “1” indicates the remote relay configuration is incompatible with the local relay (e.g. one is single-pole the other is three-pole).

Ping-Pong Alarm Comms1

A logical “1” indicates there is a ping-pong alarm active.

Address Fail Comms1

A logical "1" indicates the local and remote address settings are not consistent.

Comms1 Fail

A logical "1" indicates the communications channel has failed.

Comms1 Alarm

A logical "1" indicates the communications channel has an active alarm condition.

Comms1 Primary GB4T

A logical "1" indicates the primary guard before trip requirements have been satisfied.

Comms1 Backup GB4T

A logical "1" indicates the backup guard before trip requirements have been satisfied.

LB Input 89B

A logical "1" indicates the logic bus input to the relay representing the 89B signal is active.

LB Input Trip Enable

A logical "1" indicates the logic bus input to the relay representing the trip enable signal is active.

LB Input Tx Transferred Status #0 through #7

A logical "1" indicates the corresponding logic bus input to the relay is active.

LB Output Phase, A, B, C, and Ground Trips

A logical "1" indicates the relay has tripped the corresponding phase and is sending the trip out to the logic bus.

LB Output Comms 1 Fail

A logical "1" indicates the relay has detected a communications failure and is sending this information out to the logic bus.

LB Output Relay Out of Service

A logical "1" indicates the relay is out of service and is sending this information out to the logic bus.

LB Output Current Differential Alarm

A logical "1" indicates the relay has calculated a current differential alarm condition and is sending this information out to the logic bus.

LB Output LOL/OC Alarm

A logical "1" indicates the relay has calculated either a loss of load (backup mode) or open conductor (primary mode) condition and is sending this information out to the logic bus.

LB Output Single-Pole

A logical "1" indicates the relay has been configured for single-pole mode and is sending this information out to the logic bus (only meaningful in a single-pole relay).

LB Output Major Alarm

A logical "1" indicates the relay is in a major alarm condition and is sending this information out to the logic bus.

LB Output Minor Alarm

A logical “1” indicates the relay is in a minor alarm condition and is sending this information out to the logic bus.

LB Output Backup Mode

A logical “1” indicates the relay is in backup mode and is sending this information out to the logic bus.

LB Output Startup Mode

A logical “1” indicates the relay is in startup mode and is sending this information out to the logic bus.

LB Outputs Rx Transfer Status #0 through #7

A logical “1” indicates the corresponding logic bus output from the relay is active.

Phase A, B, C, and Ground Overcurrent FDs

A logical “1” indicates the corresponding phase has detected an overcurrent fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Peak Change FDs

A logical “1” indicates the corresponding phase has detected a peak change fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Pulse Width FDs

A logical “1” indicates the corresponding phase has detected a pulse width fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Slope Change FDs

A logical “1” indicates the corresponding phase has detected a slope change fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Polarity Change FDs

A logical “1” indicates the corresponding phase has detected a polarity change fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Breaker Closing FDs

A logical “1” indicates the corresponding phase has detected a breaker closing fault. Note that this is tied to an algorithm internal parameter and is not fully processed into a true fault detector. This parameter should be reviewed in conjunction with the “aggregate FD” described below.

Phase A, B, C, and Ground Aggregate FDs

A logical “1” indicates the corresponding phase has an active fault detector. This is the aggregate FD – it is the combined and processed result from all of the individual FD elements. As described in the individual FDs above, this is the only true indication that the relay has an active fault detector. All of the above contributors to the FD are combined and extended as required to generate the aggregate fault detector.

Phase A, B, C, and Ground Aggregate Trips

A logical "1" indicates the corresponding phase has tripped. This is the aggregate trip – it is the combined and processed result from all of the individual trip elements. This is the phase-specific trip signal that is sent to the logic bus and is used to generate the actual trip signal. All of the contributors to the tripping process (as listed below) are combined and extended as required to generate the aggregate trip signals.

Phase A, B, and C Open Conductor Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the open conductor (primary) algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground Curr Diff Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the current differential (primary) algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground HST Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the HST (primary) algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground Breaker Open

A logical "1" indicates the corresponding phase has determined the breaker to be open. In a single-pole system the phases operate independently, in a three-pole system they will all be the same.

Phase A, B, C, and Ground TOC Backup Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the TOC (backup) algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground Overcurrent Backup Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the overcurrent backup algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground LOL Backup Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the LOL backup algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Phase A, B, C, and Ground CIF Backup Trips

A logical "1" indicates the corresponding phase has detected a trip condition based upon the CIF backup algorithm. Note that this is tied to an algorithm internal parameter and is not fully processed into a true trip output. This parameter should be reviewed in conjunction with the "aggregate trips" described above.

Remote #1 Phase A, B, C, and Ground TCDT Received

Setting this to "Yes" will allow the receipt of a TCDT message from the remote relay to trigger an oscillography recording.

Remote #1 Phase A, B, C, and Ground HST Received

Setting this to "Yes" will allow the receipt of a HST message from the remote relay to trigger an oscillography recording.

14.6.2.6 VIEWING RECORDED OSCILLOGAPHIC RECORDS

All oscillography records are stored locally in the relay in a compacted format. To view the records the user must transfer the data from the GARD 8000 system to a PC for viewing. During this process the data is converted to a COMTRADE (1999) format.

Once in the PC the files may be viewed with any standard COMTRADE reader or the ZIVerCOM Analyzer provided with the GARD 8000 System.

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