Section 5 Protection related functions

5.1 Three-phase transformer inrush detector INR

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase inrush detector	INRPHAR	3I2f>	INR

5.1.2 Function block

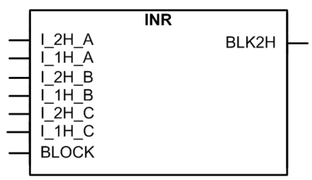

Figure 184: Function block

5.1.3 Functionality

The transformer inrush detection INR is used to coordinate transformer inrush situations in distribution networks.

Transformer inrush detection is based on the following principle: the output signal `BLK2H` is activated once the numerically derived ratio of second harmonic current I_2H and the fundamental frequency current I_1H exceeds the set value.

The trip time characteristic for the function is of definite time (DT) type.

The function contains a blocking functionality. Blocking deactivates all outputs and resets timers.

5.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of an inrush current detection function can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

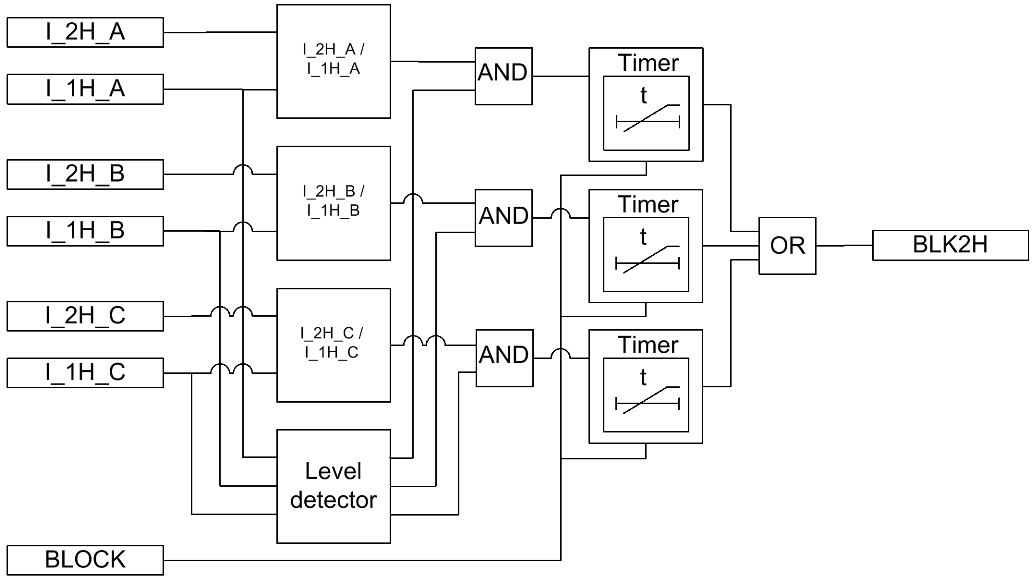

Figure 185: Functional module diagram. I_1H and I_2H represent fundamental and second harmonic values of phase currents.

I_2H/I_1H

This module calculates the ratio of the second harmonic (I_2H) and fundamental frequency (I_1H) phase currents. The calculated value is compared with the set *Pickup value*. If the calculated value exceeds the set *Pickup value*, the module output is activated.

Level detector

The output of the phase specific level detector is activated when the fundamental frequency current I_1H exceeds five percent of the nominal current.

Timer

Once activated, the timer runs until the set *Trip delay time* value. The time characteristic is according to DT. When the trip timer has reached the *Trip delay time* value, the BLK2H output is activated. After the timer has elapsed and the inrush situation still exists, the BLK2H signal remains active until the I_2H/I_1H ratio drops below the value set for the ratio in all phases, that is, until the inrush situation is over. If the drop-off situation occurs within the trip time up counting, the reset timer is activated. If the drop-off time exceeds *Reset delay time*, the trip timer is reset.

The BLOCK input can be controlled with a binary input, a horizontal communication input or an internal signal of the relay program. The activation of the BLOCK input prevents the BLK2H output from being activated.

5.1.5 Application

Transformer protections require high stability to avoid tripping during magnetizing inrush conditions. A typical example of an inrush detector application is doubling the pickup value of an overcurrent protection during inrush detection.

The inrush detection function can be used to selectively block overcurrent and ground-fault function stages when the ratio of second harmonic component over the fundamental component exceeds the set value.

Other applications of this function include the detection of inrush in lines connected to a transformer.

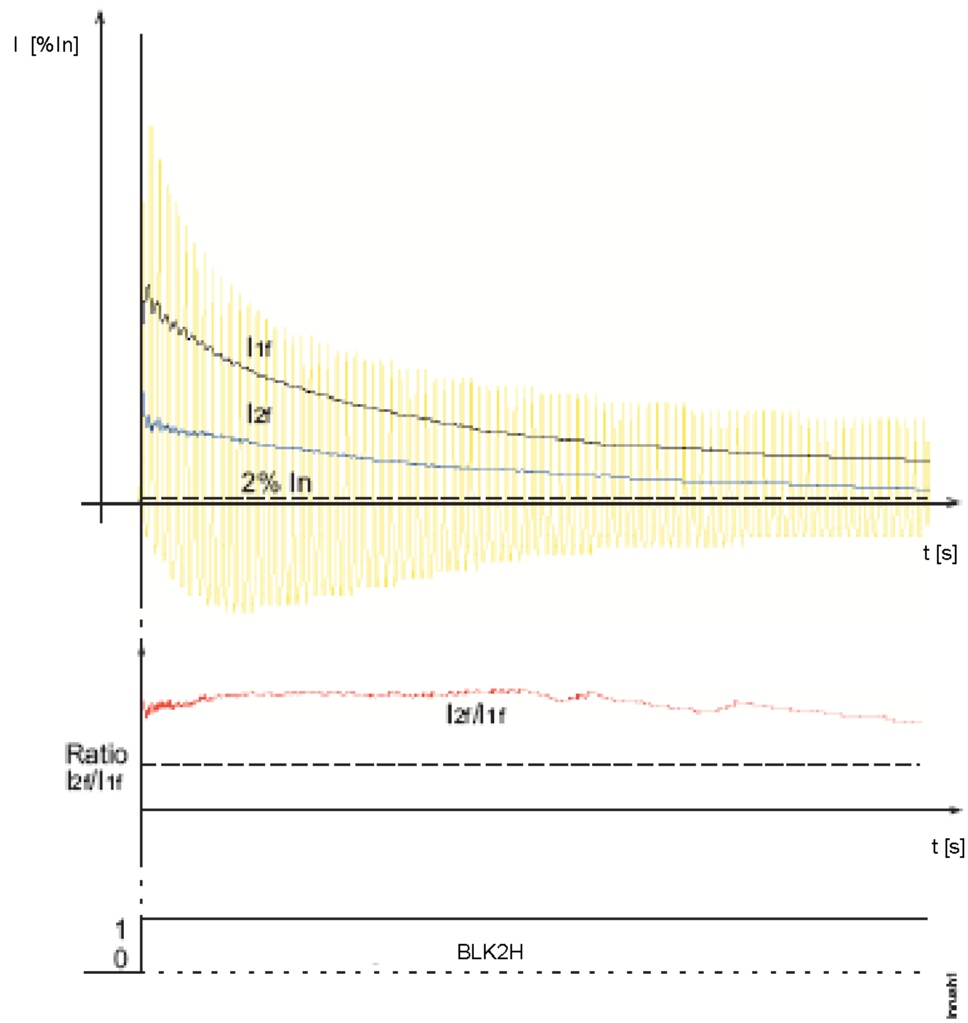

Figure 186: Inrush current in transformer

It is recommended to use the second harmonic and the waveform based inrush blocking from the transformer differential protection function 87T if available.

5.1.6 Signals

Table 334: INR Input signals

Name	Type	Default	Description
I_2H_A	SIGNAL	0	Second harmonic phase A current
I_1H_A	SIGNAL	0	Fundamental frequency phase A current
I_2H_B	SIGNAL	0	Second harmonic phase B current
I_1H_B	SIGNAL	0	Fundamental frequency phase B current
I_2H_C	SIGNAL	0	Second harmonic phase C current
I_1H_C	SIGNAL	0	Fundamental frequency phase C current
BLOCK	BOOLEAN	0=False	Block input status

Table 335: INR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

5.1.7 Settings

Table 336: INR Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
PIckup value	5...100	%	1	20	Ratio of the 2. to the 1. harmonic leading to restraint
Operate delay time	20...60000	ms	1	20	Operate delay time

Table 337: INR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time

5.1.8 Monitored data

Table 338: INR Monitored data

Name	Type	Values (Range)	Unit	Description
INR	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

5.1.9 Technical data

Table 339: INR Technical data

Characteristic	Value
Pickup accuracy	At the frequency f=f_n
	Current measurement: ±1.5% of the set value or ±0.002 x I_n Ratio I2f/I1f measurement: ±5.0% of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typical 0.96
Trip time accuracy	+35 ms / -0 ms

5.2 Circuit breaker failure protection 50BF

5.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker failure protection	CCBRBRF	3I>/Io>BF	50BF

5.2.2 Function block

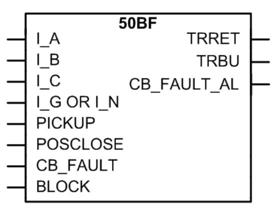

Figure 187: Function block

5.2.3 Functionality

The breaker failure function 50BF is activated by trip commands from the protection functions. The commands are either internal commands to the terminal or external commands through binary inputs. The pickup command is always a default for three-phase operation. 50BF includes a three-phase conditional or unconditional re-trip function, and also a three-phase conditional back-up trip function.

50BF uses the same levels of current detection for both re-trip and back-up trip. The operating values of the current measuring elements can be set within a predefined setting range. The function has two independent timers for trip purposes: a re-trip timer for the repeated tripping of its own breaker and a back-up timer for the trip logic operation for upstream breakers. A minimum trip pulse length can be set independently for the trip output.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

5.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of breaker failure protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections. Also further information on retrip and back-up trip logics is given in sub-module diagrams.

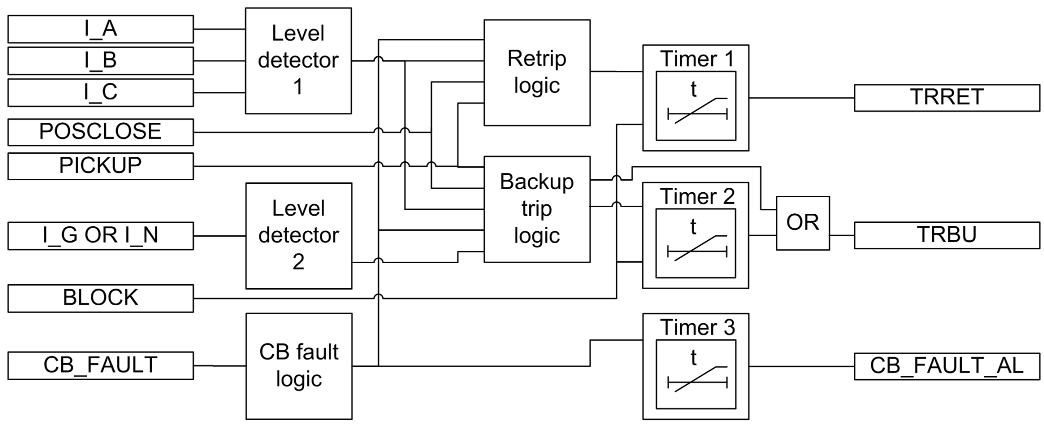

Figure 188: Functional module diagram. I_A, I_B and I_C represent phase currents and I_0 residual current.

Level detector 1

The measured phase currents are compared phase-wise with the set *Current value*. If the measured value exceeds the set *Current value*, the level detector reports the exceeding of the value to the retrip and back-up trip logics. The parameter should be set low enough so that situations with small fault current or high load current can be detected. The setting can be chosen in accordance with the most sensitive protection function to start the breaker failure protection.

Level detector 2

The measured ground current is compared with the set *Current value Res*. If the measured value exceeds the set *Current value Res*, the level detector reports the exceeding of the value to the back-up trip logic. In high impedance grounded systems, the ground current at phase to ground faults are normally much smaller than the short circuit currents. To detect a breaker failure at single-phase ground faults in these systems, it is necessary to measure the ground current separately. In effectively grounded systems, also the setting of the ground-fault current protection can be chosen at a relatively low current level. The *CB failure trip mode* is set "1 out of 4". The current setting should be chosen in accordance with the setting of the sensitive ground-fault protection.

Retrip logic

The operation of the retrip logic can be described by using a module diagram:

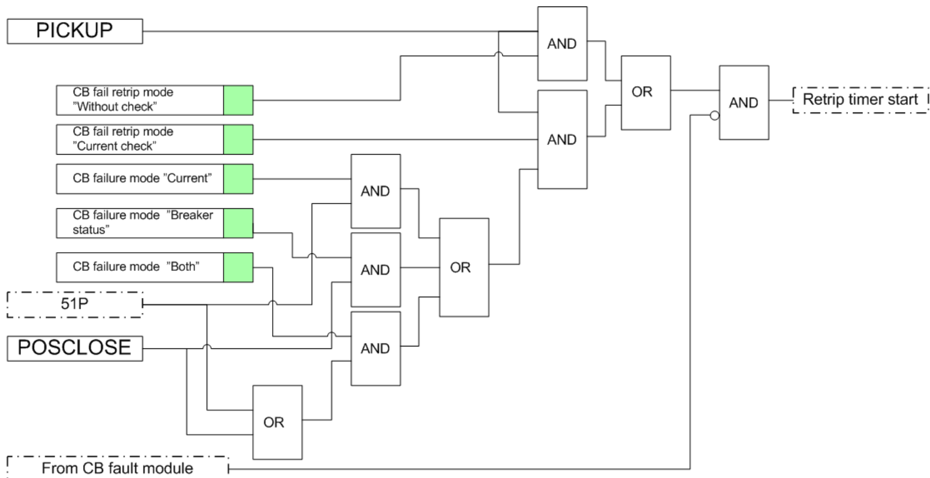

Figure 189: Retrip logic internal design

The retrip function operates with or without a current check selected with the *CB fail retrip mode* setting. In "Current check" mode, the retrip is only performed if the current through the circuit breaker exceeds the *Current value* level. In "Without check" mode, the retrip is done without checking the phase currents.

The *CB failure mode* setting is used to select the mode the breaker fault is detected with. In "Current" mode, the detection is based on the current level exceeding. In "Breaker status" mode, the detection is based on the closed position of the circuit breaker after a trip signal is issued, that is, after a long duration of the trip signal. In "Both" mode, the detection is based either on the exceeding of *Current value* level or on the long duration of the trip signal. When external information of a circuit breaker fault is connected to the active `CB_FAULT` input, the retrip function is not allowed to trip.. The blocking is used to disable the whole function.

Back-up trip logic

The operation of the back-up trip logic can be described by using a module diagram:

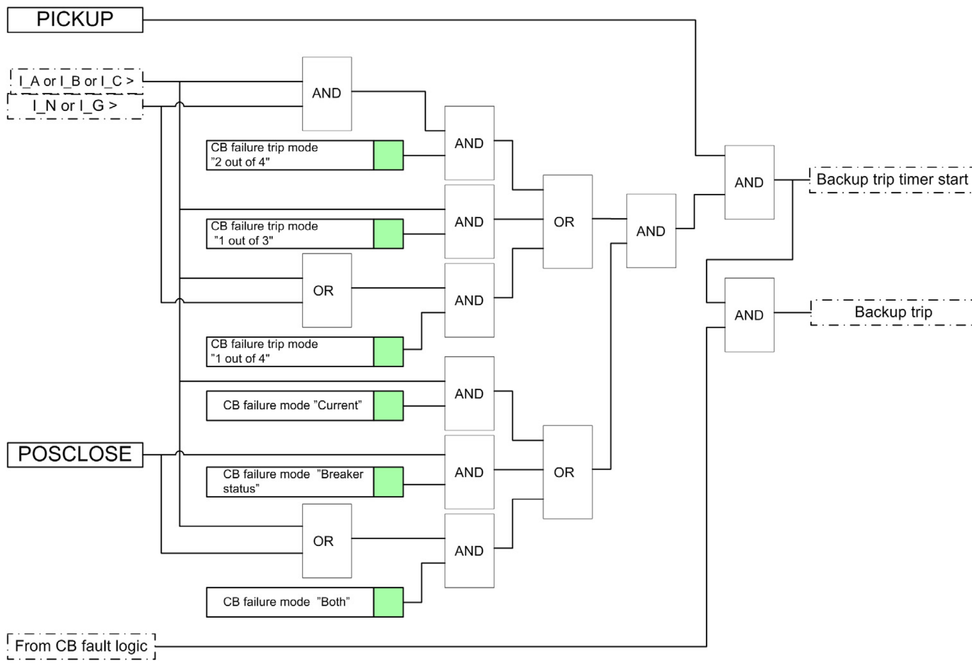

Figure 190: Back-up trip logic internal design

The current detection characteristics can be selected with the *CB failure trip mode* setting in three following options:

- "1 out of 3" in which detecting opening failure (high current) in one phase only is sufficient
- "1 out of 4" in which detecting opening failure (high current) or high ground current in one phase only is sufficient
- "2 out of 4" in which at least two high currents (phase current and/or ground current) are required for breaker failure detection.

In most applications, "1 out of 3" is sufficient. In the "Breaker status" mode, the back-up trip is done when the status inputs indicate that the circuit breaker is in closed state.

The setting *CB failure mode* is used to select the mode the breaker fault is detected with. In "Current" mode, the detection is based on the current level exceeding. In "Breaker status" mode, the detection is based on the closed position of the circuit breaker after a trip signal is issued, that is, after a long duration of the trip signal. In "Both" mode, the detection is based either on the exceeding of the *Current value Res* level, depending on the current detection mode, or on the long duration of the trip signal. When external information on a circuit breaker fault is connected to the active `CB_FAULT` input, the back-up trip function is issued to the upstream breaker without delay. The blocking is used for disabling the whole function.

Timer 1

Once activated, the timer runs until the set *Retrip time* value has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `TRRET` output is activated. A typical setting is 0 - 50 ms.

Timer 2

Once activated, the timer runs until the set *CB failure delay* value is elapsed. The time characteristic is according to DT. When the operation timer has reached the set maximum time value *CB failure delay*, the `TRBU` output is activated. The value of this setting is made as low as possible at the same time as any unwanted operation is avoided. A typical setting is 90 - 150 ms which is also dependent on the retrip timer.

The minimum time delay for the retrip can be estimated as:

$$CBfailuredelay \geq Retriptime + t_{cbopen} + t_{BFP\_reset} + t_{margin} \quad \text{(Equation 49)}$$

t_{cbopen}	maximum opening time for the circuit breaker
t_{BFP_reset}	is the maximum time for the breaker failure protection to detect the correct breaker function (the current criteria reset)
t_{margin}	safety margin

It is often required that the total fault clearance time is less than the given critical time. This time is often dependent on the ability to maintain transient stability in case of a fault close to a power plant.

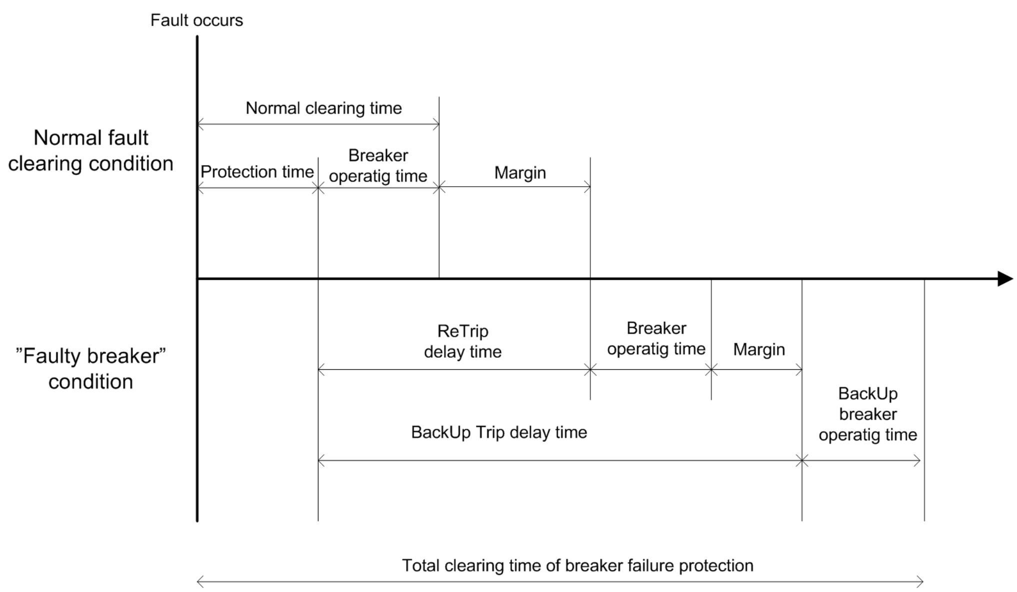

Figure 191: Time line of breaker failure protection

Timer 3

This module is activated by the `CB_FAULT` signal. Once activated, the timer runs until the set *CB fault delay* value is elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `CB_FAULT_AL` output is activated. After the set time an alarm is given so that actions can be done to repair the circuit breaker. A typical value is 5 s.

5.2.5 Application

The n-1 criterion is often used in the design of a fault clearance system. This means that the fault is cleared even if some component in the fault clearance system is faulty. A circuit breaker is a necessary component in the fault clearance system. For practical and economical reasons, it is not feasible to duplicate the circuit breaker for the protected component, but breaker failure protection is used instead.

The breaker failure function issues a back-up trip command to adjacent circuit breakers in case the original circuit breaker fails to trip for the protected component. The detection of a failure to break the current through the breaker is made by measuring the current or by detecting the remaining trip signal (unconditional).

50BF can also retrip. This means that a second trip signal is sent to the protected circuit breaker. The retrip function is used to increase the operational reliability of the breaker. The function can also be used to avoid back-up tripping of several breakers in case mistakes occur during IED maintenance and tests.

50BF is initiated by operating different protection functions or digital logics inside the IED. It is also possible to initiate the function externally through a binary input.

50BF can be blocked by using an internally assigned signal or an external signal from a binary input. This signal blocks the function of the breaker failure protection even when the timers have started or the timers are reset.

The retrip timer is initiated after the pickup input is set to true. When the pre-defined time setting is exceeded, 50BF issues the retrip and sends a trip command, for example, to the circuit breaker's second trip coil. Both a retrip with current check and an unconditional retrip are available. When a retrip with current check is chosen, the retrip is performed only if there is a current flow through the circuit breaker.

The backup trip timer is also initiated at the same time as the retrip timer. If 50BF detects a failure in tripping the fault within the set backup delay time, which is longer than the retrip time, it sends a backup trip signal to the chosen backup breakers. The circuit breakers are normally upstream breakers which feed fault current to a faulty feeder.

The backup trip always includes a current check criterion. This means that the criterion for a breaker failure is that there is a current flow through the circuit breaker after the set backup delay time.

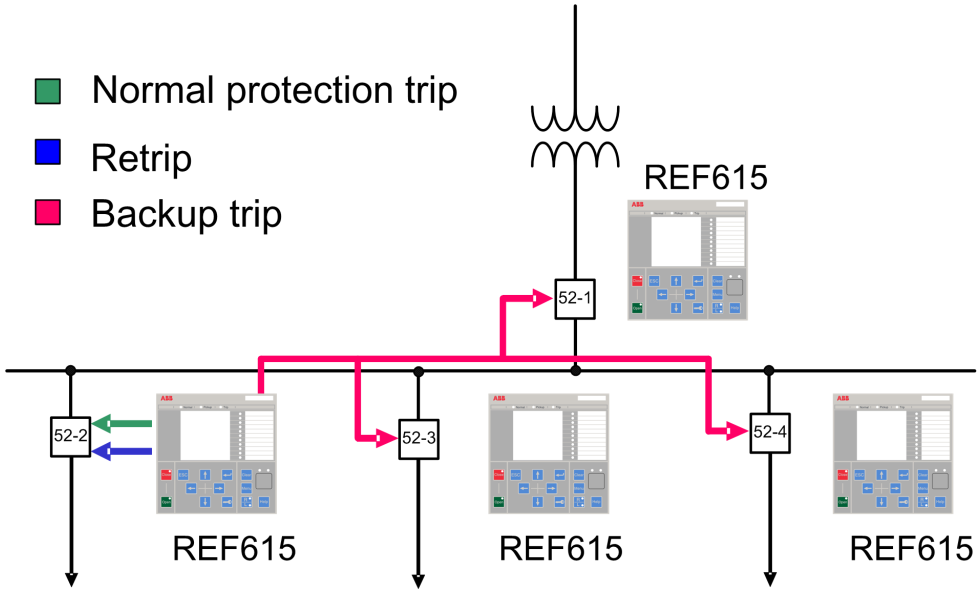

Figure 192: Typical breaker failure protection scheme in distribution substations

5.2.6 Signals

Table 340: 50BF Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_N	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block CBFP operation
PICKUP	BOOLEAN	0=False	CBFP pickup command
POSCLOSE	BOOLEAN	0=False	CB in closed position
CB_FAULT	BOOLEAN	0=False	CB faulty and unable to trip

Table 341: 50BF Output signals

Name	Type	Description
CB_FAULT_AL	BOOLEAN	Delayed CB failure alarm
TRBU	BOOLEAN	Backup trip
TRRET	BOOLEAN	Retrip

5.2.7 Settings

Table 342: 50BF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Off / On
Current value	0.05...1.00	xIn	0.05	0.30	Operating phase current
Current value Gnd	0.05...1.00	xIn	0.05	0.30	Operating ground current
CB failure trip mode	1=2 out of 4 2=1 out of 3 3=1 out of 4			1=2 out of 4	Backup trip current check mode
CB failure mode	1=Current 2=Breaker status 3=Both			1=Current	Operating mode of function
CB fail retrip mode	1=Disabled 2=Without Check 3=Current check			1=Disabled	Operating mode of retrip logic
Retrip time	0...60000	ms	10	20	Delay timer for retrip
CB failure delay	0...60000	ms	10	150	Delay timer for backup trip
CB fault delay	0...60000	ms	10	5000	Circuit breaker faulty delay
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Phase current measurement mode of function
Trip pulse time	0...60000	ms	10	20	Pulse length of retrip and backup trip outputs

5.2.8 Monitored data

Table 343: 50BF Monitored data

Name	Type	Values (Range)	Unit	Description
50BF	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

5.2.9 Technical data

Table 344: 50BF Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	±1.5% of the set value or ±0.002 x I_n
Trip time accuracy	±1.0% of the set value or ±20 ms

5.3 Protection trip conditioning 86/94

5.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Protection trip conditioning	TRPPTRC	Master Trip	86/94

5.3.2 Function block

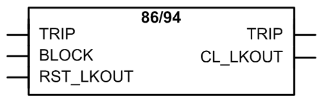

Figure 193: Function block

5.3.3 Functionality

The protection trip conditioning function 86/94 is intended to be used as a trip command collector and handler after the protection functions. The features of this function influence the trip signal behavior of the circuit breaker. The user can set the minimum trip pulse length when the non-latched mode is selected. It is also possible to select the latched or lockout mode for the trip signal.

5.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

When the 86/94 function is disabled, all trip outputs which are intended to go through the function to the circuit breaker trip coil are blocked!

The operation of a trip logic function can be described by using a module diagram. All the blocks in the diagram are explained in the next sections:

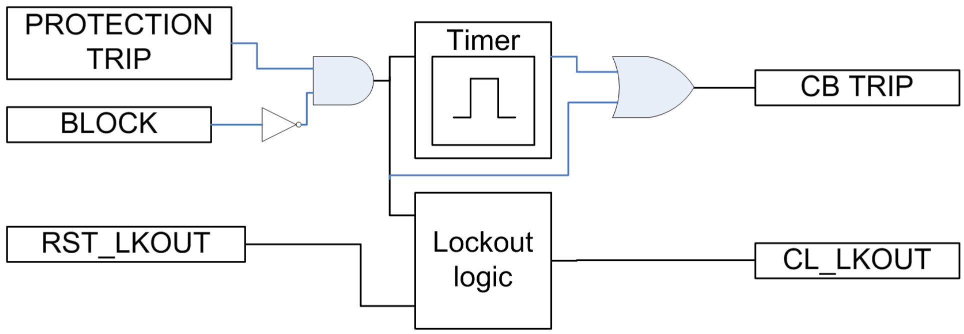

Figure 194: Functional module diagram

Timer

The user can adjust the duration of a trip output signal from the 86/94 function with the *Trip pulse time* setting. The pulse length should be long enough to secure the opening of the breaker. For three-pole tripping, 86/94 has a single input TRIP, through which all trip output signals are routed from the protection functions within the IED, or from external protection functions via one or more of the IED's binary inputs. The function has a single trip output CB TRIP for connecting the function to one or more of the IED's binary outputs, as well as to other functions within the IED requiring this signal.

The BLOCK input blocks the CB TRIP output and resets the timer.

Lockout logic

The user can select the behavior of 86/94 in trip situation with the *Trip output mode* setting. The user can select between three different modes: "Non-latched", "Latched" and "Lockout". When using the "Latched" mode, the RST_LKOUT input can be used to reset the CB TRIP output. The output can be reset also via communication or LHMI. The CL_LKOUT output is activated only in the "Lockout" mode.

The CL_LKOUT can be blocked with the BLOCK input.

Table 345: Operation modes for the 86/94 trip output

Mode	Operation
Non-latched	The *Trip pulse length* parameter gives the minimum pulse length for the CB TRIP
Latched	The CB TRIP is latched ; both local and remote clearing is possible.
Lockout	The CB TRIP is locked and can be cleared only locally via menu or the RST_LKOUT input.

5.3.5 Application

All trip signals from different protection functions are routed through the trip logic. The most simplified application of the logic function is linking the trip signal and ensuring that the signal is long enough.

The tripping logic in the protection relay is intended to be used in the three-phase tripping for all fault types (3ph operating). To prevent the closing of a circuit breaker after a trip, the function can block the 52 closing.

The 86/94 function is intended to be connected to one trip coil of the corresponding circuit breaker. If tripping is needed for another trip coil or another circuit breaker which needs, for example, different trip pulse time, another trip logic function can be used. The two instances of the PTRC function are identical, only the names of the functions, 86/94-1 and 86/94-2, are different. Therefore all references made to only 86/94-1 apply to 86/94-2 as well.

The inputs from the protection functions are connected to the `TRIP` input. Usually, a logic block OR is required to combine the different function outputs to this input. The `CB TRIP` output is connected to the digital outputs on the IO board. This signal can also be used for other purposes within the IED, for example when starting the breaker failure protection.

86/94 is used for simple three-phase tripping applications.

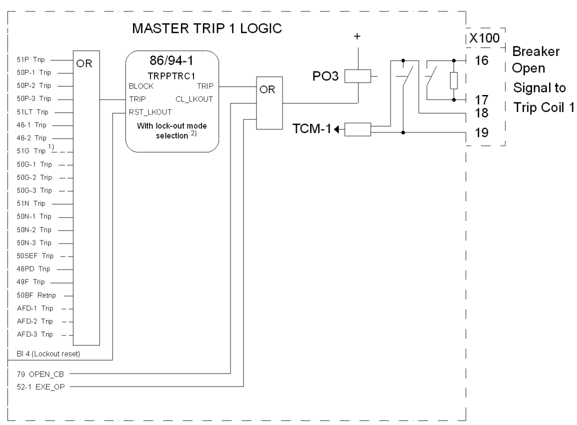

Figure 195: Typical 86/94 connection

Lock-out

86/94 is provided with possibilities to activate a lockout. When activated, the lockout can be manually reset after checking the primary fault by activating the RST_LKOUT input or from the LHMI clear menu parameter. When using the “Latched” mode, the resetting of the TRIP output can done similarly as when using the “Lockout” mode. It is also possible to reset the “Latched” mode remotely through a separate communication parameter.

The minimum pulse trip pulse function is not active when using the “Lockout” or “Latched” modes but only when the “Non-latched” mode is selected.

5.3.6 Signals

Table 346: 86/94 Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block of function
TRIP	BOOLEAN	0=False	Trip
RST_LKOUT	BOOLEAN	0=False	Input for resetting the circuit breaker lockout function

Table 347: 86/94 Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip output signal
CL_LKOUT	BOOLEAN	Circuit breaker lockout output (set until reset)

5.3.7 Settings

Table 348: 86/94 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Disable / Enable
Trip pulse time	20...60000	ms	1	150	Minimum duration of trip output signal
Trip output mode	1=Non-latched 2=Latched 3=Lockout			1=Non-latched	Select the operation mode for trip output

5.3.8 Monitored data

Table 349: 86/94 Monitored data

Name	Type	Values (Range)	Unit	Description
86/94	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

5.4 High impedance fault detector HIZ

5.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
High impedance fault detector	PHIZ	HIF	HIZ

5.4.2 Function block symbol

Figure 196: Function block symbol

5.4.3 Functionality

A small percentage of ground faults have a very large impedance. They are comparable to load impedance and consequently have very little fault current. These high impedance faults do not pose imminent danger to power system equipment. However, they are a substantial threat to humans and properties; people can touch or get close to conductors carrying large amounts of energy.

ABB has developed a patented technology (US Patent 7,069,116 B2 June 27, 2006, US Patent 7,085,659 B2 August 1, 2006) to detect high impedance fault.

The high impedance fault-detector function HIZ also contains a blocking functionality. It is possible to block function outputs, if desired.

5.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

HIZ uses a multi-algorithm approach. Each algorithm uses various features of ground currents to detect a high impedance fault.

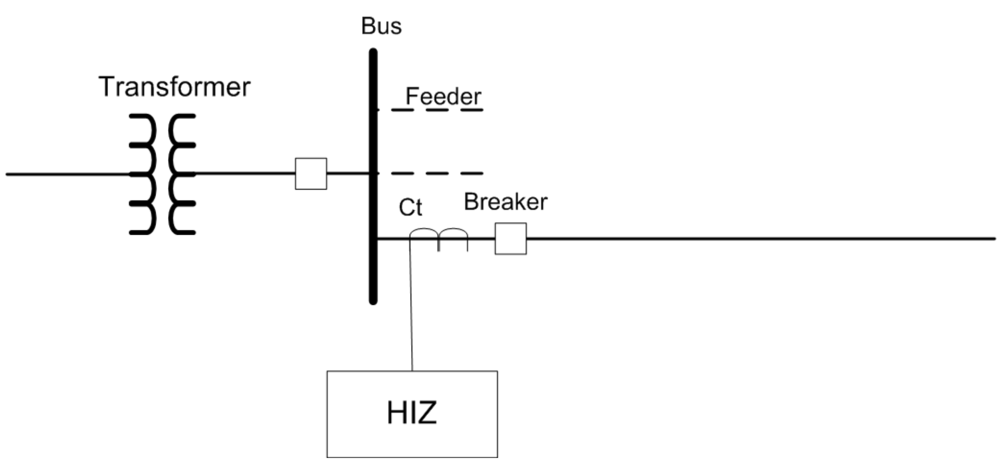

Figure 197: Electrical power system equipped with HIZ

Power system signals are acquired, filtered, and then processed by individual high impedance fault detection algorithm. The results of these individual algorithms are further processed by decision logic to provide the detection decision. The decision logic can be modified depending on the application requirement.

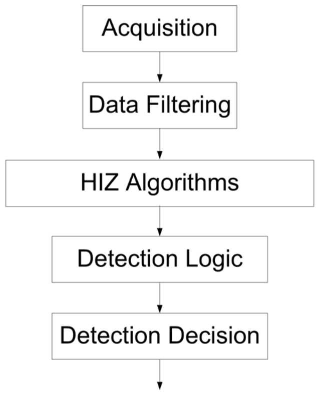

Figure 198: Block diagram of HIZ

HIZ is based on algorithms that use ground current signatures which are considered non stationary, temporally volatile, and of various burst duration. All harmonic and non-harmonic components within the available data window can play a vital role in the high impedance fault detection. A major challenge is to develop a data model that acknowledges that high impedance faults could take place at any time within the observation window of the signal and could be delayed randomly and attenuated substantially. The model is motivated by extensive research, actual experimental observations in the laboratory, field testing, and what traditionally represents an accurate depiction of a non stationary signal with a time dependent spectrum.

Figure 199: Validation of HIZ on gravel

Figure 200: Validation of HIZ on concrete

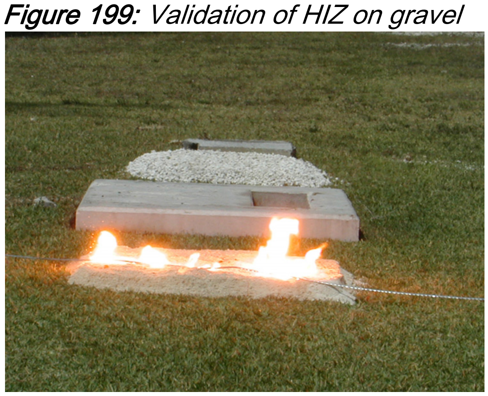

Figure 201: Validation of HIZ on sand

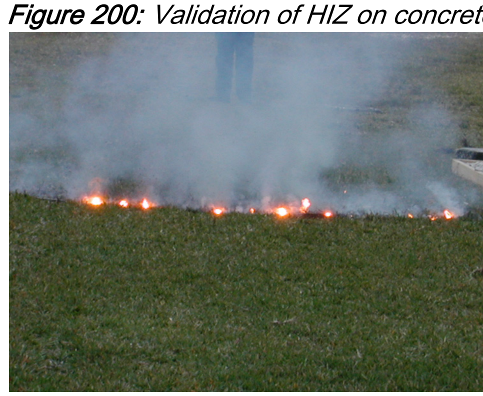

Figure 202: Validation of HIZ on grass

5.4.5 Application

Electric power lines experience faults for many reasons. In most cases, electrical faults manifest in mechanical damage, which must be repaired before returning the line to service.

Most of these faults are ground faults. Conventional protection systems based on overcurrent, impedance, or other principles are suitable for detecting relatively low impedance faults, which have a relatively large fault current.

However, a small percentage of the ground faults have a very large impedance. They are comparable to load impedance and consequently have very little fault current. These high impedance faults do not pose imminent danger to power system equipment. However, they are a considerable threat to people and property. The IEEE Power System Relay Committee working group on High Impedance Fault Detection Technology defines High Impedance Faults as those that 'do not produce enough fault current to be detectable by conventional overcurrent relays or fuses'.

High impedance fault (HIZ) detection requires a different approach than that for conventional low impedance faults. Reliable detection of HIZ provides safety to humans and animals. HIZ detection can also prevent fire and minimize property damage. ABB has developed innovative technology for high impedance fault detection with over seven years of research resulting in many successful field tests.

5.4.6 Signals

Table 350: HIZ Input signals

Name	Type	Default	Description
IG	SIGNAL	0	Ground current measured using SEF CT
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 351: HIZ Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip

5.4.7 Settings

Table 352: HIZ Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Security level	1...10		1	5	Security Level

Table 353: HIZ Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
System type	1=Grounded 2=Ungrounded			1=Grounded	System Type

5.4.8 Monitored data

Table 354: HIZ Monitored data

Name	Type	Values (Range)	Unit	Description
Position	Enum	0=intermediate 1=open 2=closed 3=faulty		Position
HIZ	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

5.5 Arc protection, AFD

5.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Arc protection	ARCSARC	ARC	AFD

5.5.2 Function block

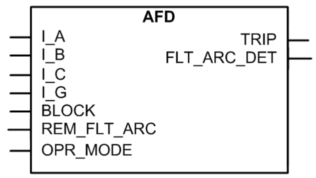

Figure 203: Function block

5.5.3 Functionality

The arc flash detector AFD detects arc situations in air insulated metal-clad switchgears caused by, for example, human errors during maintenance or insulation breakdown during operation.

The function detects light from an arc either locally or via a remote light signal. The function also monitors phase and ground currents to be able to make accurate decisions on ongoing arcing situations.

The function contains a blocking functionality. Blocking deactivates all outputs and resets timers.

5.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of the arc flash detector can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

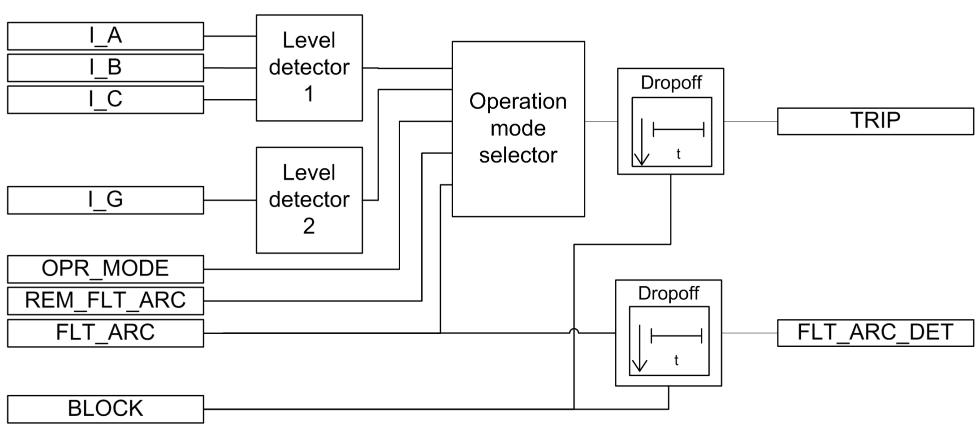

Figure 204: Functional module diagram. I_A, I_B and I_C represent phase currents.

Level detector 1

The measured phase currents are compared phase-wise with the set *Phase pickup value*. If the measured value exceeds the set *Phase pickup value*, the level detector reports the exceeding of the value to the operation mode selector.

Level detector 2

The measured ground currents are compared with the set *Ground pickup value*. If the measured value exceeds the set *Ground pickup value*, the level detector reports the exceeding of the value to the operation mode selector.

Operation mode selector

Depending on the *Operation mode* setting, the operation mode selector makes sure that all required criteria are fulfilled for a reliable decision of an arc fault situation. The user can select either "Light+current", "Light only" or "BI controlled" operation mode. The operation is based on both current and light information in “Light+current” mode, on light information only in “Light only” mode or on remotely controlled information in “BI controlled” mode. When the "BI controlled" mode is in use and the `OPR_MODE` input is activated, the operation of the function is based on light information only. When the `OPR_MODE` input is deactivated, the operation of the function is based on both light and current information. When the required criteria are met, the drop-off timer is activated.

Drop-off timer

Once activated, the drop-off timer remains active until the input is deactivated or at least during the drop-off time. The `BLOCK` signal can be used to block the `TRIP` signal or the light signal output `FLT_ARC_DET`.

5.5.5 Application

The arc flash detector can be realized as a stand-alone function in a single relay or as a station-wide arc flash detector, including several protection relays. If realized as a station-wide arc flash detector, different tripping schemes can be selected for the operation of the circuit breakers of the incoming and outgoing feeders. Consequently, the relays in the station can, for example, be set to trip the circuit breaker of either the incoming or the outgoing feeder, depending on the fault location in the switchgear. For maximum safety, the relays can be set to always trip both the circuit breaker of the incoming feeder and that of the outgoing feeder.

The arc flash detector consists of:

- Optional arc light detection hardware with automatic backlight compensation for lens type sensors
- Light signal output `FLT_ARC_DET` for routing indication of locally detected light signal to another relay
- Protection stage with phase- and ground-fault current measurement.

The function detects light from an arc either locally or via a remote light signal. Locally, the light is detected by lens sensors connected to the inputs Light sensor 1, Light sensor 2, or Light sensor 3 on the communication module of the relay. The lens sensors can be placed, for example, in the busbar compartment, the breaker compartment, and the cable compartment of the metal-clad cubicle.

The light detected by the lens sensors is compared to an automatically adjusted reference level. Light sensor 1, Light sensor 2, and Light sensor 3 inputs have their own reference levels. When the light exceeds the reference level of one of the inputs, the light is detected locally. When the light has been detected locally or remotely and, depending on the operation mode, if one or several phase currents exceed the set *Phase pickup value* limit, or the ground-fault current the set *Ground pickup value* limit, the arc flash detector stage generates a trip signal. The stage is reset in 30 ms, after all three-phase currents and the ground-fault current have fallen below the set current limits.

The light signal output from an arc flash detector stage `FLT_ARC_DET` is activated immediately in the detection of light in all situations. A station-wide arc flash detector is realized by routing the light signal output to an output contact connected to a binary input of another relay, or by routing the light signal output through the communication to an input of another relay.

It is possible to block the tripping and the light signal output of the arc flash detector stage with a binary input or a signal from another function block.

Cover unused inputs with dust caps.

Arc flash detector with one IED

In installations, with limited possibilities to realize signalling between IEDs protecting incoming and outgoing feeders, or if only the IED for the incoming feeder is to be exchanged, an arc flash detector with a lower protective level can be achieved with one protection relay. An arc flash detector with one IED only is realized by installing two arc lens sensors connected to the IED protecting the incoming feeder to detect an arc on the busbar. In arc detection, the arc flash detector stage trips the circuit breaker of the incoming feeder. The maximum recommended installation distance between the two lens sensors in the busbar area is six meters and the maximum distance from a lens sensor to the end of the busbar is three meters.

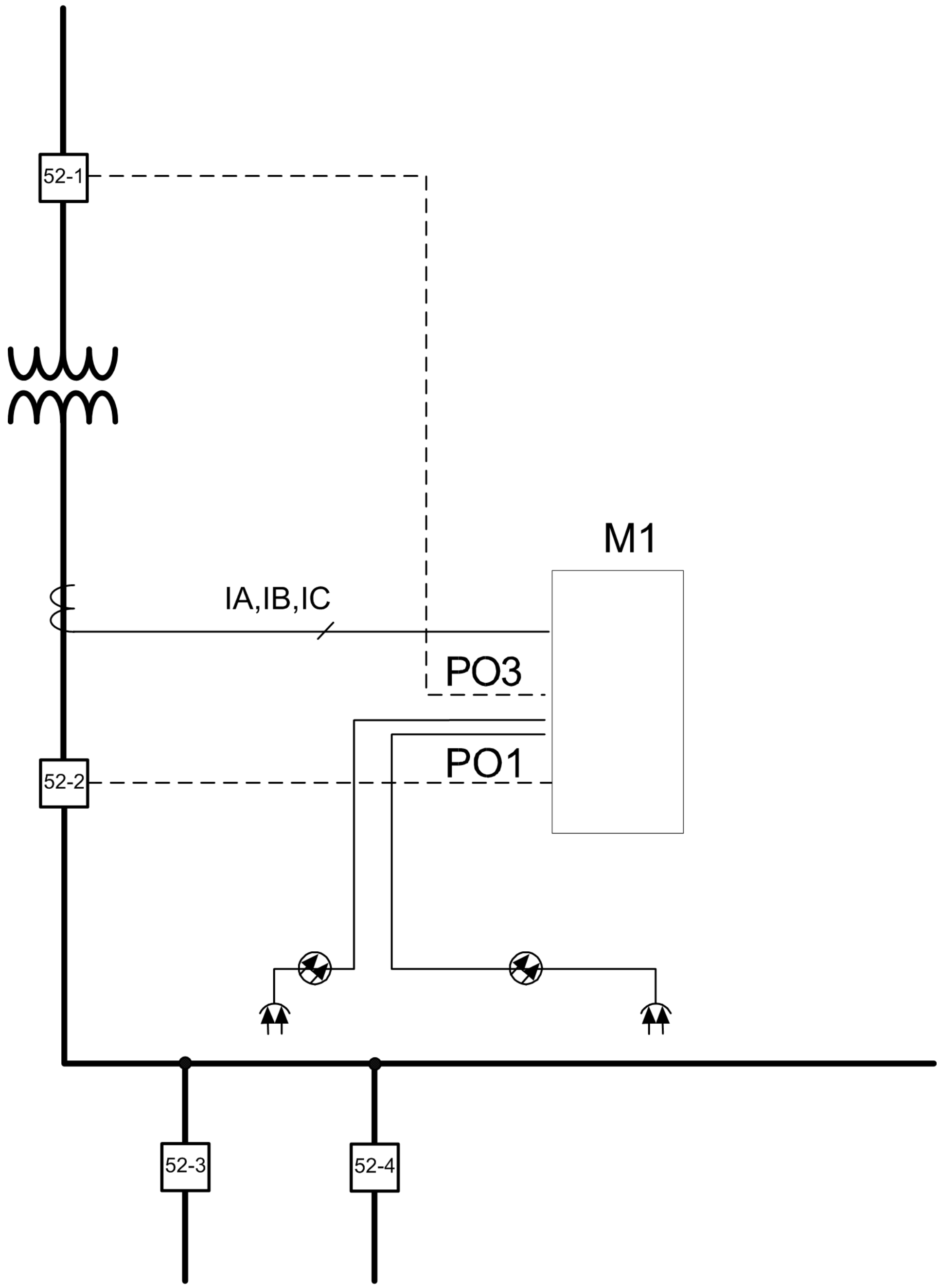

Figure 205: Arc flash detector with one IED

Arc flash detector with several IEDs

When using several IEDs, the IED protecting the outgoing feeder trips the circuit breaker of the outgoing feeder when detecting an arc at the cable terminations. If the IED protecting the outgoing feeder detects an arc on the busbar or in the breaker compartment via one of the other lens sensors, it will generate a signal to the IED protecting the incoming feeder. When detecting the signal, the IED protecting the incoming feeder trips the circuit breaker of the incoming feeder and generates an external trip signal to all IEDs protecting the outgoing feeders, which in turn results in tripping of all circuit breakers of the outgoing feeders. For maximum safety, the IEDs can be configured to trip all the circuit breakers regardless of where the arc is detected.

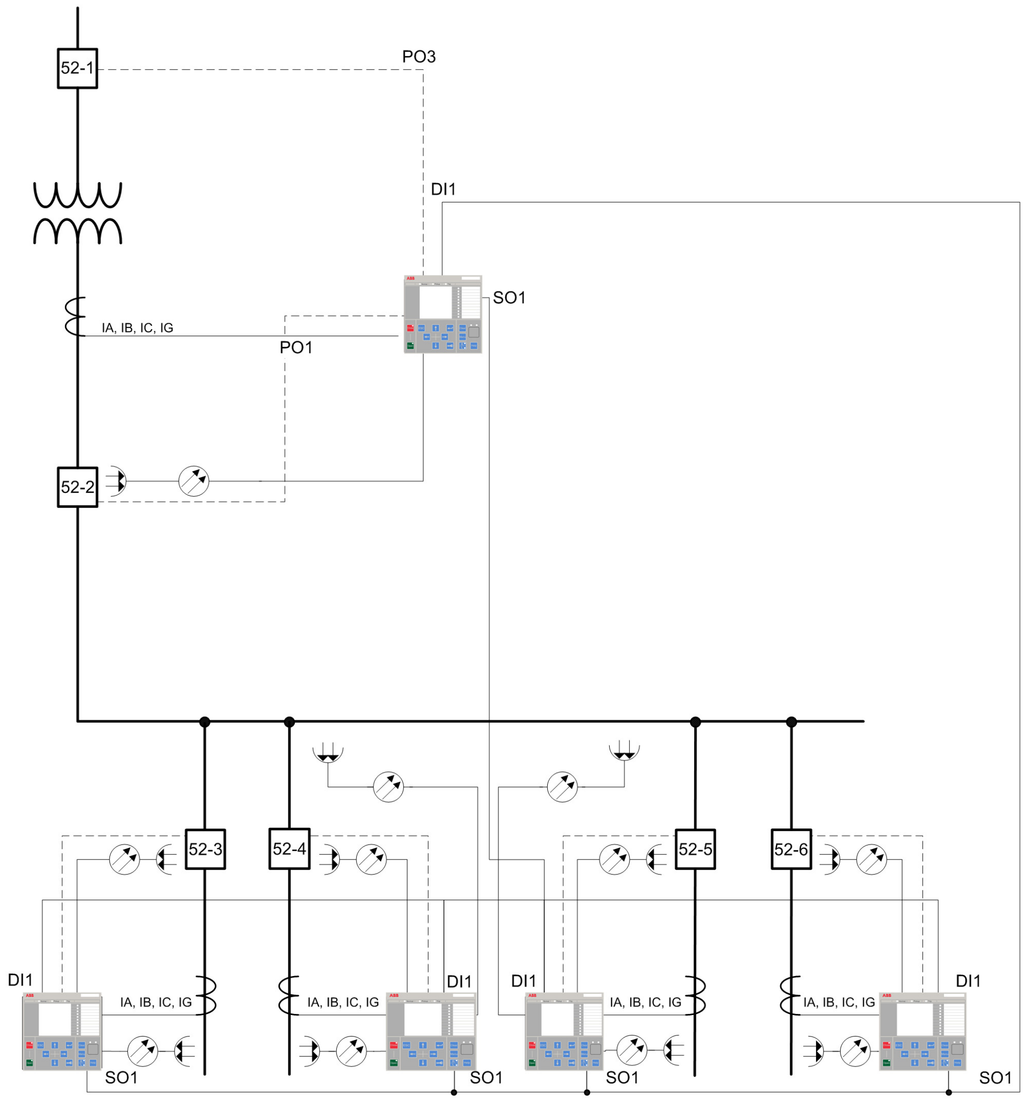

Figure 206: Arc flash detector with several IEDs

Arc flash detector with several IEDs and a separate arc flash detector system

When realizing an arc flash detector with both IEDs and a separate arc flash detector system, the cable terminations of the outgoing feeders are protected by IEDs using one lens sensor for each IED. The busbar and the incoming feeder are protected by the sensor loop of the separate arc flash detector system. With arc detection at the cable terminations, an IED trips the circuit breaker of the outgoing feeder. However, when detecting an arc on the busbar, the separate arc flash detector system trips the circuit breaker of the incoming feeder and generates an external trip signal to all IEDs protecting the outgoing feeders, which in turn results in tripping of all circuit breakers of the outgoing feeders.

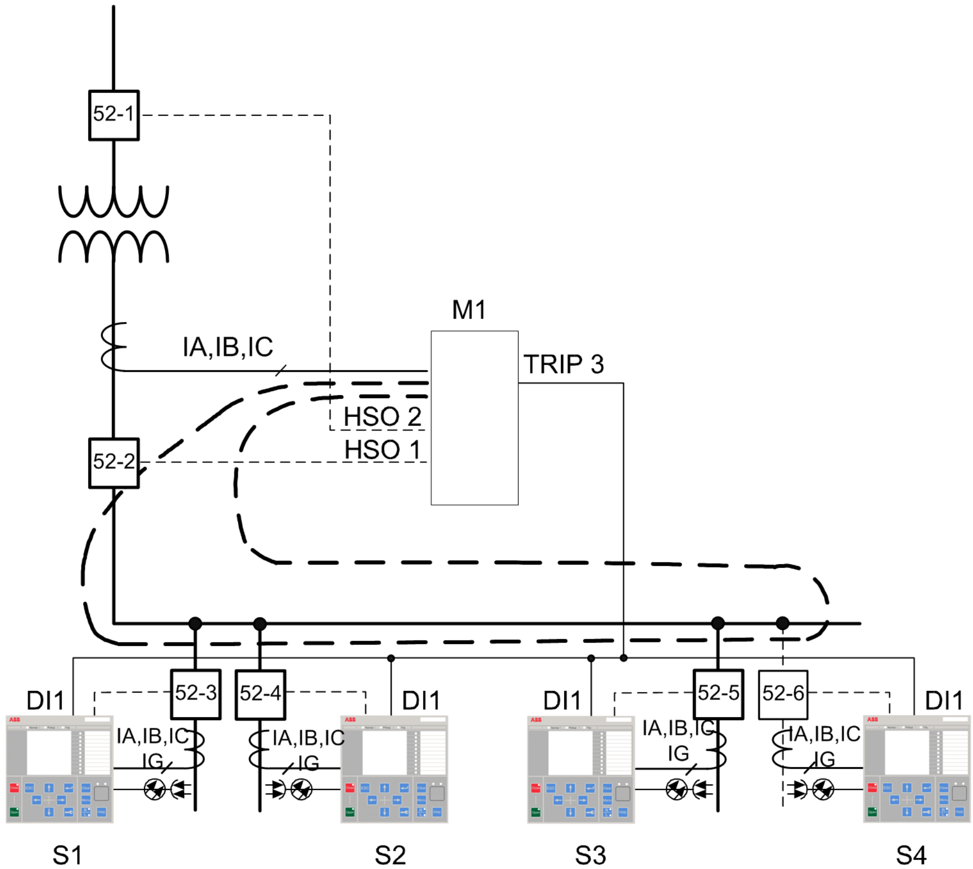

Figure 207: Arc flash detector with several IEDs and a separate arc flash detector system

5.5.6 Signals

Table 355: AFD Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_G	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs
REM_FLT_ARC	BOOLEAN	0=False	Remote Fault arc detected
OPR_MODE	BOOLEAN	0=False	Operation mode input

Table 356: AFD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
ARC_FLT_DET	BOOLEAN	Fault arc detected=light signal output

5.5.7 Settings

Table 357: AFD Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Phase pickup value	0.50...40.00	xIn	0.01	2.50	Operating phase current
Ground pickup value	0.05...8.00	xIn	0.01	0.20	Operating ground current
Operation mode	1=Light+current 2=Light only 3=BI controlled			1=Light+current	Operation mode

Table 358: AFD Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable

5.5.8 Monitored data

Table 359: AFD Monitored data

Name	Type	Values (Range)	Unit	Description
AFD	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

5.5.9 Technical data

Table 360: AFD Technical data

Characteristic		Value		
Pickup accuracy		±3% of the set value or ±0.01 x I_n		
Trip time		Minimum	Typical	Maximum
	Operation mode = “Light +current”[1] ,[2]	9 ms	12 ms	15 ms
	Operation mode = “Light only”[3]	9 ms	10 ms	12 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		

1. *Phase pickup value* = 1.0 x I_n, current before fault = 2.0 x set. *Phase pickup value*, f_n = 60 Hz, fault with nominal frequency, results based on statistical distribution of 200 measurements.
2. Includes the delay of the heavy-duty output contact.
3. Includes the delay of the heavy-duty output contact.

5.6 Multi-purpose protection, MAP

5.6.1 Identification

Table 361: Function identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Multipurpose protection	MAPGAPC	MAPGAPC	MAP

5.6.2 Function Block

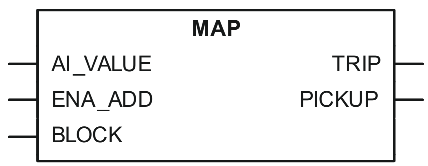

Figure 208: Function block

5.6.3 Functionality

The multipurpose protection function MAP is used as a general protection with many possible application areas as it has flexible measuring and setting facilities. The function can be used as an under- or overprotection with a settable absolute hysteresis limit. The function operates with the definite time (DT) characteristics.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer or the function itself, if desired

5.6.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are Enable and Disable.

The operation of the multipurpose protection function can be described using a module diagram. All the modules in the diagram are explained in the next sections.

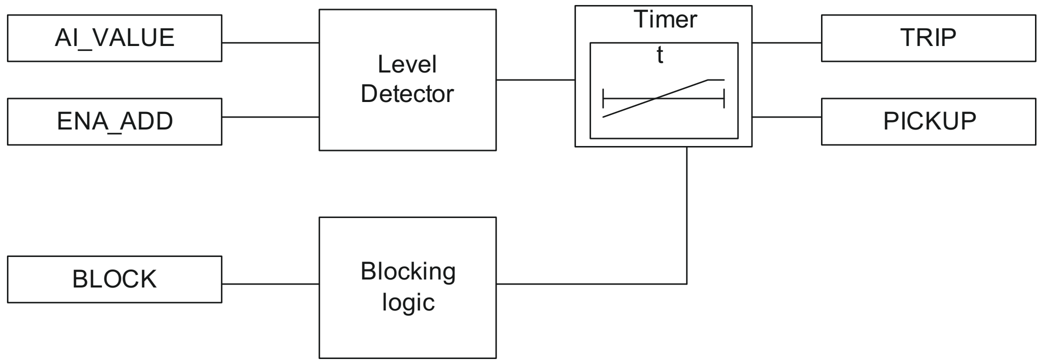

Figure 209: Functional module diagram

5.6.4.1 Level detector

The level detector compares AI_VALUE to the *Pickup Value* setting. The *Operation mode* setting defines the direction of the level detector..

Table 362: Operation mode types

Operation mode	Description
"Under"	If the input signal AI_VALUE is lower than the set value of the *Pickup Value* setting, the level detector enables the timer module
"Over"	If the input signal AI_VALUE exceeds the set value of the *Pickup Value* setting, the level detector enables the timer module.

The Absolute hysteresis setting can be used for preventing unnecessary oscillations if the input signal is slightly above or below the *Pickup Value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area. If the ENA_ADD input is activated, the threshold value of the internal comparator is the sum of the *Pickup Value Add* and *Pickup Value* settings. The resulting threshold value for the comparator can be increased or decreased depending on the sign and value of the *Pickup Value Add* setting.

5.6.4.2 Timer

Once activated, the timer activates the PICKUP output. The time characteristic is according to DT. When the operation timer has reached the value set by *Trip delay time*, the TRIP output is activated. If the pickup condition disappears before the module trips, the reset timer is activated. If the reset timer reaches the value set by Reset delay time, the operation timer resets and the PICKUP output is deactivated.

The timer calculates the pickup duration value PICKUP_DUR, which indicates the ratio of the pickup situation and the set trip time. The value is available in the monitored data view.

5.6.4.3 Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting **"Configuration/System/Blocking mode"** which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the IED program. The influence of the BLOCK signal activation is preselected with the global setting Blocking mode.

The Blocking mode setting has three blocking methods. In the "Freeze timers" mode, the trip timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block TRIP output" mode, the function operates normally but the TRIP output is not activated.

5.6.5 Application

The function block can be used for any general analog signal protection, either underprotection or overprotection. The setting range is wide, allowing various protection schemes for the function. Thus, the absolute hysteresis can be set to a value that suits the application.

The temperature protection using the RTD sensors can be done using the function block. The measured temperature can be fed from the RTD sensor to the function input that detects too high temperatures in the motor bearings or windings, for example. When the ENA_ADD input is enabled, the threshold value of the internal comparator is the sum of the *Pickup Value Add* and *Pickup Value* settings. This allows a temporal increase or decrease of the level detector depending on the sign and value of the *Pickup Value Add* setting, for example, when the emergency start is activated. If, for example, *Pickup Value* is 100, *Pickup Value Add* is 20 and the ENA_ADD input is active, the input signal needs to rise above 120 before MAP trips.

5.6.6 Signals

Table 363: MAP Input Signals

Name	Type	Default	Description
AI_VALUE	FLOAT32	0	Analogue input value
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_ADD	BOOLEAN	0=False	Enable start added

Table 364: MAP Output Signals:

Name	Type	Description
TRIP	BOOLEAN	Trip Signal
PICKUP	BOOLEAN	Pickup Indicator

5.6.7 Settings

Table 365: MAP Group Settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	-10000.0...10000.0		0.1	0	Pickup value
Pickup value Add	-100.0...100.0		0.1	0	Pickup value Add
Trip delay time	0...200000	ms	100	0	Trip delay time

Table 366: MAP Non Group Settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Enable/Disable
Operation mode	1=Over 2=Under			1=Over	Operation mode
Reset delay time	0...60000	ms	100	0	Reset delay time
Absolute hysteresis	0.01...100.00		0	0.1	Absolute hysteresis for operation

5.6.8 Monitored Data

Table 367: MAP Monitored Data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
MAP	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Technical data

Table 368: MAP Technical data

Characteristic	Value
Pickup accuracy	±1.0% of the set value or ±20 ms

5.6.9 Function data

5.6.9.1 Inputs

IEC name	ANSI Name	Type	Default	Description
AI_VALUE		FLOAT32	0	Analogue input value
ENA_ADD		BOOL	0	Enable start using added start value
BLOCK		BOOL	0	Block signal for activating the blocking modeactivting

5.6.9.2 Outputs

IEC name	ANSI Name	Type	Description
OPERATE		BOOL	Operate
START		BOOL	Start

5.6.10 Settings

5.6.10.1 Group setting (Basic)

Table 369: Group settings

IEC name	ANSI Name	Value (Range)	Unit	Default	Description
Start value		-10000.0 ... 10000.0	FLOAT32	0.0	Start value
Start value Add		-100.0 ... 100.0	FLOAT32	0.0	Added value to start value
Operate delay time		0..200000	FLOAT32	0	Operate delay time

5.6.10.2 Non-group settings (Basic)

Table 370: Non-group settings

IEC name	ANSI Name	Value (Range)	Unit	Default	Description
Operation		1..5	Enum	1	Operation Off / On
Operation mode		1..2	Enum	1	Operation mode
Reset delay time		0..60000	FLOAT32	0	Reset delay mode
Absolute hysteresis		0.10..100.00		0.10	Absolute hysteresis

Table 371: Enumeration values for non-group settings

Setting name	Enum name	Value
Operation mode	Over	1
	Under	2

5.6.11 Monitored Data

IEC name	ANSI name	Type	Description
START_DUR		FLOAT32	Ratio of start / operate time

Section 6 Supervision functions

6.1 Circuit-breaker condition monitoring 52CM

6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker condition monitoring	SSCBR	CBCM	52CM

6.1.2 Function block

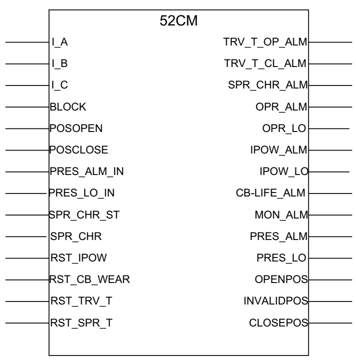

Figure 210: Function block

6.1.3 Functionality

The circuit breaker condition monitoring function 52CM is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. For proper functioning of the circuit breaker, it is essential to monitor the circuit breaker operation, spring charge indication, breaker wear, travel time, number of operation cycles and accumulated energy. The energy is calculated from the measured input currents as a sum of $I^y t$ values. Alarms are generated when the calculated values exceed the threshold settings.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

6.1.4 Operation principle

The circuit breaker condition monitoring function includes different metering and monitoring subfunctions. The functions can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable. The operation counters are cleared when *Operation* is set to Disable.

The operation of the functions can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

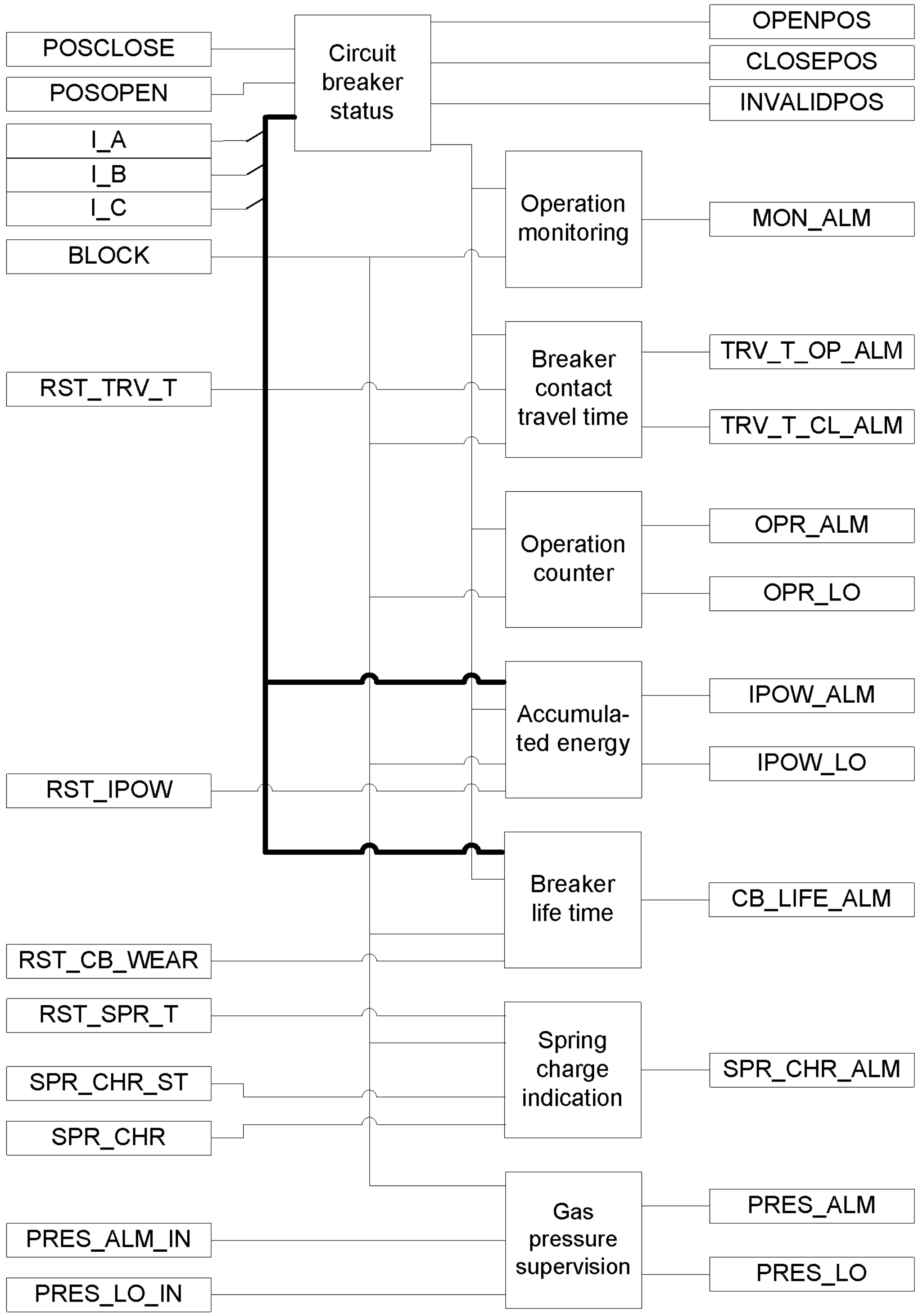

Figure 211: Functional module diagram

6.1.4.1 Circuit breaker status

The circuit breaker status subfunction monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position. The operation of the breaker status monitoring can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

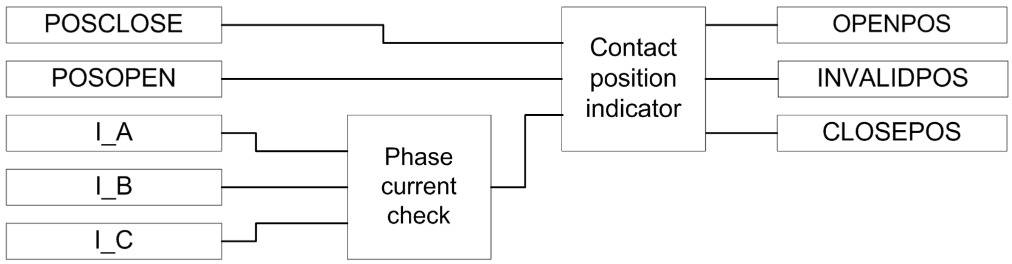

Figure 212: Functional module diagram for monitoring circuit breaker status

Phase current check

This module compares the three phase currents with the setting . If the current in a phase exceeds the set level, information about phase is reported to the contact position indicator module.

Contact position indicator

The circuit breaker status is open if the auxiliary input contact POSCLOSE is low, the POSOPEN input is high and the current is zero. The circuit breaker is closed when the POSOPEN input is low and the POSCLOSE input is high. The breaker is in the intermediate position if both the auxiliary contacts have the same value, that is, both are in the logical level "0", or if the auxiliary input contact POSCLOSE is low and the POSOPEN input is high, but the current is not zero.

The status of the breaker is indicated with the binary outputs OPENPOS, INTERMPOS, and CLOSEPOS for open, intermediate, and closed position respectively.

6.1.4.2 Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring subfunction is to indicate if the circuit breaker has not been operated for a long time.

The operation of the circuit breaker operation monitoring can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

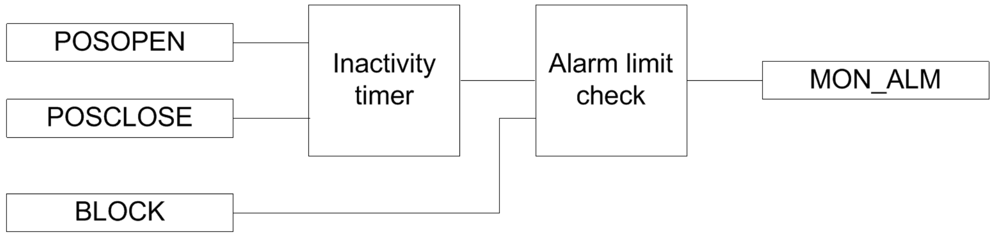

Figure 213: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

Inactivity timer

The module calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. The calculation is done by monitoring the states of the POSOPEN and POSCLOSE auxiliary contacts.

The inactive days is available through the Monitored data view. It is also possible to set the initial inactive days by using the parameter.

Alarm limit check

When the inactive days exceed the limit value defined with the setting, the alarm is initiated. The time in hours at which this alarm is activated can be set with the parameter as coordinates of UTC. The alarm signal can be blocked by activating the binary input BLOCK.

6.1.4.3 Breaker contact travel time

The breaker contact travel time module calculates the breaker contact travel time for the closing and opening operation. The operation of the breaker contact travel time measurement can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

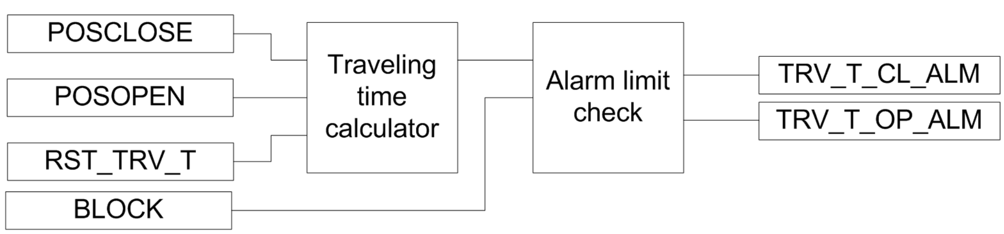

Figure 214: Functional module diagram for breaker contact travel time

Traveling time calculator

The contact travel time of the breaker is calculated from the time between auxiliary contacts' state change. The open travel time is measured between the opening of the POSCLOSE auxiliary contact and the closing of the POSOPEN auxiliary contact. Travel time is also measured between the opening of the POSOPEN auxiliary contact and the closing of the POSCLOSE auxiliary contact.

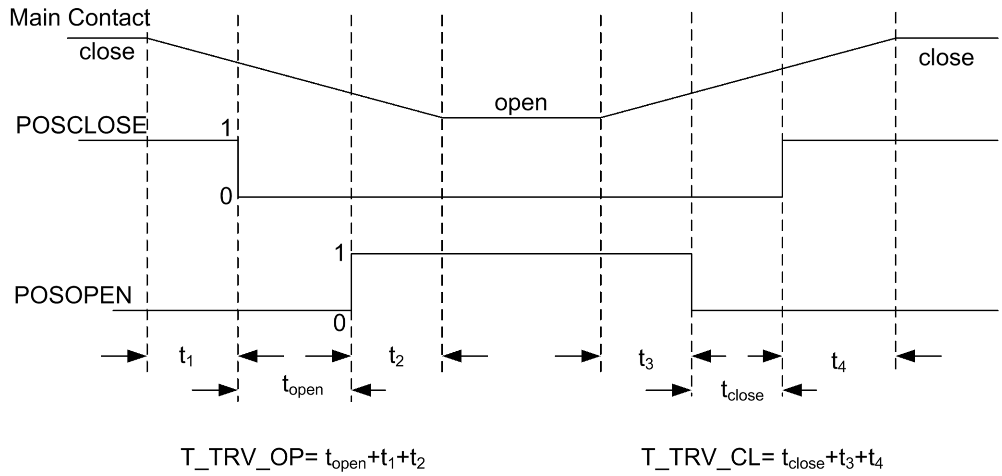

Figure 215: Travel time calculation

There is a time difference t_1 between the start of the main contact opening and the opening of the POSCLOSE auxiliary contact. Similarly, there is a time gap t_2 between the time when the POSOPEN auxiliary contact opens and the main contact is completely open. Therefore, in order to incorporate the time t_1+t_2, a correction factor needs to be added with t_{open} to get the actual opening time. This factor is added with the *Opening time Cor* ($=t_1+t_2$). The closing time is calculated by adding the value set with the *Closing time Cor* (t_3+t_4) setting to the measured closing time.

The last measured opening travel time T_TRV_OP and the closing travel time T_TRV_CL are available through the Monitored data view on the LHMI or through tools via communications.

Alarm limit check

When the measured open travel time is longer than the value set with the *Open alarm time* setting, the TRV_T_OP_ALM output is activated. Respectively, when the measured close travel time is longer than the value set with the *Close alarm time* setting, the , the TRV_T_CL_ALM output is activated.

It is also possible to block the TRV_T_CL_ALM and TRV_T_OP_ALM alarm signals by activating the BLOCK input.

6.1.4.4 Operation counter

The operation counter subfunction calculates the number of breaker operation cycles. Both open and close operations are included in one operation cycle. The operation counter value is updated after each open operation.

The operation of the subfunction can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

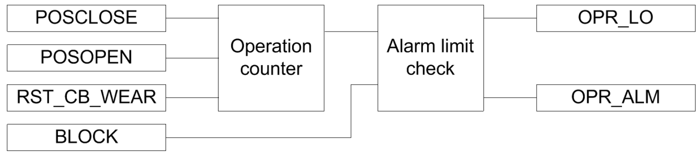

Figure 216: Functional module diagram for counting circuit breaker operations

Operation counter

The operation counter counts the number of operations based on the state change of the binary auxiliary contacts inputs `POSCLOSE` and `POSOPEN`.

The number of operations `NO_OPR` is available through the Monitored data view on the LHMI or through tools via communications. The old circuit breaker operation counter value can be taken into use by writing the value to the parameter and in the clear menu from WHMI or LHMI.

Alarm limit check

The operation alarm is generated when the number of operations exceeds the value set with the threshold setting. However, if the number of operations increases further and exceeds the limit value set with the setting, the output is activated.

The binary outputs and are deactivated when the `BLOCK` input is activated.

6.1.4.5 Accumulation of $I^y t$

Accumulation of the $I^y t$ module calculates the accumulated energy.

The operation of the module can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

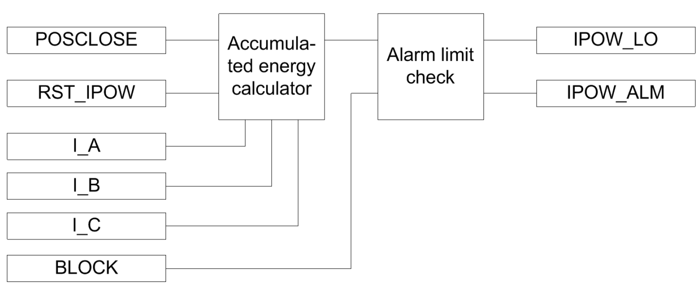

Figure 217: Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

This module calculates the accumulated energy $I^y t$. The factor y is set with the *Current exponent* setting.

The calculation is initiated with the `POSCLOSE` input open events. It ends when the RMS current becomes lower than the *Acc stop current* setting value.

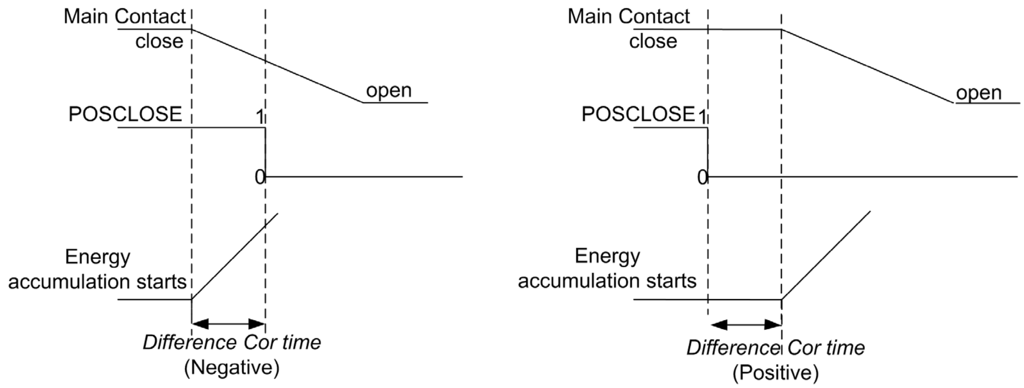

Figure 218: Significance of the Difference Cor time *setting*

The *Difference Cor time* setting is used instead of the auxiliary contact to accumulate the energy from the time the main contact opens. If the setting is positive, the calculation of energy starts after the auxiliary contact has opened and when the delay is equal to the value set with the *Difference Cor time* setting. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

The accumulated energy outputs `IPOW_A (_B, _C)` are available through the Monitored data view on the LHMI or through tools via communications. The values can be reset by setting the parameter *52CMx.acc.Energy* setting to true in the clear menu from WHMI or LHMI.

Alarm limit check

The `IPOW_ALM` alarm is activated when the accumulated energy exceeds the value set with the *Alm Acc currents Pwr* threshold setting. However, when the energy exceeds the limit value set with the *LO Acc currents Pwr* threshold setting, the `IPOW_LO` output is activated.

The `IPOW_ALM` and `IPOW_LO` outputs can be blocked by activating the binary input `BLOCK`.

6.1.4.6 Remaining life of the circuit breaker

Every time the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current, and the remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer. The remaining life is decremented at least with one when the circuit breaker is opened.

The operation of the remaining life of the circuit breaker subfunction can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

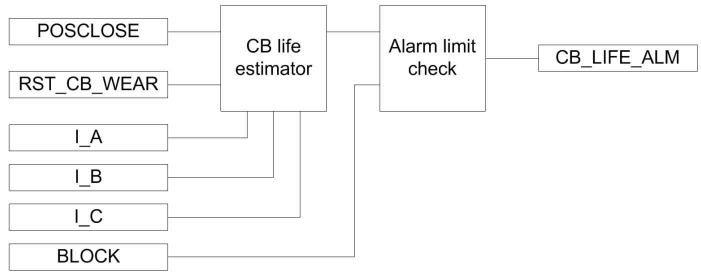

Figure 219: Functional module diagram for estimating the life of the circuit breaker

Circuit breaker life estimator

The circuit breaker life estimator module calculates the remaining life of the circuit breaker. If the tripping current is less than the rated operating current set with the *Rated Op current* setting, the remaining operation of the breaker reduces by one operation. If the tripping current is more than the rated fault current set with the *Rated fault current* setting, the possible operations are zero. The remaining life of the tripping current in between these two values is calculated based on the trip curve given by the manufacturer. The *Op number rated* and *Op number fault* parameters set the number of operations the breaker can perform at the rated current and at the rated fault current, respectively.

The remaining life is calculated separately for all three phases and it is available as a monitored data value `CB_LIFE_A (_B,_C)`. The values can be cleared by setting the parameter *CB wear values* in the clear menu from WHMI or LHMI.

Clearing *CB wear values* also resets the operation counter.

Alarm limit check

When the remaining life of any phase drops below the *Life alarm level* threshold setting, the corresponding circuit breaker life alarm `CB_LIFE_ALM` is activated.

It is possible to deactivate the `CB_LIFE_ALM` alarm signal by activating the binary input `BLOCK`. The old circuit breaker operation counter value can be taken into use by writing the value to the *Initial CB Rmn life* parameter and resetting the value via the clear menu *52 CMx.rem.life* from WHMI or LHMI under the **Clear CB wear values** menu.

6.1.4.7 Circuit breaker spring charged indication

The circuit breaker spring charged indication subfunction calculates the spring charging time.

The operation of the subfunction can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

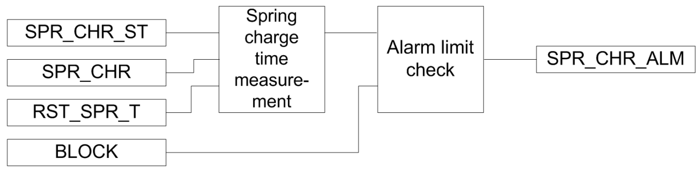

Figure 220: Functional module diagram for circuit breaker spring charged indication and alarm

Spring charge time measurement

Two binary inputs, SPR_CHR_ST and SPR_CHR, indicate spring charging started and spring charged, respectively. The spring charging time is calculated from the difference of these two signal timings.

The spring charging time T_SPR_CHR is available through the Monitored data view on the LHMI or through tools via communications.

Alarm limit check

If the time taken by the spring to charge is more than the value set with the *Spring charge time* setting, the subfunction generates the SPR_CHR_ALM alarm.

It is possible to block the SPR_CHR_ALM alarm signal by activating the BLOCK binary input.

6.1.4.8 Gas pressure supervision

The gas pressure supervision subfunction monitors the gas pressure inside the arc chamber.

The operation of the subfunction can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

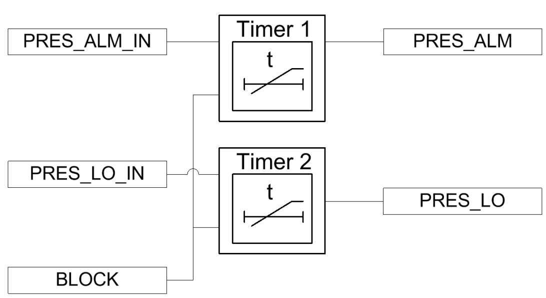

Figure 221: Functional module diagram for circuit breaker gas pressure alarm

The gas pressure is monitored through the binary input signals PRES_LO_IN and PRES_ALM_IN.

Timer 1

When the PRES_ALM_IN binary input is activated, the PRES_ALM alarm is activated after a time delay set with the *Pressure alarm time* setting. The PRES_ALM alarm can be blocked by activating the BLOCK input.

Timer 2

If the pressure drops further to a very low level, the `PRES_LO_IN` binary input becomes high, activating the lockout alarm `PRES_LO` after a time delay set with the *Pres lockout time* setting. The `PRES_LO` alarm can be blocked by activating the `BLOCK` input.

6.1.5 Application

52CM includes different metering and monitoring subfunctions.

Circuit breaker status

Circuit breaker status monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position.

Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring is to indicate that the circuit breaker has not been operated for a long time. The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.

Breaker contact travel time

High travelling times indicate the need for maintenance of the circuit breaker mechanism. Therefore, detecting excessive travelling time is needed. During the opening cycle operation, the main contact starts opening. The auxiliary contact A opens, the auxiliary contact B closes, and the main contact reaches its opening position. During the closing cycle, the first main contact starts closing. The auxiliary contact B opens, the auxiliary contact A closes, and the main contact reaches its close position. The travel times are calculated based on the state changes of the auxiliary contacts and the adding correction factor to consider the time difference of the main contact's and the auxiliary contact's position change.

Operation counter

Routine maintenance of the breaker, such as lubricating breaker mechanism, is generally based on a number of operations. A suitable threshold setting, to raise an alarm when the number of operation cycle exceeds the set limit, helps preventive maintenance. This can also be used to indicate the requirement for oil sampling for dielectric testing in case of an oil circuit breaker.

The change of state can be detected from the binary input of the auxiliary contact. There is a possibility to set an initial value for the counter which can be used to initialize this functionality after a period of operation or in case of refurbished primary equipment.

Accumulation of I^yt

Accumulation of I^yt calculates the accumulated energy ΣI^yt where the factor y is known as the current exponent. The factor y depends on the type of the circuit breaker. For oil circuit breakers the factor y is normally 2. In case of a high-voltage system, the factor y can be 1.4...1.5.

Remaining life of the breaker

Every time the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current, and the remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer.

Example for estimating the remaining life of a circuit breaker

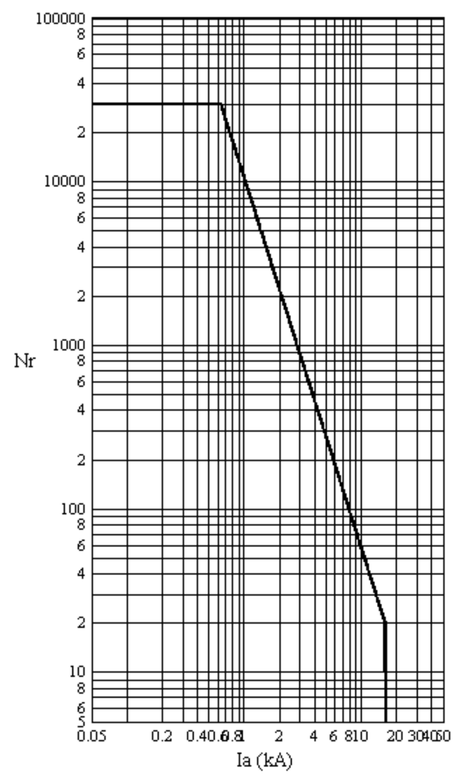

Figure 222: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

Nr the number of closing-opening operations allowed for the circuit breaker
Ia the current at the time of tripping of the circuit breaker

Calculation of Directional Coef

The directional coefficient is calculated according to the formula:

$$Directional\,Coef = \frac{\log\left(\frac{B}{A}\right)}{\log\left(\frac{I_f}{I_r}\right)} = -2.2609$$

(Equation 50)

I_r Rated operating current = 630 A

I_f Rated fault current = 16 kA

A Op number rated = 30000

B Op number fault = 20

Calculation for estimating the remaining life

The equation shows that there are 30,000 possible operations at the rated operating current of 630 A and 20 operations at the rated fault current 16 kA. Therefore, if the tripping current is 10 kA, one operation at 10 kA is equivalent to 30,000/500=60 operations at the rated current. It is also assumed that prior to this tripping, the remaining life of the circuit breaker is 15,000 operations. Therefore, after one operation of 10 kA, the remaining life of the circuit breaker is 15,000-60=14,940 at the rated operating current.

Spring charged indication

For normal operation of the circuit breaker, the circuit breaker spring should be charged within a specified time. Therefore, detecting long spring charging time indicates that it is time for the circuit breaker maintenance. The last value of the spring charging time can be used as a service value.

Gas pressure supervision

The gas pressure supervision monitors the gas pressure inside the arc chamber. When the pressure becomes too low compared to the required value, the circuit breaker operations are locked. A binary input is available based on the pressure levels in the function, and alarms are generated based on these inputs.

6.1.6 Signals

Table 372: 52CM Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block input status
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for closeposition of apparatus from I/O
PRES_ALM_IN	BOOLEAN	0=False	Binary pressure alarm input
PRES_LO_IN	BOOLEAN	0=False	Binary pressure input for lockout indication
SPR_CHR_ST	BOOLEAN	0=False	CB spring charging started input
SPR_CHR	BOOLEAN	0=False	CB spring charged input
RST_IPOW	BOOLEAN	0=False	Reset accumulation energy
RST_CB_WEAR	BOOLEAN	0=False	Reset input for CB remaining life and operation counter
RST_TRV_T	BOOLEAN	0=False	Reset input for CB closing and opening travel times
RST_SPR_T	BOOLEAN	0=False	Reset input for the charging time of the CB spring

Table 373: 52CM Output signals

Name	Type	Description
TRV_T_OP_ALM	BOOLEAN	CB open travel time exceeded set value
TRV_T_CL_ALM	BOOLEAN	CB close travel time exceeded set value
SPR_CHR_ALM	BOOLEAN	Spring charging time has crossed the set value
OPR_ALM	BOOLEAN	Number of CB operations exceeds alarm limit
OPR_LO	BOOLEAN	Number of CB operations exceeds lockout limit
IPOW_ALM	BOOLEAN	Accumulated currents power (Iyt),exceeded alarm limit
IPOW_LO	BOOLEAN	Accumulated currents power (Iyt),exceeded lockout limit
CB_LIFE_ALM	BOOLEAN	Remaining life of CB exceeded alarm limit
MON_ALM	BOOLEAN	CB 'not operated for long time' alarm
PRES_ALM	BOOLEAN	Pressure below alarm level
PRES_LO	BOOLEAN	Pressure below lockout level
OPENPOS	BOOLEAN	CB is in open position
INVALIDPOS	BOOLEAN	CB is in invalid position (not positively open or closed)
CLOSEPOS	BOOLEAN	CB is in closed position

6.1.7 Settings

Table 374: 52CM Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
Acc stop current	5.00...500.00	A	0.01	10.00	RMS current setting below which engy acm stops
Open alarm time	0...200	ms	1	40	Alarm level setting for open travel time in ms
Close alarm time	0...200	ms	1	40	Alarm level Setting for close travel time in ms
Opening time Cor	0...100	ms	1	10	Correction factor for open travel time in ms
Closing time Cor	0...100	ms	1	10	Correction factor for CB close travel time in ms
Spring charge time	0...60000	ms	10	1000	Setting of alarm for spring charging time of CB in ms
Counter initial Val	0...9999		1	0	The operation numbers counter initialization value
Alarm Op number	0...9999		1	200	Alarm limit for number of operations
Lockout Op number	0...9999		1	300	Lock out limit for number of operations
Current exponent	0.00...2.00		0.01	2.00	Current exponent setting for energy calculation
Difference Cor time	-10...10	ms	1	5	Corr. factor for time dif in aux. and main contacts open time
Alm Acc currents Pwr	0.00...20000.00		0.01	2500.00	Setting of alarm level for accumulated currents power
LO Acc currents Pwr	0.00...20000.00		0.01	2500.00	Lockout limit setting for accumulated currents power
Ini Acc currents Pwr	0.00...20000.00		0.01	0.00	Initial value for accumulation energy (Iyt)
Directional Coef	-3.00...-0.50		0.01	-1.50	Directional coefficient for CB life calculation
Operation cycle	0...9999		1	5000	Operation cycle at rated current
Rated Op current	100.00...5000.00	A	0.01	1000.00	Rated operating current of the breaker
Rated fault current	500.00...75000.00	A	0.01	5000.00	Rated fault current of the breaker
Op number rated	1...99999		1	10000	Number of operations possible at rated current
Op number fault	1...10000		1	1000	Number of operations possible at rated fault current
Life alarm level	0...99999		1	500	Alarm level for CB remaining life
Pressure alarm time	0...60000	ms	1	10	Time delay for gas pressure alarm in ms
Pres lockout time	0...60000	ms	10	10	Time delay for gas pressure lockout in ms
Inactive Alm days	0...9999		1	2000	Alarm limit value of the inactive days counter
Ini inactive days	0...9999		1	0	Initial value of the inactive days counter
Inactive Alm hours	0...23	h	1	0	Alarm time of the inactive days counter in hours

6.1.8 Monitored data

Table 375: 52CM Monitored data

Name	Type	Values (Range)	Unit	Description
T_TRV_OP	FLOAT32	0...60000	ms	Travel time of the CB during opening operation
T_TRV_CL	FLOAT32	0...60000	ms	Travel time of the CB during closing operation
T_SPR_CHR	FLOAT32	0.00...99.99	s	The charging time of the CB spring
NO_OPR	INT32	0...99999		Number of CB operation cycle
INA_DAYS	INT32	0...9999		The number of days CB has been inactive
CB_LIFE_A	INT32	-9999...9999		CB Remaining life phase A
CB_LIFE_B	INT32	-9999...9999		CB Remaining life phase B
CB_LIFE_C	INT32	-9999...9999		CB Remaining life phase C
IPOW_A	FLOAT32	0.00...30000.00		Accumulated currents power (Iyt), phase A
IPOW_B	FLOAT32	0.00...30000.00		Accumulated currents power (Iyt), phase B
IPOW_C	FLOAT32	0.00...30000.00		Accumulated currents power (Iyt), phase C
52CM	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.1.9 Technical data

Table 376: 52CM Technical data

Current measuring accuracy	±1.5% or ±0.002 x I_n (at currents in the range of 0.1…10 x In) ±5.0% (at currents in the range of 10…40 x In)
Operate time accuracy	±1.0% of the set value or ±20 ms
Travelling time measurement	+10 ms / -0 ms

6.2 Trip circuit supervision, TCM

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip circuit supervision	TCSSCBR	TCS	TCM

6.2.2 Function block

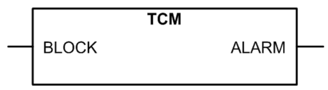

Figure 223: Function block

6.2.3 Functionality

The trip circuit monitoring function TCM is designed for supervision of control circuits. A fault in a control circuit is detected by using a dedicated output contact that contains the monitoring functionality. The failure of a circuit is reported to the corresponding function block in the IED configuration.

The function pickups and trips when TCM detects a trip circuit failure. The trip time characteristic for the function is of definite time (DT) type. The function trips after a predefined operating time and resets when the fault disappears.

The function contains a blocking functionality. Blocking deactivates the `ALARM` output and resets the timer.

6.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of trip circuit monitoring can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

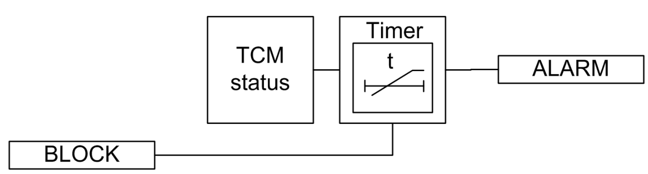

Figure 224: Functional module diagram

TCM status

This module receives the trip circuit status from the hardware. A detected failure in the trip circuit activates the timer.

Timer

Once activated, the timer runs until the set value *Trip delay time* is elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `ALARM` output is activated. If a drop-off situation occurs during the trip time up counting, the reset timer is activated. If the drop-off time exceeds *Reset delay time*, the trip timer is reset.

The BLOCK input can be controlled with a binary input, a horizontal communication input or an internal signal of the relay program. The activation of the BLOCK input prevents the ALARM output to be activated.

6.2.5 Application

TCM detects faults in the electrical control circuit of the circuit breaker. The function can supervise both open and closed coil circuits. This kind of monitoring is necessary to find out the vitality of the control circuits continuously.

The following figure shows an application of the trip-circuit monitoring function usage. The best solution is to connect an external R_{ext} shunt resistor in parallel with the circuit breaker internal contact. Although the circuit breaker internal contact is open, TCM can see the trip circuit through R_{ext}. The R_{ext} resistor should have such a resistance that the current through the resistance remains small, that is, it does not harm or overload the circuit breaker's trip coil.

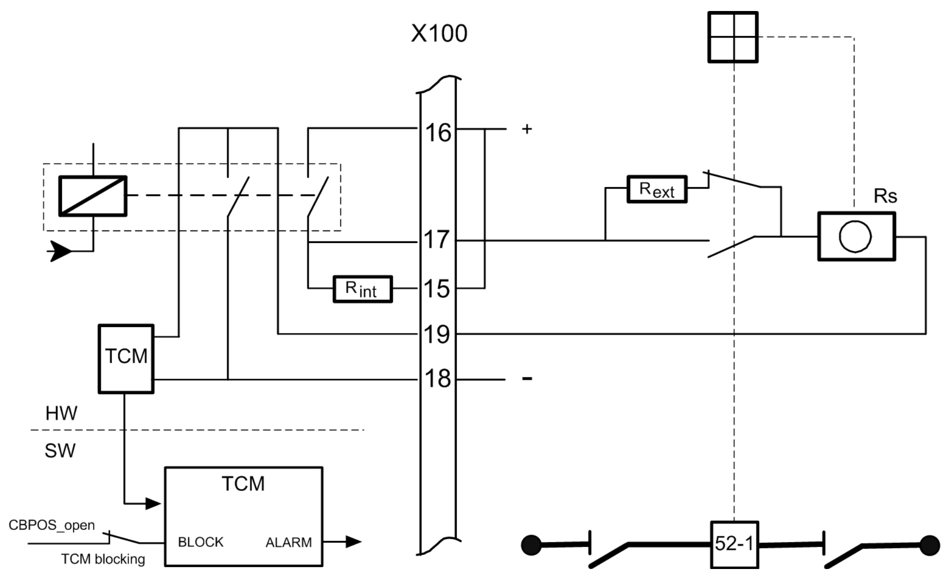

Figure 225: Operating principle of the trip-circuit supervision with an external resistor. The TCM blocking switch is not required since the external resistor is used.

If the TCM is required only in a closed position, the external shunt resistance may be omitted. When the circuit breaker is in the open position, the TCM sees the situation as a faulty circuit. One way to avoid TCM operation in this situation would be to block the monitoring function whenever the circuit breaker is open.

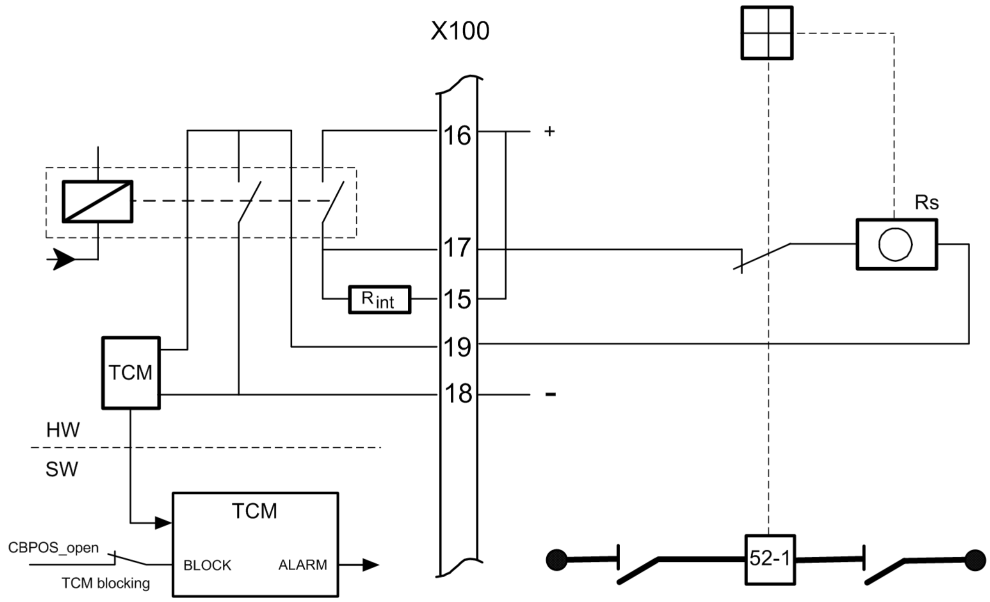

Figure 226: Operating principle of the trip-circuit supervision without an external resistor. The circuit breaker open indication is set to block TCM when the circuit breaker is open.

Trip-circuit monitoring and other trip contacts

It is typical that the trip circuit contains more than one trip contact in parallel, for example in transformer feeders where the trip of a Buchholz relay is connected in parallel with the feeder terminal and other relays involved. The supervising current cannot detect if one or all the other contacts connected in parallel are not connected properly.

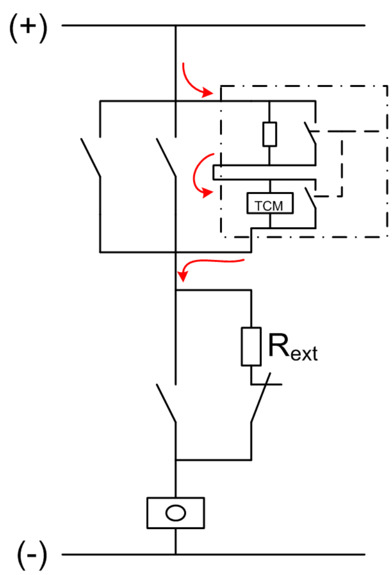

Figure 227: Constant test current flow in parallel trip contacts and trip-circuit monitoring

In case of parallel trip contacts, the recommended way to do the wiring is that the TCM test current flows through all wires and joints as shown in the following figure.

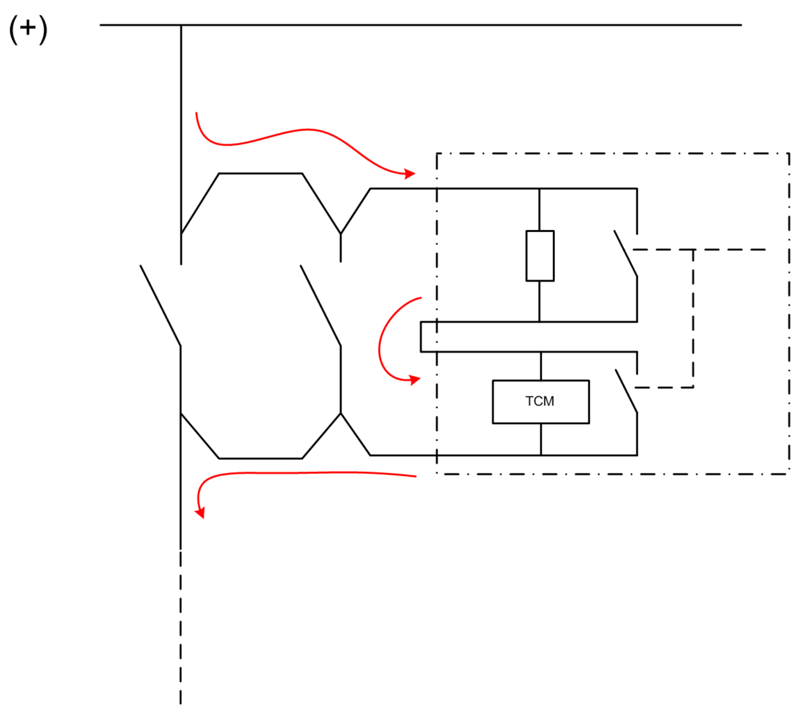

Figure 228: Improved connection for parallel trip contacts

Several trip-circuit monitoring functions parallel in circuit

Not only the trip circuit often have parallel trip contacts, it is also possible that the circuit has multiple TCM circuits in parallel. Each TCM circuit causes its own supervising current to flow through the monitored coil and the actual coil current is a sum of all TCM currents. This must be taken into consideration when determining the resistance of R_{ext}.

Setting the TCM function in a protection IED not-in-use does not typically affect the supervising current injection.

Trip-circuit monitoring with auxiliary relays

Many retrofit projects are carried out partially, that is, the old electromechanical relays are replaced with new ones but the circuit breaker is not replaced. This creates a problem that the coil current of an old type circuit breaker can be too high for the protection IED trip contact to break.

The circuit breaker coil current is normally cut by an internal contact of the circuit breaker. In case of a circuit breaker failure, there is a risk that the protection IED trip contact is destroyed since the contact is obliged to disconnect high level of electromagnetic energy accumulated in the trip coil.

An auxiliary relay can be used between the protection IED trip contact and the circuit breaker coil. This way the breaking capacity question is solved, but the TCM circuit in the protection IED monitors the healthy auxiliary relay coil, not the circuit breaker coil. The separate trip circuit monitoring relay is applicable for this to supervise the trip coil of the circuit breaker.

Dimensioning of the external resistor

Under normal operating conditions, the applied external voltage is divided between the relay's internal circuit and the external trip circuit so that at the minimum 10 V (3...10 V) remains over the relay's internal circuit. Should the external circuit's resistance be too high or the internal circuit's too low, for example due to welded relay contacts, the fault is detected.

Mathematically, the operation condition can be expressed as:

$$V_C - (R_{ext} + R_{int} + R_s) \times I_c \geq 20V \quad AC/DC$$

(Equation 51)

$$V_c - (R_{ext} + R_s) \times I_c \geq 10V\ DC$$

(Equation 52)

V_c Operating voltage over the supervised trip circuit
I_c Measuring current through the trip circuit, appr. 1.0 mA (0.85...1.20 mA)
R_{ext} external shunt resistance
R_s trip coil resistance

If the external shunt resistance is used, it has to be calculated not to interfere with the functionality of the supervision or the trip coil. Too high a resistance causes too high a voltage drop, jeopardizing the requirement of at least 20 V over the internal circuit, while a resistance too low can enable false operations of the trip coil.

Table 377: Values recommended for the external resistor R_{ext}

Operating voltage U_c	Shunt resistor R_{ext}
48 V DC	10 kΩ, 5 W
60 V DC	22 kΩ, 5 W
110 V DC	33 kΩ, 5 W
220 V DC	68 kΩ, 5 W

Due to the requirement that the voltage over the TCM contact must be 20V or higher, the correct operation is not guaranteed with auxiliary operating voltages lower than 48V DC because of the voltage drop in the R_{ext} and operating coil or even voltage drop of the feeding auxiliary voltage system which can cause too low voltage values over the TCM contact. In this case, erroneous alarming can occur.

At lower (<48V DC) auxiliary circuit operating voltages, it is recommended to use the circuit breaker position to block unintentional operation of TCM. The use of the position indication is described earlier in this chapter.

Using power output contacts without trip-circuit monitoring

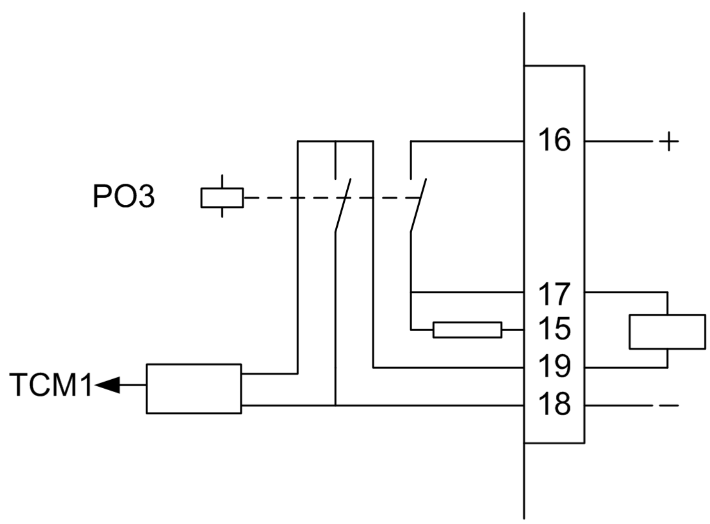

Figure 229: Connection of a power output in a case when TCM is not used and the internal resistor is disconnected

Incorrect connections and usage of trip-circuit monitoring

Although the TCM circuit consists of two separate contacts, it must be noted that those are designed to be used as series connected to guarantee the breaking capacity given in the technical manual of the IED. In addition to the weak breaking capacity, the internal resistor is not dimensioned to withstand current without a TCM circuit. As a result, this kind of incorrect connection causes immediate burning of the internal resistor when the circuit breaker is in the close position and the voltage is applied to the trip circuit. The following picture shows incorrect usage of a TCM circuit when only one of the contacts is used.

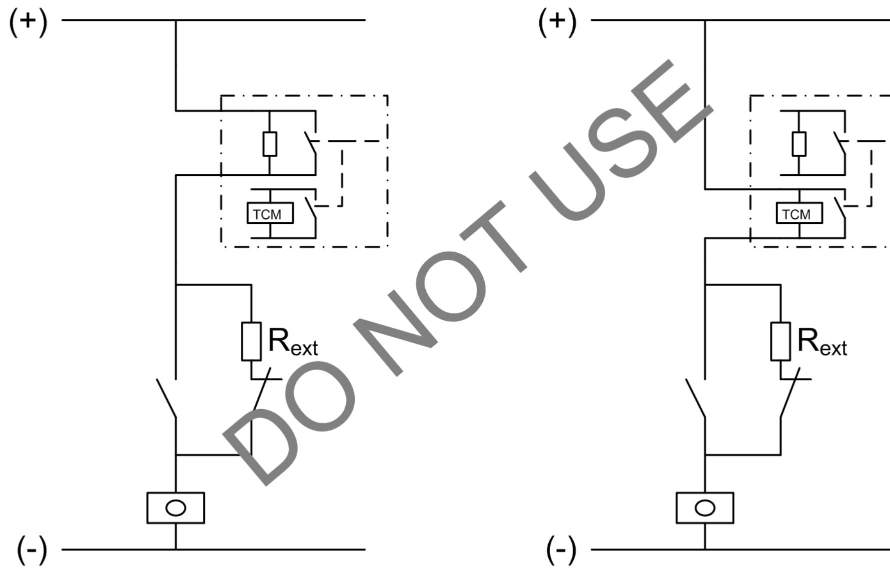

Figure 230: Incorrect connection of trip-circuit monitoring

A connection of three protection IEDs with a double pole trip circuit is shown in the following figure. Only the IED R3 has an internal TCM circuit. In order to test the operation of the IED R2, but not to trip the circuit breaker, the upper trip contact of the IED R2 is disconnected, as shown in the figure, while the lower contact is still connected. When the IED R2 operates, the coil current starts to flow through the internal resistor of the IED R3 and the resistor burns immediately. As proven with the previous examples, both trip contacts must operate together. Attention should also be paid for correct usage of the trip-circuit monitoring while, for example, testing the IED.

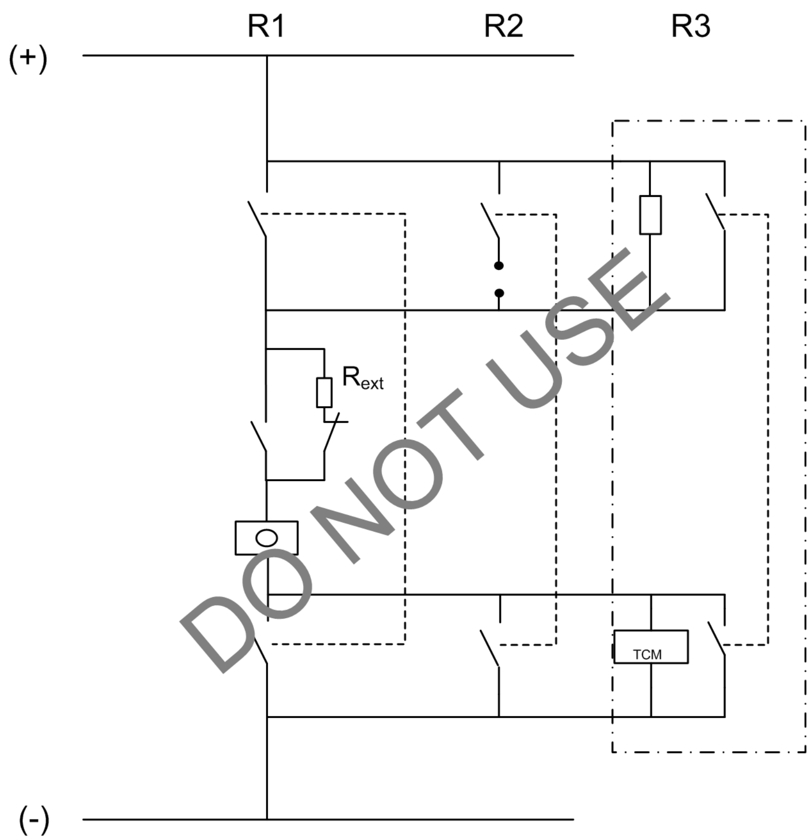

Figure 231: Incorrect testing of IEDs

6.2.6 Signals

Table 378: TCM Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block input status

Table 379: TCM Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

6.2.7 Settings

Table 380: TCM Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Disable / Enable
Trip delay time	20...300000	ms	1	3000	Operate delay time
Reset delay time	20...60000	ms	1	1000	Reset delay time

6.2.8 Monitored data

Table 381: TCM Monitored data

Name	Type	Values (Range)	Unit	Description
TCM	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.3 Current circuit supervision CCM

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current circuit supervision	CCRDIF	MCS 3I	CCM

6.3.2 Function block

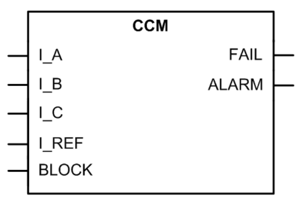

Figure 232: Function block

6.3.3 Functionality

The current circuit supervision function CCM is used for monitoring current transformers.

CCM calculates internally the sum of phase currents (I_A, I_B and I_C) and compares the sum against the measured single reference current (I_REF). The reference current must originate from other three-phase CT cores than the phase currents (I_A, I_B and I_C) and it is to be externally summated, that is, outside the IED.

CCM detects a fault in the measurement circuit and issues an alarm or blocks the protection functions to avoid unwanted tripping.

It must be remembered that the blocking of protection functions at an occurring open CT circuit means that the situation remains unchanged and extremely high voltages stress the secondary circuit.

6.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of current circuit supervision can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

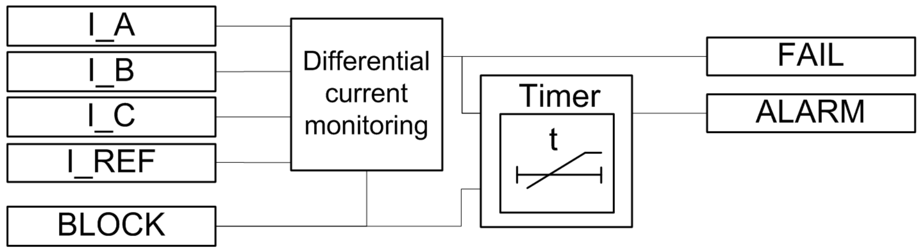

Figure 233: Functional module diagram

Differential current monitoring

Differential current monitoring supervises the difference between the summed phase currents I_A, I_B and I_C and the reference current I_REF.

The current operating characteristics can be selected with the *Pickup value* setting. When the highest phase current is less than 1.0 xIn, the differential current limit is defined with *Pickup value*. When the highest phase current is more that 1.0 xIn, the differential current limit is calculated with the formula:

$$MAX(I\_A, I\_B, I\_C) \times Pickupvalue$$

(Equation 53)

The differential current is limited to 1.0 xIn.

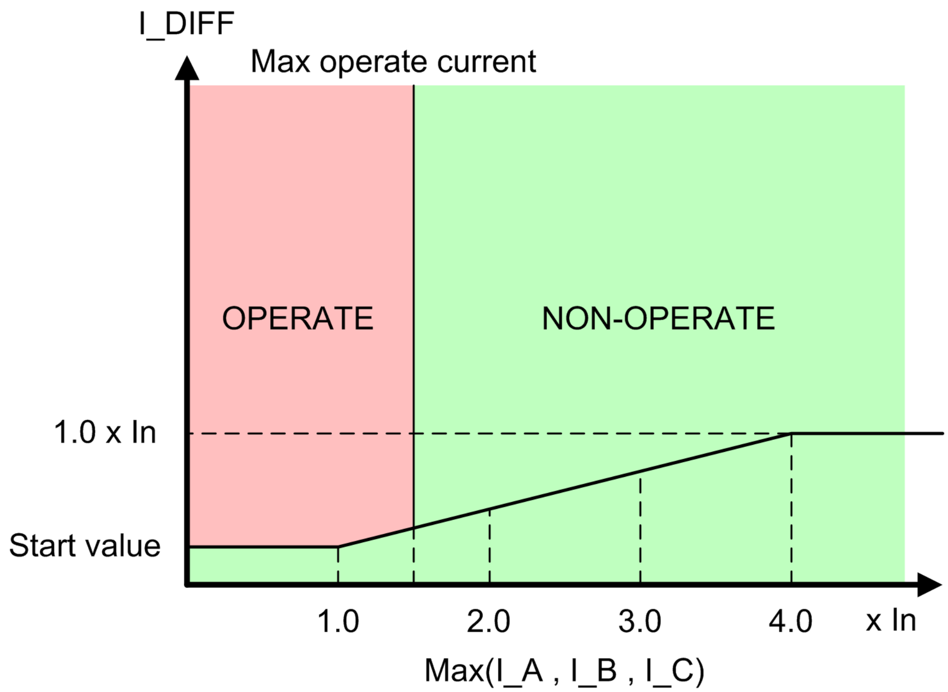

Figure 234: CCM operating characteristics

When the differential current I_DIFF is in the operating region, the FAIL output is activated.

The function is internally blocked if any phase current is higher than the set *Max trip current*. When the internal blocking activates, the FAIL output is deactivated immediately. The internal blocking is used for avoiding false operation during a fault situation when the current transformers are saturated due to high fault currents.

The value of the differential current is available through the Monitored data view on the LHMI or through other communication tools. The value is calculated with the formula:

$$I\_DIFF = \left| \overline{I\_A} + \overline{I\_B} + \overline{I\_C} \right| - \left| \overline{I\_REF} \right|$$

(Equation 54)

The *Pickup value* setting is given in units of xIn of the phase current transformer. The possible difference in the phase and reference current transformer ratios is internally compensated by scaling I_REF with the value derived from the *Primary current* setting values. These setting parameters can be found in the Basic functions section.

The activation of the BLOCK input activates the FAIL output immediately.

Timer

The timer is activated with the FAIL signal. The ALARM output is activated after a fixed 200 ms delay. FAIL needs to be active during the delay.

When the internal blocking is activated, the FAIL output is deactivated immediately. The ALARM output is deactivated after a fixed 3 s delay, and the FAIL is deactivated.

The deactivation happens only when the highest phase current is more than 5 percent of the nominal current (0.05 xIn).

When the line is de-energized, the deactivation of the `ALARM` output is prevented.

The activation of the `BLOCK` input deactivates the `ALARM` output.

6.3.5 Application

Open or short-circuited current transformer cores can cause unwanted operation in many protection functions such as differential, ground-fault current and negative sequence current functions. When currents from two independent three-phase sets of CTs or CT cores measuring the same primary currents are available, reliable current circuit supervision can be arranged by comparing the currents from the two sets. When an error in any CT circuit is detected, the protection functions concerned can be blocked and an alarm given.

In case of high currents, the unequal transient saturation of CT cores with a different remanence or saturation factor may result in differences in the secondary currents from the two CT cores. Unwanted blocking of protection functions during the transient stage must then be avoided.

The supervision function must be sensitive and have a short trip time in order to prevent unwanted tripping from fast-acting, sensitive numerical protections in case of faulty CT secondary circuits.

Open CT circuits create extremely high voltages in the circuits which may damage the insulation and cause further problems. This must be taken into consideration especially when the protection functions are blocked.

When the reference current is not connected to the IED, the function should be turned off. Otherwise, the `FAIL` output is activated when unbalance occurs in the phase currents even if there was nothing wrong with the measurement circuit.

Reference current measured with core-balanced current transformer

The function compares the sum of phase currents to the current measured with the core-balanced CT.

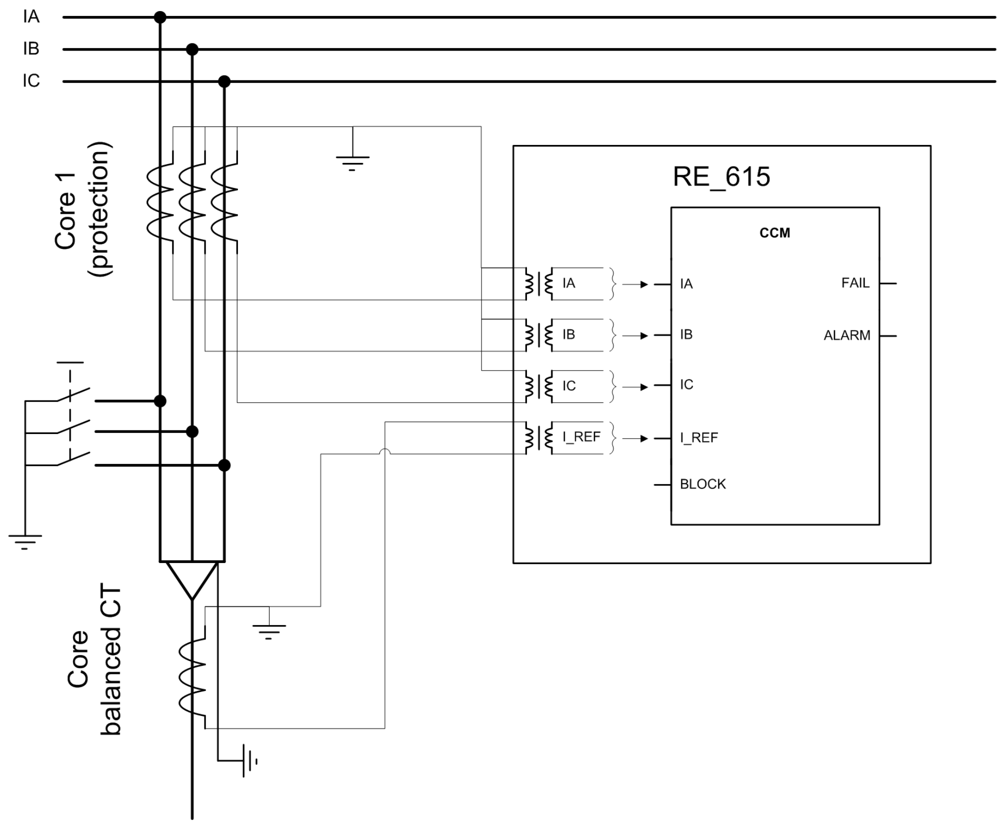

Figure 235: Connection diagram for reference current measurement with core balanced current transformer

Current measurement with two independent three-phase sets of CT cores

The figures show diagrams of connections where the reference current is measured with two independent three-phase sets of CT cores.

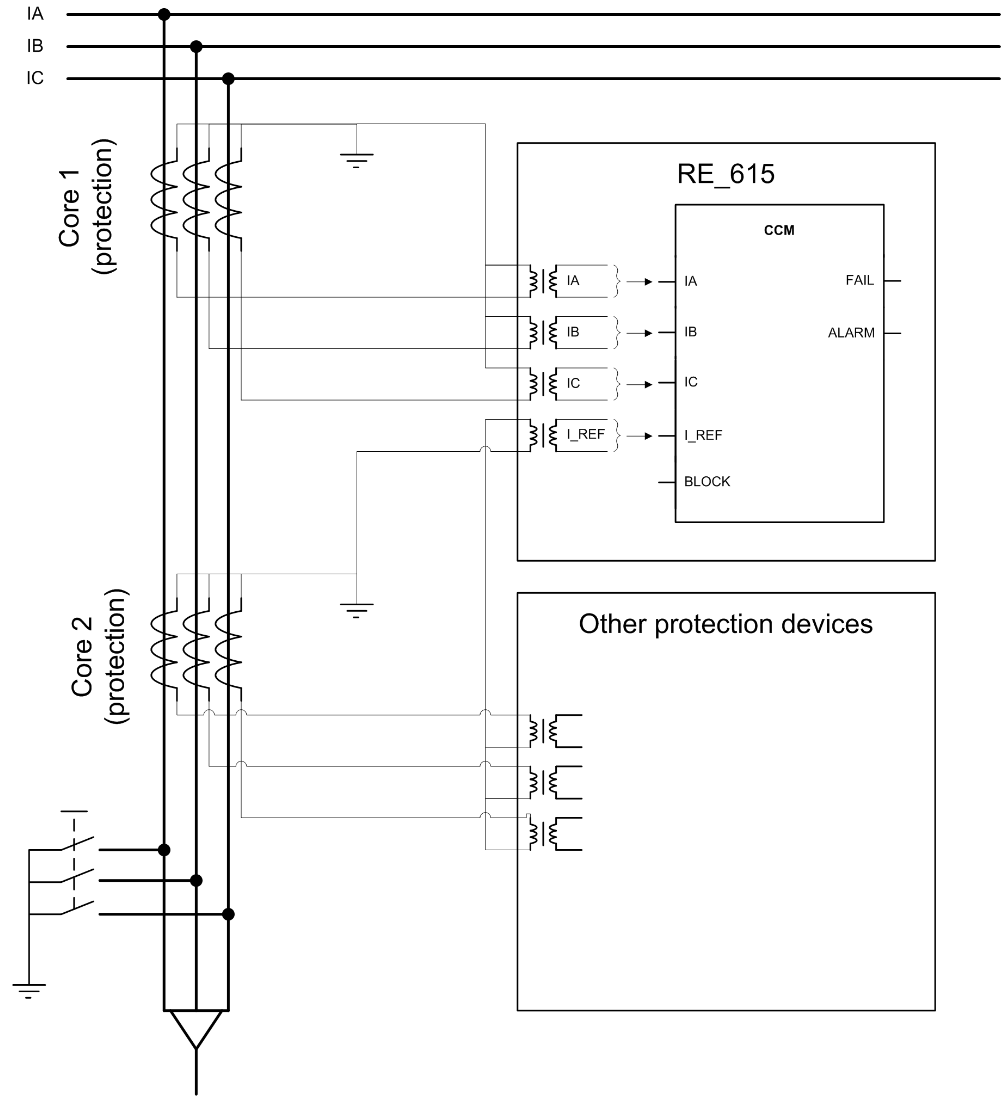

Figure 236: Connection diagram for current circuit supervision with two sets of three-phase current transformer protection cores

When using the measurement core for reference current measurement, it should be noted that the saturation level of the measurement core is much lower than with the protection core. This should be taken into account when setting the current circuit supervision function.

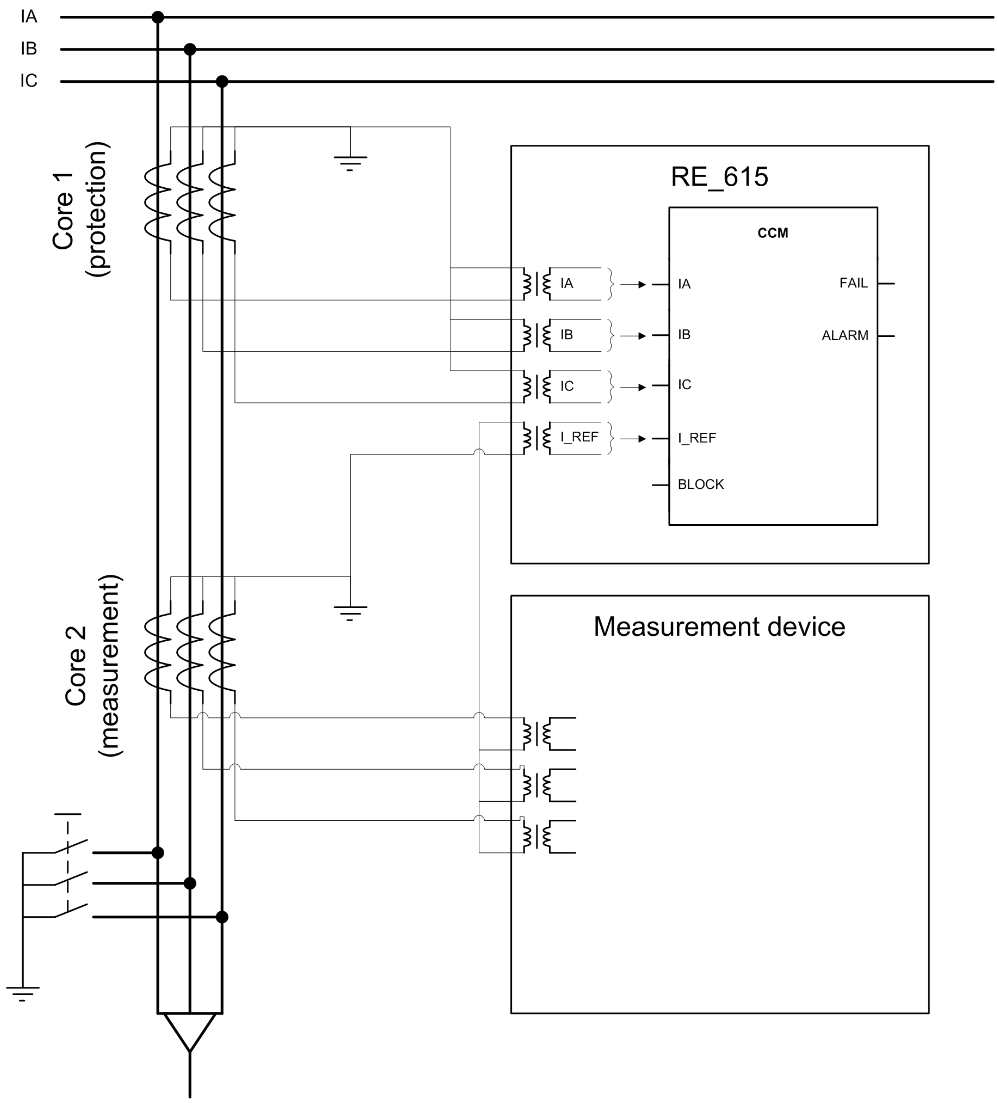

Figure 237: Connection diagram for current circuit supervision with two sets of three-phase current transformer cores (protection and measurement)

Example of incorrect connection

The currents must be measured with two independent cores, that is, the phase currents must be measured with a different core than the reference current. A connection diagram shows an example of a case where the phase currents and the reference currents are measured from the same core.

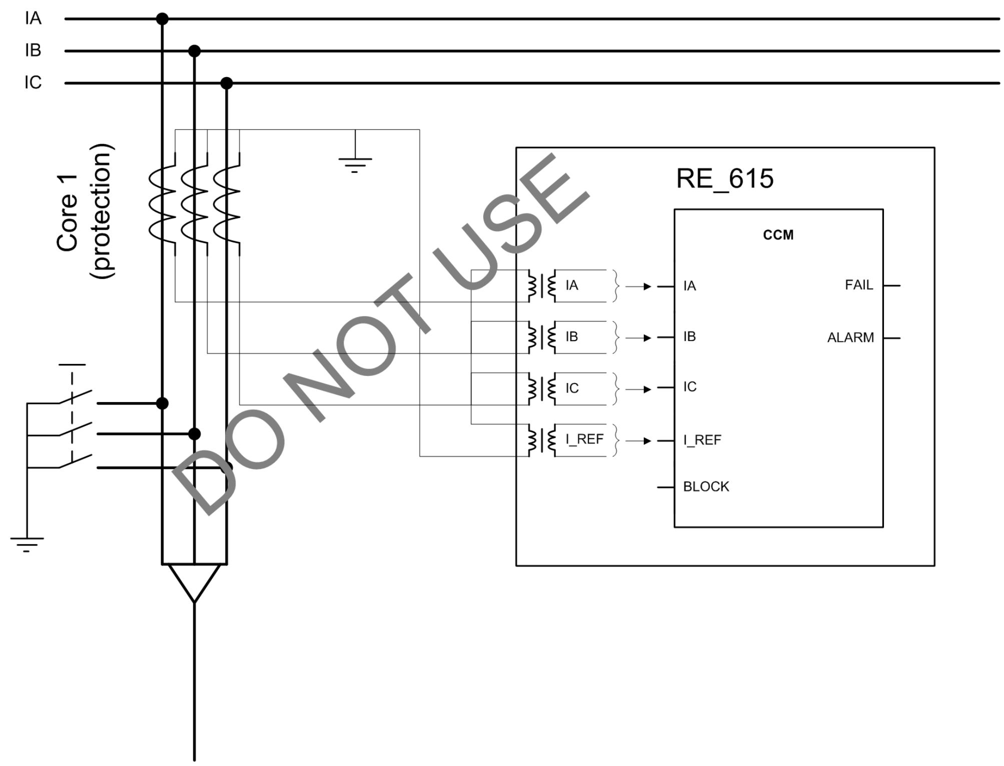

Figure 238: Example of incorrect reference current connection

6.3.6 Signals

Table 382: CCM Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_REF	SIGNAL	0	Reference current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 383: CCM Output signals

Name	Type	Description
FAIL	BOOLEAN	Fail output
ALARM	BOOLEAN	Alarm output

6.3.7 Settings

Table 384: CCM Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Enable / Disable
Pickup value	0.05...0.20	xIn	0.01	0.05	Minimum trip current differential level
Max trip current	1.00...5.00	xIn	0.01	1.50	Block of the function at high phase current

6.3.8 Monitored data

Table 385: CCM Monitored data

Name	Type	Values (Range)	Unit	Description
I_DIFF	FLOAT32	0.00...40.00	xIn	Differential current
CCM	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.3.9 Technical data

Table 386: CCM Technical data

Characteristic	Value
Trip time[1]	< 30 ms

1. Including the delay of the output contact.

6.4 Advanced current circuit supervision for transformers, MCS 3I, I2

6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
CT secondary circuit supervision	MCS 3I, I2	MCS 3I,I2	MCS 3I,I2

6.4.2 Function block

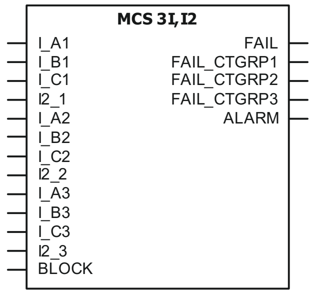

Figure 239: Function block

6.4.3 Functionality

The CT secondary circuit supervision function MCS 3I, I2 is used for monitoring the current transformer secondary circuit where a separate reference current transformer input for comparison is not available or where a separate voltage channel for calculating or measuring the zero-sequence voltage is not available.

MCS 3I, I2 can be used for detecting the single-phase failure on the current transformer secondary for protection application involving two or three sets of the three-phase current transformers.

MCS 3I, I2 detects a fault in the measurement circuit and issues an alarm which can be used for blocking the protection functions, for example, differential protection, to avoid unwanted tripping.

MCS 3I, I2 is internally blocked in case of a transformer under no-load condition or if a current in any one phase exceeds the set maximum limit.

6.4.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are "Enabled" and "Disabled".

The operation of the CT secondary circuit supervision function can be described with a module diagram. All the modules in the diagram are explained in the next sections.

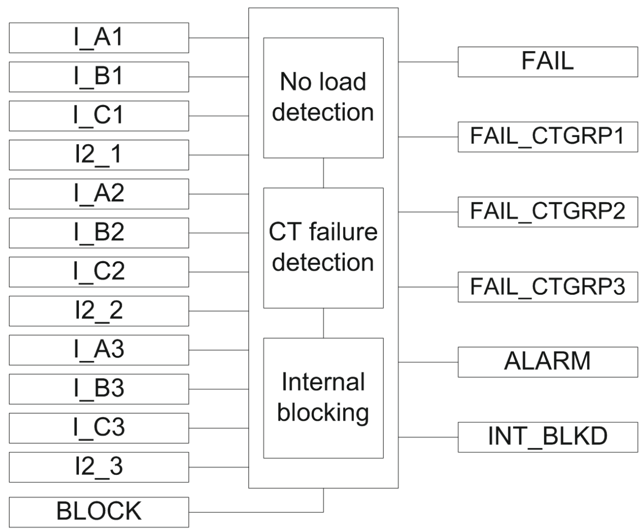

Figure 240: Functional module diagram

6.4.4.1 No-load detection

No-load detection module detects the loading condition. If all the three-phase currents of any two sets of current transformer are zero, the protected equipment is considered to be in the no-load condition and the function is internally blocked by activating the INT_BLKD output.

To avoid any false operation, the function is also internally blocked if any two-phase currents of any set of current transformers are below Min alarm current. This activates INT_BLKD. The value of the Min alarm current setting depends on the type of equipment to be protected. For example, in case of transformer protection, Min alarm current depends on the no-load current rating. Typically, it can be set equal to the transformer no-load current rating.

6.4.4.2 CT failure detection

This module detects the CT secondary failure in any sets of current transformers. The module continuously scans the value of all the three-phase currents in all groups of current transformers to detect any sudden drop in the current value to zero. The detection of a zero current should not be the only criterion for considering a fault in the current transformer secondary. Two other criteria are evaluated to confirm the CT failure:

- A zero current due to the CT failure does not result in a negative-sequence current on healthy CT sets.

  On the detection of a zero current in any phase on either group of CT, the negative-sequence current I2 is further evaluated. For a genuine CT secondary failure, the magnitude of I2 changes only on the side where zero current has been detected. The change in the magnitude of I2 (ΔI2) on the other sets of the current transformer (other than where zero current is detected) is calculated. If the change is detected on the healthy sets of CT, it is an indication of system failure.

- A zero current due to the CT failure does not result in a phase angle difference between the healthy phases.

  If a system faults happens on the phase A, it results in a change in the phase angle difference between phase B and phase C. This change in the phase angle difference between the healthy phases is evaluated in all three sets of current transformer, and if the change is detected in any set of CT, it is an indication of the system failure.

If both conditions are satisfied at zero current, the FAIL output is activated immediately. The ALARM output is activated after a fixed 200 ms delay. FAIL needs to be active during the delay. The outputs FAIL, CTGRP1, FAIL_CTGRP2 and FAIL_CTGRP3 are activated according to the CT group where the secondary failure is detected.

Activation of the BLOCK input deactivates the FAIL and ALARM outputs

It is not possible to detect the CT secondary failure happening simultaneously with the system faults or failures or two simultaneous failures in the secondary circuit. The function resets if the zero current does not exist longer than 200 ms.

6.4.4.3 Internal blocking

This module blocks the function internally under specific condition to avoid any false operation during a system fault situation. When any of the following condition is satisfied, the function is internally blocked and the FAIL output is deactivated immediately

- Magnitude of any phase current for any group of current transformers exceeds the Max alarm current setting. The magnitude of phase current is calculated from the peak-to-peak value.
- Magnitude of the negative-sequence current I2 on the healthy set of current transformer exceeds the Max Nq Seq current setting.

The INT_BLKD output is activated when FAIL is deactivated if any of the above conditions is satisfied. The ALARM output is also deactivated after a fixed three-second delay after the FAIL output is deactivated.

6.4.5 Application

Open or short-circuited current transformer secondary can cause unwanted operation in many protection functions, such as ground-fault current and differential. The simplest method for detecting the current transformer secondary failure is by comparing currents from two independent three-phase sets of CTs or the CT cores measuring the same primary currents. Another widely used method is the detection of a zero-sequence current and zero-sequence voltage. The detection of a zero-sequence current in the absence of a zero-sequence voltage is an indication of the current transformer secondary failure.

However, both methods have disadvantages as they require an additional set of current transformer, or a voltage channel is needed for detecting a zero-sequence voltage.

The methods may not be applicable where additional current channels or voltage channels are not available. This CT secondary circuit supervision presents an algorithm that can be used as an example for detecting the CT secondary failure used for the unit protection of a two-winding or three-winding transformer. However, the function has a limitation that it cannot detect failure in case of equipment under protection in no-load condition or when two simultaneous secondary CT failures occur.

The detection of a zero current in any one phase is a partial indication of failure in the current transformer secondary. Furthermore, if this current zero is due to the failure in the current transformer secondary, it results in a change in the magnitude of the negative-sequence current in the group only where current zero has been detected. However, changes in the negative-sequence current in other groups of three-phase current transformers at the instance of zero-current detection is an indication of a system problem. Also, it may happen that after the detection of a failure in the current transformer secondary, a fault may occur in the system. During such condition, functions are internally blocked.

Phase discontinuity

A zero current detected due to the phase discontinuity results in an asymmetry in all the sets of the current transformer, which then results in a change in the negative-sequence current (?I2) in the healthy set. This change in the negative-sequence current on the healthy sides, that is, other than where a zero current has been detected, blocks the function.

In case of a lightly loaded transformer (up to 30%) the change in the negative-sequence current may be very negligible. However, a phase discontinuity results in a change in the phase angle difference between two healthy phases in the set of CTs where a zero current has been detected as well as on the primary side of the transformer. This change in the value of the angle blocks the function internally.

Overload / System short circuit condition

It is required that any overload or short circuit conditions after a CT failure should block the function. During overload or short circuit condition, the phase current increases beyond its rated value; if any phase current on any set of current transformer exceeds the set limit, the function is blocked internally. Also in case of an unsymmetrical fault, the negative-sequence current increases. If the negative-sequence current increases beyond the set limit, the function is blocked internally. The overcurrent and negative-sequence current setting both can be set equal to the overcurrent and negative-sequence protection function pickup value.

The internal blocking is thus useful for avoiding false operation during a fault situation.

6.4.6 Signals

Table 387: MCS 3I, I2 Input signals

Name	Type	Default	Description
I_A1	SIGNAL	0	Phase A current from set 1
I_B1	SIGNAL	0	Phase B current from set 1
I_C1	SIGNAL	0	Phase C current from set 1
I2_1	SIGNAL	0	Negative-sequence current from set 1
I_A2	SIGNAL	0	Phase A current from set 2
I_B2	SIGNAL	0	Phase B current from set 2
I_C2	SIGNAL	0	Phase C current from set 2
I2_2	SIGNAL	0	Negative-sequence current from set 2
I_A3	SIGNAL	0	Phase A current from set 3
I_B3	SIGNAL	0	Phase B current from set 3
I_C3	SIGNAL	0	Phase C current from set 3
I2_3	SIGNAL	0	Negative-sequence current from set 3
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 388: MCS 3I, I2 Output signals

Name	Type	Description
FAIL	BOOLEAN	CT secondary failure
FAIL_CTGRP1	BOOLEAN	CT secondary failure group 1
FAIL_CTGRP2	BOOLEAN	CT secondary failure group 2
FAIL_CTGRP3	BOOLEAN	CT secondary failure group3
ALARM	BOOLEAN	Alarm

6.4.7 Settings

Table 389: : MCS 3I, I2 Non-group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1 = on 5 = off			1 = on	Operation Off / On
Min alarm current	0.01...0.50	xIn	0.01	0.02	Minimum alarm current
Max alarm current	1.00...5.00	xIn	0.01	1.30	Maximum alarm current
Max Ng Seq current	0.01...1.00	xIn	0.01	0.10	Maximum I2 current in healthy set

6.4.8 Monitored data

Table 390: MCS 3I, I2 Monitored data

Name	Type	Values (Range)	Unit	Description
INT_BLKD	BOOLEAN	0=False 1=True		Function blocked internally
MCS 3I, I2	Enum	1=on		Status
		2=blocked		
		3=test		
		4=test/blocked		
		5=off		

6.5 Fuse failure supervision 60

6.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fuse failure supervision	SEQRFUF	FUSEF	60

6.5.2 Function block

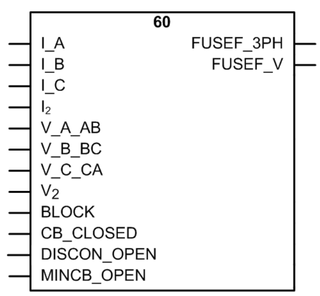

Figure 241: Function block

6.5.3 Functionality

The fuse failure supervision function SEQRFUF is used to block the voltage measuring functions at a failure in the secondary circuits between the voltage transformer and IED to avoid misoperations of the voltage protection functions.

SEQRFUF has two algorithms, a negative sequence-based algorithm and a delta current and delta voltage algorithm.

A criterion based on the delta current and the delta voltage measurements can be activated to detect three-phase fuse failures which usually are more associated with the voltage transformer switching during station operations.

6.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of the fuse failure supervision function can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

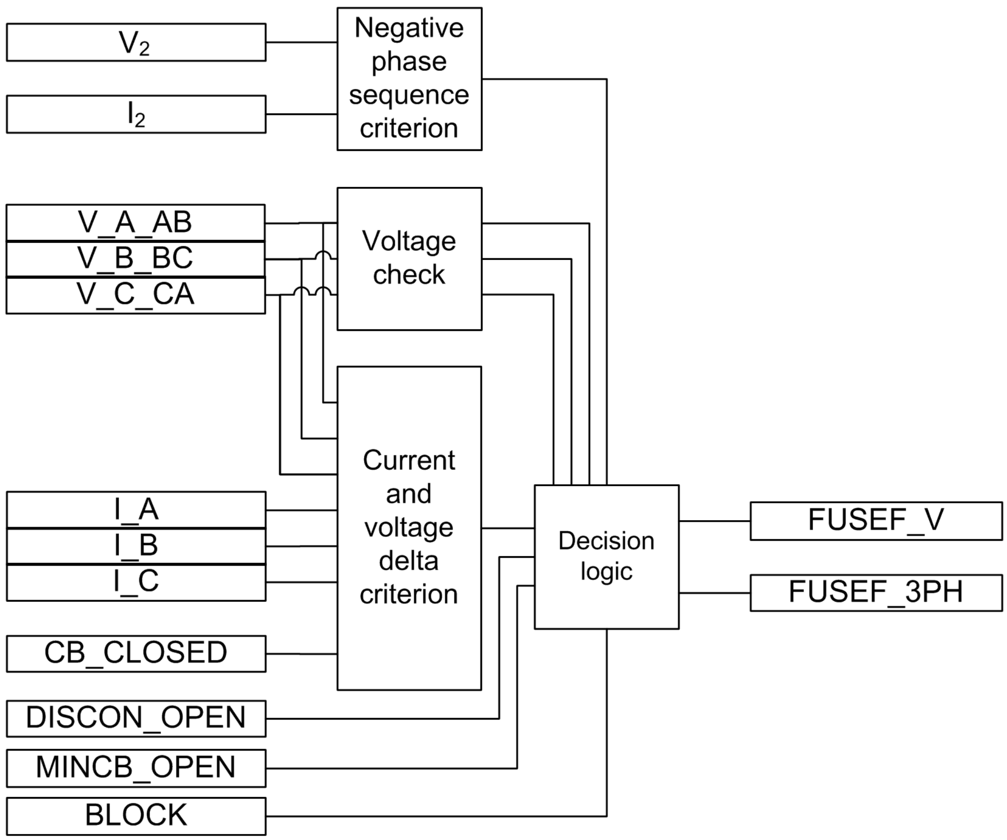

Figure 242: Functional module diagram

Negative phase-sequence criterion

A fuse failure based on negative phase-sequence criterion is detected if the measured negative phase-sequence voltage exceeds the set *Neg Seq voltage Lev* value and the measured negative phase-sequence current is below the set *Neg Seq current Lev* value. The detected fuse failure is reported to the decision logic module.

Voltage check

The phase voltage magnitude is checked when deciding whether the fuse failure is a three, two or a single-phase fault.

The module makes a phase-specific comparison between each voltage input and the *Seal in voltage* setting. In case the input voltage is lower than the setting, the corresponding phase is reported to the decision logic module.

Current and voltage delta criterion

The delta function can be activated by setting the *Change rate enable* parameter to "True". Once the function is activated, it operates in parallel with the negative phase-sequence based algorithm. The current and voltage are continuously measured in all three phases to calculate:

- Change of voltage dV/dt
- Change of current dI/dt

The calculated delta quantities are compared to the respective set values of the *Current change rate* and *Voltage change rate* settings.

The delta current and delta voltage algorithms detect a fuse failure if there is a sufficient negative change in the voltage amplitude without a sufficient change in the current amplitude in each phase separately. This is performed when the circuit breaker is closed. Information about the circuit breaker position is connected to the `CB_CLOSED` input.

There are two conditions for activating the current and voltage delta function:

- The magnitude of ΔV exceeds the corresponding value of the *Min Op voltage delta* setting and the magnitude of ΔI is below the value of the *Min Op current delta* setting in any phase at the same time due to the closure of the circuit breaker, that is, `CB_CLOSED` = TRUE.
- The magnitude of ΔV exceeds the value of the *Min Op voltage delta* setting and the magnitude of ΔI is below the *Min Op current delta* setting in any phase at the same time since the magnitude of the phase current in the same phase exceeds the *Current level* setting.

The first condition requires the delta criterion to be fulfilled in any phase at the same time as the circuit breaker is closed. Opening the circuit breaker at one end and energizing the line from the other end onto a fault could lead to an improper operation of 60 with an open breaker. If this is considered to be an important disadvantage, the `CB_CLOSED` input is to be connected to FALSE.

The second condition requires the delta criterion to be fulfilled in one phase together with high current for the same phase. The measured phase current is used to reduce the risk of a false fuse-failure detection. If the current on the protected line is low, a voltage drop in the system (not caused by the fuse failure) is not followed by a current change and a false fuse failure can occur. To prevent this, the minimum phase current criterion is checked.

The fuse-failure detection is active until the voltages return above the *Min Op voltage delta* setting. If a voltage in a phase is below the *Min Op voltage delta* setting, a new fuse failure detection for that phase is not possible until the voltage returns above the setting value.

Decision logic

The fuse-failure detection outputs `FUSEF_V` and `FUSEF_3PH` are controlled according to the detection criteria or external signals.

Table 391: Fuse failure output control

Fuse-failure detection criterion	Conditions and function response
Negative phase sequence criterion	If a fuse failure is detected based on the negative phase-sequence criterion, the FUSEF_U output is activated.
	If the fuse-failure detection is active for more than five seconds and at the same time all the phase voltage values are below the set value of the *Seal in voltage* setting with *Enable seal in* turned to "Yes", the function activates the FUSE_3PH output signal.
	The FUSEF_U output signal is also activated if all the phase voltages are above the *Seal in voltage* setting for more than 60 seconds and at the same time the negative sequence voltage is above *Neg Seq voltage Lev* for more than 5 seconds, all the phase currents are below the *Current dead Lin Val* setting and the circuit breaker is closed, that is,CB_CLOSED is TRUE.
Current and voltage delta function criterion	If the current and voltage delta criterion detects a fuse failure condition, but all the voltages are not below the *Seal in voltage* setting, only the FUSEF_U output is activated.
	If the fuse-failure detection is active for more than five seconds and at the same time all the phase voltage values are below the set value of the *Seal in voltage* setting with *Enable seal in* turned to "Yes", the function activates the FUSE_3PH output signal.
External fuse-failure detection	The MINCB_OPEN input signal is supposed to be connected through an IED binary input to the N.C. auxiliary contact of the miniature circuit breaker protecting the VT secondary circuit. The MINCB_OPEN signal sets the FUSEF_U output signal to block all the voltage-related functions when MCB is in the open state.
	The DISCON_OPEN input signal is supposed to be connected through an IED binary input to the N.C. auxiliary contact of the line disconnector. The DISCON_OPEN signal sets the FUSEF_U output signal to block the voltage-related functions when the line disconnector is in the open state.

It is recommended to always set *Enable seal in* to "Yes". This secures that the blocked protection functions remain blocked until normal voltage conditions are restored if the fuse-failure has been active for 5 seconds, that is, the fuse failure outputs are deactivated when the normal voltage conditions are restored.

The activation of the BLOCK input deactivates both FUSEF_U and FUSEF_3PH outputs.

6.5.5 Application

Some protection functions operate on the basis of the measured voltage value in the IED point. These functions can fail if there is a fault in the measuring circuits between the voltage transformers and the IED.

A fault in the voltage measuring circuit is referred to as a fuse failure. This term is misleading since a blown fuse is just one of the many possible reasons for a broken circuit.

Since incorrectly measured voltage can result in a misoperation of some of the protection functions, fast failure detection is one of the means to block voltage-based functions before they operate.

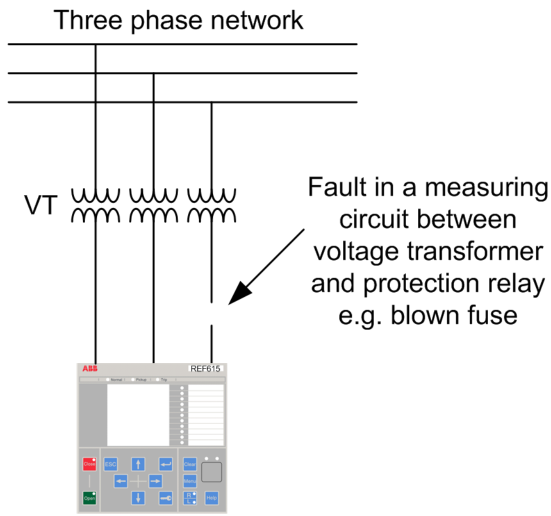

Figure 243: Fault in a circuit from the voltage transformer to the IED

A fuse failure occurs due to blown fuses, broken wires or intended substation operations. The negative sequence component-based function can be used to detect different types of single-phase or two-phase fuse failures. However, at least one of the three circuits from the voltage transformers must not be broken. The supporting delta-based function can also detect a fuse failure due to three-phase interruptions.

In the negative sequence component-based part of the function, a fuse failure is detected by comparing the calculated value of the negative sequence component voltage to the negative sequence component current. The sequence entities are calculated from the measured current and voltage data for all three phases. The purpose of this function is to block voltage-dependent functions when a fuse failure is detected. Since the voltage dependence differs between these functions, 60 has two outputs for this purpose.

6.5.6 Signals

Table 392: 60 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative sequence current
V_A_AB	SIGNAL	0	Phase A voltage
V_B_BC	SIGNAL	0	Phase B voltage
V_C_CA	SIGNAL	0	Phase C voltage
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block of function
CB_CLOSED	BOOLEAN	0=False	Active when circuit breaker is closed
DISCON_OPEN	BOOLEAN	0=False	Active when line disconnector is open
MINCB_OPEN	BOOLEAN	0=False	Active when external MCB opens protected voltage circuit

Table 393: 60 Output signals

Name	Type	Description
FUSEF_3PH	BOOLEAN	Three-phase pickup of function
FUSEF_V	BOOLEAN	General pickup of function

6.5.7 Settings

Table 394: 60 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Disable / Enable
Neg Seq current Lev	0.03...0.20	xIn	0.01	0.03	Operate level of neg seq undercurrent element
Neg Seq voltage Lev	0.03...0.20	xVn	0.01	0.10	Operate level of neg seq overvoltage element
Current change rate	0.01...0.50	xIn	0.01	0.15	Operate level of change in phase current
Voltage change rate	0.50...0.90	xVn	0.01	0.60	Operate level of change in phase voltage
Change rate enable	0=False 1=True			0=False	Enabling operation of change based function
Min Op voltage delta	0.01...1.00	xVn	0.01	0.70	Minimum operate level of phase voltage for delta calculation
Min Op current delta	0.01...1.00	xIn	0.01	0.10	Minimum operate level of phase current for delta calculation
Seal in voltage	0.01...1.00	xVn	0.01	0.70	Operate level of seal-in phase voltage
Enable seal in	0=False 1=True			0=False	Enabling seal in functionality
Current dead Lin Val	0.05...1.00	xIn	0.01	0.05	Operate level for open phase current detection

6.5.8 Monitored data

Table 395: 60 Monitored data

Name	Type	Values (Range)	Unit	Description
60	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.5.9 Technical data

Table 396: 60 Technical data

Characteristic	Value	
Trip time[1]		
• NPS function	V_{Fault} = 1.1 x set *Neg Seq voltage Lev*	< 33 ms
	V_{Fault} = 5.0 x set *Neg Seq voltage Lev*	< 18 ms
• Delta function	ΔV = 1.1 x set *Voltage change rate*	< 30 ms
	ΔV = 2.0 x set *Voltage change rate*	< 24 ms

1. Includes the delay of the signal output contact, f_n = 60 Hz, fault voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

6.6 Motor startup supervision 66/51LRS

6.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor startup supervision	STTPMSU	Is2tn<	66/51LRS

6.6.2 Function block

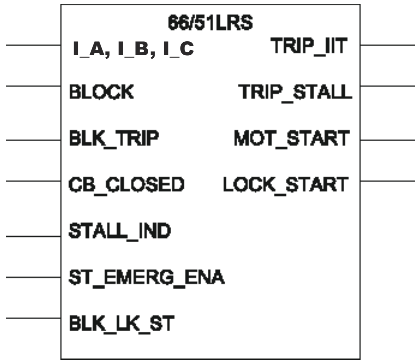

Figure 244: Function block

6.6.3 Functionality

The motor startup supervision function 66/51LRS is designed for protection against excessive starting time and locked rotor conditions of the motor during starting. For the reliable operation of the motor, the thermal stress during the motor starting is maintained within the allowed limits.

The starting of the motor is supervised by monitoring the TRMS magnitude of all the phase currents or by monitoring the status of the circuit breaker connected to the motor.

During the startup period of the motor, 66/51LRS calculates the integral of the I^2t value. If the calculated value exceeds the set value, the trip signal is activated.

66/51LRS has the provision to check the locked rotor condition of the motor using the speed switch, which means checking if the rotor is able to rotate or not. This feature trips after a predefined operating time.

66/51LRS also protects the motor from an excessive number of startups. Upon exceeding the specified number of startups within certain duration, 66/51LRS blocks further starts. The restart of the motor is also inhibited after each start and continues to be inhibited for a set duration. When the lock of startup of motor is enabled, 66/51LRS gives the time remaining until the restart of the motor.

66/51LRS contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

6.6.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of the motor startup supervision function can be described using a module diagram. All the modules in the diagram are explained in the next sections.

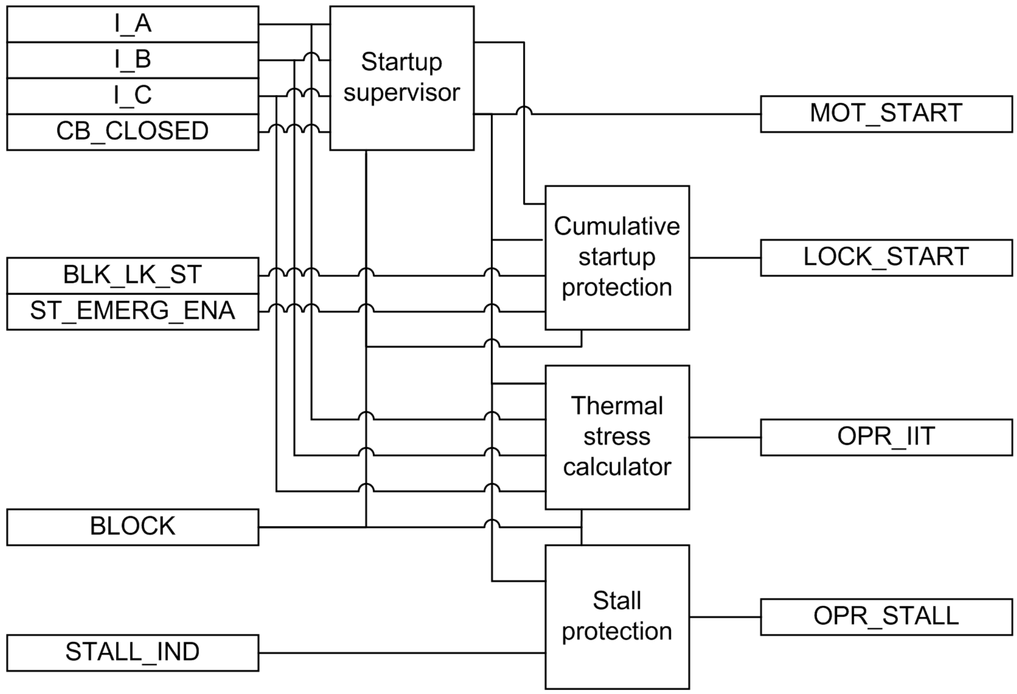

Figure 245: Functional module diagram

Startup supervisor

This module detects the starting of the motor. The starting and stalling motor conditions are detected in four different modes of operation. This is done through the *Operation mode* setting.

When the *Operation mode* setting is operated in the “IIt” mode, the function calculates the value of the thermal stress of the motor during the startup condition. In this mode, the startup condition is detected by monitoring the TRMS currents.

The *Operation mode* setting in the “IIt, CB” mode enables the function to calculate the value of the thermal stress when a startup is monitored in addition to the `CB_CLOSED` input.

In the “IIt & stall” mode, the function calculates the thermal stress of the motor during the startup condition. In this mode, the startup condition is detected by monitoring the TRMS currents. In the “IIt & stall” mode, the function also checks for motor stalling by monitoring the speed switch.

In the “IIt & stall, CB” mode, the function calculates the thermal stresses of the motor during the startup condition. The startup condition is monitored in addition to the circuit breaker status. In the “IIt & stall, CB” mode, the function also checks for motor stalling by monitoring the speed switch.

When the measured current value is used for startup supervision in the “IIt” and “IIt & stall” modes, the module initially recognizes the de-energized condition of the motor when the values of all three phase currents are less than *Motor standstill A* for longer than 100 milliseconds. If any of the phase currents of the de-energized condition rises to a value equal or greater than the *Motor standstill A*, the MOT_START output signal is activated indicating that the motor startup is in progress. The MOT_START output remains active until the values of all three phase currents drop below 90 percent of the set value of *Start detection A* and remain below that level for a time of *Str over delay time*, that is, until the startup situation is over.

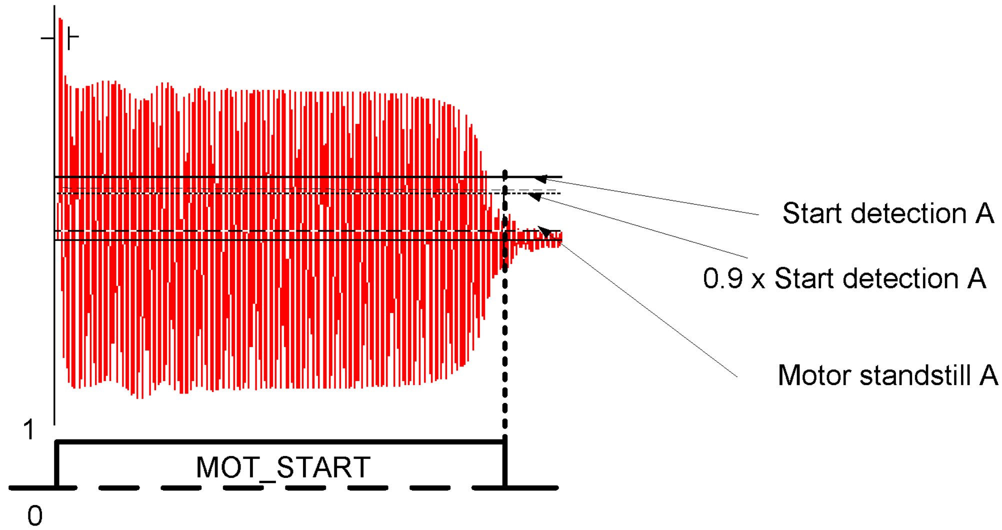

Figure 246: Functionality of startup supervision in "IIt and IIt&stall" mode

In case of the “IIt, CB” or “IIt & stall, CB” modes, the function initially recognizes the de-energized condition of the motor when the value of all three phase currents is below the value of the *Motor standstill A* setting for 100 milliseconds. The beginning of the motor startup is recognized when CB is closed, that is, when the CB_CLOSED input is activated and at least one phase current value exceeds the *Motor standstill A* setting.

But in normal practice, these two events do not take place at the same instant, that is, the CB main contact is closed first, in which case the phase current value rises above 0.1 pu and after some delay the CB auxiliary contact gives the information of the CB_CLOSED input. In some cases, the CB_CLOSED input can be active but the value of current may not be greater than the value of the *Motor standstill A* setting. To allow both possibilities, a time slot of 200 milliseconds is provided for current and the CB_CLOSED input. If both events occur during this time, the motor startup is recognized.

The motor startup ends either within the value of the *Str over delay time* setting from the beginning of the startup or the opening of CB or when the CB_CLOSED input is deactivated. The operation of the MOT_START output signal in this operation mode is as illustrated

This CB mode can be used in soft-started or slip ring motors for protection against a large starting current, that is, a problem in starting and so on.

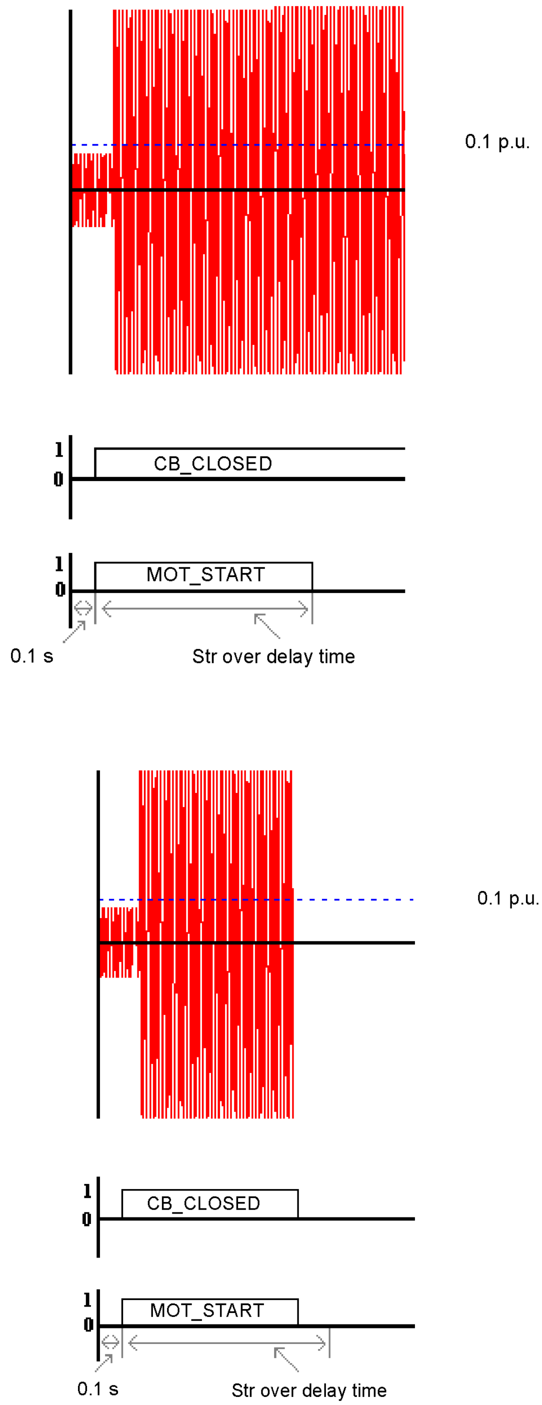

Figure 247: Functionality of startup supervision in "IIt, CB" mode and "IIt and stall, CB" mode

The *Str over delay time* setting has different purposes in different modes of operation:

- In the "IIt" or "IIt & stall" modes, the aim of this setting is to check for the completion of the motor startup period. The purpose of this time delay setting is to allow for short interruptions in the current without changing the state of the MOT_START output. In this mode of operation, the value of the setting is in the range of around 100 milliseconds.
- In the "IIt, CB" or "IIt & stall, CB" modes, the purpose of this setting is to check for the life of the protection scheme after the CB_CLOSED input has been activated. Based on the values of the phase currents, the completion of the startup period cannot be judged. So in this mode of operation, the value of the time delay setting can even be as high as within the range of seconds, for example around 30 seconds.

The BLOCK input signal is used to block the operation of the MOT_START output. The activation of the BLOCK input signal deactivates the MOT_START output.

Thermal stress calculator

Because of the high current surges during the startup period, a thermal stress is imposed on the rotor. With less air circulation in the ventilation of the rotor before it reaches its full speed, the situation becomes even worse. Consequently, a long startup causes a rapid heating of the rotor.

This module calculates the thermal stress developed in the motor during startup. The heat developed during the starting can be calculated using the formula,

$$W = R_s \int_0^t i_s^2(t)\, dt$$

(Equation 55)

R_s	combined rotor and stator resistance
i_s	starting current of the motor
t	starting time of the motor

This equation is normally represented as the integral of I^2t. It is a commonly used method in protective relays to protect the motor from thermal stress during starting. The advantage of this method over the traditional definite time overcurrent protection is that when the motor is started with a reduced voltage as in the star-delta starting method, the starting current is lower. This allows more starting time for the motor since the module is monitoring the integral of I^2t.

The module calculates the accumulated heat continuously and compares it to the limiting value obtained from the product of the square of the values of the *Motor start-up A* and *Motor start-up time* settings. When the calculated value of the thermal stress exceeds this limit, the OPR_IIT output is activated.

The module also measures the time START_TIME required by the motor to attain the rated speed and the relative thermal stress IIT_RL. The values are available through the monitored data view.

The BLOCK input is used to reset the operation of thermal stress calculator. The activation of the BLOCK input signal blocks the operation of the OPR_IIT output.

Stall protection

This module is activated only when the selected *Operation mode* setting value is “IIt & stall” or “IIt & stall, CB”.

The startup current is specific to each motor and depends on the startup method used, like direct on-line, autotransformer and rotor resistance insertion, and so on. The startup time is dependent of the load connected to the motor.

Based on the motor characteristics supplied by the manufacturer, this module is required if the stalling time is shorter than or too close to the starting time. In such cases, a speed switch must be used to indicate whether a motor is accelerating during startup or not.

At motor standstill, the `STALL_IND` input is active. It indicates that the motor is not running. When the motor is started, at certain revolution the `STALL_IND` input is deactivated by the speed switch that indicates the motor is running. If the input is not deactivated within *Lock rotor time*, the `OPR_STALL` output is activated.

The module calculates the duration of the motor in stalling condition, the `STALL_RL` output indicating the percent ratio of the start situation and the set value of *Lock rotor time*. The value is available through the monitored data view.

The `BLOCK` input signal is used to block the operation of the `OPR_STALL` output. The activation of the `BLOCK` input resets the operate timer.

Cumulative startup protection

This module protects the motor from an excessive number of startups.

Whenever the motor is started, the latest value of `START_TIME` is added to the existing value of `T_ST_CNT` and the updated cumulative startup time is available at `T_ST_CNT`. If the value of `T_ST_CNT` is greater than the value of *Cumulative time Lim*, the `LOCK_START` output, that is, the lockout condition for the restart of motor, is enabled. The `LOCK_START` output remains high until the `T_ST_CNT` value reduces to a value less than the value of *Cumulative time Lim*. The start time counter reduces at the rate of the value of *Counter Red rate*.

The `LOCK_START` output becomes activated at the start of `MOT_START`. The output remains active for a period of *Restart inhibit time*.

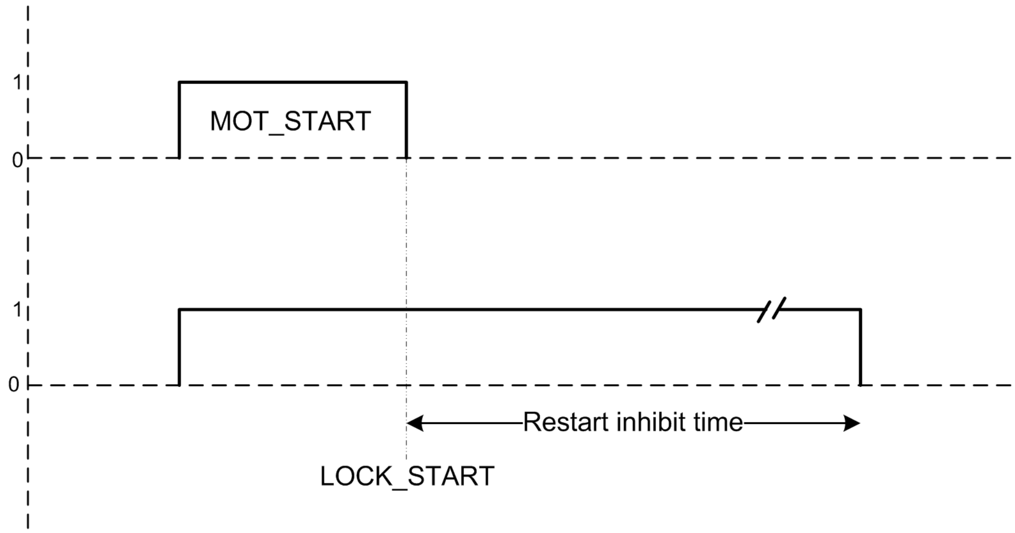

Figure 248: Time delay for cumulative start

This module also protects the motor from consecutive startups. When the LOCK_START output is active, T_RST_ENA shows the possible time for next restart. The value of T_RST_ENA is calculated by the difference of *Restart inhibit time* and the elapsed time from the instant LOCK_START is enabled.

When the ST_EMERG_ENA emergency start is set high, the value of the cumulative startup time counter is set to *Cumulative time Lim* - 60s x *Emg start Red rate*. This disables LOCK_START and in turn makes the restart of the motor possible.

This module also calculates the total number of startups occurred, START_CNT. The value can be reset from the clear menu.

The calculated values of T_RST_ENA, T_ST_CNT and START_CNT are available through the monitored data view.

The BLK_LK_ST input signal is used to block the operation of the LOCK_START output. The activation of the BLOCK input resets the complete operation of the cumulative startup counter module.

6.6.5 Application

When a motor is started, it draws a current well in excess of the motor's full load rating throughout the period it takes for the motor to run up to the rated speed. The motor starting current decreases as the motor speed increases and the value of current remains close to the rotor locked value for most of the acceleration period.

The full voltage starting or the direct-on-line starting method is used out of the many methods used for starting the induction motor. If there is either an electrical or mechanical constraint, this starting method is not suitable. The full voltage starting produces the highest starting torque. A high starting torque is generally required to start a high-inertia load to limit the acceleration time. In this method, full voltage is applied to the motor when the switch is in the "On" position. This method of starting results in a large initial current surge, which is typically four to eight times that of the full-load current drawn by the motor. If a star-delta starter is used, the value of the line current will only be about one-third of the direct-on-line starting current.

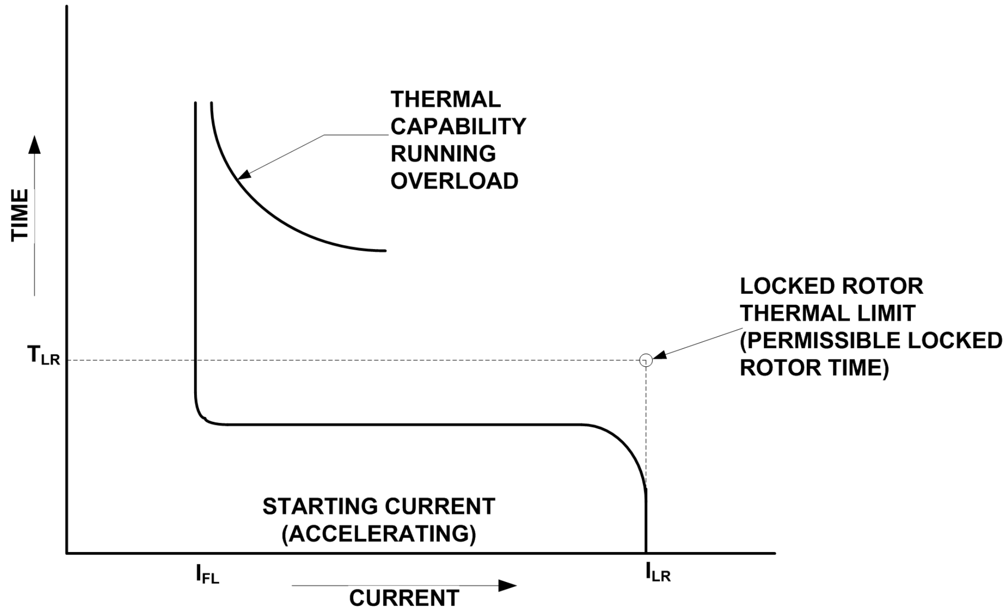

Figure 249: Typical motor starting and capability curves

The startup supervision of a motor is an important function because of the higher thermal stress developed during starting. During the startup, the current surge imposes a thermal strain on the rotor. This is exaggerated as the air flow for cooling is less because the fans do not rotate in their full speed. Moreover, the difference of speed between the rotating magnetic field and the rotor during the startup time induces a high magnitude of slip current in the rotor at frequencies higher than when the motor is at full speed. The skin effect is stronger at higher frequencies and all these factors increase the losses and the generated heat. This is worse when the rotor is locked.

The starting current for slip-ring motors is less than the full load current and therefore it is advisable to use the circuit breaker in the closed position to indicate the starting for such type of motors.

The starting times vary depending on motor design and load-torque characteristics. The time taken may vary from less than two seconds to more than 60 seconds. The starting time is determined for each application.

When the permissible stall time is less than the starting time of the motor, the stalling protection is used and the value of the time delay setting should be set slightly less than the permissible stall time. The speed switch on the motor shaft must be used for detecting whether the motor begins to accelerate or not. However, if the safe stall time is longer than the startup time of the motor, the speed switch is not required.

The failure of a motor to accelerate or to reach its full nominal speed in an acceptable time when the stator is energized is caused by several types of abnormal conditions, including a mechanical failure of the motor or load bearings, low supply voltage, open circuit in one phase of a three-phase voltage supply or too high starting voltage. All these abnormal conditions result in overheating.

Repeated starts increase the temperature to a high value in the stator or rotor windings, or both, unless enough time is allowed for the heat to dissipate. To ensure a safe operation it is necessary to provide a fixed-time interval between starts or limit the number of starts within a period of time. This is why the motor manufacturers have restrictions on how many starts are allowed in a defined time interval. This function does not allow starting of the motor if the number of starts exceeds the set level in the register that calculates them. This insures that the thermal effects on the motor for consecutive starts stay within permissible levels.

For example, the motor manufacturer may state that three starts at the maximum are allowed within 4 hours and the startup situation time is 60 seconds. By initiating three successive starts we reach the situation as illustrated. As a result, the value of the register adds up to a total of 180 seconds. Right after the third start has been initiated, the output lock of start of motor is activated and the fourth start will not be allowed, provided the time limit has been set to 121 seconds.

Furthermore, a maximum of three starts in 4 hours means that the value of the register should reach the set start time counter limit within 4 hours to allow a new start. Accordingly, the start time counter reduction should be 60 seconds in 4 hours and should thus be set to 60 s / 4 h = 15 s / h.

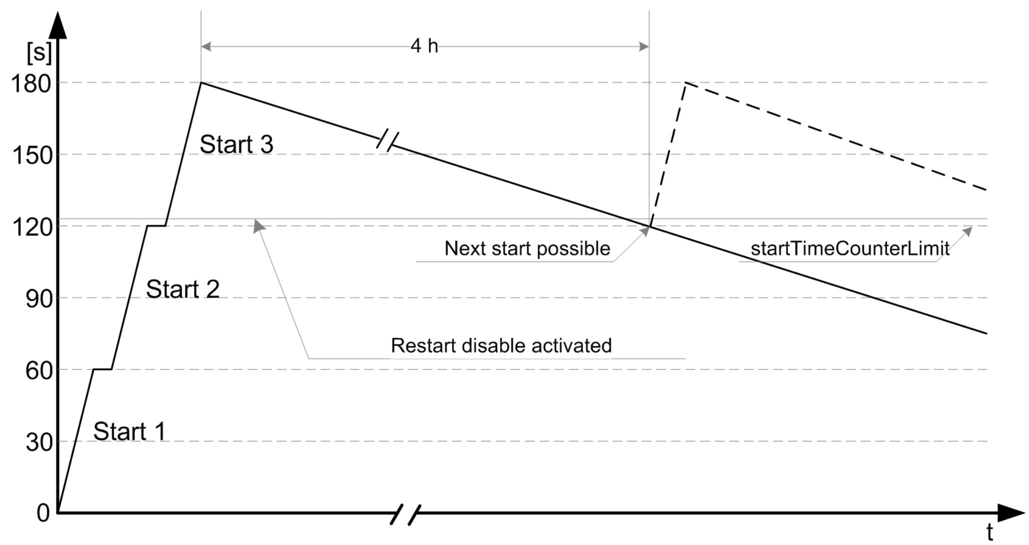

Figure 250: Typical motor-starting and capability curves

Setting of *Cumulative time Lim*

Cumulative time Lim is calculated by

$$\sum t_{si} = (n-1) \times t + margin \qquad \text{(Equation 56)}$$

n	specified maximum allowed number of motor startups
t	startup time of the motor (in seconds)
margin	safety margin (~10...20 percent)

Setting of *Counter Red rate*

Counter Red rate is calculated by

$$\Delta\sum t_s = \frac{t}{t_{reset}}$$ (Equation 57)

t specified start time of the motor in seconds

t_{reset} duration during which the maximum number of motor startups stated by the manufacturer can be made; time in hours

6.6.6 Signals

Table 397: 66/51LRS Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block of function
BLK_LK_ST	BOOLEAN	0=False	Blocks lock out condition for restart of motor
CB_CLOSED	BOOLEAN	0=False	Input showing the status of motor circuit breaker
STALL_IND	BOOLEAN	0=False	Input signal for showing the motor is not stalling
ST_EMERG_ENA	BOOLEAN	0=False	Enable emergency start to disable lock of start of motor

Table 398: 66/51LRS Output signals

Name	Type	Description
OPR_IIT	BOOLEAN	Trip signal for thermal stress.
OPR_STALL	BOOLEAN	Trip signal for stalling protection.
MOT_START	BOOLEAN	Signal to show that motor startup is in progress
LOCK_START	BOOLEAN	Lock out condition for restart of motor.

6.6.7 Settings

Table 399: 66/51LRS Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start detection A	0.1...10.0	xIn	0.1	1.5	Current value for detecting starting of motor.
Motor start-up A	1.0...10.0	xIn	0.1	2.0	Motor starting current
Motor start-up time	1...80	s	1	5	Motor starting time
Lock rotor time	2...120	s	1	10	Permitted stalling time
Str over delay time	0...60000	ms	1	100	Time delay to check for completion of motor startup period

Table 400: 66/51LRS Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Disable / Enable
Operation mode	1=IIt 2=IIt, CB 3=IIt + stall 4=IIt + stall, CB			1=IIt	Motor start-up operation mode
Counter Red rate	2.0...250.0	s/h	0.1	60.0	Start time counter reduction rate
Cumulative time Lim	1...500	s	1	10	Cumulative time based restart inhibit limit
Emg start Red rate	0.00...100.00	%	0.01	20.00	Start time reduction factor when emergency start is On
Restart inhibit time	0...250	min	1	30	Time delay between consecutive startups
Motor standstill A	0.05...0.20	xIn	0.01	0.12	Current limit to check for motor standstill condition

6.6.8 Monitored data

Table 401: 66/51LRS Monitored data

Name	Type	Values (Range)	Unit	Description
START_CNT	INT32	0...999999		Number of motor start-ups occurred
START_TIME	FLOAT32	0.0...999.9	s	Measured motor latest startup time in sec
T_ST_CNT	FLOAT32	0.0...99999.9	s	Cumulated start-up time in sec
T_RST_ENA	INT32	0...999	min	Time left for restart when lockstart is enabled in minutes
IIT_RL	FLOAT32	0.00...100.00	%	Thermal stress relative to set maximum thermal stress
STALL_RL	FLOAT32	0.00...100.00	%	Pickup time relative to the trip time for stall condition
66/51LRS	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.6.9 Technical data

Table 402: 27PS Technical data

<table>
<tr><th colspan="2">Characteristic</th><th colspan="3">Value</th></tr>
<tr><td colspan="2" rowspan="2">Pickup accuracy</td><td colspan="3">Depending on the frequency of the current measured: f_n ±2Hz</td></tr>
<tr><td colspan="3">±1.5% of the set value or ±0.002 x I_n</td></tr>
<tr><td rowspan="2">Pickup time[1, 2]</td><td rowspan="2">I_{Fault} = 1.1 x set Pickup detection A</td><td>Minimum</td><td>Typical</td><td>Maximum</td></tr>
<tr><td>27 ms</td><td>30 ms</td><td>34 ms</td></tr>
<tr><td colspan="2">Trip time accuracy</td><td colspan="3">±1.0% of the set value or ±20 ms</td></tr>
<tr><td colspan="2">Reset ratio</td><td colspan="3">Typical 0.90</td></tr>
</table>

1. Current before = 0.0 x I_n, f_n = 60 Hz, overcurrent in one phase, results based on statistical distribution of 1000 measurements.
2. Includes the delay of the signal output contact.

6.7 Cable fault detection, CFD

6.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase discontinuity protection	RCFD	RCFD	CFD

6.7.2 Function block

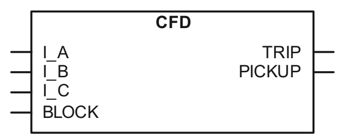

Figure 251: Function block

6.7.3 Functionality

The self-clearing fault detection function (CFD) calculates half cycle DFT of the current signal for all the three phases and uses it to detect a self clearing fault pronounced primarily in underground circuits.

The function provides individual counter values for number of times a self-clearing fault is observed in each phase. The function also determines whether the self-clearing fault is observed in all the three phases or not.

This function contains a blocking functionality. It is possible to block the function outputs, or the function itself, if desired.

6.7.4 Operation principle

The *Operation* setting is used to enable or disable the function. When selected "On" the function is enabled and respectively "Off" means function is disabled.

The operation of CFD can be described by using a module diagram (see Figure 252 below). All the modules in the diagram are explained in the next sections.

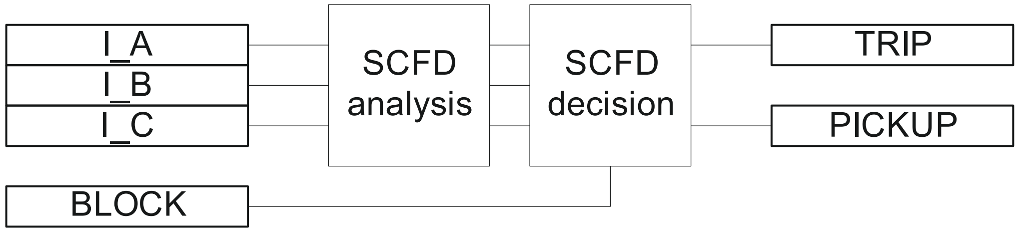

Figure 252: Functional module diagram.

SCFD analysis

The SCFD (Self Clearing Fault Detection) Analysis module detects the self clearing fault in each phase by comparing the corresponding phase current magnitude with the set value *PhPu*.

If the phase current I_A magnitude goes above 2 times the set value *PhPu*, the module calculates the time duration for which the current I_A is continuously stays above 2 times the set value *PhPu.* If the calculated time duration is greater than ¼ cycles, and less than the number of cycles set by *CyMulit*, it regards that the self clearing fault is observed in phase A and DetectfaultPhA in monitored data is set to TRUE. If the time duration criterion fails, the PickUpNoTripA in monitored data is set to TRUE. Once the self clearing fault is detected in phase A, function increments the count SCA in monitored data, which keeps record of the number of times the fault has been detected.

Self clearing faults in phase B and phase C are detected similarly as explained for phase A in above paragraph, by comparing I_B and I_C magnitudes with the set value *PhPu* and by checking the time duration. If the fault is detected in phase B or phase C the DetectfaultPhB or respectively DetectfaultPhC in monitored data are set to TRUE. If the time duration criterion fails for phase B or phase C, the corresponding PickUpNoTripB or PickUpNoTripC in monitored data is set to TRUE. Once the fault is detected in phase B or phase C, the corresponding fault counts SCB or SCC is incremented.

If the setting *AdapPhPu* is set to TRUE, the threshold setting value *PhPu* is adaptively calculated for each phase separately. The adaptive threshold value set equal to the average of the phase current over the 2^{nd} and 3^{rd} cycle after the setting *AdapPhPu* is set to TRUE. Until the 3^{rd} cycle the set value *PhPu* is used for detecting the self clearing fault. After the 3^{rd} cycle adaptively calculated threshold value for each phase is used for detecting the self clearing fault.

This adaptive threshold implementation for each phase is considered only if the average of the phase current over the 2^{nd} and 3^{rd} cycle is greater than setting *AbsMinLoad.* Otherwise the set value *PhPu* is considered for corresponding phase fault detection.

SCFD decision

If the self clearing fault is detected in at least one phase, the PICKUP and TRIP outputs are set to TRUE. Also SCDetect in monitored data is set to TRUE.

When one phase detects a fault, the algorithm waits for 1 cycle time and during this period if other two phases have detected a fault, the event is considered as three phase event and the Event3Ph in monitored data is set to TRUE.

Activation of the BLOCK input deactivates all the binary outputs.

6.7.5 Signals

Table 403: CFD Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOL	0=FALSE	Block overall function.

Table 404: CFD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

6.7.6 Settings

Table 405: CFD Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
PhPu	0 …. 100000		1	500	Fault Pickup parameter Threshold
CyMulit	1 … 20		1	5	Fault detect threshold parameter cycles
AbsMinLoad	0 …300		1	100	Absolute min loading on the feeder
AdapPhPu	0 ..1		1	1	Adaptive phase pickup

Table 406: CFD Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable

6.7.7 Monitored data

Table 407: CFD Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP	BOOLEAN	0=False 1=True		Pickup
TRIP	BOOLEAN	0=False 1=True		Trip
PICKUP_DUR	FLOAT32	0.00…100.00	%	Ratio of pickup time/trip time
SCDetect	BOOLEAN	0=False 1=True		SC Fault detect
Event3Ph	BOOLEAN	0=False 1=True		Three phase event
PickUpNoTripA	BOOLEAN	0=False 1=True		Pick up no trip Phase A
PickUpNoTripB	BOOLEAN	0=False 1=True		Pick up no trip Phase B
PickUpNoTripC	BOOLEAN	0=False 1=True		Pick up no trip Phase C
SCA				Number of faults in Phase A
SCB				Number of faults in Phase B
SCC				Number of faults in Phase C
DetectfaultPhA	BOOLEAN	0=False 1=True		Fault detected in Phase A
DetectfaultPhB	BOOLEAN	0=False 1=True		Fault detected in Phase B
DetectfaultPhC	BOOLEAN	0=False 1=True		Fault detected in Phase C

6.8 Runtime counter for machines and devices, OPTM

6.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Operation time counter	MDSOPT	OPTS	OPTM

6.8.2 Function block

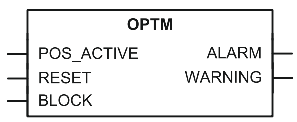

Figure 253: Function block

6.8.3 Functionality

The generic operation time counter function OPTM calculates and presents the accumulated operation time of a machine or device as the output. The unit of time for accumulation is hour. The function generates a warning and an alarm when the accumulated operation time exceeds the set limits. It utilizes a binary input to indicate the active operation condition.

The accumulated operation time is one of the parameters for scheduling a service on the equipment like motors. It indicates the use of the machine and hence the mechanical wear and tear. Generally, the equipment manufacturers provide a maintenance schedule based on the number of hours of service.

6.8.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of the generic operation time counter can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

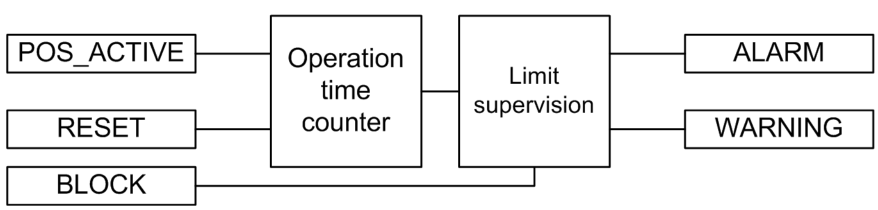

Figure 254: Functional module diagram

Operation time counter

This module counts the operation time. When `POS_ACTIVE` is active, the count is continuously added to the time duration until it is deactivated. At any time the `OPR_TIME` output is the total duration for which POS_ACTIVE is active. The unit of time duration count for OPR_TIME is hour. The value is available through the Monitored data view.

The OPR_TIME output is a continuously increasing value and it is stored in a non-volatile memory. When POS_ACTIVE is active, the OPR_TIME count starts increasing from the previous value. The count of OPR_TIME saturates at the final value of 299999, that is, no further increment is possible. The activation of RESET can reset the count to the *Initial value* setting.

Limit Supervision

This module compares the motor run-time count to the set values of *Warning value* and *Alarm value* to generate the WARNING and ALARM outputs respectively when the counts exceed the levels.

The activation of the WARNING and ALARM outputs depends on the *Operating time mode* setting. Both WARNING and ALARM occur immediately after the conditions are met if *Operating time mode* is set to “Immediate”. If *Operating time mode* is set to “Timed Warn”, WARNING is activated within the next 24 hours at the time of the day set using the *Operating time hour* setting. If *Operating time mode* is set to “Timed Warn Alm”, the WARNING and ALARM outputs are activated at the time of day set using *Operating time hour*.

The *Operating time hour* setting is used to set the hour of day in Coordinated Universal Time (UTC). The setting has to be adjusted according to the local time and local daylight-saving time.

The function contains a blocking functionality. Activation of the BLOCK input blocks both WARNING and ALARM.

6.8.5 Application

The machine operating time since commissioning indicates the use of the machine. For example, the mechanical wear and lubrication requirement for the shaft bearing of the motors depend on the use hours.

If some motor is used for long duration runs, it might require frequent servicing, while for a motor that is not used regularly the maintenance and service are scheduled less frequently. The accumulated operating time of a motor together with the appropriate settings for warning can be utilized to trigger the condition based maintenance of the motor.

The operating time counter combined with the subsequent reset of the operating-time count can be used to monitor the motor's run time for a single run.

Both the long term accumulated operating time and the short term single run duration provide valuable information about the condition of the machine and device. The information can be co-related to other process data to provide diagnoses for the process where the machine or device is applied.

6.8.6 Signals

Table 408: OPTM Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block input status
POS_ACTIVE	BOOLEAN	0=False	When active indicates the equipment is running
RESET	BOOLEAN	0=False	Resets the accumulated operation time to initial value

Table 409: OPTM Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm accumulated operation time exceeds Alarm value
WARNING	BOOLEAN	Warning accumulated operation time exceeds Warning value

6.8.7 Settings

Table 410: OPTM Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Warning value	0...299999	h	1	8000	Warning value for operation time supervision
Alarm value	0...299999	h	1	10000	Alarm value for operation time supervision
Initial value	0...299999	h	1	0	Initial value for operation time supervision
Operating time hour	0...23	h	1	0	Time of day when alarm and warning will occur
Operating time mode	1=Immediate 2=Timed Warn 3=Timed Warn Alm			1=Immediate	Operating time mode for warning and alarm

6.8.8 Monitored data

Table 411: OPTM Monitored data

Name	Type	Values (Range)	Unit	Description
OPTM	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status
OPR_TIME	INT32	0...299999	h	Total operation time in hours

6.8.9 Technical data

Table 412: OPTM Technical data

Description	Value
Motor run-time measurement accuracy[1]	±0.5%

1. Of the reading, for a stand-alone IED, without time synchronization.

Section 7 Control functions

7.1 Circuit-breaker control, 52

7.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker control	CBXCBR	I<->0 CB	52

7.1.2 Function block

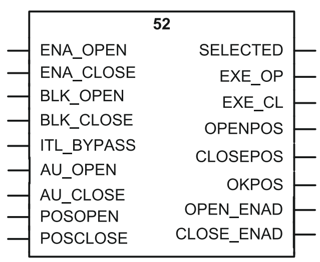

Figure 255: Function block

7.1.3 Functionality

The circuit breaker control function 52 is intended for circuit breaker control and status information purposes. This function executes commands and evaluates block conditions and different time supervision conditions. The function performs an execution command only if all conditions indicate that a switch operation is allowed. If erroneous conditions occur, the function indicates an appropriate cause value. The function is designed according to the IEC 61850-7-4 standard with logical nodes CILO, CSWI and XCBR.

The circuit breaker control function has an operation counter for closing and opening cycles. The operator can read and write the counter value remotely from an operator place or via LHMI.

7.1.4 Operation principle

Status indication and validity check

The object state is defined by two digital inputs `POSOPEN` and `POSCLOSE` which are also available as outputs `OPENPOS` and `CLOSEPOS` together with the `OKPOS` information. The debouncing and short disturbances in an input are eliminated by filtering. The binary input filtering time can be adjusted separately for each digital input used by the function block. The validity of the digital inputs that indicate the object state is used as additional information in indications and event logging. The reporting of faulty or intermediate position circuit breaker contacts occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 413: Status indication

Status (POSITION)	POSOPEN/OPENPOS	POSCLOSE/CLOSEPOS	OKPOS
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

Blocking

52 has a blocking functionality to prevent human errors that can cause serious injuries for the operator and damages for the system components.

The basic principle for all blocking signals is that they affect the commands of other clients: the operator place and protection and autoreclose functions, for example. The blocking principles are the following:

- Enabling the open command: the function is used to block the operation of the open command. Note that this block signal also affects the `OPEN` input of immediate command.
- Enabling the close command: the function is used to block the operation of the close command. Note that this block signal also affects the `CLOSE` input of immediate command.

The `ITL_BYPASS` input is used if the interlocking functionality needs to be bypassed. When `INT_BYPASS` is TRUE, the circuit breaker control is made possible by discarding the `ENA_OPEN` and `ENA_CLOSE` input states. However, the `BLK_OPEN` and `BLK_CLOSE` input signals are not bypassed with the interlocking bypass functionality since they always have higher priority.

Open and close operations

The corresponding open and close operations are available via communication, binary inputs or LHMI commands. As a prerequisite for control commands, there are enable and block functionalities for both the close and open commands. If the control command is executed against the blocking, or if the enabling of the corresponding command is not valid, CBXCBR generates an error message.

Open and close pulse widths

The pulse width type can be defined with the *Adaptive pulse* setting. The function provides two modes to characterize the opening and closing pulse widths. When the *Adaptive pulse* is set to TRUE, it causes a variable pulse width, which means that the output pulse is deactivated when the object state shows that the circuit breaker has entered the correct state. When the *Adaptive pulse* is set to FALSE, the function always uses the maximum pulse width, defined by the user-configurable *Pulse length* setting. The *Pulse length* setting is the same for both the opening and closing commands. When the circuit breaker already is in the right position, the maximum pulse length is given. Note that the *Pulse length* setting does not affect the length of the trip pulse.

Control methods

The command execution mode can be set with the *Control model* setting. The alternatives for command execution are direct control and secured object control, which can be used to secure controlling.

The secured object control SBO is an important feature of the communication protocols that support horizontal communication, because the command reservation and interlocking signals can be transferred with a bus. All secured control operations require two-step commands: a selection step and an execution step. The secured object control is responsible for the following tasks:

- Command authority: ensures that the command source is authorized to operate the object
- Mutual exclusion: ensures that only one command source at a time can control the object
- Interlocking: allows only safe commands
- Execution: supervises the command execution
- Command cancelling: cancels the controlling of a selected object.

In direct operate, a single message is used to initiate the control action of a physical device. The direct operate method uses less communication network capacity and bandwidth than the SBO method, because the procedure needs fewer messages for accurate operation.

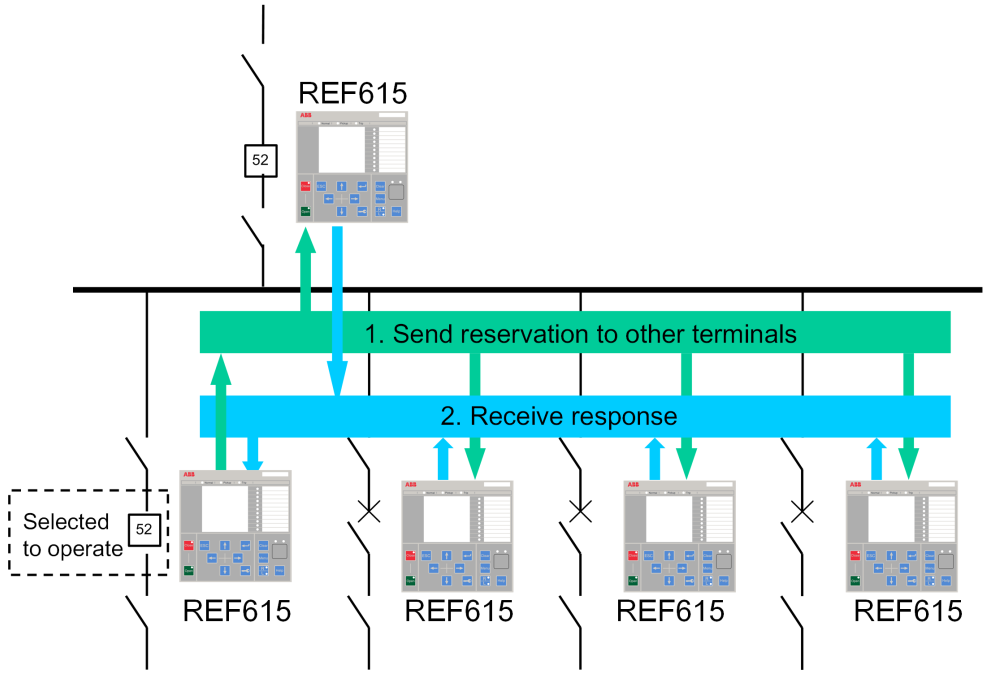

Figure 256: Control procedure in SBO method

7.1.5 Application

In the field of distribution and sub-transmission automation, reliable control and status indication of primary switching components both locally and remotely is in a significant role. They are needed especially in modern remotely controlled substations.

Control and status indication facilities are implemented in the same package with 52. When primary components are controlled in the energizing phase, for example, the user must ensure that the control commands are executed in a correct sequence. This can be achieved, for example, with interlocking based on the status indication of the related primary components. An example of how the interlocking on substation level can be applied by using the IEC61850 GOOSE messages between feeders is as follows:

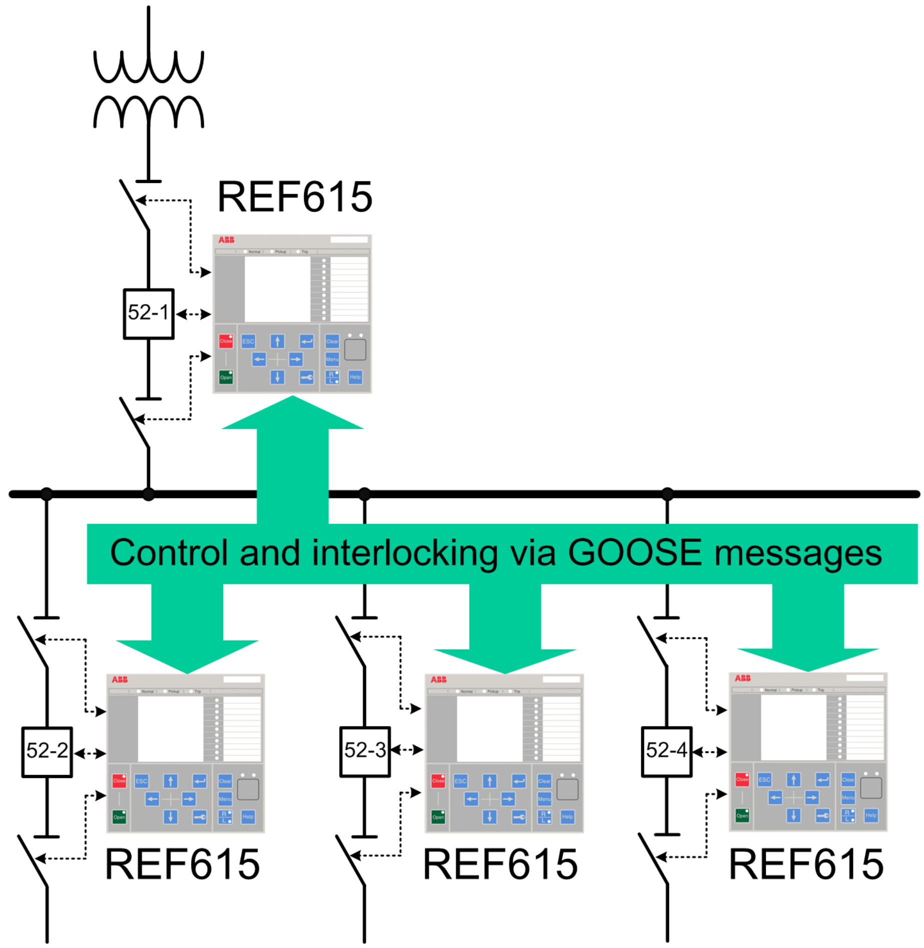

Figure 257: Status indication based interlocking via GOOSE messaging

7.1.6 Signals

Table 414: 52 Input signals

Name	Type	Default	Description
ENA_OPEN	BOOLEAN	1=True	Enables opening
ENA_CLOSE	BOOLEAN	1=True	Enables closing
BLK_OPEN	BOOLEAN	0=False	Blocks opening
BLK_CLOSE	BOOLEAN	0=False	Blocks opening
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE
AU_OPEN	BOOLEAN	0=False	Input signal used to open the breaker[1]
AU_CLOSE	BOOLEAN	0=False	Input signal used to close the breaker
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for closed position of apparatus from I/O

1. Not available for monitoring

Table 415: 52 Output signals

Name	Type	Description
SELECTED	BOOLEAN	Object selected
EXE_OP	BOOLEAN	Executes the command for open direction
EXE_CL	BOOLEAN	Executes the command for close direction
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok
OPEN_ENAD	BOOLEAN	Opening is enabled based on the input status
CLOSE_ENAD	BOOLEAN	Closing is enabled based on the input status

7.1.7 Settings

Table 416: 52 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Select timeout	10000...300000	ms	10000	60000	Select timeout in ms
Pulse length	10...60000	ms	1	100	Open and close pulse length
Operation	1=Enable 5=Disable			1=Enable	Operation mode on/off/test
Operation counter	0...10000			0	Breaker operation cycles
Control model	0=status-only 1=direct-with-normal-security 4=sbo-with-enhanced-security			4=sbo-with-enhanced-security	Select control model
Adaptive pulse	0=False 1=True			1=True	Stop in rigth position
Event delay	0...10000	ms	1	100	Event delay of the intermediate position
Operation timeout	10...60000	ms		500	Timeout for negative termination

7.1.8 Monitored data

Table 417: 52 Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication

7.1.9 Technical revision history

Table 418: CBXCBR Technical revision history

Technical revision	Change
B	Interlocking bypass input (ITL_BYPASS) and opening enabled (OPEN_ENAD)/closing enabled (CLOSE_ENAD) outputs added. ITL_BYPASS bypasses the ENA_OPEN and ENA_CLOSE states.

7.2 Auto-reclosing 79

7.2.1 Identification

Function description	IEC 61850 logical node name	IEC 60617 identification	ANSI/IEEE C37.2 device number
Auto-recloser	DARREC	O-->I	79

7.2.2 Function block

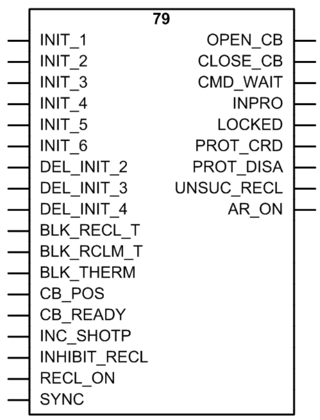

Figure 258: Function block

7.2.3 Functionality

About 80 to 85 percent of faults in the MV overhead lines are transient and automatically cleared with a momentary de-energization of the line. The rest of the faults, 15 to 20 percent, can be cleared by longer interruptions. The de-energization of the fault location for a selected time period is implemented through automatic reclosing, during which most of the faults can be cleared.

In case of a permanent fault, the automatic reclosing is followed by final tripping. A permanent fault must be located and cleared before the fault location can be re-energized.

The autoreclose function AR can be used with any circuit breaker suitable for autoreclosing. The function provides five programmable autoreclose shots which can perform one to five successive autoreclosing of desired type and duration, for instance one high-speed and one delayed autoreclosing.

When the reclosing is initiated with pickup of the protection function, the autoreclose function can execute the final trip of the circuit breaker in a short trip time, provided that the fault still persists when the last selected reclosing has been carried out.

7.2.3.1 Protection signal definition

The *Control line* setting defines which of the initiation signals are protection pickup and trip signals and which are not. With this setting, the user can distinguish the blocking signals from the protection signals. The *Control line* setting is a bit mask, that is, the lowest bit controls the `INIT_1` line and the highest bit the `INIT_6` line. Some example combinations of the *Control line* setting are as follows:

Table 419: Control line setting definition

Control line setting	INIT_1	INIT_2 DEL_INIT_2	INIT_3 DEL_INIT_3	INIT_4 DEL_INIT_4	INIT_5	INIT_6
0	other	other	other	other	other	other
1	prot	other	other	other	other	other
2	other	prot	other	other	other	other
3	prot	prot	other	other	other	other
4	other	other	prot	other	other	other
5	prot	other	prot	other	other	other
...63	prot	prot	prot	prot	prot	prot

prot = protection signal
other = non-protection signal

When the corresponding bit or bits in both the *Control line* setting and the `INIT_X` line are TRUE:

- The `CLOSE_CB` output is blocked until the protection is reset
- If the `INIT_X` line defined as the protection signal is activated during the discrimination time, the AR function goes to lockout
- If the `INIT_X` line defined as the protection signal stays active longer than the time set by the *Max trip time* setting, the AR function goes to lockout (long trip)
- The `UNSUC_RECL` output is activated after a pre-defined two minutes (alarming ground-fault).

7.2.3.2 Zone coordination

Zone coordination is used in the zone sequence between local protection units and downstream devices. At the falling edge of the `INC_SHOTP` line, the value of the shot pointer is increased by one, unless a shot is in progress or the shot pointer already has the maximum value.

The falling edge of the `INC_SHOTP` line is not accepted if any of the shots are in progress.

7.2.3.3 Master and slave scheme

With the co-operation between the AR units in the same IED or between IEDs, the user can achieve sequential reclosings of two breakers at a line end in a 1½-breaker, double breaker or ring-bus arrangement. One unit is defined as a master and it executes the reclosing first. If the reclosing is successful and no trip takes place, the second unit, that is the slave, is released to complete the reclose shot. With persistent faults, the breaker reclosing is limited to the first breaker.

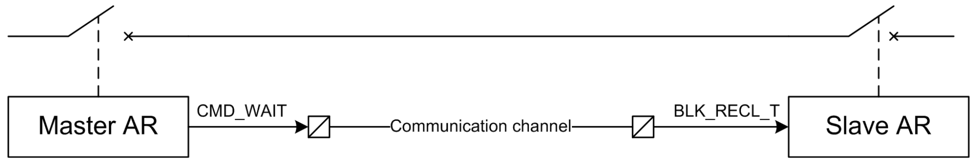

Figure 259: Master and slave scheme

If the AR unit is defined as a master by setting its terminal priority to high:

- The unit activates the `CMD_WAIT` output to the low priority slave unit whenever a shot is in progress, a reclosing is unsuccessful or the `BLK_RCLM_T` input is active
- The `CMD_WAIT` output is reset one second after the reclose command is given or if the sequence is unsuccessful when the reclaim time elapses.

If the AR unit is defined as a slave by setting its terminal priority to low:

- The unit waits until the master releases the `BLK_RECL_T` input (the `CMD_WAIT` output in the master). Only after this signal has been deactivated, the reclose time for the slave unit can be started.
- The slave unit is set to a lockout state if the `BLK_RECL_T` input is not released within the time defined by the *Max wait time* setting , which follows the initiation of an autoreclose shot.

If the terminal priority of the AR unit is set to "none", the AR unit skips all these actions.

7.2.3.4 Thermal overload blocking

An alarm or pickup signal from the thermal overload protection 49F can be routed to the input `BLK_THERM` to block and hold the reclose sequence. The `BLK_THERM` signal does not affect the starting of the sequence. When the reclose time has elapsed and the `BLK_THERM` input is active, the shot is not ready until the `BLK_THERM` input deactivates. Should the `BLK_THERM` input remain active longer than the time set by the setting *Max block time*, the AR function goes to lockout.

If the `BLK_THERM` input is activated when the auto wait timer is running, the auto wait timer is reset and the timer restarted when the `BLK_THERM` input deactivates.

7.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The reclosing operation can be enabled and disabled with the *Reclosing operation* setting. This setting does not disable the function, only the reclosing functionality. The setting has three parameter values: “Enable”, “External Ctl” and ”Disable”. When the setting value “External Ctl” is selected, the reclosing operation is controlled with the `RECL_ON` input .

The operation of the autoreclosing function can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

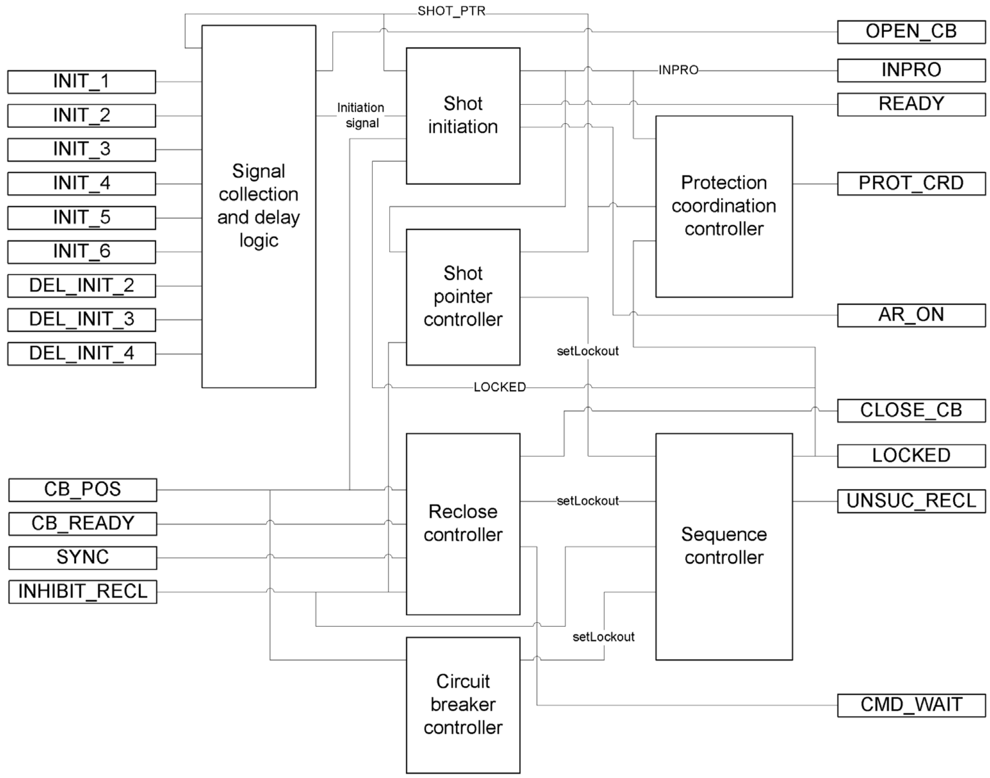

Figure 260: Functional module diagram

7.2.4.1 Signal collection and delay logic

When the protection trips, the initiation of autoreclose shots is in most applications executed with the `INIT_1...6` inputs. The `DEL_INIT2...4` inputs are not used. In some situations, pickup of the protection stage is also used for the shot initiation. This is the only time when the `DEL_INIT` inputs are used.

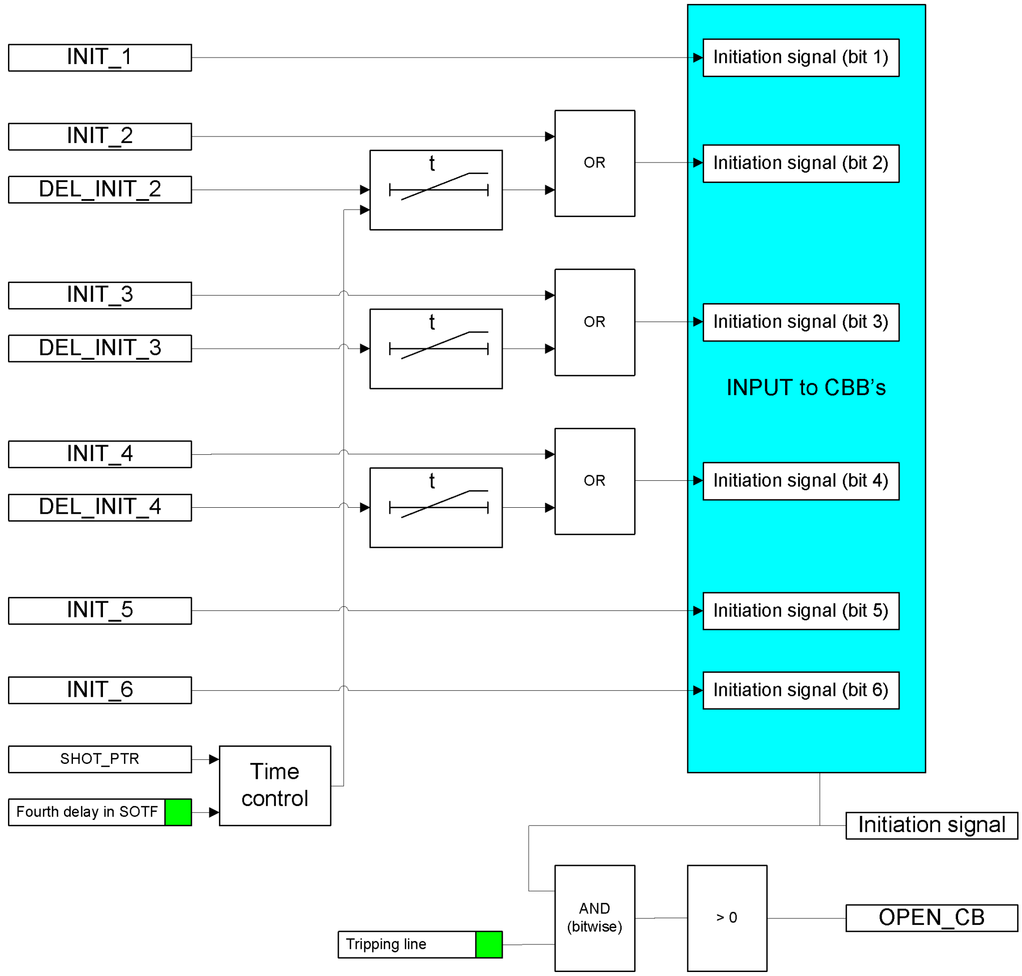

Figure 261: Schematic diagram of delayed initiation input signals

In total, the AR function contains six separate initiation lines used for the initiation or blocking of the autoreclose shots. These lines are divided into two types of channels. In three of these channels, the signal to the AR function can be delayed, whereas the other three channels do not have any delaying capability.

Each channel that is capable of delaying a pickup signal has four time delays. The time delay is selected based on the shot pointer in the AR function. For the first reclose attempt, the first time delay is selected; for the second attempt, the second time delay and so on. For the fourth and fifth attempts, the time delays are the same.

Time delay settings for the `DEL_INIT_2` signal are as follows:

- *Str 2 delay shot 1*
- *Str 2 delay shot 2*
- *Str 2 delay shot 3*
- *Str 2 delay shot 4*

Time delay settings for the `DEL_INIT_3` signal are as follows:

- *Str 3 delay shot 1*

- *Str 3 delay shot 2*
- *Str 3 delay shot 3*
- *Str 3 delay shot 4*

Time delay settings for the `DEL_INIT_4` signal are as follows:

- *Str 4 delay shot 1*
- *Str 4 delay shot 2*
- *Str 4 delay shot 3*
- *Str 4 delay shot 4*

Normally, only two or three reclose attempts are made. The third and fourth times are used to provide the so called fast final trip to lockout.

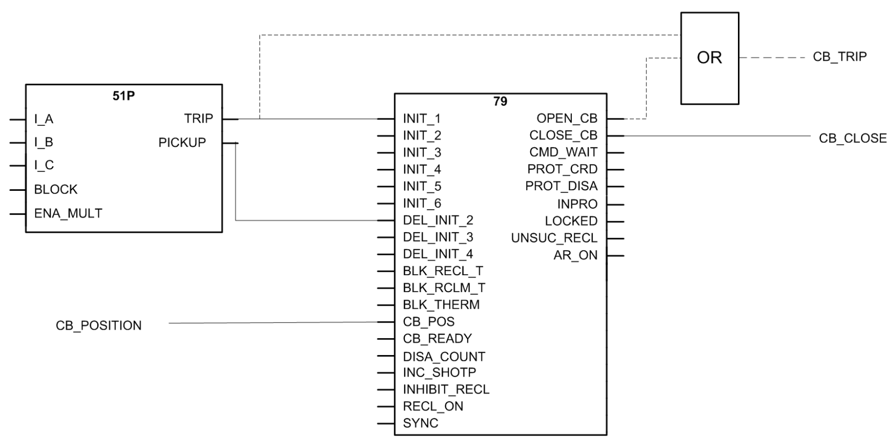

Figure 262: Autoreclose configuration example

Delayed `DEL_INIT_2...4` signals are used only when the autoreclose shot is initiated with the pickup signal of a protection stage. After a pickup delay, the AR function opens the circuit breaker and an autoreclose shot is initiated. When the shot is initiated with the trip signal of the protection, the protection function trips the circuit breaker and simultaneously initiates the autoreclose shot.

If the circuit breaker is manually closed against the fault, that is, if SOTF is used, the fourth time delay can automatically be taken into use. This is controlled with the internal logic of the AR function and the *Fourth delay in SOTF* parameter.

A typical autoreclose situation is where one autoreclose shot has been performed after the fault was detected. There are two types of such cases: operation initiated with protection pickup signal and operation initiated with protection trip signal. In both cases, the autoreclose sequence is successful: the reclaim time elapses and no new sequence is started.

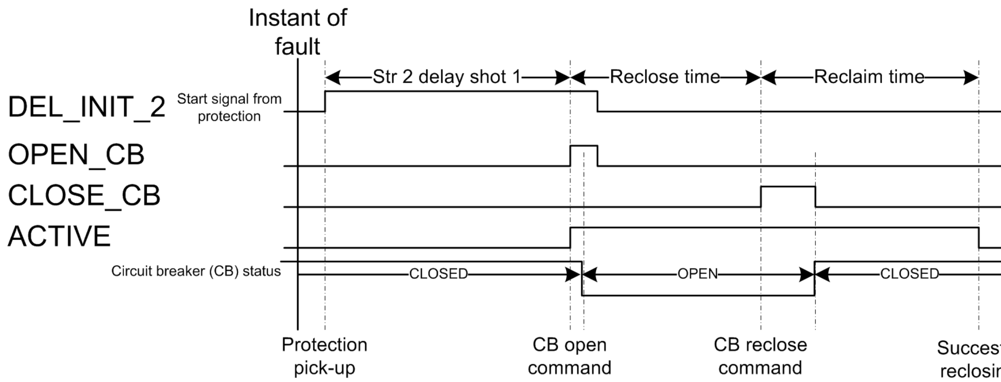

Figure 263: Signal scheme of autoreclose operation initiated with protection pickup signal

The autoreclose shot is initiated with a trip signal of the protection function after the pickup delay time has elapsed. The autoreclose picks up when the *Str 2 delay shot 1* setting elapses.

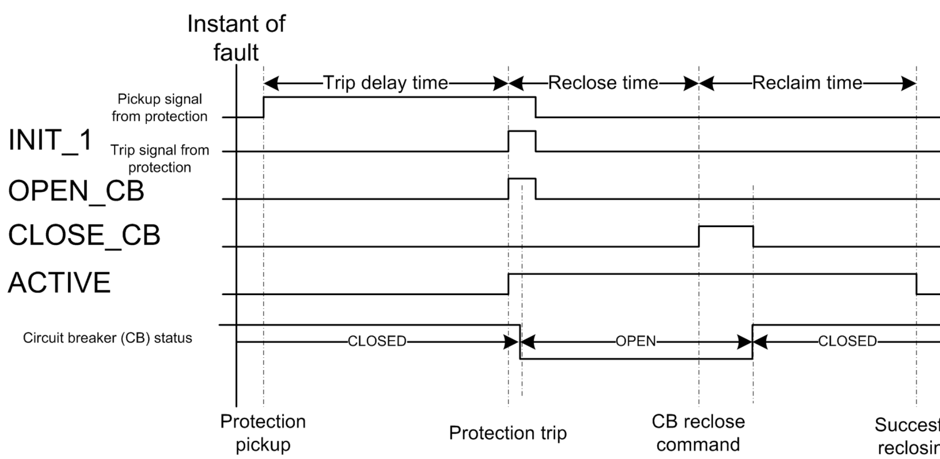

Figure 264: Signal scheme of autoreclose operation initiated with protection trip signal

The autoreclose shot is initiated with a trip signal of the protection function. The autoreclose picks up when the protection trip delay time elapses.

Normally, all trip and pickup signals are used to initiate an autoreclose shot and trip the circuit breaker. If any of the input signals `INIT_X` or `DEL_INIT_X` are used for blocking, the corresponding bit in the *Tripping line* setting must be FALSE. This is to ensure that the circuit breaker does not trip from that signal, that is, the signal does not activate the `OPEN_CB` output. The default value for the setting is "63", which means that all initiation signals activate the `OPEN_CB` output. The lowest bit in the *Tripping line* setting corresponds to the `INIT_1` input, the highest bit to the `INIT_6` line.

7.2.4.2 Shot initiation

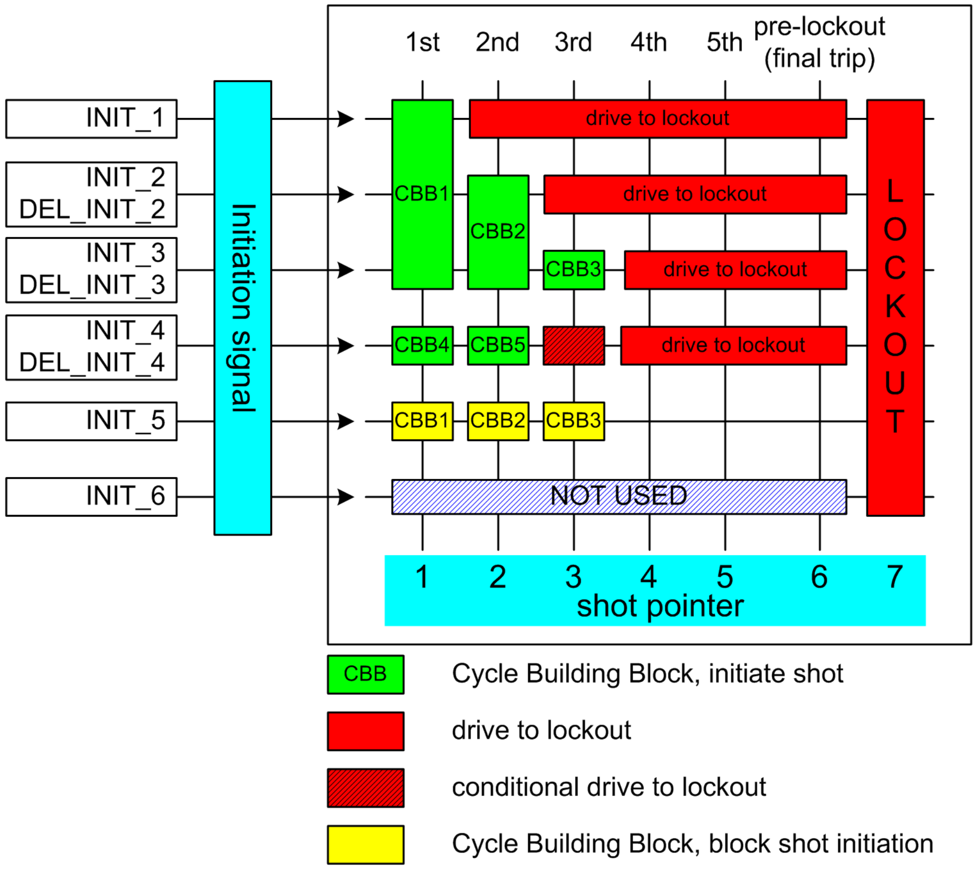

Figure 265: Example of an autoreclose program with a reclose scheme matrix

In the AR function, each shot can be programmed to locate anywhere in the reclose scheme matrix. The shots are like building blocks used to design the reclose program. The building blocks are called CBBs. All blocks are alike and have settings which give the attempt number (columns in the matrix), the initiation or blocking signals (rows in the matrix) and the reclose time of the shot.

The settings related to CBB configuration are:

- *First...Seventh reclose time*
- *Init signals CBB1…CBB7*
- *Blk signals CBB1…CBB7*
- *Shot number CBB1…CBB7*

The reclose time defines the open and dead times, that is, the time between the `OPEN_CB` and the `CLOSE_CB` commands. The *Init signals CBBx* setting defines the initiation signals. The *Blk signals CBBx* setting defines the blocking signals that are related to the CBB (rows in the matrix). The *Shot number CBB1…CBB7* setting defines which shot is related to the CBB (columns in the matrix). For example, CBB1 settings are:

- *First reclose time* = 1.0s
- *Init signals CBB1* = 7 (three lowest bits: 000111 = 7)

- *Blk signals CBB1* = 16 (the fifth bit: 010000 = 16)
- *Shot number CBB1* = 1

CBB2 settings are:

- *Second reclose time* = 10s
- *Init signals CBB2* = 6 (the second and third bits: 000110 = 6)
- *Blk signals CBB2* = 16 (the fifth bit: 010000 = 16)
- *Shot number CBB2* = 2

CBB3 settings are:

- *Third reclose time* = 30s
- *Init signals CBB3* = 4 (the third bit: 000100 = 4)
- *Blk signals CBB3* = 16 (the fifth bit: 010000 = 16)
- *Shot number CBB3* = 3

CBB4 settings are:

- *Fourth reclose time* = 0.5s
- *Init signals CBB4* = 8 (the fourth bit: 001000 = 8)
- *Blk signals CBB4* = 0 (no blocking signals related to this CBB)
- *Shot number CBB4* = 1

If a shot is initiated from the `INIT_1` line, only one shot is allowed before lockout. If a shot is initiated from the `INIT_3` line, three shots are allowed before lockout.

A sequence initiation from the `INIT_4` line leads to a lockout after two shots. In a situation where the initiation is made from both the `INIT_3` and `INIT_4` lines, a third shot is allowed, that is, CBB3 is allowed to start. This is called conditional lockout. If the initiation is made from the `INIT_2` and `INIT_3` lines, an immediate lockout occurs.

The `INIT_5` line is used for blocking purposes. If the `INIT_5` line is active during a sequence start, the reclose attempt is blocked and the AR function goes to lockout.

If more than one CBBs are started with the shot pointer, the CBB with the smallest individual number is always selected. For example, if the `INIT_2` and `INIT_4` lines are active for the second shot, that is, the shot pointer is 2, CBB2 is started instead of CBB5.

Even if the initiation signals are not received from the protection functions, the AR function can be set to continue from the second to the fifth reclose shot. The AR function can, for example, be requested to automatically continue with the sequence when the circuit breaker fails to close when requested. In such a case, the AR function issues a `CLOSE_CB` command. When the wait close time elapses, that is, the closing of the circuit breaker fails, the next shot is automatically started. Another example is the embedded generation on the power line, which can make the synchronism check fail and prevent the reclosing. If the autoreclose sequence is continued to the second shot, a successful synchronous reclosing is more likely than with the first shot, since the second shot lasts longer than the first one.

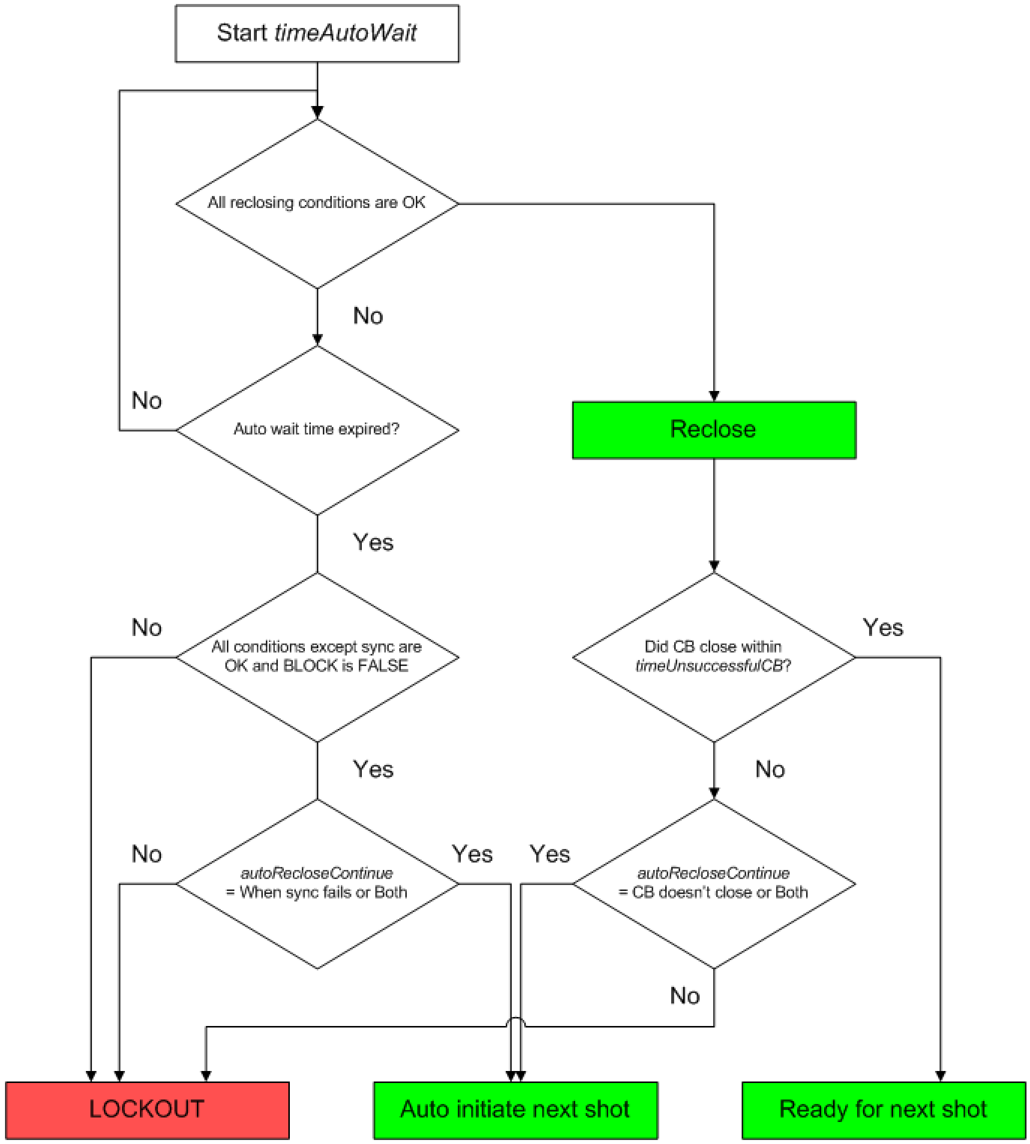

Figure 266: Logic diagram of auto-initiation sequence detection

Automatic initiation can be selected with the *Auto initiation Cnd* setting to be the following:

- Not allowed: no automatic initiation is allowed
- When the synchronization fails, the automatic initiation is carried out when the auto wait time elapses and the reclosing is prevented due to a failure during the synchronism check
- When the circuit breaker does not close, the automatic initiation is carried out if the circuit breaker does not close within the wait close time after issuing the reclose command
- Both: the automatic initiation is allowed when synchronization fails or the circuit breaker does not close.

The *Auto init* parameter defines which `INIT_X` lines are activated in the auto-initiation. The default value for this parameter is "0", which means that no auto-initiation is selected.

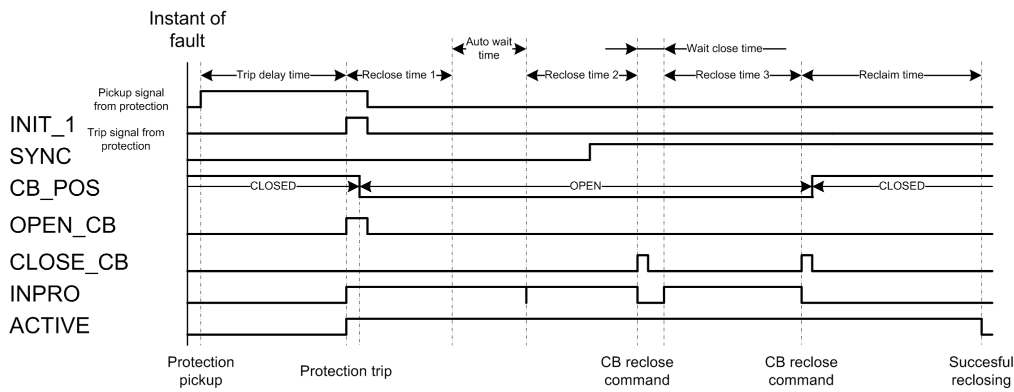

Figure 267: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

In the first shot, the synchronization condition is not fulfilled (`SYNC` is FALSE). When the auto wait timer elapses, the sequence continues to the second shot. During the second reclosing, the synchronization condition is fulfilled and the close command is given to the circuit breaker after the second reclose time has elapsed.

After the second shot, the circuit breaker fails to close when the wait close time has elapsed. The third shot is started and a new close command is given after the third reclose time has elapsed. The circuit breaker closes normally and the reclaim time starts. When the reclaim time has elapsed, the sequence is concluded successful.

7.2.4.3 Shot pointer controller

The execution of a reclose sequence is controlled by a shot pointer. It can be adjusted with the `SHOT_PTR` monitored data.

The shot pointer starts from an initial value "1" and determines according to the settings whether or not a certain shot is allowed to be initiated. After every shot, the shot pointer value increases. This is carried out until a successful reclosing or lockout takes place after a complete shot sequence containing a total of five shots.

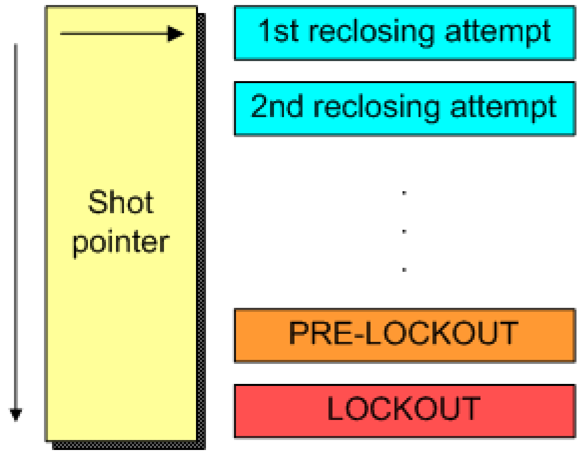

Figure 268: Shot pointer function

Every time the shot pointer increases, the reclaim time starts. When the reclaim time ends, the shot pointer sets to its initial value, unless no new shot is initiated. The shot pointer increases when the reclose time elapses or at the falling edge of the `INC_SHOTP` signal.

When `SHOT_PTR` has the value six, the AR function is in a so called pre-lockout state. If a new initiation occurs during the pre-lockout state, the AR function goes to lockout. Therefore, a new sequence initiation during the pre-lockout state is not possible.

The AR function goes to the pre-lockout state in the following cases:

- During SOTF
- When the AR function is active, it stays in a pre-lockout state for the time defined by the reclaim time
- When all five shots have been executed
- When the frequent operation counter limit is reached. A new sequence initiation forces the AR function to lockout.

7.2.4.4 Reclose controller

The reclose controller calculates the reclose, discrimination and reclaim times. The reclose time is started when the `INPRO` signal is activated, that is, when the sequence starts and the activated CBB defines the reclose time.

When the reclose time has elapsed, the `CLOSE_CB` output is not activated until the following conditions are fulfilled:

- The `SYNC` input must be TRUE if the particular CBB requires information about the synchronism
- All AR initiation inputs that are defined protection lines (using the *Control line* setting) are inactive
- The circuit breaker is open
- The circuit breaker is ready for the close command, that is, the `CB_READY` input is TRUE.

If at least one of the conditions is not fulfilled within the time set with the *Auto wait time* parameter, the autoreclose sequence is locked.

The synchronism requirement for the CBBs can be defined with the *Synchronisation set* setting, which is a bit mask. The lowest bit in the *Synchronisation set* setting is related to CBB1 and the highest bit to CBB7. For example, if the setting is set to "1", only CBB1 requires synchronism. If the setting is it set to "7", CBB1, CBB2 and CBB3 require the `SYNC` input to be TRUE before the reclosing command can be given.

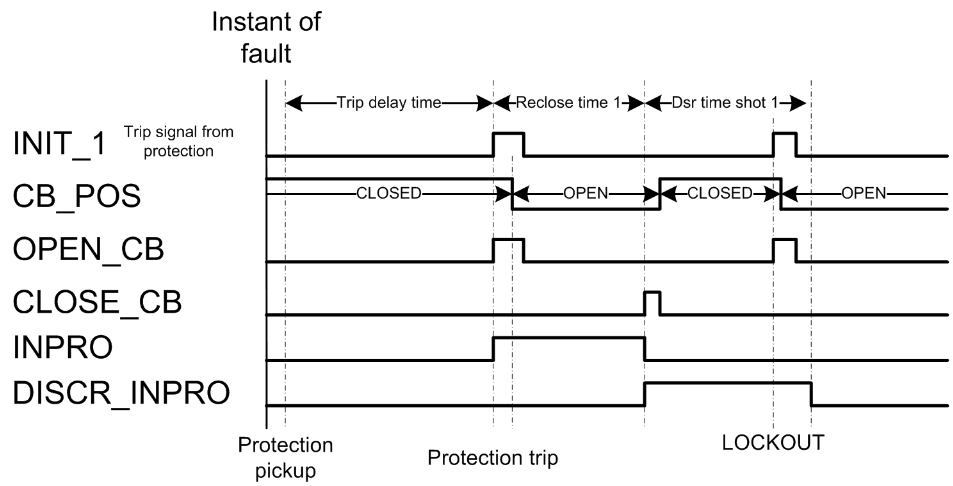

Figure 269: Initiation during discrimination time - AR function goes to lockout

The discrimination time starts when the close command `CLOSE_CB` has been given. If a pickup input is activated before the discrimination time has elapsed, the AR function goes to lockout. The default value for each discrimination time is zero. The discrimination time can be adjusted with the *Dsr time shot 1…4* parameter.

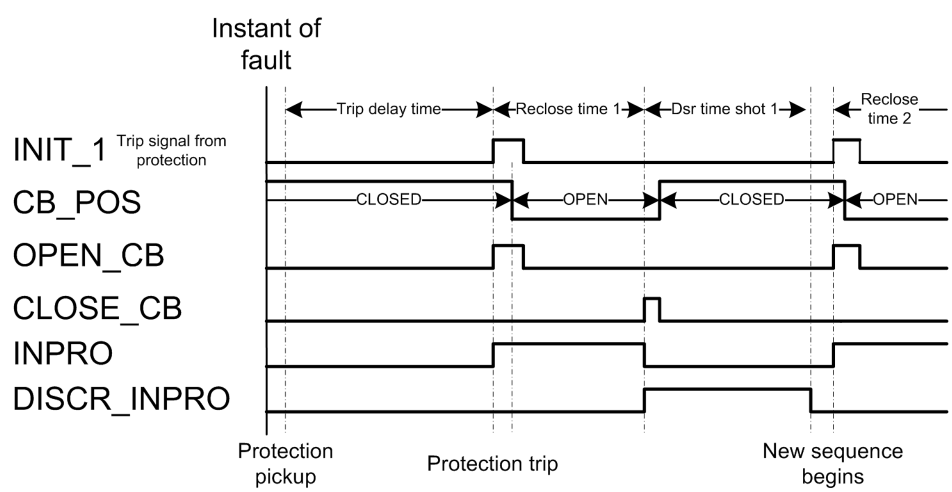

Figure 270: Initiation after elapsed discrimination time - new shot begins

7.2.4.5 Sequence controller

When the `LOCKED` output is active, the AR function is in lockout. This means that new sequences cannot be initialized, because AR is insensitive to initiation commands. It can be released from the lockout state in the following ways:

- The function is reset through communication with the *RsRec* parameter
- The lockout is automatically reset after the reclaim time, if the *Auto lockout reset* setting is in use.

If the *Auto lockout reset* setting is not in use, the lockout can be released only with the *RsRec* parameter.

The AR function can go to lockout for many reasons:

- The `INHIBIT_RECL` input is active
- All shots have been executed and a new initiation is made (final trip)
- The time set with the *Auto wait time* parameter expires and the automatic sequence initiation is not allowed because of a synchronization failure
- The time set with the *Wait close time* parameter expires, that is, the circuit breaker does not close or the automatic sequence initiation is not allowed due to a closing failure of the circuit breaker
- A new shot is initiated during the discrimination time
- The time set with the *Max wait time* parameter expires, that is, the master unit does not release the slave unit
- The frequent operation counter limit is reached and new sequence is initiated. The lockout is released when the recovery timer elapses
- The protection trip signal has been active longer than the time set with the *Max wait time* parameter since the shot initiation
- The circuit breaker is closed manually during an autoreclose sequence and the manual close mode is FALSE.

7.2.4.6 Protection coordination controller

The `PROT_CRD` output is used for controlling the protection functions. In several applications, such as fuse-saving applications involving down-stream fuses, tripping and initiation of shot 1 should be fast (instantaneous or short-time delayed). The tripping and initiation of shots 2, 3 and definite tripping time should be delayed.

In this example, two overcurrent elements 51P and 50P-2 are used. 50P-2 is given an instantaneous characteristic and 51P is given a time delay.

The `PROT_CRD` output is activated, if the `SHOT_PTR` value is higher than the value defined with the *Protection crd limit* setting and all initialization signals have been reset. The `PROT_CRD` output is reset under the following conditions:

- If the cut-out time elapses
- If the reclaim time elapses and the AR function is ready for a new sequence
- If the AR function is in lockout or disabled, that is, if the value of the *Protection crd mode* setting is "AR inoperative" or "AR inop, CB man".

The `PROT_CRD` output can also be controlled with the *Protection crd mode* setting. The setting has the following modes:

- "no condition": the `PROT_CRD` output is controlled only with the *Protection crd limit* setting

- "AR inoperative": the `PROT_CRD` output is active, if the AR function is disabled or in the lockout state, or if the `INHIBIT_RECL` input is active
- "CB close manual": the `PROT_CRD` output is active for the reclaim time if the circuit breaker has been manually closed, that is, the AR function has not issued a close command
- "AR inop, CB man": both the modes "AR inoperative" and "CB close manual" are effective
- "always": the `PROT_CRD` output is constantly active

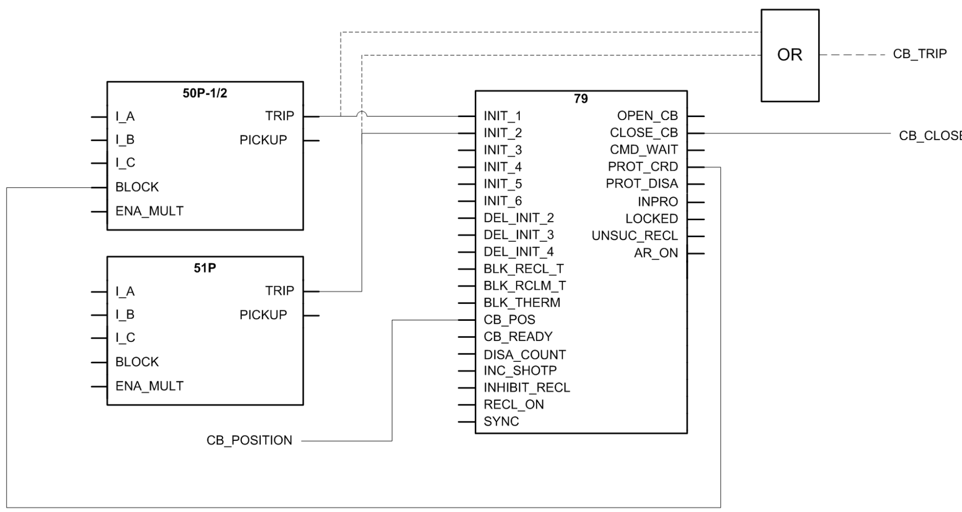

Figure 271: Configuration example of using the `PROT_CRD` output for protection blocking

If the *Protection crd limit* setting has the value "1", the instantaneous three-phase overcurrent protection function 50P-3 is disabled or blocked after the first shot.

7.2.4.7 Circuit breaker controller

Circuit breaker controller contains two features: SOTF and frequent-operation counter. SOTF protects the AR function in permanent faults.

The circuit breaker position information is controlled with the *CB closed Pos status* setting. The setting value "TRUE” means that when the circuit breaker is closed, the `CB_POS` input is TRUE. When the setting value is “FALSE”, the `CB_POS` input is FALSE, provided that the circuit breaker is closed. The reclose command pulse time can be controlled with the *Close pulse time* setting: the `CLOSE_CB` output is active for the time set with the *Close pulse time* setting. The `CLOSE_CB` output is deactivated also when the circuit breaker is detected to be closed, that is, when the `CB_POS` input changes from open state to closed state. The *Wait close time* setting defines the time after the `CLOSE_CB` command activation, during which the circuit breaker should be closed. If the closing of circuit breaker does not happen during this time, the autoreclose function is driven to lockout or, if allowed, an auto-initiation is activated.

The main motivation for autoreclosing to begin with is the assumption that the fault is temporary by nature, and that a momentary de-energizing of the power line and an automatic reclosing restores the power supply. However, when the power line is manually energized and an immediate protection trip is detected, it is very likely that the fault is of a permanent type. An example of a permanent fault is, for example, energizing a power line into a forgotten grounding after a maintenance work along the power line. In such cases, SOTF is activated, but only for the reclaim time after energizing the power line and only when the circuit breaker is closed manually and not by the AR function.

SOTF disables any initiation of an autoreclose shot. The energizing of the power line is detected from the `CB_POS` information.

SOTF is activated when the AR function is enabled or when the AR function is started and the SOTF should remain active for the reclaim time.

When SOTF is detected, the parameter *SOTF* is active.

If the *Manual close mode* setting is set to FALSE and the circuit breaker has been manually closed during an autoreclose shot, the AR unit goes to an immediate lockout.

If the *Manual close mode* setting is set to TRUE and the circuit breaker has been manually closed during an autoreclose shot (the `INPRO` is active), the shot is considered as completed.

When SOTF starts, reclaim time is restarted, provided that it is running.

The frequent-operation counter is intended for blocking the autoreclose function in cases where the fault causes repetitive autoreclose sequences during a short period of time. For instance, if a tree causes a short circuit and, as a result, there are autoreclose shots within a few minutes interval during a stormy night. These types of faults can easily damage the circuit breaker if the AR function is not locked by a frequent-operation counter.

The frequent-operation counter has three settings:

- *Frq Op counter limit*
- *Frq Op counter time*
- *Frq Op recovery time*

The *Frq Op counter limit* setting defines the number of reclose attempts that are allowed during the time defined with the *Frq Op counter time* setting. If the set value is reached within a pre-defined period defined with the *Frq Op counter time* setting, the AR function goes to lockout when a new shot begins, provided that the counter is still above the set limit. The lockout is released after the recovery time has elapsed. The recovery time can be defined with the *Frq Op recovery time* setting .

If the circuit breaker is manually closed during the recovery time, the reclaim time is activated after the recovery timer has elapsed.

7.2.5 Counters

The AR function contains six counters. Their values are stored in a semi-retain memory. The counters are increased at the rising edge of the reclose command. The counters count the following situations:

- `COUNTER`: counts every reclose command activation
- `CNT_SHOT1`: counts reclose commands that are executed from shot 1
- `CNT_SHOT2`: counts reclose commands that are executed from shot 2
- `CNT_SHOT3`: counts reclose commands that are executed from shot 3
- `CNT_SHOT4`: counts reclose commands that are executed from shot 4
- `CNT_SHOT5`: counts reclose commands that are executed from shot 5

The counters are disabled through communication with the *DsaCnt* parameter. When the counters are disabled, the values are not updated.

The counters are reset through communication with the *RsCnt* parameter.

7.2.6 Application

Modern electric power systems can deliver energy to users very reliably. However, different kind of faults can occur. Protection relays play an important role in detecting failures or abnormalities in the system. They detect faults and give commands for corresponding circuit breakers to isolate the defective element before excessive damage or a possible power system collapse occurs. A fast isolation also limits the disturbances caused for the healthy parts of the power system.

The faults can be transient, semi-transient or permanent. For example, a permanent fault in power cables means that there is a physical damage in the fault location that must first be located and repaired before the network voltage can be restored.

In overhead lines, the insulating material between phase conductors is air. The majority of the faults are flash-over arcing faults caused by lightning, for example. Only a short interruption is needed for extinguishing the arc. These faults are transient by nature.

A semi-transient fault can be caused for example by a bird or a tree branch falling on the overhead line. The fault disappears on its own if the fault current burns the branch or the wind blows it away.

Transient and semi-transient faults can be cleared by momentarily de-energizing the power line. Using the autoreclose function minimizes interruptions in the power system service and brings the power back on-line quickly and effortlessly.

The basic idea of the autoreclose function is simple. In overhead lines, where the possibility of self-clearing faults is high, the autoreclose function tries to restore the power by reclosing the breaker. This is a method to get the power system back into normal operation by removing the transient or semi-transient faults. Several trials, that is, autoreclose shots are allowed. If none of the trials is successful and the fault persists, definite final tripping follows.

The autoreclose function can be used with every circuit breaker that has the ability for a reclosing sequence. In 79 autoreclose function the implementing method of autoreclose sequences is patented by ABB

Table 420: Important definitions related to autoreclosing

autoreclose shot	an operation where after a preset time the breaker is closed from the breaker tripping caused by protection
autoreclose sequence	a predefined method to do reclose attempts (shots) to restore the power system
SOTF	If the protection detects a fault immediately after an open circuit breaker has been closed, it indicates that the fault was already there. It can be, for example, a forgotten grounding after maintenance work. Such closing of the circuit breaker is known as switch on to fault. Autoreclosing in such conditions is prohibited.
final trip	Occurs in case of a permanent fault, when the circuit breaker is opened for the last time after all programmed autoreclose operations. Since no autoreclosing follows, the circuit breaker remains open. This is called final trip or definite trip.

7.2.6.1 Shot initiation

In some applications, the `PICKUP` signal is used for initiating or blocking autoreclose shots, in other applications the `TRIP` command is needed. In its simplest, the autoreclose function is initiated after the protection has detected a fault, issued a trip and opened the breaker. One input is enough for initiating the function.

The function consists of six individual initiation lines `INIT_1, INIT_2 .. INIT 6` and delayed initiation lines `DEL_INIT_x`. The user can use as many of the initiation lines as required. Using only one line makes setting easier, whereas by using multiple lines, higher functionality can be achieved. Basically, there are no differences between the initiation lines, except that the lines 2, 3 and 4 have the delayed initiation `DEL_INIT` inputs, and lines 1, 5 and 6 do not.

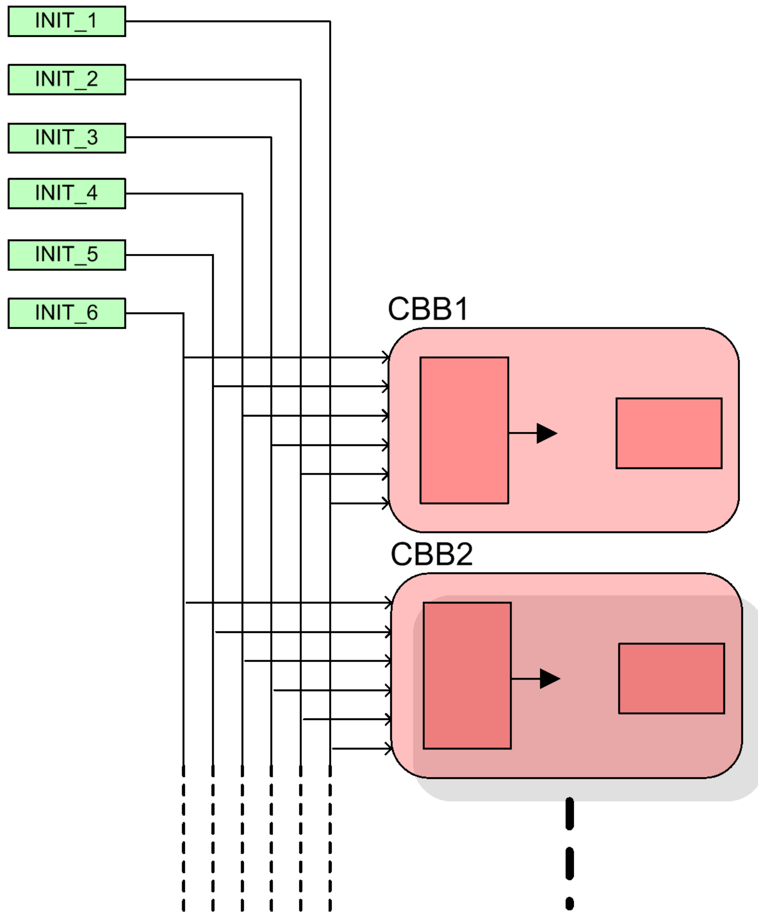

Figure 272: Simplified CBB initiation diagram

INIT_1...	6initiation lines
CBB1...CBB2	first two cycle building blocks

The operation of a CBB consists of two parts: initiation and execution. In the initiation part, the status of the initiation lines is compared to the CBB settings. In order to allow the initiation at any of the initiation line activation, the corresponding switch in the *Init signals CBB_* parameter must be set to TRUE. In order to block the initiation, the corresponding switch in the *Blk signals CBB_* parameter must be set to TRUE.

If any of the initiation lines set with the *Init signals CBB_* parameter is active and no initiation line causes blocking, the CBB requests for execution.

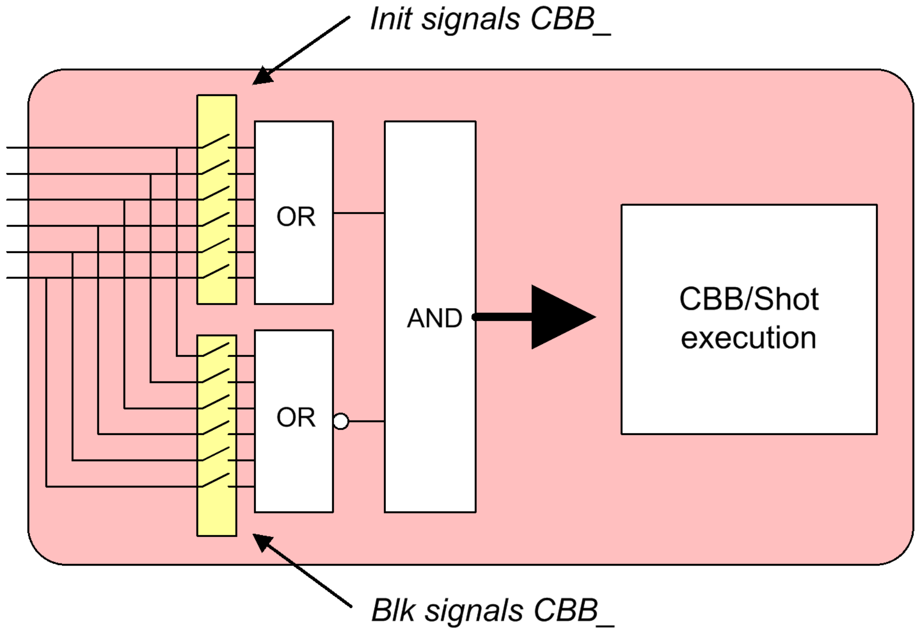

Figure 273: Simplified CBB diagram

Each CBB has individual *Init signals CBB_* and *Blk signals CBB_* settings. Therefore, each initiation line can be used for both initiating and blocking any or all autoreclose shots.

Other conditions that must be fulfilled before any CBB can be initiated are, for example, the closed position of the circuit breaker.

7.2.6.2 Sequence

The autoreclose sequence is implemented by using up to seven CBBs. For example, if the user wants a sequence of three shots then only the first three CBBs are needed. Using building blocks instead of fixed shots gives enhanced flexibility, allowing multiple and adaptive sequences.

Each CBB is identical. The *Shot number CBB_* setting defines at which point in the autoreclose sequence the CBB should be performed, that is, whether the particular CBB is going to be the first, second, third, fourth or fifth shot.

During the initiation of a CBB, the conditions of initiation and blocking are checked. This is done for all CBBs simultaneously. Each CBB that fulfils the initiation conditions requests an execution.

The function also keeps track of shots already performed. That is, at which point the autoreclose sequence is from shot 1 to lockout. For example, if shots 1 and 2 have already been performed, only shots 3 to 5 are allowed.

Additionally, the *Enable shot jump* setting gives two possibilities:

- Only such CBBs that are set for the next shot in the sequence can be accepted for execution. For example, if the next shot in the sequence should be shot 2, a request from CBB set for shot 3 is rejected.
- Any CBB that is set for the next shot or any of the following shots can be accepted for execution. For example, if the next shot in the sequence should be shot 2, also

CBBs that are set for shots 3, 4 and 5 are accepted. In other words, shot 2 can be ignored.

In case there are multiple CBBs allowed for execution, the CBB with the smallest number is chosen. For example, if CBB2 and CBB4 request an execution, CBB2 is allowed to execute the shot.

The autoreclose function can perform up to five autoreclose shots or cycles.

7.2.6.3 Configuration examples

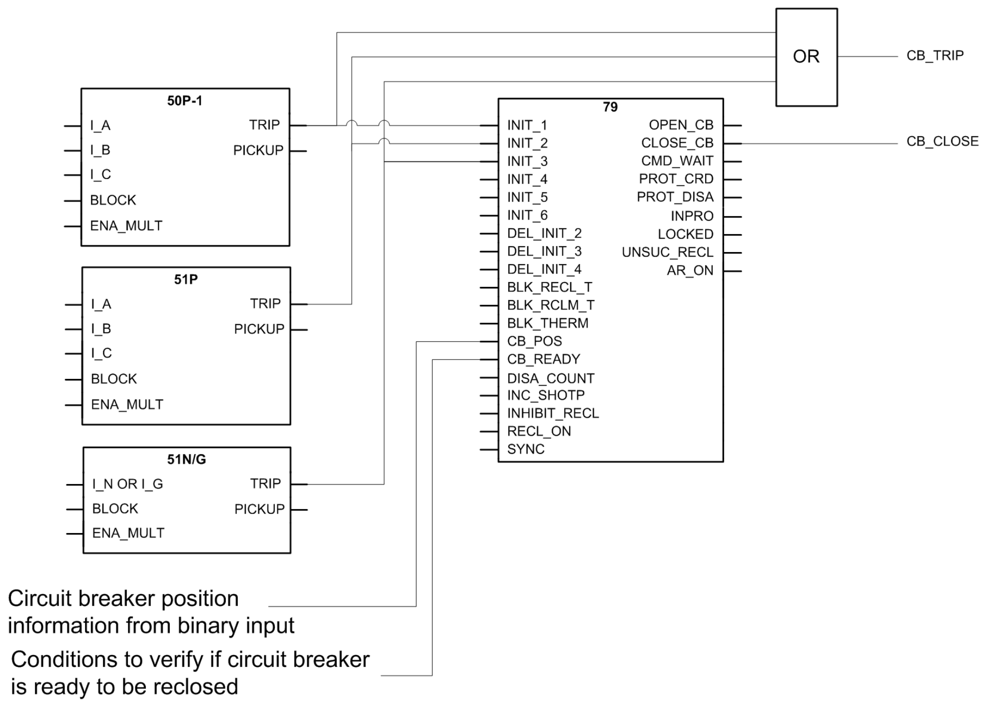

Figure 274: Example connection between protection and autoreclose functions in IED configuration

It is possible to create several sequences for a configuration.

Autoreclose sequences for overcurrent and non-directional ground-fault protection applications where high speed and delayed autoreclosings are needed can be as follows:

Example 1

The sequence is implemented by two shots which have the same reclose time for all protection functions, namely 50P-1, 51P and 51N/G. The initiation of the shots is done by activating the trip signals of the protection functions.

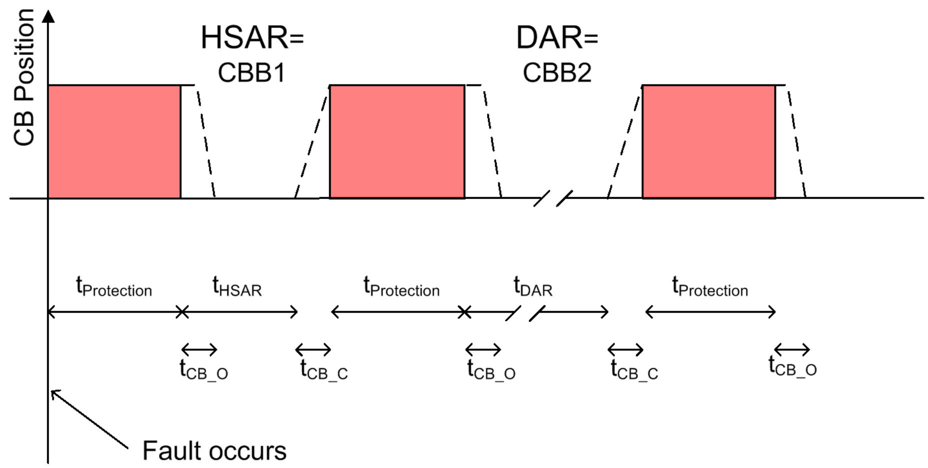

Figure 275: Autoreclose sequence with two shots

t_{HSAR}	Time delay of high-speed autoreclosing, here: *First reclose time*
t_{DAR}	Time delay of delayed autoreclosing, here: *Second reclose time*
$t_{Protection}$	Operating time for the protection stage to clear the fault
t_{CB_O}	Operating time for opening the circuit breaker
t_{CB_C}	Operating time for closing the circuit breaker

In this case, the sequence needs two CBBs. The reclosing times for shot 1 and shot 2 are different, but each protection function initiates the same sequence. The CBB sequence is as follows:

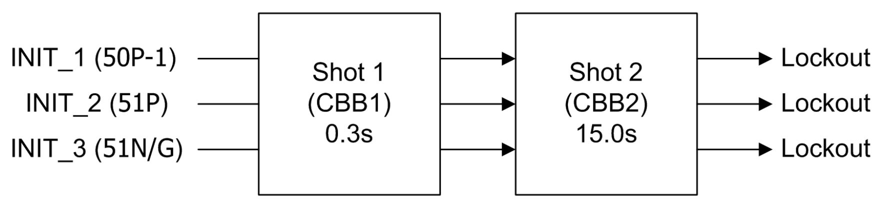

Figure 276: Two shots with three initiation lines

Table 421: Settings for configuration example 1

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	7 (lines 1,2 and 3 = 1+2+4 = 7)
First reclose time	0.3s (an example)
Shot number CBB2	2
Init signals CBB2	7 (lines 1,2 and 3 = 1+2+4 = 7)
Second reclose time	15.0s (an example)

Example 2

There are two separate sequences implemented with three shots. Shot 1 is implemented by CBB1 and it is initiated with the high stage of the overcurrent protection (50P-1). Shot 1 is set as a high-speed autoreclosing with a short time delay. Shot 2 is implemented with

CBB2 and meant to be the first shot of the autoreclose sequence initiated by the low stage of the overcurrent protection (51P) and the low stage of the non-directional ground-fault protection (51N/G). It has the same reclose time in both situations. It is set as a high-speed autoreclosing for corresponding faults. The third shot, which is the second shot in the autoreclose sequence initiated by 51P or 51N/G, is set as a delayed autoreclosing and executed after an unsuccessful high-speed autoreclosing of a corresponding sequence.

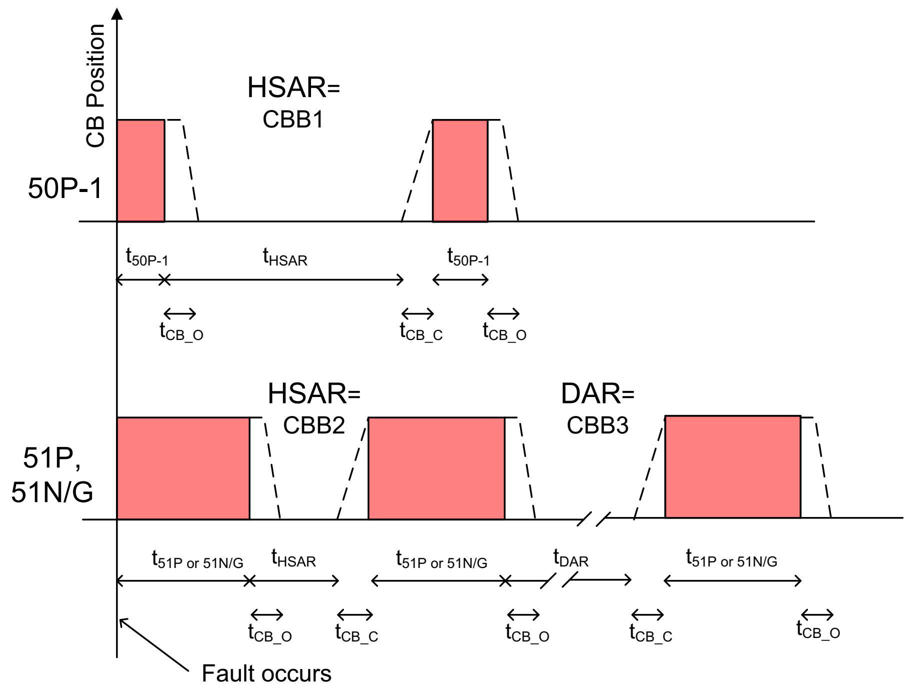

Figure 277: Autoreclose sequence with two shots with different shot settings according to initiation signal

t_{HSAR}	Time delay of high-speed autoreclosing, here: *First reclose time*
t_{DAR}	Time delay of delayed autoreclosing, here: *Second reclose time*
$t_{I>>}$	Operating time for the 50P-1 protection stage to clear the fault
$t_{I>}$ or $_{Io>}$	Operating time for the 51P or 51N/G protection stage to clear the fault
t_{CB_O}	Operating time for opening the circuit breaker
t_{CB_C}	Operating time for closing the circuit breaker

In this case, the number of needed CBBs is three, that is, the first shot's reclosing time depends on the initiation signal. The CBB sequence is as follows:

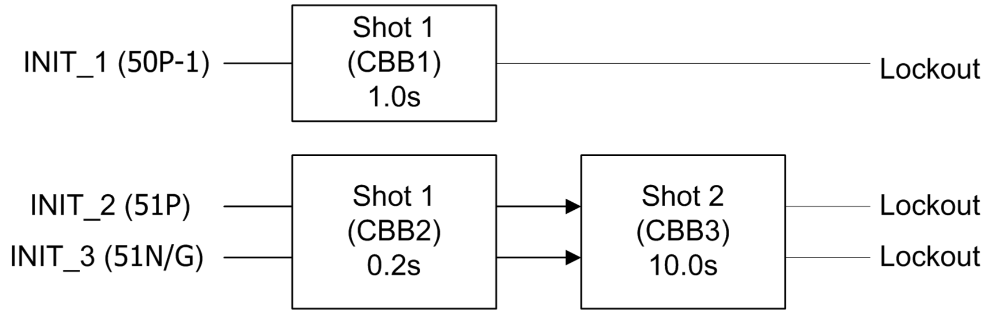

Figure 278: Three shots with three initiation lines

If the sequence is initiated from the INIT_1 line, that is, the overcurrent protection high stage, the sequence is one shot long. On the other hand, if the sequence is initiated from the INIT_2 or INIT_3 lines, the sequence is two shots long.

Table 422: Settings for configuration example 2

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	1 (line 1)
First reclose time	0.0s (an example)
Shot number CBB2	1
Init signals CBB2	6 (lines 2 and 3 = 2+4 = 6)
Second reclose time	0.2s (an example)
Shot number CBB3	2
Init signals CBB3	6 (lines 2 and 3 = 2+4 = 6)
Third reclose time	10.0s

7.2.6.4 Delayed initiation lines

The autoreclose function consists of six individual autoreclose initiation lines INIT_1...INIT 6 and three delayed initiation lines:

- DEL_INIT_2
- DEL_INIT_3
- DEL_INIT_4

DEL_INIT_2 and INIT_2 are connected together with an OR-gate, as are inputs 3 and 4. Inputs 1, 5 and 6 do not have any delayed input. From the autoreclosing point of view, it does not matter whether INIT_x or DEL_INIT_x line is used for shot initiation or blocking.

The autoreclose function can also open the circuit breaker from any of the initiation lines. It is selected with the *Tripping line* setting. As a default, all initiation lines activate the OPEN_CB output.

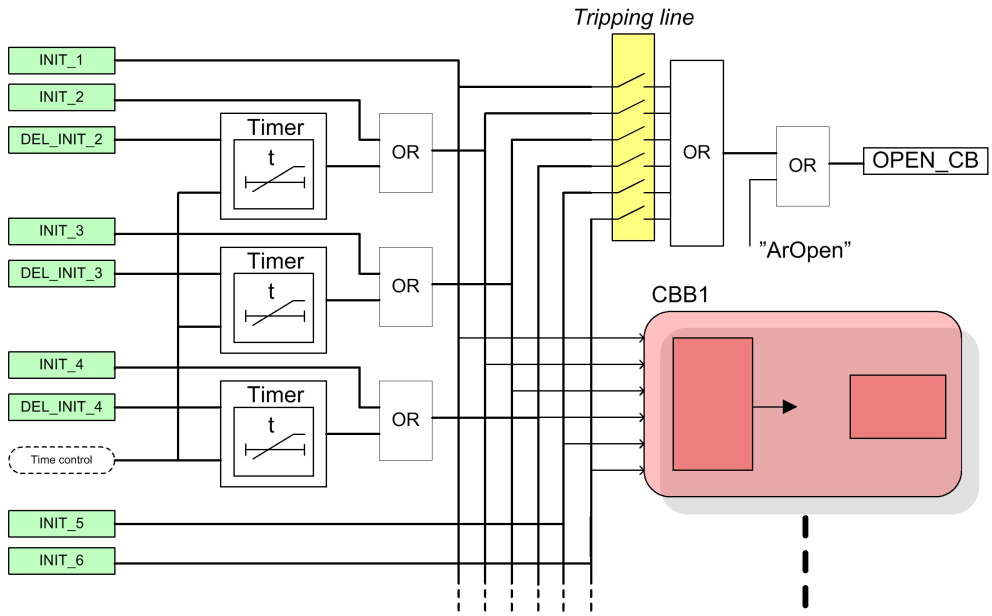

Figure 279: Simplified logic diagram of initiation lines

Each delayed initiation line has four different time settings:

Table 423: Settings for delayed initiation lines

Setting name	Description and purpose
Str x delay shot 1	Time delay for the `DEL_INIT_x` line, where x is the number of the line 2, 3 or 4. Used for shot 1.
Str x delay shot 2	Time delay for the `DEL_INIT_x` line, used for shot 2.
Str x delay shot 3	Time delay for the `DEL_INIT_x` line, used for shot 3.
Str x delay shot 4	Time delay for the `DEL_INIT_x` line, used for shots 4 and 5. Optionally, can also be used with SOTF.

7.2.6.5 Shot initiation from protection pickup signal

All autoreclose shots are initiated by protection trips. As a result, all trip times in the sequence are the same. This is why using protection trips may not be the optimal solution. Using protection pickup signals instead of protection trips for initiating shots shortens the trip times.

Example 1

When a two-shot-sequence is used, the pickup information from the protection function is routed to the `DEL_INIT 2` input and the trip information to the `INIT_2` input. The following conditions have to apply:

- protection trip time = 0.5s
- *Str 2 delay shot 1* = 0.05s
- *Str 2 delay shot 2* = 60s
- *Str 2 delay shot 3* = 60s

Operation in a permanent fault:

1. Protection picks up and activates the `DEL_INIT 2` input.
2. After 0.05 seconds, the first autoreclose shot is initiated. The function opens the circuit breaker: the `OPEN_CB` output activates. The total trip time is the protection pickup delay + 0.05 seconds + the time it takes to open the circuit breaker.
3. After the first shot, the circuit breaker is reclosed and the protection picks up again.
4. Because the delay of the second shot is 60 seconds, the protection is faster and trips after the set operation time, activating the `INIT 2` input. The second shot is initiated.
5. After the second shot, the circuit breaker is reclosed and the protection picks up again.
6. Because the delay of the second shot is 60 seconds, the protection is faster and trips after the set operation time. No further shots are programmed after the final trip. The function is in lockout and the sequence is considered unsuccessful.

Example 2

The delays can be used also for fast final trip. The conditions are the same as in Example 1, with the exception of *Str 2 delay shot 3* = 0.10 seconds.

The operation in a permanent fault is the same as in Example 1, except that after the second shot when the protection picks up again, *Str 2 delay shot 3* elapses before the protection trip time and the final trip follows. The total trip time is the protection pickup delay + 0.10 seconds + the time it takes to open the circuit breaker.

7.2.6.6 Fast trip in Switch on to fault

The *Str _ delay shot 4* parameter delays can also be used to achieve a fast and accelerated trip with SOTF. This is done by setting the *Fourth delay in SOTF* parameter to "1" and connecting the protection pickup information to the corresponding `DEL_INIT_` input.

When the function detects a closing of the circuit breaker, that is, any other closing except the reclosing done by the function itself, it always prohibits shot initiation for the time set with the *Reclaim time* parameter. Furthermore, if the *Fourth delay in SOTF* parameter is "1", the *Str _ delay shot 4* parameter delays are also activated.

Example 1

The protection operation time is 0.5 seconds, the *Fourth delay in SOTF* parameter is set to "1" and the *Str 2 delay shot 4* parameter is 0.05 seconds. The protection pickup signal is connected to the `DEL_INIT_2` input.

If the protection picks up after the circuit breaker closes, the fast trip follows after the set 0.05 seconds. The total trip time is the protection pickup delay + 0.05 seconds + the time it takes to open the circuit breaker.

7.2.7 Signals

Table 424: 79 Input signals

Name	Type	Default	Description
INIT_1	BOOLEAN	0=False	AR initialization / blocking signal 1
INIT_2	BOOLEAN	0=False	AR initialization / blocking signal 2
INIT_3	BOOLEAN	0=False	AR initialization / blocking signal 3
INIT_4	BOOLEAN	0=False	AR initialization / blocking signal 4
INIT_5	BOOLEAN	0=False	AR initialization / blocking signal 5
INIT_6	BOOLEAN	0=False	AR initialization / blocking signal 6
DEL_INIT_2	BOOLEAN	0=False	Delayed AR initialization / blocking signal 2
DEL_INIT_3	BOOLEAN	0=False	Delayed AR initialization / blocking signal 3
DEL_INIT_4	BOOLEAN	0=False	Delayed AR initialization / blocking signal 4
BLK_RECL_T	BOOLEAN	0=False	Blocks and resets reclose time
BLK_RCLM_T	BOOLEAN	0=False	Blocks and resets reclaim time
BLK_THERM	BOOLEAN	0=False	Blocks and holds the reclose shot from the thermal overload
CB_POS	BOOLEAN	0=False	Circuit breaker position input
CB_READY	BOOLEAN	1=True	Circuit breaker status signal
INC_SHOTP	BOOLEAN	0=False	A zone sequence coordination signal
INHIBIT_RECL	BOOLEAN	0=False	Interrupts and inhibits reclosing sequence
RECL_ON	BOOLEAN	0=False	Level sensitive signal for allowing (high) / not allowing (low) reclosing
SYNC	BOOLEAN	0=False	Synchronizing check fulfilled

Table 425: 79 Output signals

Name	Type	Description
OPEN_CB	BOOLEAN	Open command for circuit breaker
CLOSE_CB	BOOLEAN	Close (reclose) command for circuit breaker
CMD_WAIT	BOOLEAN	Wait for master command
INPRO	BOOLEAN	Reclosing shot in progress, activated during dead time
LOCKED	BOOLEAN	Signal indicating that AR is locked out
PROT_CRD	BOOLEAN	A signal for coordination between the AR and the protection
UNSUC_RECL	BOOLEAN	Indicates an unsuccessful reclosing sequence
AR_ON	BOOLEAN	Autoreclosing allowed
READY	BOOLEAN	Indicates that the AR is ready for a new sequence

7.2.8 Settings

Table 426: 79 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Off/On
Reclosing operation	1=Off 2=External Ctl 3=On			1=Off	Reclosing operation (Off, External Ctl / On)
Manual close mode	0=False 1=True			0=False	Manual close mode
Wait close time	50...10000	ms	50	250	Allowed CB closing time after reclose command
Max wait time	100...1800000	ms	100	10000	Maximum wait time for haltDeadTime release
Max trip time	100...10000	ms	100	10000	Maximum wait time for deactivation of protection signals
Close pulse time	10...10000	ms	10	200	CB close pulse time
Max Thm block time	100...1800000	ms	100	10000	Maximum wait time for thermal blocking signal deactivation
Cut-out time	0...1800000	ms	100	10000	Cutout time for protection coordination
Reclaim time	100...1800000	ms	100	10000	Reclaim time
Dsr time shot 1	0...10000	ms	100	0	Discrimination time for first reclosing
Dsr time shot 2	0...10000	ms	100	0	Discrimination time for second reclosing
Dsr time shot 3	0...10000	ms	100	0	Discrimination time for third reclosing
Dsr time shot 4	0...10000	ms	100	0	Discrimination time for fourth reclosing
Terminal priority	1=None 2=Low (follower) 3=High (master)			1=None	Terminal priority
Synchronisation set	0...127			0	Selection for synchronizing requirement for reclosing
Auto wait time	0...60000	ms	10	2000	Wait time for reclosing condition fullfilling
Auto lockout reset	0=False 1=True			1=True	Automatic lockout reset
Protection crd limit	1...5			1	Protection coordination shot limit
Protection crd mode	1=No condition 2=AR inoperative 3=CB close manual 4=AR inop, CB man 5=Always			4=AR inop, CB man	Protection coordination mode
Auto initiation cnd	1=Not allowed 2=When sync fails 3=CB doesn't close 4=Both			2=When sync fails	Auto initiation condition
Tripping line	0...63			0	Tripping line, defines INIT inputs which cause OPEN_CB activation
Control line	0...63			63	Control line, defines INIT inputs which are protection signals
Enable shot jump	0=False 1=True			1=True	Enable shot jumping
CB closed Pos status	0=False 1=True			1=True	Circuit breaker closed position status

Parameter	Values (Range)	Unit	Step	Default	Description
Fourth delay in SOTF	0=False 1=True			0=False	Sets 4th delay into use for all DEL_INIT signals during SOTF
First reclose time	0...300000	ms	10	5000	Dead time for CBB1
Second reclose time	0...300000	ms	10	5000	Dead time for CBB2
Third reclose time	0...300000	ms	10	5000	Dead time for CBB3
Fourth reclose time	0...300000	ms	10	5000	Dead time for CBB4
Fifth reclose time	0...300000	ms	10	5000	Dead time for CBB5
Sixth reclose time	0...300000	ms	10	5000	Dead time for CBB6
Seventh reclose time	0...300000	ms	10	5000	Dead time for CBB7
Init signals CBB1	0...63			0	Initiation lines for CBB1
Init signals CBB2	0...63			0	Initiation lines for CBB2
Init signals CBB3	0...63			0	Initiation lines for CBB3
Init signals CBB4	0...63			0	Initiation lines for CBB4
Init signals CBB5	0...63			0	Initiation lines for CBB5
Init signals CBB6	0...63			0	Initiation lines for CBB6
Init signals CBB7	0...63			0	Initiation lines for CBB7
Blk signals CBB1	0...63			0	Blocking lines for CBB1
Blk signals CBB2	0...63			0	Blocking lines for CBB2
Blk signals CBB3	0...63			0	Blocking lines for CBB3
Blk signals CBB4	0...63			0	Blocking lines for CBB4
Blk signals CBB5	0...63			0	Blocking lines for CBB5
Blk signals CBB6	0...63			0	Blocking lines for CBB6
Blk signals CBB7	0...63			0	Blocking lines for CBB7
Shot number CBB1	0...5			0	Shot number for CBB1
Shot number CBB2	0...5			0	Shot number for CBB2
Shot number CBB3	0...5			0	Shot number for CBB3
Shot number CBB4	0...5			0	Shot number for CBB4
Shot number CBB5	0...5			0	Shot number for CBB5
Shot number CBB6	0...5			0	Shot number for CBB6
Shot number CBB7	0...5			0	Shot number for CBB7
Str 2 delay shot 1	0...300000	ms	10	0	Delay time for start2, 1st reclose
Str 2 delay shot 2	0...300000	ms	10	0	Delay time for start2 2nd reclose
Str 2 delay shot 3	0...300000	ms	10	0	Delay time for start2 3rd reclose
Str 2 delay shot 4	0...300000	ms	10	0	Delay time for start2, 4th reclose
Str 3 delay shot 1	0...300000	ms	10	0	Delay time for start3, 1st reclose
Str 3 delay shot 2	0...300000	ms	10	0	Delay time for start3 2nd reclose
Str 3 delay shot 3	0...300000	ms	10	0	Delay time for start3 3rd reclose
Str 3 delay shot 4	0...300000	ms	10	0	Delay time for start3, 4th reclose
Str 4 delay shot 1	0...300000	ms	10	0	Delay time for start4, 1st reclose
Str 4 delay shot 2	0...300000	ms	10	0	Delay time for start4 2nd reclose
Str 4 delay shot 3	0...300000	ms	10	0	Delay time for start4 3rd reclose

Parameter	Values (Range)	Unit	Step	Default	Description
Str 4 delay shot 4	0...300000	ms	10	0	Delay time for start4, 4th reclose
Frq Op counter limit	0...250			0	Frequent operation counter lockout limit
Frq Op counter time	1...250	min		1	Frequent operation counter time
Frq Op recovery time	1...250	min		1	Frequent operation counter recovery time
Auto init	0...63			0	Defines INIT lines that are activated at auto initiation

7.2.9 Monitored data

Table 427: 79 Monitored data

Name	Type	Values (Range)	Unit	Description
DISA_COUNT	BOOLEAN	0=False 1=True		Signal for counter disabling
FRQ_OPR_CNT	INT32	0...2147483647		Frequent operation counter
FRQ_OPR_AL	BOOLEAN	0=False 1=True		Frequent operation counter alarm
STATUS	Enum	-2=Unsuccessful -1=Not defined 1=Ready 2=In progress 3=Successful		AR status signal for IEC61850
ACTIVE	BOOLEAN	0=False 1=True		Reclosing sequence is in progress
INPRO_1	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 1
INPRO_2	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 2
INPRO_3	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 3
INPRO_4	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 4
INPRO_5	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 5
DISCR_INPRO	BOOLEAN	0=False 1=True		Signal indicating that discrimination time is in progress
CUTOUT_INPRO	BOOLEAN	0=False 1=True		Signal indicating that cut-out time is in progress
SUC_RECL	BOOLEAN	0=False 1=True		Indicates a successful reclosing sequence
UNSUC_CB	BOOLEAN	0=False 1=True		Indicates an unsuccessful CB closing
CNT_SHOT1	INT32	0...2147483647		Resetable operation counter, shot 1
CNT_SHOT2	INT32	0...2147483647		Resetable operation counter, shot 2
CNT_SHOT3	INT32	0...2147483647		Resetable operation counter, shot 3
CNT_SHOT4	INT32	0...2147483647		Resetable operation counter, shot 4
CNT_SHOT5	INT32	0...2147483647		Resetable operation counter, shot 5
COUNTER	INT32	0...2147483647		Resetable operation counter, all shots
SHOT_PTR	INT32	0...6		Shot pointer value
MAN_CB_CL	BOOLEAN	0=False 1=True		Indicates CB manual closing during reclosing sequence
SOTF	BOOLEAN	0=False 1=True		Switch-onto-fault
79	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

7.2.10 Technical data

Table 428: 79 Technical data

Characteristic	Value
Trip time accuracy	±1.0% of the set value or ±20 ms

7.3 Synchronism and energizing check, 25

7.3.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Synchronism and energizing check	SECRSYN	SYNC	25

7.3.2 Function block

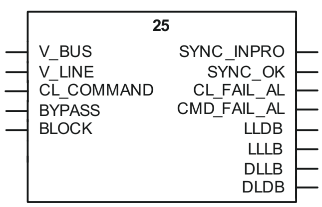

Figure 280: Function block

7.3.3 Functionality

The synchrocheck function 25 checks the condition across the circuit breaker from separate power system parts and gives the permission to close the circuit breaker. 25 function includes the functionality of synchrocheck and energizing check.

Asynchronous operation mode is provided for asynchronously running systems. The main purpose of the asynchronous operation mode is to provide a controlled closing of circuit breakers when two asynchronous systems are connected.

The synchrocheck operation mode checks that the voltages on both sides of the circuit breaker are perfectly synchronized. It is used to perform a controlled reconnection of two systems which are divided after islanding and it is also used to perform a controlled reconnection of the system after reclosing.

The energizing check function checks that at least one side is dead to ensure that closing can be done safely.

The function contains a blocking functionality. It is possible to block function outputs and timers if desired.

7.3.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are Enable and Disable.

The synchrocheck function has two parallel functionalities, the synchrocheck and energizing check functionality. The operation of the synchronism and energizing check function can be described using a module diagram. All the modules in the diagram are explained in the next sections.

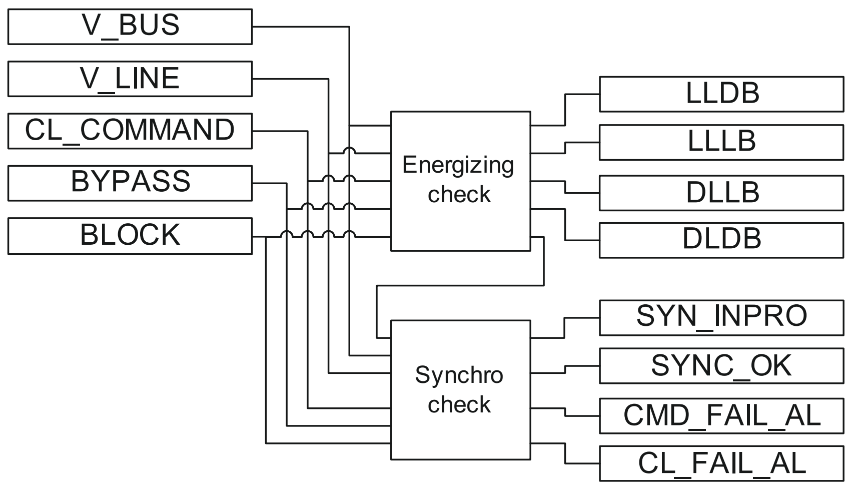

Figure 281: Functional module diagram

The synchrocheck function can operate either with V_AB or V_A voltages. The selection of used voltages is defined with the VT connection setting of the line voltage general parameters.

Energizing check

The energizing check function checks the energizing direction. Energizing is defined as a situation where a dead network part is connected to an energized section of the network. The conditions of the network sections to be controlled by the circuit breaker, that is, which side has to be live and which side dead, are determined by the setting. A situation where both sides are dead is possible as well. The actual value for defining the dead line or bus is given with the *Dead bus value* and *Dead line value* settings. Similarly, the actual values of live line or bus are defined with the *Live bus value* and *Live line value* settings.

Table 429: Live dead mode of operation under which switching can be carried out

Live dead mode	Description
Both Dead	Both Line and Bus de-energized
Live L, Dead B	Bus de-energized and Line energized
Dead L, Live B	Line de-energized and Bus energized
Dead Bus, L Any	Both Line and Bus de-energized or Bus de-energized and Line energized
Dead L, Bus Any	Both Line and Bus de-energized or Line de-energized and bus energized
One Live, Dead	Bus de-energized and Line energized or Line de-energized and Bus energized
Not Both Live	Both Line and Bus de-energized or Bus de-energized and Line energized or Line de-energized and Bus energized

When the energizing direction corresponds to the settings, the situation has to be constant for a time set with the *Energizing time* setting, before the circuit breaker closing is permitted. The purpose of this time delay is to make sure that the dead side remains de-energized and also that the situation is not caused by a temporary interference. If the conditions do not persist for a specified operate time, timer is reset and the procedure is restarted when the conditions allow again. The circuit breaker closing is not permitted, if the measured voltage on the live side is greater than the set value of *Max energizing V*.

The measured energized state is available as monitored data value ENERG_STATE and as four function outputs LLDB (live line / dead bus), LLLB (live line / live bus), DLLB (dead line / live bus) and DLDB (dead line / dead bus) of which only one can be active at a time. It is also possible that the measured energized state indicates "Unknown", if at least one of the measured voltages is between the limits set with the dead and live settings parameters.

Synchro check

The synchrocheck function measures the difference between the line voltage and bus voltage. The function trips and issues a closing command to the circuit breaker when the calculated closing angle is equal to the measured phase angle and if the following conditions are simultaneously fulfilled.

- The measured line and bus voltages are higher than set values of Live bus value and Live line value (ENERG_STATE equals to "Both Live").
- The measured bus and line frequency are both within the range of 95 to 105 percent of the value of fn.
- The measured voltages for the line and bus are less than set value of Max energizing V.

In case *Syncro check mode* is set to "Synchronous", the additional conditions must be fulfilled:

- In the synchronous mode, the closing is attempted so that the phase difference at closing is close to zero.
- The synchronous mode is only possible when the frequency slip is below 0.1 percent of the value of fn.
- The voltage difference must not exceed the 1 percent of the value of U_n.

In case *Syncro check mode* is set to "Asynchronous", the additional conditions must be fulfilled

- The measured difference of the voltages is less than the set value of *Difference voltage.*
- The measured difference of the phase angles is less than the set value of *Difference angle.*
- The measured difference in frequency is less than the set value of *Frequency difference.*
- The estimated breaker closing angle is decided to be less than the set value of *Difference angle.*

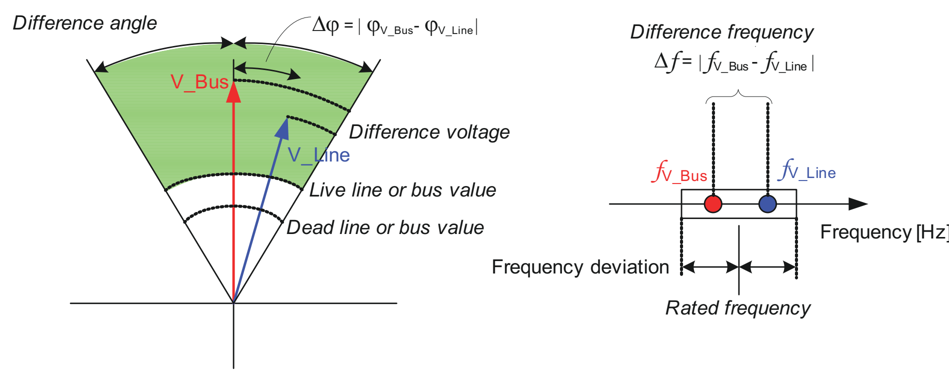

Figure 282: Conditions to be fulfilled when detecting synchronism between systems

When the frequency, phase angle and voltage conditions are fulfilled, the duration of the synchronism conditions is checked so as to ensure that they are still met when the condition is determined on the basis of the measured frequency and phase difference. Depending on the circuit breaker and the closing system, the delay from the moment the closing signal is given until the circuit breaker finally closes is about 50 - 250 ms. The selected *Closing time* of CB informs the function how long, the conditions have to persist. The synchrocheck function compensates for the measured slip frequency and the circuit breaker closing delay. The phase angle advance is calculated continuously with the formula:

φ_{V_BUS}	Measured bus voltage phase angle
φ_{V_LINE}	Measured line voltage phase angle
f_{V_BUS}	Measured bus frequency
f_{V_LINE}	Measured line frequency
T_{CB}	Total circuit breaker closing delay, including the delay of the relay output contacts defined with the Closing time of CB setting parameter value

The closing angle is the estimated angle difference after the breaker closing delay.

The *Minimum Syn time* setting time can be set, if required, to demand the minimum time within which conditions must be simultaneously fulfilled before the SYNC_OK output is activated.

The measured voltage, frequency and phase angle difference values between the two sides of the circuit breaker are available as monitored data values V_DIFF_MEAS, FR_DIFF_MEAS and PH_DIFF_MEAS. Also, the indications of the conditions that are not fulfilled and thus preventing the breaker closing permission, are available as monitored data values V_DIFF_SYNC, PH_DIF_SYNC and FR_DIFF_SYNC. These monitored data values are updated only when the synchrocheck enabled with the *Synchro check mode* setting and the measured ENERG_STATE is "Both Live".

Continuous mode

The synchrocheck functionality can be selected with the *Control mode* setting. The "Continuous" mode can be used for two different operating conditions, the most typical of which is where both sides of the circuit breaker to be closed are live. The synchronism is always checked before the circuit breaker is given the permission to close. The other situation is where one or both sides of the circuit breaker to be closed are dead and, consequently, the frequency and phase difference cannot be measured. In this case, the function checks the energizing direction. The user is able to define the voltage range within which the measured voltage is determined to be "live" or "dead".

The continuous control mode is selected with the *Control mode* setting. In the continuous control mode, the synchrocheck is continuously checking the synchronism. When the synchronism conditions or the energizing check conditions are fulfilled, the SYNC_OK output is activated and it remains activated as long as the conditions remain fulfilled. The command input is ignored in the continuous control mode. The mode is used for situations where the synchrocheck only gives the permission to the control block that executes the CB closing.

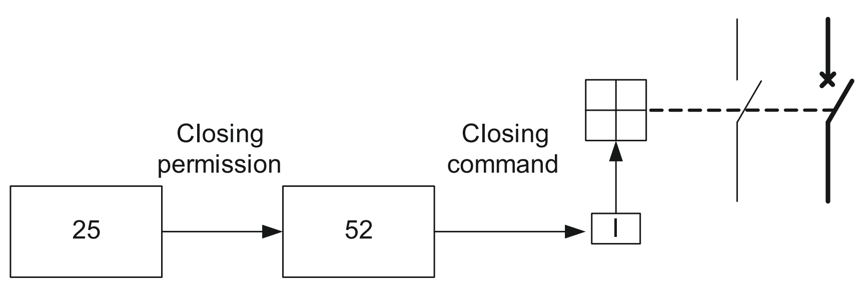

Figure 283: A simplified block diagram of the synchrocheck function in the continuous mode operation

Command mode

If *Control mode* is set to "Command", the purpose of the synchrocheck functionality in the command mode is to find the instant when the voltages on both sides of the circuit breaker are in synchronism. The conditions for synchronism are met when the voltages on both sides of the circuit breaker have the same frequency and are in phase with a magnitude that makes the concerned busbars or lines can be regarded as live.

In the command control mode operation, an external command signal CL_COMMAND, besides the normal closing conditions, is needed for delivering the closing signal. In the command control mode operation, the synchrocheck function itself closes the breaker via the SYNC_OK output when the conditions are fulfilled. In this case, the control function block delivers the command signal to close the synchrocheck function for the releasing of a closing signal pulse to the circuit breaker. If the closing conditions are fulfilled during a permitted check time set with *Maximum Syn time*, after the command signal is delivered for closing, the synchrocheck function delivers a closing signal to the circuit breaker.

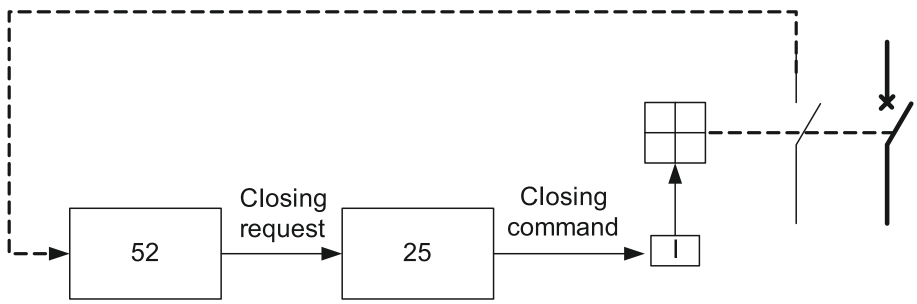

Figure 284: A simplified block diagram of the synchrocheck function in the command mode operation

The closing signal is delivered only once for each activated external closing command signal. The pulse length of the delivered closing is set with the Close pulse setting.

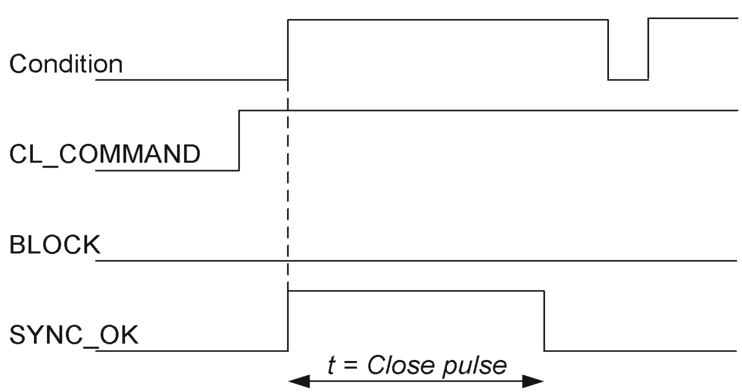

Figure 285: Determination of the pulse length of the closing signal

In the command control mode operation, there are alarms for a failed closing attempt (CL_FAIL_AL) and for a command signal that remains active too long (CMD_FAIL_AL).

If the conditions for closing are not fulfilled within set time of Maximum Syn time, a failed closing attempt alarm is given. The CL_FAIL_AL alarm output signal is pulse shaped and the pulse length is 500 ms. If the external command signal is removed too early, that is, before conditions are fulfilled and close pulse is given, the alarm timer is reset.

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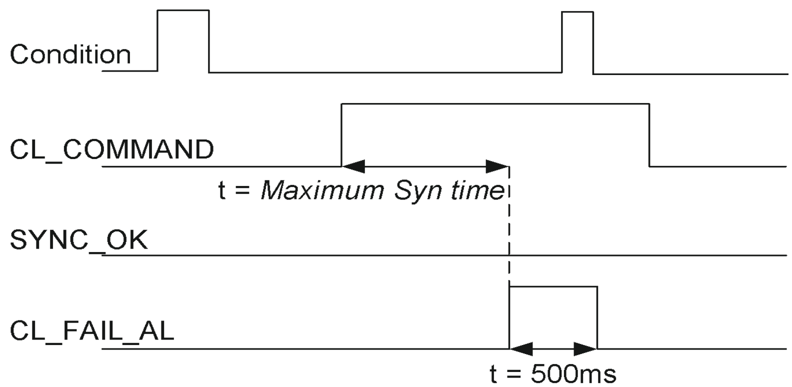

Figure 286: Determination of the checking time for closing

The control module receives information about the circuit breaker status and thus is able to adjust the command signal to be delivered to the synchrocheck function. If the external command signal CL_COMMAND is kept active longer than necessary, CMD_FAIL_AL alarm output is activated. The alarm indicates that the control module has not removed the external command signal after the closing operation. To avoid unnecessary alarms, the duration of the command signal should be set in such a way that the maximum length of the signal is always below Maximum Syn time + 5s.

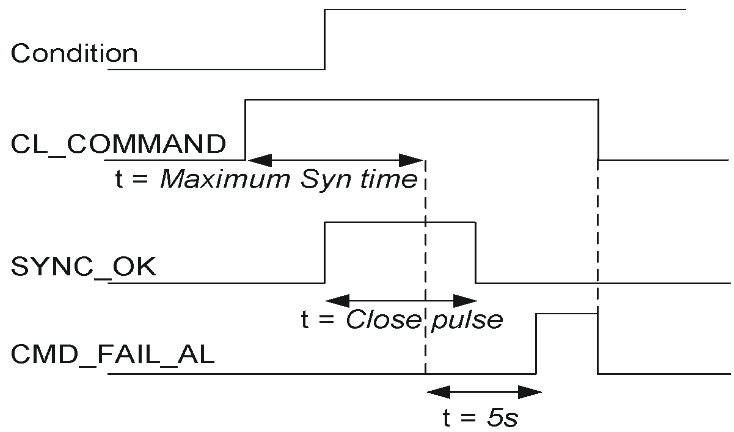

Figure 287: Determination of the alarm limit for a still-active command signal

Closing is permitted during Maximum Syn time, starting from the moment the external command signal CL_COMMAND is activated. The CL_COMMAND input must be kept active for the whole time that the closing conditions are waited to be fulfilled. Otherwise, the procedure is cancelled. If the closing command conditions are fulfilled during Maximum Syn time, a closing pulse is delivered to the circuit breaker. If the closing conditions are not fulfilled during the checking time, the alarm CL_FAIL_AL is activated as an indication of a failed closing attempt. The closing pulse is not delivered if the closing conditions become valid after Maximum Syn time has elapsed. The closing pulse is delivered only once for each activated external command signal and new closing command sequence cannot be started until the external command signal is reset and then activated again. The SYNC_INPRO output is active when the closing command sequence is in progress and it is reset when the CL_COMMAND input is reset or Maximum Syn time has elapsed.

Bypass mode

25 can be set into bypass mode by setting the parameters Synchro check mode and Energizing check mode to "Off" or alternatively, by activating the BYPASS input.

In bypass mode, the closing conditions are always considered to be fulfilled by the 25 function. Otherwise, the operation is similar to the normal mode.

Voltage angle difference adjustment

In application where the power transformer is located between the voltage measurement and the vector group connection gives phase difference to the voltages between the high and low-voltage sides, the angle adjustment can be used to meet synchronism.

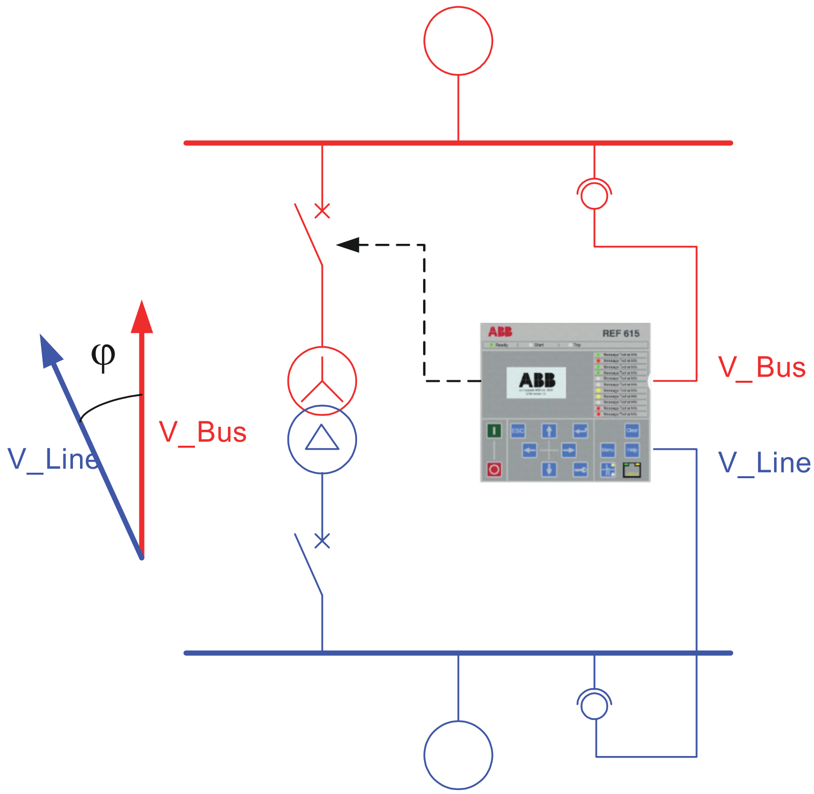

Figure 288: Angle difference when power transformer is in sychrocheck zone

The vector group of the power transformer is defined with clock numbers, where the value of the hour pointer defines the low voltage-side phasor and the high voltage-side phasor is always fixed to the clock number 12 which is same as zero. The angle between clock numbers is 30 degrees. When comparing phase angles, the V_BUS input is always the reference. This means that when the Yd11 power transformer is used, the low voltage-side voltage phasor leads by 30 degrees or lags by 330 degrees the high voltage-side phasor. The rotation of the phasors is counterclockwise.

The generic rule is that a low voltage-side phasor lags the high voltage-side phasor by clock number * 30º. This is called angle difference adjustment and can be set for the function with the Phase shift setting.

7.3.5 Application

The main purpose of the synchrocheck function is to provide control over the closing of the circuit breakers in power networks to prevent the closing if the conditions for synchronism are not detected. This function is also used to prevent the reconnection of two systems which are divided after islanding and a three-pole reclosing.

The synchrocheck function block includes both the synchronism check function and the energizing function to allow closing when one side of the breaker is dead.

Network and the generator running in parallel with the network are connected through the line AB. When a fault occurs between A and B, the IED protection opens the circuit breakers A and B, thus isolating the faulty section from the network and making the arc that caused the fault extinguish. The first attempt to recover is a delayed autoreclosure made a few seconds later. Then, the autoreclose function DARREC gives a command signal to the synchrocheck function to close the circuit breaker A. 25 performs an energizing check, as the line AB is de-energized (V_BUS> *Live bus value*, V_LINE< *Dead line value*). After verifying the line AB is dead and the energizing direction is correct, the IED energizes the line (V_BUS -> V_LINE) by closing the circuit breaker A. The PLC of the power plant discovers that the line has been energized and sends a signal to the other synchrocheck function to close the circuit breaker B. Since both sides of the circuit breaker B are live (V_BUS > *Live bus value*, V_LINE > *Live bus value*), the synchrocheck function controlling the circuit breaker B performs a synchrocheck and, if the network and the generator are in synchronism, closes the circuit breaker.

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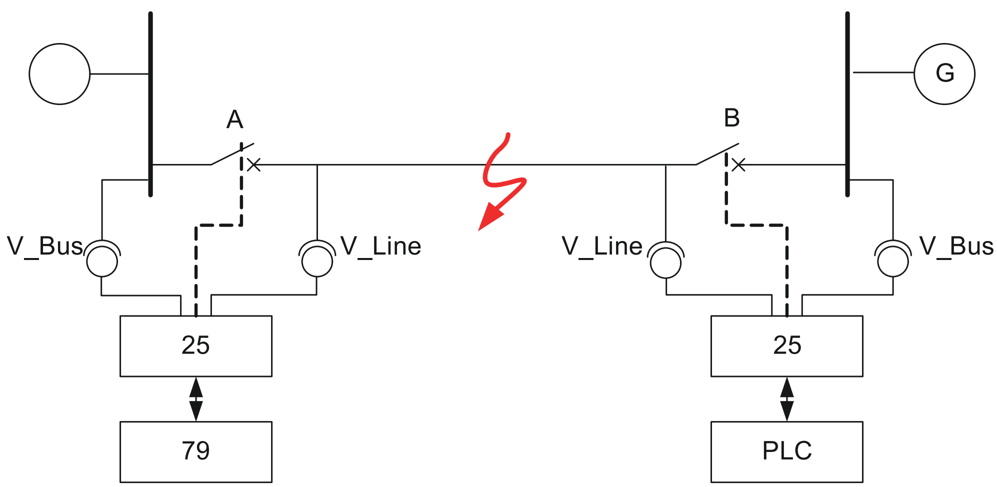

Figure 289: Synchrocheck function 25 checking energizing conditions and synchronism

Connections

A special attention is paid to the connection of the relay. Further, it is checked that the primary side wiring is correct.

A faulty wiring of the voltage inputs of the IED causes a malfunction in the synchrocheck function. If the wires of an energizing input have changed places, the polarity of the input voltage is reversed (180°). In this case, the IED permits the circuit breaker closing in a situation where the voltages are in opposite phases. This can damage the electrical devices in the primary circuit. Therefore, it is extremely important that the wiring from the voltage transformers to the terminals on the rear of the IED is consistent regarding the energizing inputs V_BUS (bus voltage) and V_LINE (line voltage).

The wiring should be verified by checking the reading of the phase difference measured between the V_BUS and V_LINE voltages. The phase difference measured by the IED has to be close to zero within the permitted accuracy tolerances. The measured phase differences are indicated in the LHMI. At the same time, it is recommended to check the voltage difference and the frequency differences presented in the Monitored data view. These values should be within the permitted tolerances, that is, close to zero.

Figure 290 shows an example where the synchrocheck is used for the circuit breaker closing between a busbar and a line. The phase-to-phase voltages are measured from the busbar and also one phase-to-phase voltage from the line is measured.

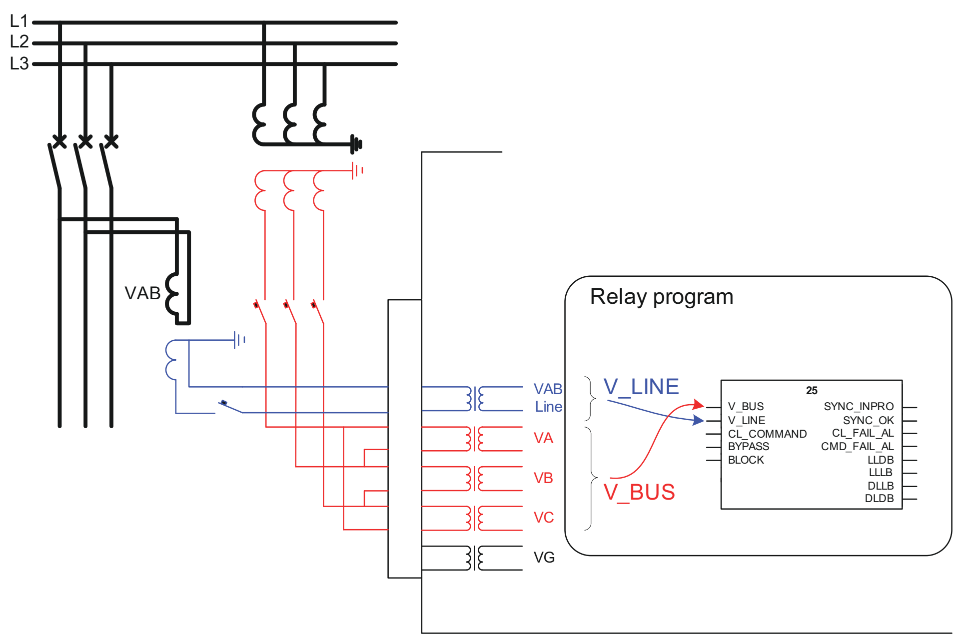

Figure 290: Connection of voltages for the IED and signals used in synchrocheck

7.3.6 Signals

Table 430: 25 input signals

Name	Type	Default	Description
V_BUS	SIGNAL	0=False	Busbar Voltage
V_LINE	SIGNAL	0=False	Line Voltage
CL_COMMAND	BOOLEAN	0=False	External closing request
BLOCK	BOOLEAN	0=False	Blocking signal of the synchro check and voltage check function
BYPASS	BOOLEAN	0=False	Request to bypass synchronism check and voltage check

Table 431: 25 output signals

Name	Type	Description
SYNC_INPRO	BOOLEAN	Synchronizing in progress
SYNC_OK	BOOLEAN	Systems in synchronism
CL_FAIL_AL	BOOLEAN	CB closing failed
CMD_FAIL_AL	BOOLEAN	CB closing request failed
LLDB	BOOLEAN	Live Line, Dead Bus
LLLB	BOOLEAN	Live Line, Live Bus
DLLB	BOOLEAN	Dead Line, Live Bus
DLDB	BOOLEAN	Dead Line, Dead Bus

7.3.7 Settings

Table 432: 25 group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Live dead mode	-1=Off			1=Both Dead	Energizing check mode
	1=Both Dead				
	2=Live L, Dead B				
	3=Dead L, Live B				
	4=Dead Bus, L Any				
	5=Dead L, Bus Any				
	6=One Live, Dead				
	7=Not Both Live				
Difference voltage	0.01...0.50	xVn	0.01	0.05	Maximum voltage difference limit
Difference frequency	0.001...0.100	xFn	0	0.001	Maximum frequency difference limit
Difference angle	5...90	deg	1	5	Maximum angle difference limit

Table 433: 25 non-group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable			1=enable	Operation Off / On
	5=disable				
Synchro check mode	1=Off			2=Synchronous	Synchro check operation mode
	2=Synchronous				
	3=Asynchronous				
Control mode	1=Continuous			1=Continuous	Selection of synchro check command or Continuous control mode
	2=Command				
Dead line value	0.1...0.8	xVn	0.1	0.2	Voltage low limit line for energizing check
Live line value	0.2...1.0	xVn	0.1	0.5	Voltage high limit line for energizing check
Dead bus value	0.1...0.8	xVn	0.1	0.2	Voltage low limit bus for energizing check
Live bus value	0.2...1.0	xVn	0.1	0.5	Voltage high limit bus for energizing check
Close pulse	200...60000	ms	10	200	Breaker closing pulse duration
Max energizing V	0.50...1.15	xVn	0.01	1.05	Maximum voltage for energizing
Phase shift	-180...180	deg	1	180	Correction of phase difference between measured U_BUS and U_LINE
Minimum Syn time	0...60000	ms	10	0	Minimum time to accept synchronizing
Maximum Syn time	100...6000000	ms	10	2000	Maximum time to accept synchronizing
Energizing time	100...60000	ms	10	100	Time delay for energizing check
Closing time of CB	40...250	ms	10	60	Closing time of the breaker

7.3.8 Monitored data

Table 434: 25 monitored data

Name	Type	Values (Range)	Unit	Description
ENERG_STATE	Enum	0=Unknown 1=Both Live 2=Live L, Dead B 3=Dead L, Live B 4=Both Dead		Energization state of Line and Bus
U_DIFF_MEAS	FLOAT32	0.00...1.00	xVn	Calculated voltage amplitude difference
FR_DIFF_MEAS	FLOAT32	0.000...0.100	xFn	Calculated voltage frequency difference
PH_DIFF_MEAS	FLOAT32	0.00...180.00	deg	Calculated voltage phase angle difference
U_DIFF_SYNC	BOOLEAN	0=False 1=True		Voltage difference out of limit for synchronizing
PH_DIF_SYNC	BOOLEAN	0=False 1=True		Phase angle difference out of limit for synchronizing
FR_DIFF_SYNC	BOOLEAN	0=False 1=True		Frequency difference out of limit for synchronizing
25	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

7.3.9 Technical data

Table 435: 25 technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the voltage measured: f_n ±1 Hz
	Voltage: ±3.0% of the set value or ±0.01 xV_n Frequency: ±10 mHz Phase angle: ±3°
Reset time	< 50 ms
Reset ratio	Typical 0.96
Trip time accuracy in definite time mode	±1.0% of the set value or ±20 ms

7.4 Emergency startup 62EST

7.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Emergency start function	ESMGAPC	ESTART	62EST

7.4.2 Function block symbol

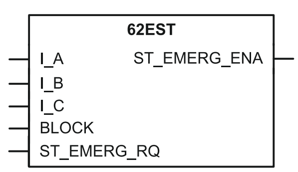

Figure 291: Function block

7.4.3 Functionality

An emergency condition can arise in cases where the motor needs to be started despite knowing that this can increase the temperature above limits or cause a thermal overload that can damage the motor. The emergency start function 62EST allows motor startups during such emergency conditions. 62EST is only to force the IED to allow the restarting of the motor. After the emergency start input is activated, the motor can be started normally. 62EST itself does not actually restart the motor.

The function contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

7.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

The operation of the emergency start function can be described using a module diagram. All the modules in the diagram are explained in the next sections.

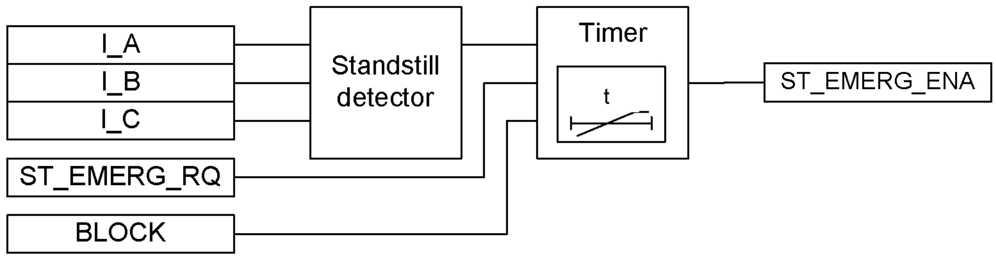

Figure 292: Functional module diagram

Standstill detector

The module detects if the motor is in a standstill condition. The standstill condition can be detected based on the phase current values. If all three phase currents are below the set value of *Motor standstill A*, the motor is considered to be in a standstill condition.

Timer

The timer is a fixed 10 minute timer which is activated when the `ST_EMERG_RQ` input is activated and motor standstill condition is fulfilled. Thus, the activation of the `ST_EMERG_RQ` input activates the `ST_EMERG_ENA` output, provided that the motor is in a standstill condition. The `ST_EMERG_ENA` output remains active for 10 minutes or as long as the `ST_EMERG_RQ` input is high, whichever takes longer.

The activation of the `BLOCK` input blocks and also resets the timer.

The function also provides the `ST_EMERG_ENA` output change date and time, `T_ST_EMERG`. The information is available through the Monitored data view.

7.4.5 Application

If the motor needs to be started in an emergency condition at the risk of damaging the motor, all the external restart inhibits are ignored, allowing the motor to be restarted. Furthermore, if the calculated thermal level is higher than the restart inhibit level at an emergency start condition, the calculated thermal level is set slightly below the restart inhibit level. Also, if the register value of the cumulative startup time counter exceeds the restart inhibit level, the value is set slightly below the restart disable value to allow at least one motor startup.

The activation of the `ST_EMERG_RQ` digital input allows to perform emergency start. The IED is forced to a state which allows the restart of motor, and the operator can now restart the motor. A new emergency start cannot be made until the 10 minute time-out has passed or until the emergency start is released, whichever takes longer.

The last change of the emergency start output signal is recorded.

7.4.6 Signals

Table 436: 62EST Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ST_EMERG_RQ	BOOLEAN	0=False	Emergency start input

Table 437: 62EST Output signals

Name	Type	Description
ST_EMERG_ENA	BOOLEAN	Emergency start

7.4.7 Settings

Table 438: 62EST Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Motor standstill A	0.05...0.20	xIn	0.01	0.12	Current limit to check for motor standstill condition

Table 439: 62EST Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable5=Disable			1=Enable	Operation Disable / Enable

7.4.8 Monitored data

Table 440: 62EST Monitored data

Name	Type	Values (Range)	Unit	Description
T_ST_EMERG	Timestamp			Emergency start activation timestamp
62EST	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

Section 8 Measurement functions

8.1 Basic measurements

8.1.1 Functions

The single-phase power and energy measurement SPEMMXU and the three-phase power and energy measurement PEMMXU are used for monitoring and metering the active power (P), reactive power (Q), apparent power (S), power factor (PF) and for calculating the accumulated energy separately as forward active, reversed active, forward reactive and reversed reactive. PEMMXU calculates these quantities by using the fundamental frequency phasors, that is, the DFT values of the measured phase current and phase voltage signals.

The three-phase current measurement function, IA, IB, IC, is used for monitoring and metering the phase currents of the power system.

The three-phase voltage measurement function, VA, VB, VC, is used for monitoring and metering the phase-to-phase voltages of the power system. The phase-to-ground voltages are also available in VA, VB, VC.

The ground current measurement function, IG, is used for monitoring and metering the ground current of the power system.

The ground voltage measurement function, VG, is used for monitoring and metering the ground voltage of the power system.

The sequence current measurement, I1, I2, I0, is used for monitoring and metering the phase sequence currents.

The sequence voltage measurement, V1, V2, V0, is used for monitoring and metering the phase sequence voltages.

The frequency measurement, FMMXU, is used for monitoring and metering the power system frequency.

The three-phase power and energy measurement P, E is used for monitoring and metering the active power P, reactive power Q, apparent power S, power factor PF and for calculating the accumulated energy separately as forward active, reverse active, forward reactive and reverse reactive. P, E calculates these quantities with the fundamental frequency phasors, that is, the DFT values of the measured phase current and phase voltage signals.

The information of the measured quantity is available for the operator both locally in LHMI and remotely to a network control center with communication.

8.1.2 Measurement functionality

The functions can be enabled or disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable.

Some of the measurement functions operate on two alternative measurement modes: "DFT" and "RMS". The measurement mode is selected with the *X Measurement mode* setting. Depending on the measuring function if the measurement mode cannot be selected, the measuring mode is "DFT".

Table 441: Zero point clamping limits

Function	Zero clamping limit
Three-phase current measurement (CMMXU)	1% of nominal (In)
Three-phase voltage measurement (VMMXU)	1% of nominal (Un)
Residual current measurement (RESCMMXU)	1% of nominal (In)
Residual voltage measurement (RESVMMXU)	1% of nominal (Un)
Phase sequence current measurement (CSMSQI)	1% of the nominal (In)
Phase sequence voltage measurement (VSMSQI)	1% of the nominal (Un)
The single-phase power and energy measurement (SPEMMXU)	1.5% of the nominal (Sn)
Three-phase power and energy measurement (PEMMXU)	1.5% of the nominal (Sn)

Demand value calculation

The demand value is calculated separately for each phase. The demand function is implemented by means of a function that calculates the linear average of the signal measured over a settable demand time interval. A new demand value is obtained once in a minute, indicating the analog signal demand over the demand time interval preceding the update time. The actual rolling demand values are stored in the memory until the value is updated at the end of the next time interval. The switching of the demand interval without the loss of data is done by storing the one minute demand values in the memory until the longest demand interval is available. The maximum demand values for each phase are recorded with time stamps. The recorded values are reset with a command.

The demand value calculation is only available in the three-phase current measurement function, IA, IB, IC.

Value reporting

The measurement functions are capable to report new values for network control center (SCADA system) based on the following functions:

- Zero point clamping
- Deadband supervision
- Limit value supervision

In the three-phase voltage measurement function, VA, VB, VC, the supervision functions are based on the phase-to-phase voltages. However, the phase-to-ground voltage values are also reported together with the phase-to-phase voltages.

Zero point clamping

A measured value under zero point clamping limit is forced to zero. This allows the noise in the input signal to be ignored. The active clamping function forces both the actual measurement value and the angle value of the measured signal to zero. In the three-phase or sequence measuring functions, each phase or sequence component has a separate zero point clamping function. The zero value detection operates so that, once the measured value exceeds or falls below the value of zero clamping limit, new values are reported.

Table 442: Zero point clamping limits

Function	Zero clamping limit
Three-phase current measurement (IA, IB, IC)	1%of nominal (In)
Three-phase voltage measurement (VA, VB, VC)	1% of nominal (Vn)
Ground current measurement (IG)	1% of nominal (In)
Ground voltage measurement (VG)	1% of nominal (Vn)
Phase sequence current measurement (I1, I2, I0)	1% of the nominal (In)
Phase sequence voltage measurement (V1, V2, V0)	1% of the nominal (Vn)
Three-phase power and energy measurement (P, E)	1.5% of the nominal (Sn)

Limit value supervision

The limit value supervision function indicates whether the measured value of `X_INST` exceeds or falls below the set limits. The measured value has the corresponding range information `X_RANGE` and has a value in the range of 0 to 4:

- 0: "normal"
- 1: "high"
- 2: "low"
- 3: "high-high"
- 4: "low-low"

The range information changes and the new values are reported.

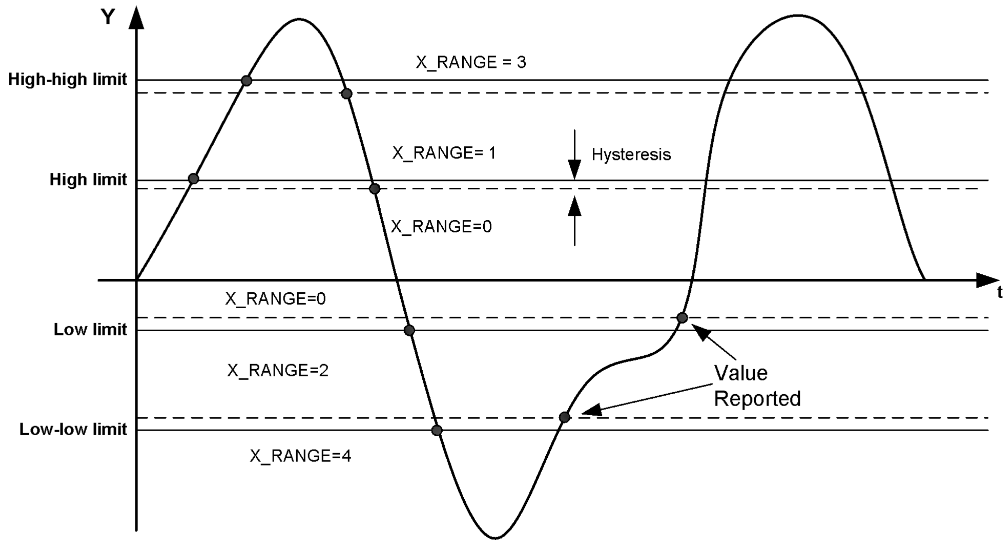

Figure 293: Presentation of operating limits

The range information can also be decoded into boolean output signals on some of the measuring functions and the number of phases required to exceed or undershoot the limit before activating the outputs and can be set with the *Num of phases* setting in the three-phase measurement functions, IA, IB, IC and VA, VB, VC. The limit supervision boolean alarm and warning outputs can be blocked. The settings involved for limit value supervision are :

Table 443: Settings for limit value supervision

Function	Settings for limit value supervision	
Three-phase current measurement (IA, IB, IC)	High limit	*A high limit*
	Low limit	*A low limit*
	High-high limit	*A high high limit*
	Low-low limit	*A low low limit*
Three-phase voltage measurement (VA, VB, VC)	High limit	*V high limit*
	Low limit	*V low limit*
	High-high limit	*V high high limit*
	Low-low limit	*V low low limit*
Ground current measurement (IG)	High limit	*A high limit res*
	Low limit	-
	High-high limit	*A Hi high limit res*
	Low-low limit	-
Ground voltage measurement (VG)	High limit	*V high limit res*
	Low limit	-
	High-high limit	*V Hi high limit res*
	Low-low limit	-
Phase sequence current measurement (I1, I2, I0)	High limit	*Ps Seq A high limit, Ng Seq A high limit, Zro A high limit*
	Low limit	*Ps Seq A low limit, Ng Seq A low limit, Zro A low limit*
	High-high limit	*Ps Seq A Hi high Lim, Ng Seq A Hi high Lim, Zro A Hi high Lim*
	Low-low limit	*Ps Seq A low low Lim, Ng Seq A low low Lim, Zro A low low Lim*
Phase sequence voltage measurement (V1, V2, V0)	High limit	*Ps Seq V high limit, Ng Seq V high limit, Zro V high limit*
	Low limit	*Ps Seq V low limit, Ng Seq V low limit, Zro V low limit*
	High-high limit	*Ps Seq V Hi high Lim, Ng Seq V Hi high Lim, Zro V Hi high Lim*
	Low-low limit	*Ps Seq V low low Lim, Ng Seq V low low Lim,*
Three-phase power and energy measurement (P, E)	High limit	-
	Low limit	-
	High-high limit	-
	Low-low limit	-

Deadband supervision

The deadband supervision function reports the measured value according to integrated changes over a time period.

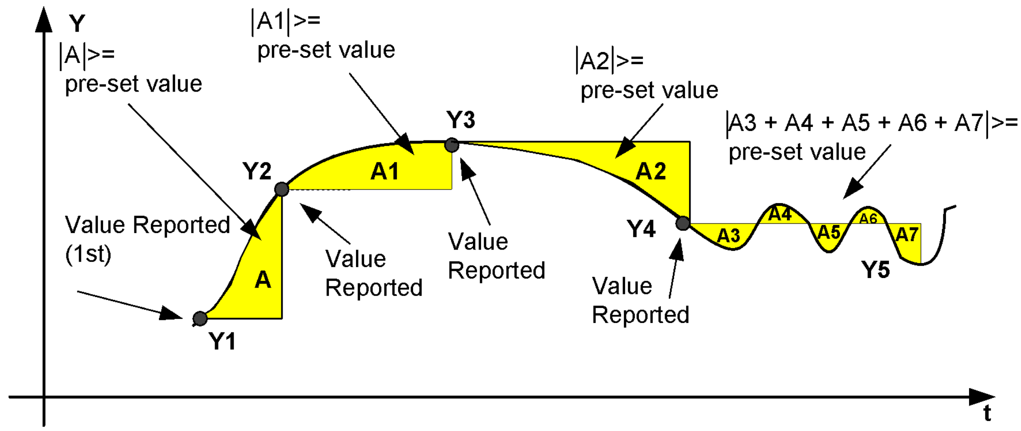

Figure 294: Integral deadband supervision

The deadband value used in the integral calculation is configured with the *X deadband* setting. The value represents the percentage of the difference between the maximum and minimum limit in the units of 0.001 percent * seconds.

The reporting delay of the integral algorithms in seconds is calculated with the formula:

$$t(s) = \frac{(\max - \min) \times deadband / 1000}{|\Delta Y| \times 100\%}$$

(Equation 60)

Example for IA, IB, IC:

A deadband = 2500 (2.5% of the total measuring range of 40)

`I_INST_A` = `I_DB_A` = 0.30

If `I_INST_A` changes to 0.40, the reporting delay is:

$$t(s) = \frac{(40 - 0) \times 2500 / 1000}{|0.40 - 0.30| \times 100\%} = 10s$$

Table 444: Parameters for deadband calculation

Function	Settings	Maximum/minimum (=range)
Three-phase current measurement (IA, IB, IC)	*A deadband*	40 / 0 (=40xIn)
Three-phase voltage measurement (VA, VB, VC)	*V Deadband*	4 / 0 (=4xVn)
Ground current measurement (IG)	*A deadband res*	40 / 0 (=40xIn)
Ground voltage measurement (VG)	*V deadband res*	4 / 0 (=4xVn)
Phase sequence current measurement (I1, I2, I0)	*Ps Seq A deadband, Ng Seq A deadband, Zro A deadband*	40 / 0 (=40xIn)
Phase sequence voltage measurement (V1, V2, V0)	*Ps Seq V deadband, Ng Seq V deadband, Zro V deadband*	4/0 (=4xVn)
Three-phase power and energy measurement (P, E)	-	

In the three-phase power and energy measurement function, P, E, the deadband supervision is done separately for apparent power S, with the pre-set value of fixed 10 percent of the Sn and the power factor PF, with the pre-set values fixed at 0.10. All the power measurement related values P, Q, S and PF are reported simultaneously when either one of the S or PF values exceeds the pre-set limit.

Power and energy calculation

The three-phase power is calculated from the phase-to-ground voltages and phase-to-grond currents. The power measurement function is capable of calculating complex power based on the fundamental frequency component phasors (DFT).

$$\overline{S} = (\overline{V}_A \cdot \overline{I}^*_A + \overline{V}_B \cdot \overline{I}^*_B + \overline{V}_C \cdot \overline{I}^*_C)$$

(Equation 61)

Once the complex apparent power is calculated, P, Q, S and PF are calculated with the equations:

$$Q = \mathrm{Im}(\overline{S})$$

(Equation 62)

$$Q = \mathrm{Im}(\overline{S})$$

(Equation 63)

$$S = \left|\overline{S}\right| = \sqrt{P^2 + Q^2}$$

(Equation 64)

$$Cos\varphi = \frac{P}{S}$$

(Equation 65)

Depending on the unit multiplier selected with *Power unit Mult*, the calculated power values are presented in units of kVA/kW/kVAr or in units of MVA/MW/MVAr.

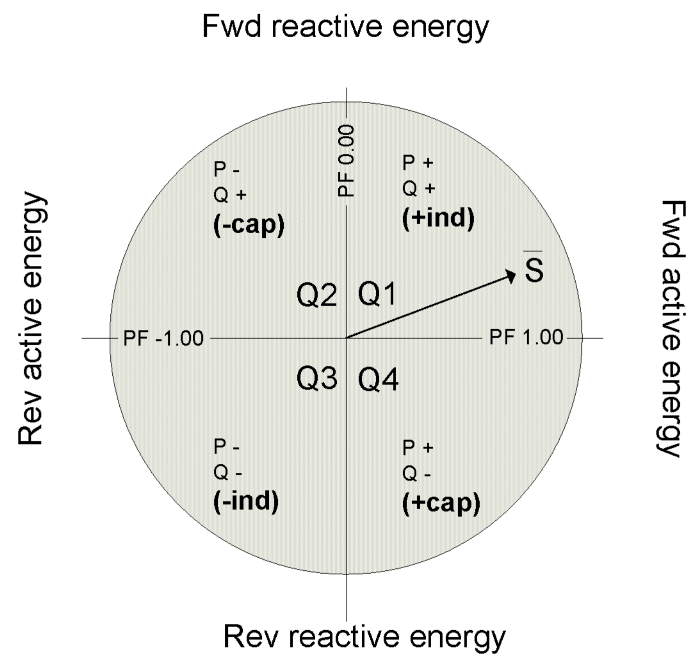

Figure 295: Complex power and power quadrants

Table 445: Power quadrants

Quadrant	Current	P	Q	PF	Power
Q1	Lagging	+	+	0…+1.00	+ind
Q2	Lagging	-	+	0…-1.00	-cap
Q3	Leading	-	-	0…-1.00	-ind
Q4	Leading	+	-	0…+1.00	+cap

The active power P direction can be selected between forward and reverse with *Active power Dir* and correspondingly the reactive power Q direction can be selected with *Reactive power Dir*. This affects also the accumulated energy directions.

The accumulated energy is calculated separately as forward active (`EA_FWD_ACM`), reverse active (`EA_RV_ACM`), forward reactive (`ER_FWD_ACM`) and reverse active (`ER_RV_ACM`). Depending on the value of the unit multiplier selected with *Energy unit Mult*, the calculated power values are presented in units of kWh/kVArh or in units of MWh/MVArh.

When the energy counter reaches its maximum value defined, the counter value is reset and restarted from the zero. Changing the value of the *Energy unit Mult* setting resets the accumulated energy values to the initial values, that is, `EA_FWD_ACM` to *Forward Wh Initial*, `EA_RV_ACM` to *Reverse Wh Initial*, `ER_FWD_ACM` to *Forward WArh Initial* and `ER_RV_ACM` to *Reverse WArh Initial*. It is also possible to reset the accumulated energy to initial values through a parameter or with the `RSTACM` input.

Sequence components

The phase-sequence current components are calculated from the phase currents according to:

$$\overline{I}_0 = (\overline{I}_A + \overline{I}_B + \overline{I}_C)/3$$

(Equation 66)

$$\overline{I}_1 = (\overline{I}_A + a \cdot \overline{I}_B + a^2 \cdot \overline{I}_C)/3$$

(Equation 67)

$$\overline{I}_2 = (\overline{I}_A + a^2 \cdot \overline{I}_B + a \cdot \overline{I}_C)/3$$

(Equation 78)

The phase-sequence voltage components are calculated from the phase-to-ground voltages when *VT connection* is selected as “Wye” with the formulae:

$$\overline{V}_0 = (\overline{V}_A + \overline{V}_B + \overline{V}_C)/3$$

(Equation69)

$$\overline{V}_1 = (\overline{V}_A + a \cdot \overline{V}_B + a^2 \cdot \overline{V}_C)/3$$

(Equation70)

$$\overline{V}_2 = (\overline{V}_A + a^2 \cdot \overline{V}_B + a \cdot \overline{V}_C)/3$$

(Equation 71)

When *VT connection* is selected as “Delta”, the positive and negative phase sequence voltage components are calculated from the phase-to-phase voltages according to the formulae:

$$\overline{V}_1 = (\overline{V}_{AB} - a^2 \cdot \overline{V}_{BC})/3$$

(Equation 72)

$$\overline{V}_2 = (\overline{V}_{AB} - a \cdot \overline{V}_{BC})/3$$

(Equation 73)

8.1.2.1 Limit value supervision

Table 446: Settings for limit value supervision

Function	Settings for limit value supervision	
Three-phase current measurement (CMMXU)	High limit	A high limit
	Low limit	A low limit
	High-high limit	A high high limit
	Low-low limit	A low low limit
Three-phase voltage measurement (VMMXU)	High limit	V high limit
	Low limit	V low limit
	High-high limit	V high high limit
	Low-low limit	V low low limit
Residual current measurement (RESCMMXU)	High limit	A high limit res
	Low limit	-
	High-high limit	A Hi high limit res
	Low-low limit	-
The frequency measurement (FMMXU)	High limit	F high limit
	Low limit	F low limit
	High-high limit	F high high limit
	Low-low limit	F low low limit
Residual voltage measurement (RESVMMXU)	High limit	V high limit res
	Low limit	-
	High-high limit	V Hi high limit res
	Low-low limit	-
Phase sequence current measurement (CSMSQI)	High limit	Ps Seq A high limit, Ng Seq A high limit, Zro A high limit
	Low limit	Ps Seq A low limit, Ng Seq A low limit, Zro A low limit
	High-high limit	Ps Seq A Hi high Lim, Ng Seq A Hi high Lim, Zro A Hi high Lim
	Low-low limit	Ps Seq A low low Lim, Ng Seq A low low Lim, Zro A low low Lim
Phase sequence voltage measurement (VSMSQI)	High limit	Ps Seq V high limit, Ng Seq V high limit, Zro V high limit
	Low limit	Ps Seq V low limit, Ng Seq V low limit, Zro V low limit
	High-high limit	Ps Seq V Hi high Lim, Ng Seq V Hi high Lim, Zro V Hi high Lim
	Low-low limit	Ps Seq V low low Lim, Ng Seq V low low Lim, Zro V low low Lim
Single-phase power and energy measurement (SPEMMXU)	High limit	-
	Low limit	-
	High-high limit	-
	Low-low limit	-
Three-phase power and energy measurement (PEMMXU)	High limit	-
	Low limit	-
	High-high limit	-
	Low-low limit	-

8.1.2.2 Deadband supervision

Table 447: Parameters for deadband calculation

Function	Settings	Maximum/minimum (=range)
Three-phase current measurement (CMMXU)	*A deadband*	40 / 0 (=40xIn)
Three-phase voltage measurement (VMMXU)	*V Deadband*	4 / 0 (=4xVn)
Residual current measurement (RESCMMXU)	*A deadband res*	40 / 0 (=40xIn)
Residual voltage measurement (RESVMMXU)	*V deadband res*	4 / 0 (=4xVn)
The frequency measurement (FMMXU)	F deadband	75 / 35 (=40Hz)
Phase sequence current measurement (CSMSQI)	Ps Seq A deadband, Ng Seq A deadband, Zro A deadband	40 / 0 (=40xIn)
Phase sequence voltage measurement (VSMSQI)	Ps Seq V deadband, Ng Seq V deadband, Zro V deadband	4/0 (=4xVn)
Single-phase power and energy measurement (SPEMMXU)	-	
Three-phase power and energy measurement (PEMMXU)	-	

In the power and energy measurement functions, SPEMMXU and PEMMXU, the deadband supervision is done separately for apparent power (S, with the pre-set value of fixed 10% of the Sn) and the power factor (PF, with the pre-set values of fixed 0.10). All of the power measurement related values: P, Q, S and PF are reported simultaneously when either one of the S or PF values exceed the pre-set limit.

8.1.2.3 Power and energy calculation

The single- and three-phase power is calculated from the phase-to-ground voltages and phase-to-ground currents. Power measurement function is capable of calculating complex power based on the fundamental frequency component phasors (DFT) as following:

$$\overline{S} = (\overline{U}_A \cdot \overline{I}^*_A + \overline{U}_B \cdot \overline{I}^*_B + \overline{U}_C \cdot \overline{I}^*_C)$$

8.1.3 Measurement function applications

The measurement functions are used for power system measurement, supervision and reporting to LHMI, a monitoring tool within PCM600, or to the station level, for example, with IEC 61850. The possibility to continuously monitor the measured values of active power, reactive power, currents, voltages, power factors and so on, is vital for efficient production, transmission, and distribution of electrical energy. It provides a fast and easy overview of the present status of the power system to the system operator. Additionally, it can be used during testing and commissioning of protection and control IEDs to verify the proper operation and connection of instrument transformers, that is, the current transformers (CTs) and voltage transformers (VTs). The proper operation of the IED analog measurement chain can be verified during normal service by a periodic comparison of the measured value from the IED to other independent meters.

When the zero signal is measured, the noise in the input signal can still produce small measurement values. The zero point clamping function can be used to ignore the noise in the input signal and, hence, prevent the noise to be shown in the user display. The zero clamping is done for the measured analog signals and angle values.

The demand values are used to neglect sudden changes in the measured analog signals when monitoring long time values for the input signal. The demand values are linear average values of the measured signal over a settable demand interval. The demand values are calculated for the measured analog three-phase current signals.

The limit supervision indicates, if the measured signal exceeds or goes below the set limits. Depending on the measured signal type, up to two high limits and up to two low limits can be set for the limit supervision.

The deadband supervision reports a new measurement value if the input signal has gone out of the deadband state. The deadband supervision can be used in value reporting between the measurement point and operation control. When the deadband supervision is properly configured, it helps in keeping the communication load in minimum and yet measurement values are reported frequently enough.

8.2 Three-phase current measurement, IA, IB, IC

8.2.0.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase current	CMMXU	3I	IA, IB, IC

8.2.0.2 Function block

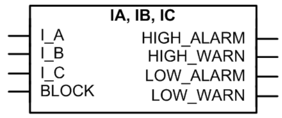

Figure 296: Function block

8.2.0.3 Signals

Table 448: IA,IB,IC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 449: IA,IB,IC Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning
LOW_WARN	BOOLEAN	Low warning
LOW_ALARM	BOOLEAN	Low alarm

8.2.0.4 Settings

Table 450: IA,IB,IC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
Num of phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required by limit supervision
Demand interval	0=1 minute 1=5 minutes 2=10 minutes 3=15 minutes 4=30 minutes 5=60 minutes 6=180 minutes			0=1 minute	Time interval for demand calculation
A high high limit	0.00...40.00	xIn		1.40	High alarm current limit
A high limit	0.00...40.00	xIn		1.20	High warning current limit
A low limit	0.00...40.00	xIn		0.00	Low warning current limit
A low low limit	0.00...40.00	xIn		0.00	Low alarm current limit
A deadband	100...100000			2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.2.0.5 Monitored data

Table 451: IA,IB,IC Monitored data

Name	Type	Values (Range)	Unit	Description
IA-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase A
IB-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase B
IC-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase C
Max demand phA	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase A
Max demand phB	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase B
Max demand phC	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase C
Time max demand phA	Timestamp			Time of maximum demand phase A
Time max demand phB	Timestamp			Time of maximum demand phase B
Time max demand phC	Timestamp			Time of maximum demand phase C
I_INST_A	FLOAT32	0.00...40.00	xIn	IA Amplitude, magnitude of instantaneous value
I_DB_A	FLOAT32	0.00...40.00	xIn	IA Amplitude, magnitude of reported value
I_DMD_A	FLOAT32	0.00...40.00	xIn	Demand value of IA current
I_RANGE_A	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IA Amplitude range
I_INST_B	FLOAT32	0.00...40.00	xIn	IB Amplitude, magnitude of instantaneous value
I_DB_B	FLOAT32	0.00...40.00	xIn	IB Amplitude, magnitude of reported value
I_DMD_B	FLOAT32	0.00...40.00	xIn	Demand value of IB current
I_RANGE_B	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IB Amplitude range
I_INST_C	FLOAT32	0.00...40.00	xIn	IC Amplitude, magnitude of instantaneous value
I_DB_C	FLOAT32	0.00...40.00	xIn	IC Amplitude, magnitude of reported value
I_DMD_C	FLOAT32	0.00...40.00	xIn	Demand value of IC current
I_RANGE_C	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IC Amplitude range

8.2.0.6 Technical data

Table 452: IA, IB, IC Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	±0.5% or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.3 Sequence current measurement, I1, I2, I0

8.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence current	CSMSQI	I1, I2, I0	I1, I2, I0

8.3.2 Function block

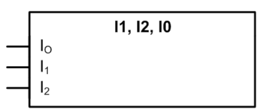

Figure 297: Function block

8.3.3 Signals

Table 453: I1, I2, I0 Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Zero sequence current
I_1	SIGNAL	0	Positive sequence current
I_2	SIGNAL	0	Negative sequence current

8.3.4 Settings

Table 454: I1, I2, I0 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Ps Seq A Hi high Lim	0.00...40.00	xIn		1.40	High alarm current limit for positive sequence current
Ps Seq A high limit	0.00...40.00	xIn		1.20	High warning current limit for positive sequence current
Ps Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for positive sequence current
Ps Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for positive sequence current
Ps Seq A deadband	100...100000			2500	Deadband configuration value for positive sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)
Ng Seq A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for negative sequence current
Ng Seq A High limit	0.00...40.00	xIn		0.05	High warning current limit for negative sequence current
Ng Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for negative sequence current
Ng Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for negative sequence current
Ng Seq A deadband	100...100000			2500	Deadband configuration value for negative sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)
Zro A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for zero sequence current
Zro A High limit	0.00...40.00	xIn		0.05	High warning current limit for zero sequence current
Zro A low limit	0.00...40.00	xIn		0.00	Low warning current limit for zero sequence current
Zro A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for zero sequence current
Zro A deadband	100...100000			2500	Deadband configuration value for zero sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.3.5 Monitored data

Table 455: I1, I2, I0 Monitored data

Name	Type	Values (Range)	Unit	Description
I2-A	FLOAT32	0.00...40.00	xIn	Measured negative sequence current
I1-A	FLOAT32	0.00...40.00	xIn	Measured positive sequence current
I0-A	FLOAT32	0.00...40.00	xIn	Measured zero sequence current
I2_INST	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, instantaneous value
I2_DB	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, reported value
I2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence current amplitude range
I1_INST	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, instantaneous value
I1_DB	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, reported value
I1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence current amplitude range
I0_INST	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, instantaneous value
I0_DB	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, reported value
I0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence current amplitude range

8.3.6 Technical data

Table 456: I1, I2, I0 Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±1.0% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.4 Residual current measurement, IG

8.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Neutral current	RESCMMXU	I0	IG

8.4.2 Function block

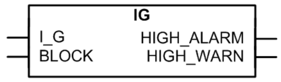

Figure 298: Function block

8.4.3 Signals

Table 457: IG Input signals

Name	Type	Default	Description
IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 458: IG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.4.4 Settings

Table 459: IG Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
A Hi high limit res	0.00...40.00	xIn		0.20	High alarm current limit
A high limit res	0.00...40.00	xIn		0.05	High warning current limit
A deadband res	100...100000			2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.4.5 Monitored data

Table 460: IG Monitored data

Name	Type	Values (Range)	Unit	Description
IG-A	FLOAT32	0.00...40.00	xIn	Measured ground current
IG_INST	FLOAT32	0.00...40.00	xIn	Ground current Amplitude, magnitude of instantaneous value
IG_DB	FLOAT32	0.00...40.00	xIn	Ground current Amplitude, magnitude of reported value
IG_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Ground current Amplitude range

8.4.6 Technical data

Table 461: IG Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±0.5% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.5 Three-phase voltage measurement, VA, VB, VC

8.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase voltage	VMMXU	3U	VA, VB, VC

8.5.2 Function block

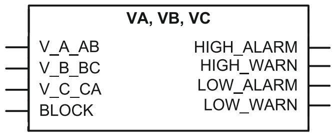

Figure 299: Function block

8.5.3 Signals

Table 462: VA, VB, VC Input signals

Name	Type	Default	Description
V_A_AB	SIGNAL	0	Phase A voltage
V_B_BC	SIGNAL	0	Phase B voltage
V_C_CA	SIGNAL	0	Phase C voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 463: VA, VB, VC Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning
LOW_WARN	BOOLEAN	Low warning
LOW_ALARM	BOOLEAN	Low alarm

8.5.4 Settings

Table 464: VA, VB, VC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
Num of phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required by limit supervision
V high high limit	0.00...4.00	xVn		1.40	High alarm voltage limit
V high limit	0.00...4.00	xVn		1.20	High warning voltage limit
V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit
V low low limit	0.00...4.00	xVn		0.00	Low alarm voltage limit
V deadband	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.5.5 Monitored data

Table 465: VA, VB, VC Monitored data

Name	Type	Values (Range)	Unit	Description
VAB-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase AB
VBC-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase B
VCA-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase C
V_INST_AB	FLOAT32	0.00...4.00	xVn	VAB Amplitude, magnitude of instantaneous value
V_DB_AB	FLOAT32	0.00...4.00	xVn	VAB Amplitude, magnitude of reported value
V_RANGE_AB	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VAB Amplitude range
V_INST_BC	FLOAT32	0.00...4.00	xVn	VBC Amplitude, magnitude of instantaneous value
V_DB_BC	FLOAT32	0.00...4.00	xVn	VBC Amplitude, magnitude of reported value
V_RANGE_BC	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VBC Amplitude range
V_INST_CA	FLOAT32	0.00...4.00	xVn	VCA Amplitude, magnitude of instantaneous value
V_DB_CA	FLOAT32	0.00...4.00	xVn	VCA Amplitude, magnitude of reported value
V_RANGE_CA	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VCA Amplitude range
V_INST_A	FLOAT32	0.00...4.00	xVn	VA Amplitude, magnitude of instantaneous value
V_INST_B	FLOAT32	0.00...4.00	xVn	VB Amplitude, magnitude of instantaneous value
V_INST_C	FLOAT32	0.00...4.00	xVn	VC Amplitude, magnitude of instantaneous value

8.5.6 Technical data

Table 466: VA, VB, VC Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz At voltages in range 0.01…1.15 x V_n
	±0.5% or ±0.002 x V_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.6 Sequence voltage measurement, V1, V2, V0

8.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence voltage	VSMSQI	U1, U2, U0	V1, V2, V0

8.6.2 Function block

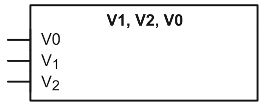

Figure 300: Function block

8.6.3 Signals

Table 467: V1, V2, V0 Input signals

Name	Type	Default	Description
V_0	SIGNAL	0	Zero sequence voltage
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage

8.6.4 Settings

Table 468: V1, V2, V0 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Ps Seq V Hi high Lim	0.00...4.00	xVn		1.40	High alarm voltage limit for positive sequence voltage
Ps Seq V high limit	0.00...4.00	xVn		1.20	High warning voltage limit for positive sequence voltage
Ps Seq V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for positive sequence voltage
Ps Seq V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for positive sequence voltage
Ps Seq V deadband	100...100000			10000	Deadband configuration value for positive sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)
Ng Seq V Hi high Lim	0.00...4.00	xVn		0.20	High alarm voltage limit for negative sequence voltage
Ng Seq V High limit	0.00...4.00	xVn		0.05	High warning voltage limit for negative sequence voltage
Ng Seq V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for negative sequence voltage
Ng Seq V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for negative sequence voltage
Ng Seq V deadband	100...100000			10000	Deadband configuration value for negative sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)
Zro V Hi high Lim	0.00...4.00	xVn		0.20	High alarm voltage limit for zero sequence voltage
Zro V High limit	0.00...4.00	xVn		0.05	High warning voltage limit for zero sequence voltage
Zro V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for zero sequence voltage
Zro V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for zero sequence voltage
Zro V deadband	100...100000			10000	Deadband configuration value for zero sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.6.5 Monitored data

Table 469: V1, V2, V0 Monitored data

Name	Type	Values (Range)	Unit	Description
V2-kV	FLOAT32	0.00...4.00	xVn	Measured negative sequence voltage
V1-kV	FLOAT32	0.00...4.00	xVn	Measured positive sequence voltage
V0-kV	FLOAT32	0.00...4.00	xVn	Measured zero sequence voltage
V2_INST	FLOAT32	0.00...4.00	xVn	Negative sequence voltage amplitude, instantaneous value
V2_DB	FLOAT32	0.00...4.00	xVn	Negative sequence voltage amplitude, reported value
V2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence voltage amplitude range
V1_INST	FLOAT32	0.00...4.00	xVn	Positive sequence voltage amplitude, instantaneous value
V1_DB	FLOAT32	0.00...4.00	xVn	Positive sequence voltage amplitude, reported value
V1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence voltage amplitude range
V0_INST	FLOAT32	0.00...4.00	xVn	Zero sequence voltage amplitude, instantaneous value
V0_DB	FLOAT32	0.00...4.00	xVn	Zero sequence voltage amplitude, reported value
V0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence voltage amplitude range

8.6.6 Technical data

Table 470: V1, V2, V0 Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz At voltages in range 0.01…1.15 x V_n
	±1.0% or ±0.002 x V_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.7 Residule voltage measurement, VG

8.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Ground voltage	RESVMMXU	U0	VG

8.7.2 Function block

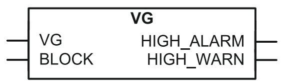

Figure 301: Function block

8.7.3 Signals

Table 471: VG Input signals

Name	Type	Default	Description
VG	SIGNAL	0	Ground voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 472: VG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.7.4 Settings

Table 473: VG Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
V Hi high limit res	0.00...4.00	xVn		0.20	High alarm voltage limit
V high limit res	0.00...4.00	xVn		0.05	High warning voltage limit
V deadband res	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.7.5 Monitored data

Table 474: VG Monitored data

Name	Type	Values (Range)	Unit	Description
VG-kV	FLOAT32	0.00...4.00	xVn	Measured ground voltage
VG_INST	FLOAT32	0.00...4.00	xVn	Ground voltage Amplitude, magnitude of instantaneous value
VG_DB	FLOAT32	0.00...4.00	xVn	xVnGround voltage Amplitude, magnitude of reported value
VG_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Ground voltage Amplitude range

8.7.6 Technical data

Table 475: VG Technical data

Characteristic	Value
Pickup accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±0.5% or ±0.002 x V_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.8 Three-phase power and energy measurement, P.E

8.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase power and energy measurement	PEMMXU	P, E	P, E

8.8.2 Function block

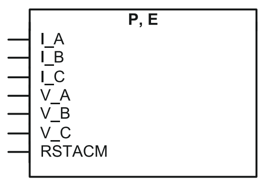

Figure 302: Function block

8.8.3 Signals

Table 476: P,E Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
V_A	SIGNAL	0	Phase A voltage
V_B	SIGNAL	0	Phase B voltage
V_C	SIGNAL	0	Phase C voltage
RSTACM	BOOLEAN	0=False	Reset of accumulated energy reading

8.8.4 Settings

Table 477: P,E Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Power unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the power related values
Energy unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the energy related values
Active power Dir	1=Forward 2=Reverse			1=Forward	Direction of active power flow: Forward, Reverse
Reactive power Dir	1=Forward 2=Reverse			1=Forward	Direction of reactive power flow: Forward, Reverse
Forward Wh Initial	0...999999999		1	0	Preset Initial value for forward active energy
Reverse Wh Initial	0...999999999		1	0	Preset Initial value for reverse active energy
Forward WArh Initial	0...999999999		1	0	Preset Initial value for forward reactive energy
Reverse WArh Initial	0...999999999		1	0	Preset Initial value for reverse reactive energy

8.8.5 Monitored data

Table 478: P,E Monitored data

Name	Type	Values (Range)	Unit	Description
S-kVA	FLOAT32	-999999.9...999999.9	kVA	Total Apparent Power
P-kW	FLOAT32	-999999.9...999999.9	kW	Total Active Power
Q-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Total Reactive Power
PF	FLOAT32	-1.00...1.00		Average Power factor
S_INST	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value
S_DB	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value
P_INST	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value
P_DB	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value
Q_INST	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value
Q_DB	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value
PF_INST	FLOAT32	-1.00...1.00		Power factor, magnitude of instantaneous value
PF_DB	FLOAT32	-1.00...1.00		Power factor, magnitude of reported value
EA_RV_ACM	INT128	0...999999999	kWh	Accumulated reverse active energy value
ER_RV_ACM	INT128	0...999999999	kVArh	Accumulated reverse reactive energy value
EA_FWD_ACM	INT128	0...999999999	kWh	Accumulated forward active energy value
ER_FWD_ACM	INT128	0...999999999	kVArh	Accumulated forward reactive energy value

8.8.6 Technical data

Table 479: P, E Technical data

Characteristic	Value
Pickup accuracy	At all three currents in range 0.10…1.20 x I_n At all three voltages in range 0.50…1.15 x V_n At the frequency f_n ±1Hz Active power and energy in range |PF| > 0.71 Reactive power and energy in range |PF| < 0.71
	±1.5% for power (S, P and Q) ±0.015 for power factor ±1.5% for energy
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.9 Single-phase power and energy measurement

8.9.1 Identification

Function description	IEC 61850 Identification	IEC 60617 Identification	ANSI/IEEE C37.2 device number
Single-phase power and energy measurement	SPEMMXU	SP, SE	SP, SE

8.9.2 Function block

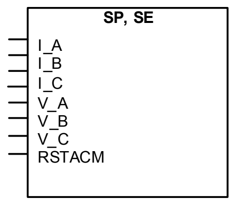

Figure 303: Function block

8.9.3 Signals

Table 480: SP, SE Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
V_A	SIGNAL	0	Phase A voltage
V_B	SIGNAL	0	Phase B voltage
V_C	SIGNAL	0	Phase C voltage
RSTACM	BOOLEAN	0=False	Reset of accumulated energy reading

8.9.4 Settings

Table 481: SP, SE Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1= enable 5= disable			1=enable	Operation Disable / Enable
Power unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the power related values.
Energy unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the energy related values.
Active power Dir	1=Forward 2=Reverse			1=Forward	Direction of active power flow: Forward, Reverse
Reactive power Dir	1=Forward 2=Reverse			1=Forward	Direction of reactive power flow: Forward, Reverse
Forward Wh Initial	0...999999999		1	0	Preset Initial value for forward active energy
Reverse Wh Initial	0...999999999		1	0	Preset Initial value for reverse active energy
Forward VArh Initial	0...999999999		1	0	Preset Initial value for forward reactive energy
Reverse VArh Initial	0...999999999		1	0	Preset Initial value for reverse reactive energy

8.9.5 Monitored data

Table 482: SP, SE Monitored data

Name	Type	Values (Range)	Unit	Description
SA-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase A
SB-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase B
SC-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase C
PA-kW	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase A
PB-kW	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase B
PC-kW	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase C
QA-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase A
QB-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase B
QC-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase C
PFA	FLOAT32	-1.00…1.00		Power factor, magnitude of instantaneous value, Phase A
PFB	FLOAT32	-1.00…1.00		Power factor, magnitude of instantaneous value, Phase B
PFC	FLOAT32	-1.00…1.00		Power factor, magnitude of instantaneous value, Phase C
Max demand SL1	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase A
Max demand SL2	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase B
Max demand SL3	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase C
Min demand SL1	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase A
Min demand SL2	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase B
Min demand SL3	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase C
Max demand PL1	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase A
Max demand PL2	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase B
Table continued on next page				

Name	Type	Values (Range)	Unit	Description
Max demand PL3	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase C
Min demand PL1	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase A
Min demand PL2	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase B
Min demand PL3	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase C
Max demand QL1	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase A
Max demand QL2	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase B
Max demand QL3	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase C
Min demand QL1	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase A
Min demand QL2	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase B
Min demand QL3	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase C
Time max dmd SL1	Timestamp			Time of maximum demand phase A
Time max dmd SL2	Timestamp			Time of maximum demand phase B
Time max dmd SL3	Timestamp			Time of maximum demand phase C
Time max dmd PL1	Timestamp			Time of maximum demand phase A
Time max dmd PL2	Timestamp			Time of maximum demand phase B
Time max dmd PL3	Timestamp			Time of maximum demand phase C
Time max dmd QL1	Timestamp			Time of maximum demand phase A
Time max dmd QL2	Timestamp			Time of maximum demand phase B
Time max dmd QL3	Timestamp			Time of maximum demand phase C
Time min dmd SL1	Timestamp			Time of minimum demand phase A
Time min dmd SL2	Timestamp			Time of minimum demand phase B
Time min dmd SL3	Timestamp			Time of minimum demand phase C
Time min dmd PL1	Timestamp			Time of minimum demand phase A
Time min dmd PL2	Timestamp			Time of minimum demand phase B
Time min dmd PL3	Timestamp			Time of minimum demand phase C
Time min dmd QL1	Timestamp			Time of minimum demand phase A
Time min dmd QL2	Timestamp			Time of minimum demand phase B
Time min dmd QL3	Timestamp			Time of minimum demand phase C
S_INST_A	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase A
S_INST_B	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase B
S_INST_C	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value, Phase C
S_DB_A	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value, Phase A
S_DB_B	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value, Phase B
S_DB_C	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value, Phase C
S_DMD_A	FLOAT32	-999999.9...999999.9	kVA	Demand value of apparent Power, Phase A
S_DMD_B	FLOAT32	-999999.9...999999.9	kVA	Demand value of apparent Power, Phase B
S_DMD_C	FLOAT32	-999999.9...999999.9	kVA	Demand value of apparent Power, Phase C
P_INST_A	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase A
P_INST_B	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase B

Table continued on next page

Name	Type	Values (Range)	Unit	Description
P_INST_C	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value, Phase C
P_DB_A	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value, Phase A
P_DB_B	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value, Phase B
P_DB_C	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value, Phase C
P_DMD_A	FLOAT32	-999999.9...999999.9	kW	Demand value of active Power, Phase A
P_DMD_B	FLOAT32	-999999.9...999999.9	kW	Demand value of active Power, Phase B
P_DMD_C	FLOAT32	-999999.9...999999.9	kW	Demand value of active Power, Phase C
Q_INST_A	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase A
Q_INST_B	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase B
Q_INST_C	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value, Phase C
Q_DB_A	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value, Phase A
Q_DB_B	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value, Phase B
Q_DB_C	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value, Phase C
Q_DMD_A	FLOAT32	-999999.9...999999.9	kVAr	Demand value of reactive Power, Phase A
Q_DMD_B	FLOAT32	-999999.9...999999.9	kVAr	Demand value of reactive Power, Phase B
Q_DMD_C	FLOAT32	-999999.9...999999.9	kVAr	Demand value of reactive Power, Phase C
PF_INST_A	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of instantaneous value, Phase A
PF_INST_B	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of instantaneous value, Phase B
PF_INST_C	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of instantaneous value, Phase C
PF_DB_A	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of reported value, Phase A
PF_DB_B	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of reported value, Phase B
PF_DB_C	FLOAT32	-999999.9...999999.9	kVAr	Power factor, magnitude of reported value, Phase C
PF_DMD_A	FLOAT32	-999999.9...999999.9	kVAr	Demand value of power factor, Phase A
PF_DMD_B	FLOAT32	-999999.9...999999.9	kVAr	Demand value of power factor, Phase B
PF_DMD_C	FLOAT32	-999999.9...999999.9	kVAr	Demand value of power factor, Phase C
EA_RV_ACM_A	INT128	0...999999999	kWh	Accumulated reverse active energy value, Phase A
EA_RV_ACM_B	INT128	0...999999999	kWh	Accumulated reverse active energy value, Phase B
EA_RV_ACM_C	INT128	0...999999999	kWh	Accumulated reverse active energy value, Phase C
ER_RV_ACM_A	INT128	0...999999999	kWh	Accumulated reverse reactive energy value, Phase A
ER_RV_ACM_B	INT128	0...999999999	kWh	Accumulated reverse reactive energy value, Phase B
ER_RV_ACM_C	INT128	0...999999999	kWh	Accumulated reverse reactive energy value, Phase C
EA_FWD_ACM_A	INT128	0...999999999	kWh	Accumulated forward active energy value, Phase A
EA_FWD_ACM_B	INT128	0...999999999	kWh	Accumulated forward active energy value, Phase B
EA_FWD_ACM_C	INT128	0...999999999	kWh	Accumulated forward active energy value, Phase C
ER_FWD_ACM_A	INT128	0...999999999	kWh	Accumulated forward reactive energy value, Phase A
ER_FWD_ACM_B	INT128	0...999999999	kWh	Accumulated forward reactive energy value, Phase B
ER_FWD_ACM_C	INT128	0...999999999	kWh	Accumulated forward reactive energy value, Phase C

8.9.6 Technical data

Table 483: SP SE Technical data

Characteristic	Value
Pickup accuracy	At all three currents in rage 0.10…1.20 x In At all three voltages in range 0.50…1.15 x Vn At the frequency fn ± 1Hz Active power and energy in range |PF| > 0.71 Reactive power and energy in range |PF| < 0.71
	± 1.5% for power (S, P and Q) ± 0.015 for power factor ± 1.5% for energy
Suppression of harmonics	DFT: -50 dB at f = n x fn, where n = 2, 3, 4, 5,…

8.10 Current total demand distortion, PQI

8.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current total demand distortion	CMHAI	PQM3I	PQI

8.10.2 Function block

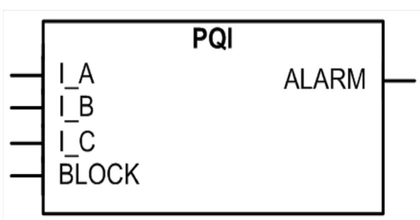

Figure 304: Function block

8.10.3 Functionality

The Current total demand distortion PQI is used for monitoring the current total demand distortion TDD.

8.10.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are Enable and Disable.

The operation of the current distortion monitoring function can be described with a module diagram. All the modules in the diagram are explained in the next sections.

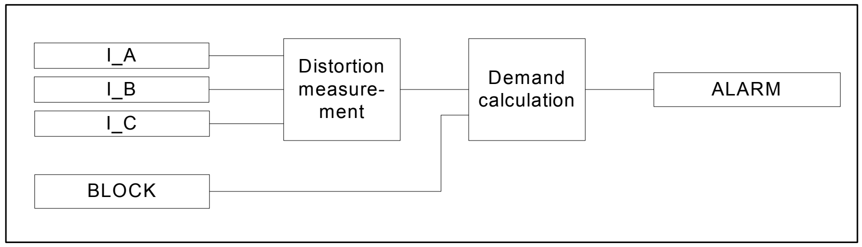

Figure 305: Functional module diagram

8.10.4.1 Distortion measurement

The distortion measurement module measures harmonics up to the 11th harmonic. The total demand distortion TDD is calculated from the measured harmonic components with the formula:

$$TDD = \frac{\sqrt{\sum_{k=2}^{N} I_k^2}}{I_{\max\_demand}}$$

(Equation 74)

I_k k^{th} harmonic component

I_{max_demand} The maximum demand current measured by IA, IB, IC

If IA, IB, IC are not available in the configuration or the measured maximum demand current is less than the *Initial Dmd current* setting, *Initial Dmd current* is used for I_{max_demand}.

8.10.4.2 Demand calculation

The demand value for TDD is calculated separately for each phase. If any of the calculated total demand distortion values is above the set alarm limit *TDD alarm limit*, the ALARM output is activated.

The demand calculation window is set with the *Demand interval* setting. It has seven window lengths from "1 minute" to "180 minutes". The window type can be set with the *Demand window* setting. The available options are "Sliding" and "Nonsliding".

The activation of the BLOCK input blocks the ALARM output.

8.10.4.3 Application

In standards, the power quality is defined through the characteristics of the supply voltage. Transients, short-duration and long-duration voltage variations, unbalance and waveform distortions are the key characteristics describing power quality. Power quality is, however, a customer-driven issue. It could be said that any power problem concerning voltage or current that results in a failure or misoperation of customer equipment is a power quality problem.

Harmonic distortion in a power system is caused by nonlinear devices. Electronic power converter loads constitute the most important class of nonlinear loads in a power system. The switch mode power supplies in a number of single-phase electronic equipment, such as personal computers, printers and copiers, have a very high third-harmonic content in the current. Three-phase electronic power converters, that is, dc/ac drives, however, do not generate third-harmonic currents. Still, they can be significant sources of harmonics.

Power quality monitoring is an essential service that utilities can provide for their industrial and key customers. Not only can a monitoring system provide information about system disturbances and their possible causes, it can also detect problem conditions throughout the system before they cause customer complaints, equipment malfunctions and even equipment damage or failure. Power quality problems are not limited to the utility side of the system. In fact, the majority of power quality problems are localized within customer facilities. Thus, power quality monitoring is not only an effective customer service strategy but also a way to protect a utility's reputation for quality power and service.

PQI provides a method for monitoring the power quality by means of the current waveform distortion. PQI provides a short-term 3-second average and a long-term demand for TDD.

8.10.5 Signals

Table 484: CMHAI Input signals

Name	Type	Default	Description
I_A	Signal	0	Phase A current
I_B	Signal	0	Phase B current
I_C	Signal	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 485: CMHAI Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm signal for TDD

8.10.6 Settings

Table 486: CMHAI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation
Demand interval	0=1 minute 1=5 minutes 2=10 minutes 3=15 minutes 4=30 minutes 5=60 minutes 6=180 minutes			2=10 minutes	Time interval for demand calculation
Demand window	1=Sliding 2=Non-sliding			1=Sliding	Demand calculation window type
TDD alarm limit	1.0...100.0	%	0.1	50.0	TDD alarm limit
Initial Dmd current	0.10...1.00	xIn	0.01	1.00	Initial demand current

8.10.7 Monitored data

Table 487: CMHAI Monitored data

Name	Type	Values (Range)	Unit	Description
Max demand TDD IA	FLOAT32	0.00...500.00	%	Maximum demand TDD for phase A
Max demand TDD IB	FLOAT32	0.00...500.00	%	Maximum demand TDD for phase B
Max demand TDD IC	FLOAT32	0.00...500.00	%	Maximum demand TDD for phase C
Time max dmd TDD IA	Timestamp			Time of maximum demand TDD phase A
Time max dmd TDD IB	Timestamp			Time of maximum demand TDD phase B
Time max dmd TDD IC	Timestamp			Time of maximum demand TDD phase C
3SMHTDD_A	FLOAT32	0.00...500.00	%	3 second mean value of TDD for phase A
DMD_TDD_A	FLOAT32	0.00...500.00	%	Demand value for TDD for phase A
3SMHTDD_B	FLOAT32	0.00...500.00	%	3 second mean value of TDD for phase B
DMD_TDD_B	FLOAT32	0.00...500.00	%	Demand value for TDD for phase B
3SMHTDD_C	FLOAT32	0.00...500.00	%	3 second mean value of TDD for phase C
DMD_TDD_C	FLOAT32	0.00...500.00	%	Demand value for TDD for phase C

8.11 Voltage total harmonic distortion, PQVPH

8.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage total harmonic distortion	VMHAI	PQM3U	PQVPH

8.11.2 Function Block

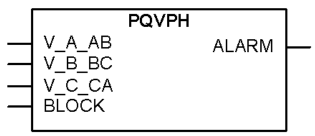

Figure 306: Function block

8.11.3 Functionality

The Voltage total harmonic distortion function PQVPH is used for monitoring the voltage total harmonic distortion THD.

8.11.4 Operation principle

The function can be enabled and disabled with the *Operation setting*. The corresponding parameter values are Enable and Disable.

The operation of the voltage distortion monitoring function can be described with a module diagram. All the modules in the diagram are explained in the next sections.

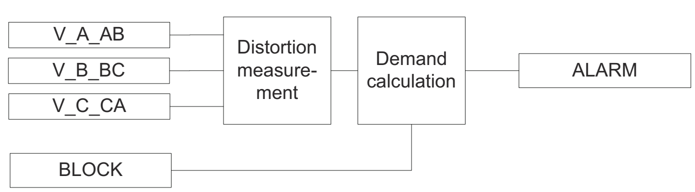

Figure 307: Functional module diagram

The distortion measurement module measures harmonics up to the 11^{th} harmonic. The total harmonic distortion THD for voltage is calculated from the measured harmonic components with the formula

$$THD = \frac{\sqrt{\sum_{k=2}^{N} V_k^2}}{V_1}$$

(Equation 75)

V_k k^{th} harmonic component

V_1 the voltage fundamental component amplitude

8.11.4.1 Demand calculation

The demand value for THD is calculated separately for each phase. If any of the calculated demand THD values is above the set alarm limit THD *alarm limit*, the ALARM output is activated.

The demand calculation window is set with the *Demand interval* setting. It has seven window lengths from "1 minute" to "180 minutes". The window type can be set with the *Demand window* setting. The available options are "Sliding" and "Nonsliding".

The activation of the BLOCK input blocks the ALARM output.

8.11.4.2 Application

PQVPH provides a method for monitoring the power quality by means of the voltage waveform distortion. PQVPH provides a short-term three-second average and long-term demand for THD.

8.11.5 Signals

Table 488: PQVPH

Name	Type	Default	Description
V_A_AB	SIGNAL	0	Phase-to-ground voltage A or phase-to-phase voltage AB
V_B_BC	SIGNAL	0	Phase-to-ground voltage B or phase-to-phase voltage BC
V_C_CA	SIGNAL	0	Phase-to-ground voltage C or phase-to-phase voltage CA
BLOCK	BOOLEAN	0 = FALSE	Block signal for all binary outputs

Table 489: PQVPH Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm signal for THD

8.11.6 Settings

Table 490: PQVPH Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Demand interval	0=1 minute 1=5 minutes 2=10 minutes 3=15 minutes 4=30 minutes 5=60 minutes 6=180 minutes			2=10 minutes	Time interval for demand calculation
Demand window	1=Sliding 2=Non-sliding			1=Sliding	Demand calculation window type
THD alarm limit	1.0...100.0	%	0.1	50.0	THD alarm limit

8.11.7 Monitored data

Table 491: PQVPH Monitored data

Name	Type	Values (Range)	Unit	Description
Max demand THD UL1	FLOAT32	0.00...500.00	%	Maximum demand THD for phase A
Max demand THD UL2	FLOAT32	0.00...500.00	%	Maximum demand THD for phase B
Max demand THD UL3	FLOAT32	0.00...500.00	%	Maximum demand THD for phase C
Time max dmd THD UL1	Timestamp			Time of maximum demand THD phase A
Time max dmd THD UL2	Timestamp			Time of maximum demand THD phase B
Time max dmd THD UL3	Timestamp			Time of maximum demand THD phase C
3SMHTHD_A	FLOAT32	0.00...500.00	%	3 second mean value of THD for phase A
DMD_THD_A	FLOAT32	0.00...500.00	%	Demand value for THD for phase A
3SMHTHD_B	FLOAT32	0.00...500.00	%	3 second mean value of THD for phase B
DMD_THD_B	FLOAT32	0.00...500.00	%	Demand value for THD for phase B
3SMHTHD_C	FLOAT32	0.00...500.00	%	3 second mean value of THD for phase C
DMD_THD_C	FLOAT32	0.00...500.00	%	Demand value for THD for phase C

8.12 Power Quality, PQSS

8.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage variation detection function	PHQVVR	PQ 3U<>	PQSS

8.12.2 Function block

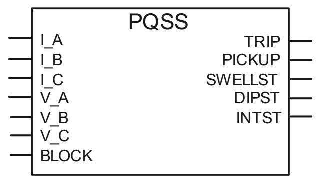

Figure 308: Function block

8.12.3 Functionality

The voltage variation measurement function PQSS is used for measuring the shortduration voltage variations in distribution networks.

Power quality in the voltage waveform is evaluated by measuring voltage swells, dips and interruptions. PQSS includes single-phase and three-phase voltage variation modes.

Typically, short-duration voltage variations are defined to last more than half of the nominal frequency period and less than one minute. The maximum magnitude (in the case of a voltage swell) or depth (in the case of a voltage dip or interruption) and the duration of the variation can be obtained by measuring the RMS value of the voltage for each phase. International standard 61000-4-30 defines the voltage variation to be implemented using the RMS value of the voltage. IEEE standard 1159-1995 provides recommendations for monitoring the electric power quality of the single-phase and polyphase ac power systems.

PQSS contains a blocking functionality. It is possible to block a set of function outputs or the function itself, if desired.

8.12.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are Enable and Disable.

The operation of the voltage variation detection function can be described with a module diagram. All the modules in the diagram are explained in the next sections

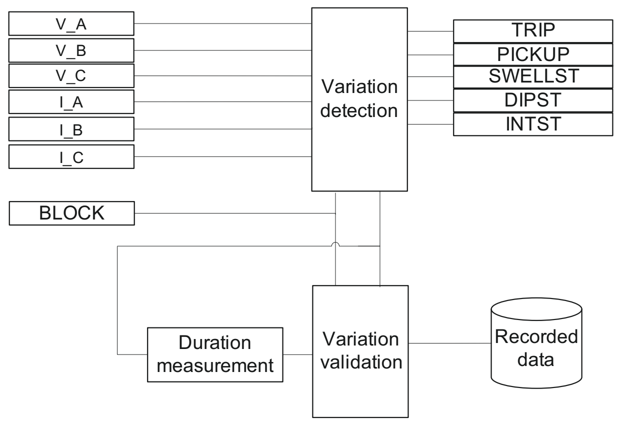

Figure 309: Functional module diagram

8.12.4.1 Phase mode setting

PQSS is designed for both single-phase and polyphase ac power systems and selection can be made with the Phase mode setting, which can be set either to the "Single Phase" or "Three Phase" mode. The default setting is "Single Phase".

The basic difference between these alternatives depends on how many phases are needed to have the voltage variation activated. When the Phase mode setting is "Single Phase", the activation is straightforward. There is no dependence between the phases for variation pickup. The PICKUP output and the corresponding phase pickup are activated when the limit is exceeded or undershot. The corresponding phase pickup deactivation takes place when the limit (includes small hysteresis) is undershot or exceeded. The PICKUP output is deactivated when there are no more active phases.

However, when Phase mode is "Three Phase", all the monitored phase signal magnitudes, defined with Phase supervision, have to fall below or rise above the limit setting to activate the PICKUP output and the corresponding phase output, that is, all the monitored phases have to be activated. Accordingly, the deactivation occurs when the activation requirement is not fulfilled, that is, one or more monitored phase signal magnitudes return beyond their limits. Phases do not need to be activated by the same variation type to activate the PICKUP output. Another consequence is that if only one or two phases are monitored, it is sufficient that these monitored phases activate the PICKUP output.

8.12.4.2 Variation detection

The module compares the measured voltage against the limit settings. If there is a permanent undervoltage or overvoltage, the Reference voltage setting can be set to this voltage level to avoid the undesired voltage dip or swell indications. This is accomplished by converting the variation limits with the Reference voltage setting in the variation detection module, that is, when there is a voltage different from the nominal voltage, the Reference voltage setting is set to this voltage.

The Variation enable setting is used for enabling or disabling the variation types. By default, the setting value is "Swell+dip+Int" and all the alternative variation types are indicated. For example, for setting "Swell+dip", the interruption detection is not active and only swell or dip events are indicated.

In a case where Phase mode is "Single Phase" and the dip functionality is available, the output DIPST is activated when the measured TRMS value drops below the Voltage dip set 3 setting in one phase and also remains above the Voltage Int set setting. If the voltage drops below the Voltage Int set setting, the output INTST is activated. INTST is deactivated when the voltage value rises above the setting Voltage Int set. When the same measured TRMS magnitude rises above the setting Voltage swell set 3, the SWELLST output is activated.

There are three setting value limits for dip (Voltage dip set 1.3) and swell activation (Voltage swell set 1..3) and one setting value limit for interruption.

If Phase mode is "Three Phase", the DIPST and INTST outputs are activated when the voltage levels of all monitored phases, defined with the parameter Phase supervision, drop below the Voltage Int set setting value. An example for the detection principle of voltage interruption for "Three Phase" when Phase supervision is "Ph A + B + C", and also the corresponding pickup signals when Phase mode is "Single Phase", are as shown in the example for the detection of a three-phase interruption.

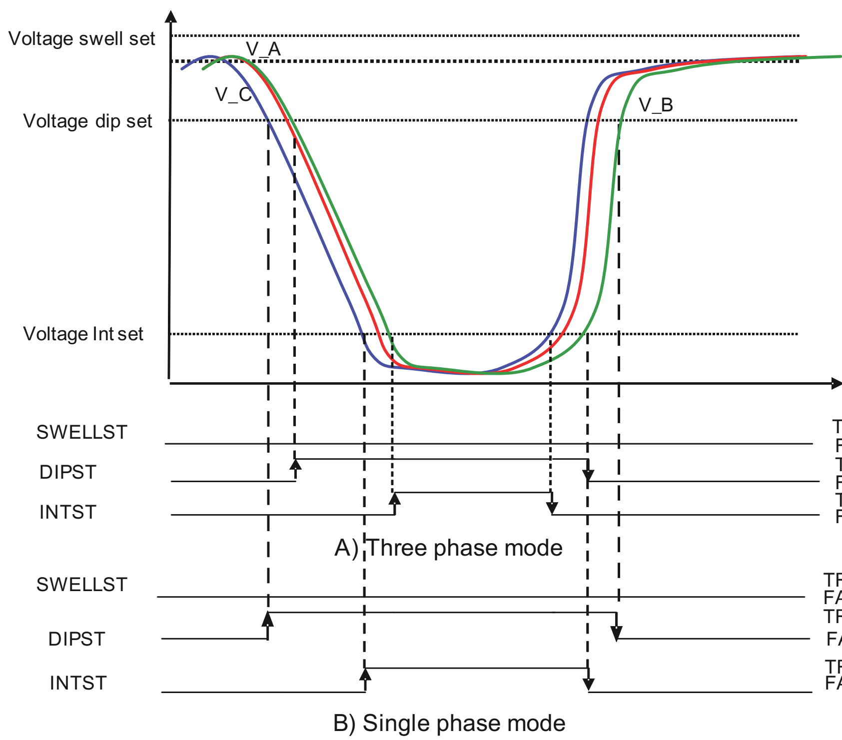

Figure 310: Detection of three-phase voltage interruption

The module measures voltage variation magnitude on each phase separately, that is, phase-segregated status for voltage variation indication is available in monitored data (PICKUP_A, PICKUP_B and PICKUP_C). The configuration parameter Phase supervision defines which voltage phase or phases are monitored. If a voltage phase is selected to be monitored, the function assumes it to be connected to a voltage measurement channel. In other words, if an unconnected phase is monitored, the function falsely detects a voltage interruption in that phase.

The maximum magnitude and depth are defined as percentage values calculated from the difference between the reference and the measured voltage. For example, a dip to 70 percent means that the minimum voltage dip magnitude variation is 70 percent of the reference dip voltage amplitude.

The activation of the BLOCK input resets the function and outputs.

8.12.4.3 Duration measurement

The duration of each voltage phase corresponds to the period during which the measured TRMS values remain above (swell) or below (dip, interruption) the corresponding limit.

Besides the three limit settings for the variation types dip and swell, there is also a specific duration setting for each limit setting. For interruption, there is only one limit setting common for the three duration settings. The maximum duration setting is common for all variation types.

The duration measurement module measures the voltage variation duration of each phase voltage separately when the Phase mode setting is "Single Phase". The phase variation durations are independent. However, when the Phase mode setting is "Three Phase", voltage variation may pick up only when all the monitored phases are active. An example of variation duration when Phase mode is "Single Phase" can be seen in Figure 311. The voltage variation in the example is detected as an interruption for the phase B and a dip for the phase A, and also the variation durations are interpreted as independent V_B and V_A durations. In case of singlephase interruption, the DIPST output is active when either PICKUP_A or PICKUP_B is active. The measured variation durations are the times measured between the activation of the PICKUP_A or PICKUP_B outputs and deactivation of the PICKUP_A or PICKUP_B outputs. When the Phase mode setting is "Three Phase", the example case does not result in any activation.

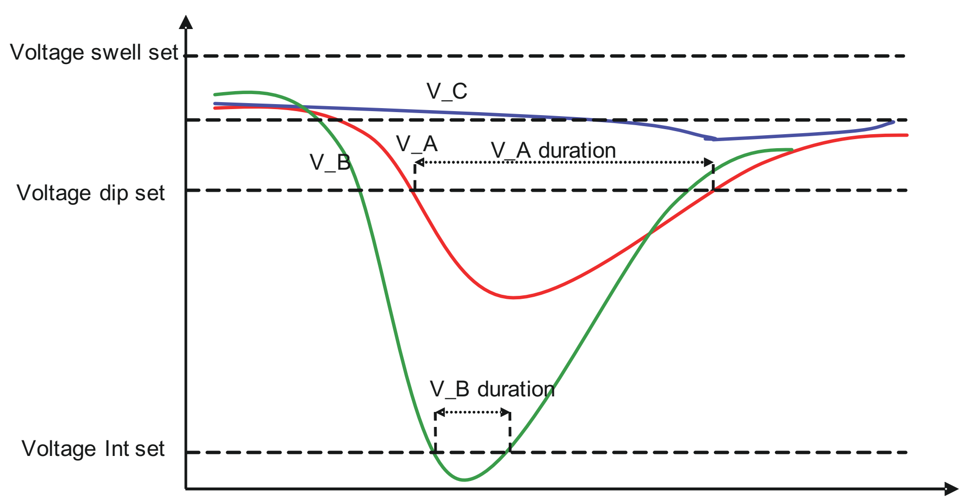

Figure 311: Single-phase interruption for the Phase mode value "Single Phase"

8.12.4.4 Variation validation

The validation criterion for voltage variation is that the measured total variation duration is between the set minimum and maximum durations (Either one of VVa dip time 1, VVa swell time 1 or VVa Int time 1, depending on the variation type, and VVa Dur Max). The maximum variation duration setting is the same for all variation types.

Figure 312 shows voltage dip operational regions. In Figure 310, only one voltage dip/swell/Int set is drawn, whereas in this figure there are three sub-limits for the dip operation. When Voltage dip set 3 is undershot, the corresponding PICKUP_x and also the DIPST outputs are activated. When the TRMS voltage magnitude remains between Voltage dip set 2 and Voltage dip set 1 for a period longer than VVa dip time 2 (shorter time than VVa dip time 3), a momentary dip event is detected. Furthermore, if the signal magnitude stays between the limits longer than VVa dip time 3 (shorter time than VVa Dur max), a temporary dip event is detected. If the voltage remains below Voltage dip set 1 for a period longer than VVa dip time 1 but a shorter time than VVa dip time 2, an instantaneous dip event is detected.

For an event detection, the TRIP output is always activated for one task cycle. The corresponding counter and only one of them (INSTDIPCNT, MOMDIPCNT or TEMPDIPCNT) is increased by one. If the dip limit undershooting duration is shorter than VVa dip time 1, VVa swell time 1 or VVa Int time 1, the event is not detected at all, and if the duration is longer than VVa Dur Max, MAXDURDIPCNT is increased by one but no event detection resulting in the activation of the TRIP output and recording data update takes place. These counters are available through the monitored data view on the LHMI or through tools via communications. There are no phase-segregated counters but all the variation detections are registered to a common time/magnitude-classified counter type. Consequently, a simultaneous multiphase event, that is, the variation-type event detection time moment is exactly the same for two or more phases, is counted only once also for single-phase power systems.

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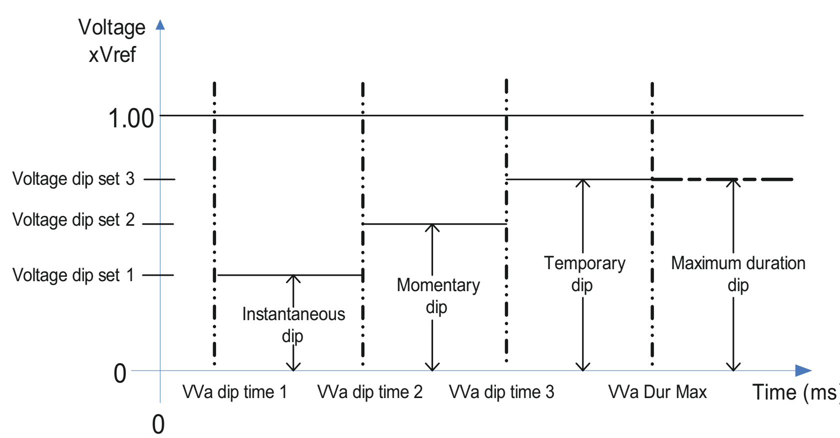

Figure 312: Voltage Dip operational regions

In Figure 313, the corresponding limits regarding the swell operation are provided with the inherent magnitude limit order difference. The swell functionality principle is the same as for dips, but the different limits for the signal magnitude and times and the inherent operating zone change (here, Voltage swell set x > 1.0 xVn) are applied.

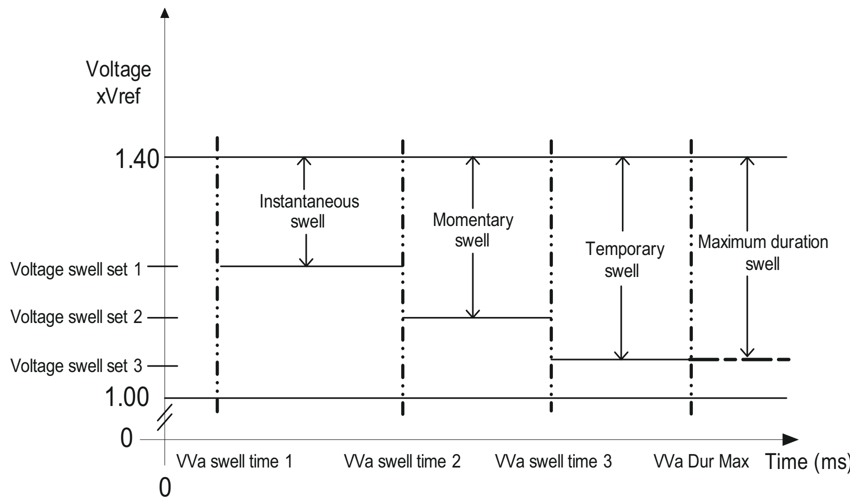

Figure 313: Voltage swell operational regions

For interruption, as shown in Figure 314, there is only one magnitude limit but four duration limits for interruption classification. Now the event and counter type depends only on variation duration time.

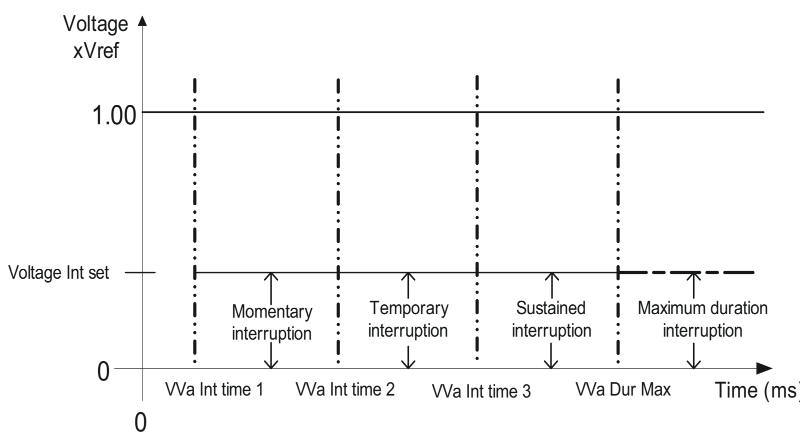

Figure 314: Interruption operating regions

Generally, no event detection is done if both the magnitude and duration requirements are not fulfilled. For example, the dip event does not indicate if the TRMS voltage magnitude remains between Voltage dip set 3 and Voltage dip set 2 for a period shorter than VVa dip time 3 before rising back above Voltage dip set 3.

The event indication ends and possible detection is done when the TRMS voltage returns above (for dip and interruption) or below (for swell) the activation pickup limit. For example, after an instantaneous dip, the event indication when the voltage magnitude exceeds Voltage dip set 1 is not detected (and recorded) immediately but only if no longer dip indication for the same dip variation takes place and the maximum duration time for dip variation is not exceeded before the signal magnitude rises above Voltage dip set 3. There is a small hysteresis for all these limits to avoid the oscillation of the output activation. No drop-off approach is applied here due to this hysteresis.

Consequently, only one event detection and recording of the same variation type can take place for one voltage variation, so the longest indicated variation of each variation type is detected. Furthermore, it is possible that another instantaneous dip event replaces the one already indicated if the magnitude again undershoots Voltage dip set 1 for the set time after the first detection and the signal magnitude or time requirement is again fulfilled. Another possibility is that if the time condition is not fulfilled for an instantaneous dip detection but the signal rises above Voltage dip set 1, the already elapsed time is included in the momentary dip timer. Especially the interruption time is included in the dip time. If the signal does not exceed Voltage dip set 2 before the timer VVa dip time 2 has elapsed when the momentary dip timer is also started after the magnitude undershooting Voltage dip set 2, the momentary dip event instead is detected. Consequently, the same dip occurrence with a changing variation depth can result in several dip event indications but only one detection. For example, if the magnitude has undershot Voltage dip set 1 but remained above Voltage Intr set for a shorter time than the value of VVa dip time 1 but the signal rises between Voltage dip set 1 and Voltage dip set 2 so that the total duration of the dip activation is longer than VVa dip time 2 and the maximum time is not overshot, this is detected as a momentary dip even though a short instantaneous dip period has been included. In text, the terms "deeper" and "higher" are used for referring to dip or interruption.

Although examples are given for dip events, the same rules can be applied to the swell and interruption functionality too. For swell indication, "deeper" means that the signal rises even more and "higher" means that the signal magnitude becomes lower respectively.

The adjustable voltage thresholds adhere to the relationships:

VVa dip time 1 ≤ VVa dip time 2 ≤ VVa dip time 3.

VVa swell time 1 ≤ VVa swell time 2 ≤ VVa swell time 3.

VVa Int time 1 ≤ VVa Int time 2 ≤ VVa Int time 3.

The user should enter the settings for "VVa x time 1" "VVa x time 2" "VVa x time 3" in the correct order to as to satisfy the relationship mentioned above as the relay will work as per the parameters set by the user..

8.12.4.5 Three/single-phase selection variation examples

The provided rules always apply for single-phase (Phase Mode is "Single Phase") power systems. However, for three-phase power systems (where Phase Mode is "Three Phase"), it is required that all the phases have to be activated before the activation of the PICKUP output. Interruption event indication requires all three phases to undershoot Voltage Int set simultaneously, as shown in Figure 310. When the requirement for interruption for "Three Phase" is no longer fulfilled, variation is indicated as a dip as long as all phases are active.

In case of a single-phase interruption of Figure 311, when there is a dip indicated in another phase but the third phase is not active, there is no variation indication pickup when

Phase Mode is "Three Phase". In this case, only the Phase Mode value "Single Phase" results in the PICKUP_B interruption and the PICKUP_A dip.

It is also possible that there are simultaneously a dip in one phase and a swell in other phases. The functionality of the corresponding event indication with one inactive phase is shown in Figure 315. Here, the "Swell + dip" variation type of Phase mode is "Single Phase". For the selection "Three Phase" of Phase mode, no event indication or any activation takes place due to a non-active phase.

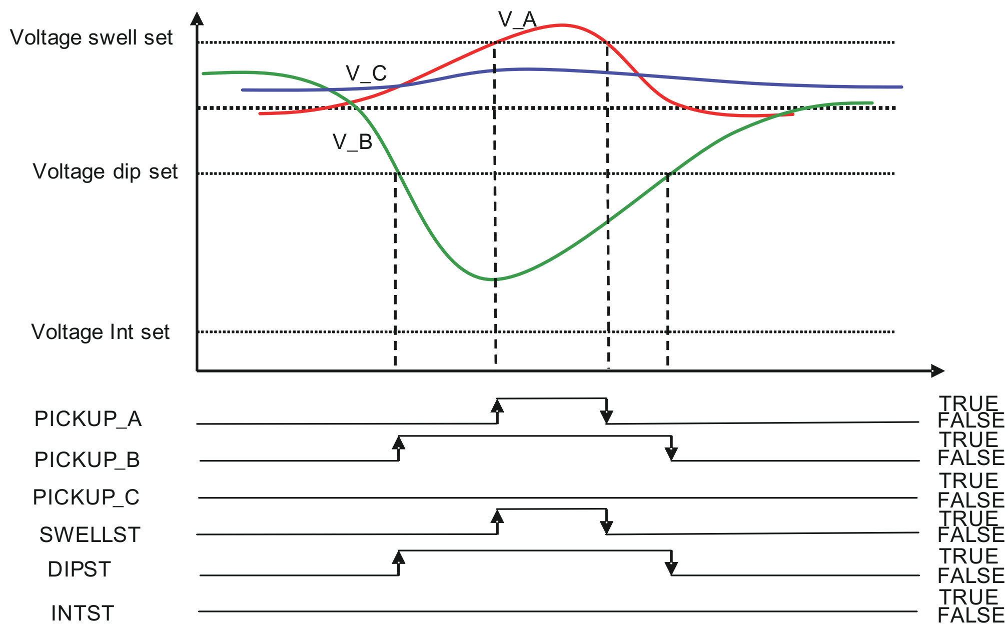

Figure 315: Concurrent dip and swell when Phase mode is "Single Phase"

In Figure 316, one phase is in dip and two phases have a swell indication. For the Phase Mode Dip value "Three Phase", the activation occurs only when all the phases are active. Furthermore, both swell and dip variation event detections take place simultaneously. In case of a concurrent voltage dip and voltage swell, both SWELLCNT and DIPCNT are incremented by one.

Also Figure 316 shows that for the Phase Mode value "Three Phase", two different time moment variation event swell detections take place and, consequently, DIPCNT is incremented by one but SWELLCNT is totally incremented by two. Both in Figure 315 and Figure 316 it is assumed that variation durations are sufficient for detections to take place.

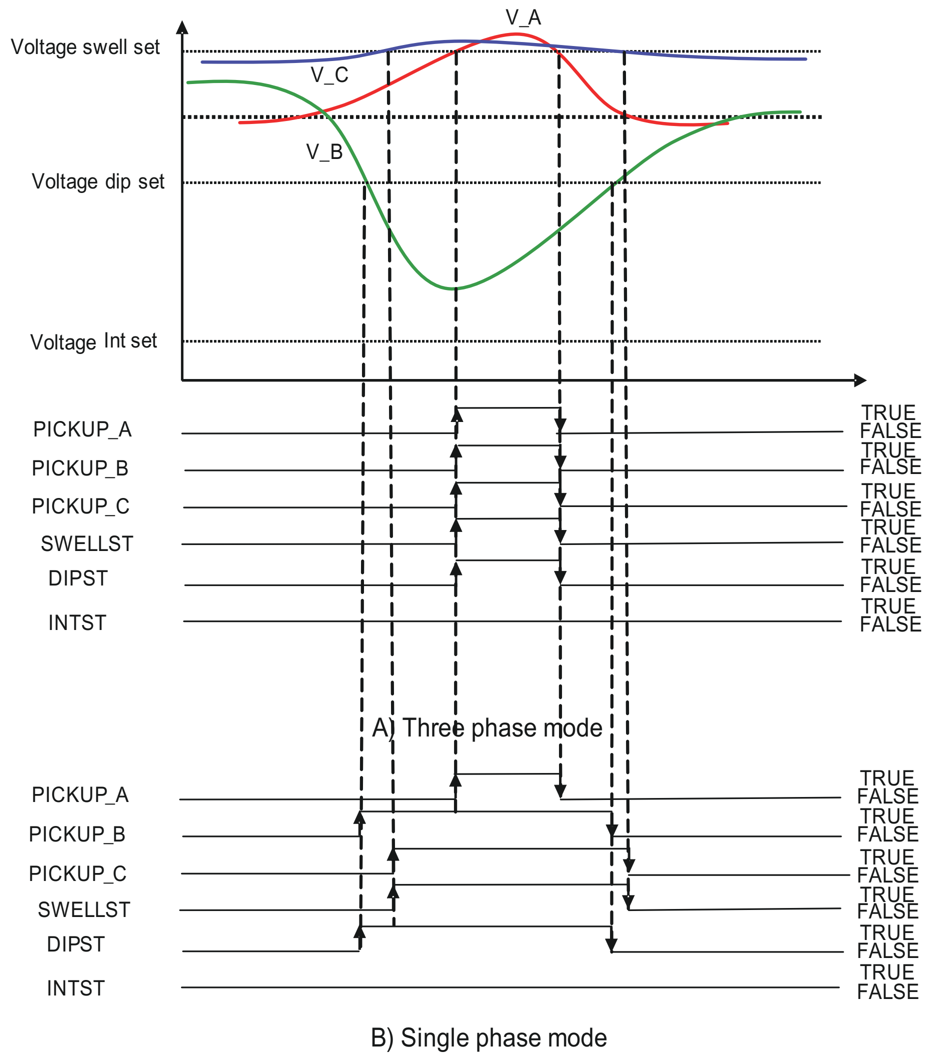

Figure 316: Concurrent dip and two-phase swell

8.12.5 Recorded data

Besides counter increments, the information required for a later fault analysis is stored after a valid voltage variation is detected.

8.12.5.1 Recorded data information

When voltage variation starts, the phase current magnitudes preceding the activation moment are stored. Also, the initial voltage magnitudes are temporarily stored at the variation pickup moment. If the variation is, for example, a two-phase voltage dip, the voltage magnitude of the non-active phase is stored from this same moment, as shown in Figure 312. The function tracks each variation-active voltage phase, and the minimum or maximum magnitude corresponding to swell or dip/ interruption during variation is temporarily stored. If the minimum or maximum is found in tracking and a new magnitude is stored, also the inactive phase voltages are stored at the same moment, that is, the inactive phases are not magnitude tracked. The time instant (time stamp) at which the minimum or maximum magnitude is measured is also temporarily stored for each voltage phase where variation is active. Finally, variation detection triggers the recorded data update when the variation activation ends and the maximum duration time is not exceeded.

The data objects to be recorded for PQSS are given in Table 492. There are totally three data banks, and the information given in the table refers to one data bank content.

The three sets of recorded data available are saved in data banks 1-3. The data bank 1 holds always the most recent recorded data, and the older data sets are moved to the next banks (1→2 and 2→3) when a valid voltage variation is detected. When all three banks have data and a new variation is detected, the newest data are placed into bank 1 and the data in bank 3 are overwritten by the data from bank 2.

Figure 312 shows a valid recorded voltage interruption and two dips for the Phase mode value "Single Phase". The first dip event duration is based on the V_A duration, while the second dip is based on the time difference between the dip stop and start times. The first detected event is an interruption based on the V_B duration given in Figure 312. It is shown also with dotted arrows how voltage time stamps are taken before the final time stamp for recording, which is shown as a solid arrow. Here, the V_B timestamp is not taken when the V_A activation starts.

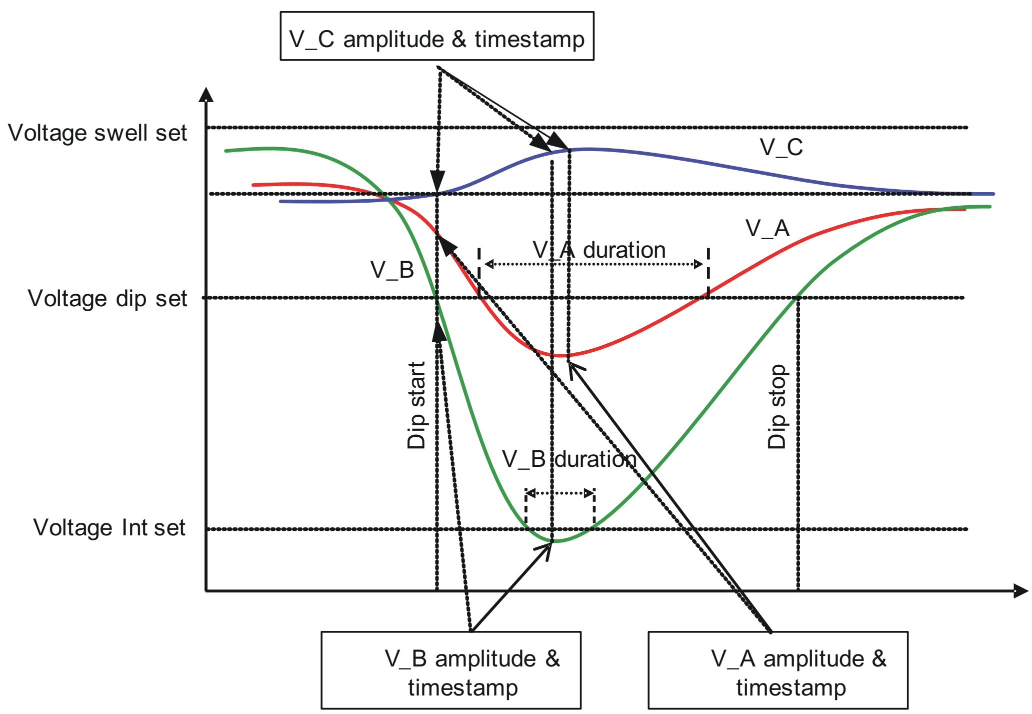

Figure 317: : Valid recorded voltage interruption and two dips

Table 492: PQSS Recording data bank parameters

Parameter description	Parameter name	Recorded Data DO
Event detection triggering time stamp	Time	(Timestamp) QVV1MSTAx.VVaTyp.t, EXT
Variation type	Variation type	(INS) QVV1MSTAx.VVaTyp.stVal, EXT
Variation magnitude Ph A	Variation Ph A	(MV) QVV1MSTAx.VVa.mag.f
Variation magnitude Ph A time stamp (maximum/minimum magnitude measuring time moment during variation)	Var Ph A rec time	(Timestamp) QVV1MSTAx.VVa.t
Variation magnitude Ph B	Variation Ph B	(MV) QVV2MSTAx.VVa.mag.f
Variation magnitude Ph B time stamp (maximum/minimum magnitude measuring time moment during variation)	Var Ph B rec time	(Timestamp) QVV2MSTAx.VVa.t
Variation magnitude Ph C	Variation Ph C	(MV) QVV3MSTAx.VVa.mag.f
Variation magnitude Ph C time stamp (maximum/minimum magnitude measuring time moment during variation)	Var Ph C rec time	(Timestamp) QVV3MSTAx.VVa.t
Variation duration Ph A	Variation Dur Ph A	(INS) QVV1MSTAx.VVaTm.stVal
Variation Ph A start time stamp (phase A variation start time moment)	Var Dur Ph A time	(Timestamp) QVV1MSTAx.VVaTm.t
Variation duration Ph B	Variation Dur Ph B	(INS) QVV2MSTAx.VVaTm.stVal
Variation Ph B start time stamp (phase B variation start time moment)	Var Dur Ph B time	(Timestamp) QVV2MSTAx.VVaTm.t
Variation duration Ph C	Variation Dur Ph C	(INS) QVV3MSTAx.VVaTm.stVal
Variation Ph C start time stamp (phase C variation start time moment)	Var Dur Ph C time	(Timestamp) QVV3MSTAx.VVaTm.t
Current magnitude Ph A preceding variation	Var current Ph A	(MV) QVV1MSTAx.APreVa.mag.f, EXT
Current magnitude Ph B preceding variation	Var current Ph B	(MV) QVV2MSTAx.APreVa.mag.f, EXT
Current magnitude Ph C preceding variation	Var current Ph C	(MV) QVV3MSTAx.APreVa.mag.f, EXT

Table 493: Enumeration values for the recorded data parameters

Setting name	Enum name	Value
Variation type	Swell	1
Variation type	Dip	2
Variation type	Swell + dip	3
Variation type	Interruption	4
Variation type	Swell + Int	5
Variation type	Dip + Int	6
Variation type	Swell+dip+Int	7

8.12.6 Application

Voltage variations are the most typical power quality variations on the public electric network. Typically, short-duration voltage variations are defined to last more than half of the nominal frequency period and less than one minute (European Standard EN 50160 and IEEE Std 1159-1995).

These short-duration voltage variations are almost always caused by a fault condition. Depending on where the fault is located, it can cause either a temporary voltage rise (swell) or voltage drop (dip). A special case of voltage drop is the complete loss of voltage (interruption).

PQSS is used for measuring short-duration voltage variations in distribution networks. The power quality is evaluated in the voltage waveform by measuring the voltage swells, dips and interruptions.

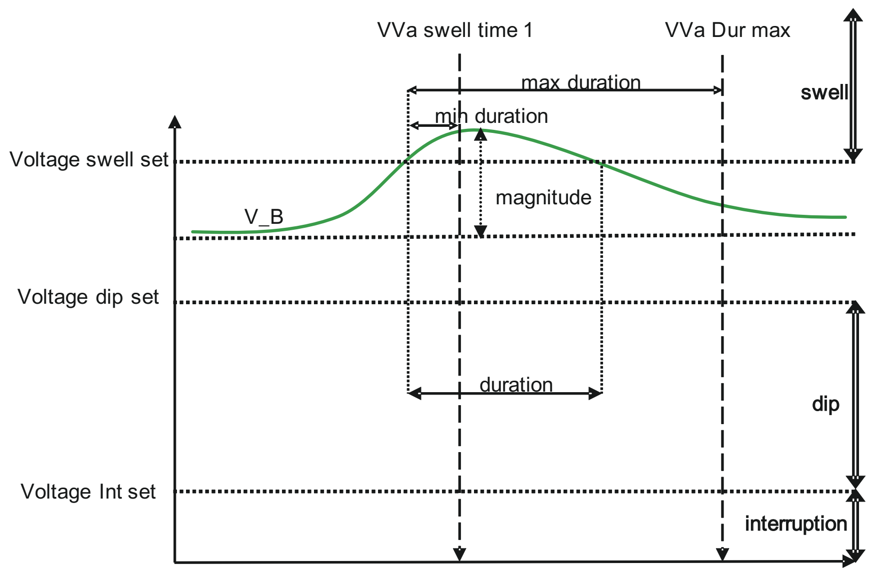

Figure 318: Duration and voltage magnitude limits for swell, dip and interruption measurement

Voltage dips disturb the sensitive equipment such as computers connected to the power system and may result in the failure of the equipment. Voltage dips are typically caused by faults occurring in the power distribution system. Typical reasons for the faults are lightning strikes and tree contacts. In addition to fault situations, the switching of heavy loads and starting of large motors also cause dips.

Voltage swells cause extra stress for the network components and the devices connected to the power system. Voltage swells are typically caused by the ground faults that occur in the power distribution system.

Voltage interruptions are typically associated with the switchgear operation related to the occurrence and termination of short circuits. The operation of a circuit breaker disconnects a part of the system from the source of energy. In the case of overhead networks, automatic reclosing sequences are often applied to the circuit breakers that interrupt fault currents. All these actions result in a sudden reduction of voltages on all voltage phases.

Due to the nature of voltage variations, the power quality standards do not specify any acceptance limits. There are only indicative values for, for example, voltage dips in the European standard EN 50160. However, the power quality standards like the international standard IEC 61000-4-30 specify that the voltage variation event is characterized by its duration and magnitude. Furthermore, IEEE Std 1159-1995 gives the recommended practice for monitoring the electric power quality.

Voltage variation measurement can be done to the phase-to-ground and phase-to-phase voltages. The power quality standards do not specify whether the measurement should be done to phase or phase-to-phase voltages. However, in some cases it is preferable to use phase-to-ground voltages for measurement. The measurement mode is always TRMS.

8.12.7 Signals

Table 494: PQSS Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current magnitude
I_B	SIGNAL	0	Phase B current magnitude
I_C	SIGNAL	0	Phase C current magnitude
V_A	SIGNAL	0	Phase-to-ground voltage A
V_B	SIGNAL	0	Phase-to-ground voltage B
V_C	SIGNAL	0	Phase-to-ground voltage C
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 495: PQSS Output signals

Name	Type	Description
TRIP	BOOLEAN	Voltage variation detected
PICKUP	BOOLEAN	Voltage variation present
SWELLST	BOOLEAN	Voltage swell active
DIPST	BOOLEAN	Voltage dip active
INTST	BOOLEAN	Voltage interruption active

8.12.8 Settings

Table 496: PQSS Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Reference voltage	10.0...200.0	%Vn	0.1	57.7	Reference supply voltage in %
Voltage dip set 1	10.0...100.0	%	0.1	80	Dip limit 1 in % of reference voltage
VVa dip time 1	0.5...54.0	cycles	0.1	3	Voltage variation dip duration 1
Voltage dip set 2	10.0...100.0	%	0.1	80	Dip limit 2 in % of reference voltage
VVa dip time 2	10.0...180.0	cycles	0.1	30	Voltage variation dip duration 2
Voltage dip set 3	10.0...100.0	%	0.1	80	Dip limit 3 in % of reference voltage
VVa dip time 3	2000...60000	ms	10	3000	Voltage variation dip duration 3
Voltage swell set 1	100.0...140.0	%	0.1	120	Swell limit 1 in % of reference voltage
VVa swell time 1	0.5...54.0	cycles	0.1	0.5	Voltage variation swell duration 1
Voltage swell set 2	100.0...140.0	%	0.1	120	Swell limit 2 in % of reference voltage
VVa swell time 2	10.0...80.0	cycles	0.1	10	Voltage variation swell duration 2
Voltage swell set 3	100.0...140.0	%	0.1	120	Swell limit 3 in % of reference voltage
VVa swell time 3	2000...60000	ms	10	2000	Voltage variation swell duration 3
Voltage Int set	0.0...100.0	%	0.1	10	Interruption limit in % of reference voltage
VVa Int time 1	0.5...30.0	cycles	0.1	3	Voltage variation Int duration 1
VVa Int time 2	10.0...180.0	cycles	0.1	30	Voltage variation Int duration 2
VVa Int time 3	2000...60000	ms	10	3000	Voltage variation interruption duration 3
VVa Dur Max	100...3600000	ms	100	60000	Maximum voltage variation duration

Table 497: PQSS Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Enable/Disable
Phase supervision	1=Ph A 2=Ph B 3=Ph A + B 4=Ph C 5=Ph A + C 6=Ph B + C 7=Ph A + B + C			7=Ph A + B + C	Monitored voltage phase
Phase mode	1=Three Phase 2=Single Phase			2=Single Phase	Three/Single phase mode
Variation enable	1=Swell 2=Dip 3=Swell + dip 4=Interruption 5=Swell + Int 6=Dip + Int 7=Swell+dip+Int			7=Swell+dip+Int	Enable variation type

8.12.9 Monitored data

Table 498: PQSS Monitored data

Name	Type	Values (Range)	Unit	Description
ST_A	BOOLEAN	0=False 1=True		Start Phase A (Voltage Variation Event in progress)
ST_B	BOOLEAN	0=False 1=True		Start Phase B (Voltage Variation Event in progress)
ST_C	BOOLEAN	0=False 1=True		Start Phase C (Voltage Variation Event in progress)
INSTSWELLCNT	INT32	0...2147483647		Instantaneous swell operation counter
MOMSWELLCNT	INT32	0...2147483647		Momentary swell operation counter
TEMPSWELLCNT	INT32	0...2147483647		Temporary swell operation counter
MAXDURSWELLCNT	INT32	0...2147483647		Maximum duration swell operation counter
INSTDIPCNT	INT32	0...2147483647		Instantaneous dip operation counter
MOMDIPCNT	INT32	0...2147483647		Momentary dip operation counter
TEMPDIPCNT	INT32	0...2147483647		Temporary dip operation counter
MAXDURDIPCNT	INT32	0...2147483647		Maximum duration dip operation counter

Table continued on next page

Name	Type	Values (Range)	Unit	Description
MOMINTCNT	INT32	0...2147483647		Momentary interruption operation counter
TEMPINTCNT	INT32	0...2147483647		Temporary interruption operation counter
SUSTINTCNT	INT32	0...2147483647		Sustained interruption operation counter
MAXDURINTCNT	INT32	0...2147483647		Maximum duration interruption operation counter
PQSS	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status
Time	Timestamp			Time
Variation type	Enum	0=No variation 1=Swell 2=Dip 3=Swell + dip 4=Interruption 5=Swell + Int 6=Dip + Int 7=Swell+dip+Int		Variation type
Variation Ph A	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase C
Var Ph C rec time	Timestamp			Variation magnitude Phase C time stamp
Variation Dur Ph A	FLOAT32	0.000...3600.000	s	Variation duration Phase A
Var Dur Ph A time	Timestamp			Variation Ph A start time stamp
Variation Dur Ph B	FLOAT32	0.000...3600.000	s	Variation duration Phase B
Var Dur Ph B time	Timestamp			Variation Ph B start time stamp
Variation Dur Ph C	FLOAT32	0.000...3600.000	s	Variation duration Phase C
Var Dur Ph C time	Timestamp			Variation Ph C start time stamp
Var current Ph A	FLOAT32	0.00...60.00	xIn	Current magnitude Phase A preceding variation
Var current Ph B	FLOAT32	0.00...60.00	xIn	Current magnitude Phase B preceding variation

Table continued on next page

Name	Type	Values (Range)	Unit	Description
Var current Ph C	FLOAT32	0.00...60.00	xIn	Current magnitude Phase C preceding variation
Time	Timestamp			Time
Variation type	Enum	0=No variation		Variation type
		1=Swell		
		2=Dip		
		3=Swell + dip		
		4=Interruption		
		5=Swell + Int		
		6=Dip + Int		
		7=Swell+dip+Int		
Variation Ph A	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase C
Var Ph C rec time	Timestamp			Variation magnitude Phase C time stamp
Variation Dur Ph A	FLOAT32	0.000...3600.000	s	Variation duration Phase A
Var Dur Ph A time	Timestamp			Variation Ph A start time stamp
Variation Dur Ph B	FLOAT32	0.000...3600.000	s	Variation duration Phase B
Var Dur Ph B time	Timestamp			Variation Ph B start time stamp
Variation Dur Ph C	FLOAT32	0.000...3600.000	s	Variation duration Phase C
Var Dur Ph C time	Timestamp			Variation Ph C start time stamp
Var current Ph A	FLOAT32	0.00...60.00	xIn	Current magnitude Phase A preceding variation
Var current Ph B	FLOAT32	0.00...60.00	xIn	Current magnitude Phase B preceding variation
Var current Ph C	FLOAT32	0.00...60.00	xIn	Current magnitude Phase C preceding variation
Time	Timestamp			Time
Variation type	Enum	0=No variation		Variation type
		1=Swell		
		2=Dip		
		3=Swell + dip		
		4=Interruption		
		5=Swell + Int		
		6=Dip + Int		
		7=Swell+dip+Int		

Table continued on next page

Name	Type	Values (Range)	Unit	Description
Variation Ph A	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xVn	Variation magnitude Phase C
Var Ph C rec time	Timestamp			Variation magnitude Phase C time stamp
Variation Dur Ph A	FLOAT32	0.000...3600.000	s	Variation duration Phase A
Var Dur Ph A time	Timestamp			Variation Ph A start time stamp
Variation Dur Ph B	FLOAT32	0.000...3600.000	s	Variation duration Phase B
Var Dur Ph B time	Timestamp			Variation Ph B start time stamp
Variation Dur Ph C	FLOAT32	0.000...3600.000	s	Variation duration Phase C
Var Dur Ph C time	Timestamp			Variation Ph C start time stamp
Var current Ph A	FLOAT32	0.00...60.00	xIn	Current magnitude Phase A preceding variation
Var current Ph B	FLOAT32	0.00...60.00	xIn	Current magnitude Phase B preceding variation
Var current Ph C	FLOAT32	0.00...60.00	xIn	Current magnitude Phase C preceding variation

8.13 Frequency measurement, f

8.13.1 Identification

Table 499: Function identification

IEC 61850 identification:	FMMXU1
IEC 60617 identification:	F
ANSI/IEEE C37.2 device number:	F

8.13.2 Function block

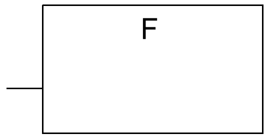

Figure 319: Function block symbol

8.13.3 Signals

Table 500: F Input signals

Name	Type	Default	Description
F	SIGNAL	-	Measured system frequency

8.13.4 Settings

Table 501: F Non group settngs

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
F high high limit	35.00...75.00	Hz		60.00	High alarm frequency limit
F high limit	35.00...75.00	Hz		55.00	High warning frequency limit
F low limit	35.00...75.00	Hz		45.00	Low warning frequency limit
F low low limit	35.00...75.00	Hz		40.00	Low alarm frequency limit
F deadband	100...100000			1000	Deadband configuration value for integral calculation (percentage of difference between min and max as 0,001 % s

8.13.5 Monitored data

Table 502: FMMXU Monitored datas

name	Type	Values (Range)	Unit	Description
f Hz	FLOAT32	35.00...75.00	Hz	Measured frequency
F_INST	FLOAT32	35.00...75.00	Hz	Frequency instantaneous value
F_DB	FLOAT32	35.00...75.00	Hz	Frequency reported value
F_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Measured frequency range

8.14 Tap change position indication, 84T

8.14.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Tap position	TPOSSLTC	TPOSM	84T

8.14.2 Function block

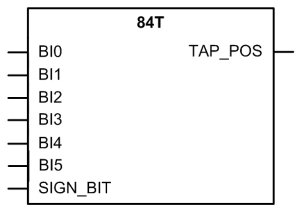

Figure 320: Function block

8.14.3 Functionality

The binary converter function 84T is used for converting binary-coded tap position inputs to their decimal equivalent when a tap position indication is received from the I/O board with the help of the coded binary inputs.

There are three user-selectable conversion modes available for the 7-bit binary inputs where MSB is used as the SIGN bit: the natural binary-coded boolean input to the signed integer output, binary coded decimal BCD input to the signed integer output and binary reflected GRAY coded input to the signed integer output.

8.14.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are Enable and Disable. When the function is disabled, the tap position quality information is changed accordingly. When the tap position information is not available, it is recommended to disable this function with the *Operation* setting.

The operation of tap position indication function can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

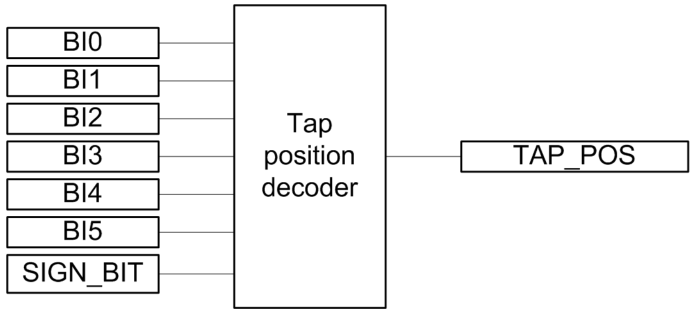

Figure 321: Functional module diagram

Tap position decoder

The function has three alternative user selectable *Operation modes*:”NAT2INT,” “BCD2INT” and “GRAY2INT”. The operation mode is selected with the *Operation mode* setting. Each operation mode can be used to convert a maximum of 6-bit coded input to an 8-bit signed short integer output. For less than 6-bit input, for example 19 positions with 5 bits when the BCD coding is used, the rest of the bits can be set to `FALSE` (0).

The operation mode “NAT2INT” is selected when the natural binary coding is used for showing the position of the transformer tap changer. The basic principle of the natural binary coding is to calculate the sum of the bits set to `TRUE` (1). The LSB has the factor 1. Each following bit has the previous factor multiplied by 2. This is also called dual coding.

The operation mode “BCD2INT” is selected when the binary-coded decimal coding is used for showing the position of the transformer tap changer. The basic principle with the binary-coded decimal coding is to calculate the sum of the bits set to TRUE (1). The four bits nibble (BI3...BI10) have a typical factor to the natural binary coding. The sum of the values should not be more than 9. If the nibble sum is greater than 9, the tap position output validity is regarded as bad.

The operation mode “GRAY2INT” is selected when the binary-reflected GRAY coding is used for showing the position of the transformer tap changer. The basic principle of the GRAY coding is that only one actual bit changes value with consecutive numbers. This function is based on the common binary-reflected GRAY code, which is used with some tap changers. Changing the bit closest to the right side bit gives a new pattern.

An additional separate input, `SIGN_BIT`, can be used for negative values. If the values are positive, the input is set to FALSE (0). If the `SIGN_BIT` is set to TRUE (1) making the number negative, the remaining bits are identical to those of the coded positive number.

The tap position validity is set to good in all valid cases. The quality is set to bad in invalid combinations in the binary inputs. For example, when the”BCD2INT” mode is selected and the input binary combination is “0001101”, the quality is set to bad and the `TAP_POS` output is in this case “9”. For negative values, when the `SIGN_BIT` is set to TRUE (1) and the input binary combination is “1011011”, the quality is set to bad and the `TAP_POS` output is in this case “-19”.

Table 503: Truth table of the decoding modes

Inputs							TAP_POS outputs		
SIGN_BIT	BI5	BI4	BI3	BI2	BI1	BI0	NAT2INT	BCD2INT	GRAY2INT
...		...		...		...	...	...	...
1	0	0	0	0	1	1	-3	-3	-3
1	0	0	0	0	1	0	-2	-2	-2
1	0	0	0	0	0	1	-1	-1	-1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1
0	0	0	0	0	1	0	2	2	3
0	0	0	0	0	1	1	3	3	2
0	0	0	0	1	0	0	4	4	7
0	0	0	0	1	0	1	5	5	6
0	0	0	0	1	1	0	6	6	4
0	0	0	0	1	1	1	7	7	5
0	0	0	1	0	0	0	8	8	15
0	0	0	1	0	0	1	9	9	14
0	0	0	1	0	1	0	10	9	12
0	0	0	1	0	1	1	11	9	13
0	0	0	1	1	0	0	12	9	8
0	0	0	1	1	0	1	13	9	9
0	0	0	1	1	1	0	14	9	11
0	0	0	1	1	1	1	15	9	10
0	0	1	0	0	0	0	16	10	31
0	0	1	0	0	0	1	17	11	30
0	0	1	0	0	1	0	18	12	28
0	0	1	0	0	1	1	19	13	29
0	0	1	0	1	0	0	20	14	24
0	0	1	0	1	0	1	21	15	25
0	0	1	0	1	1	0	22	16	27
0	0	1	0	1	1	1	23	17	26
0	0	1	1	0	0	0	24	18	16
0	0	1	1	0	0	1	25	19	17
0	0	1	1	0	1	0	26	19	19
0	0	1	1	0	1	1	27	19	18
0	0	1	1	1	0	0	28	19	23
0	0	1	1	1	0	1	29	19	22
0	0	1	1	1	1	0	30	19	20
0	0	1	1	1	1	1	31	19	21
0	1	0	0	0	0	0	32	20	63

Table continued on next page

Inputs							TAP_POS outputs		
0	1	0	0	0	0	1	33	21	62
0	1	0	0	0	1	0	34	22	60
0	1	0	0	0	1	1	35	23	61
0	1	0	0	1	0	0	36	24	56
...		...		...		...	...	...	...

8.14.5 Application

84T provides tap position information for other functions as a signed integer value that can be fed to the tap position input.

For many applications, for example differential protection algorithms, the position information of the tap changer can be coded in various methods. In this function, the binary inputs in the transformer terminal connector are used as inputs to the function. The user can choose the coding method by setting the mode parameter. The available coding methods are BCD, GRAY and Natural binary coding. Since the number of binary inputs is limited to seven, the coding functions are limited to 7-bit, including the sign bit, and thus the 6 bits are used in the coding functions. The position limits for the tap positions at BCD, GRAY and Natural binary coding are ±39, ±63 and ±63 respectively.

8.14.6 Signals

Table 504: 84T Input signals

Name	Type	Default	Description
BI0	BOOLEAN	0=False	Binary input 1
BI1	BOOLEAN	0=False	Binary input 2
BI2	BOOLEAN	0=False	Binary input 3
BI3	BOOLEAN	0=False	Binary input 4
BI4	BOOLEAN	0=False	Binary input 5
BI5	BOOLEAN	0=False	Binary input 6
SIGN_BIT	BOOLEAN	0=False	Binary input sign bit

8.14.7 Settings

Table 505: 84T Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Operation mode	1=NAT2INT 2=BCD2INT 3=GRAY2INT			2=BCD2INT	Operation mode selection

8.14.8 Monitored data

Table 506: 84T Monitored data

Name	Type	Values (Range)	Unit	Description
TAP_POS	INT8	-63...63		Tap position indication

8.14.9 Technical data

Table 507: 84T Technical data

Descrpition	Value
Response time	Typical 100 ms

Section 9 Recording functions

9.1 Disturbance recorder, DFR

9.1.1 Functionality

The IED is provided with a digital fault recorder featuring up to 12 analog and 64 binary signal channels. The analog channels can be set to record either the waveform or the trend of the currents and voltage measured.

The analog channels can be set to trigger the recording function when the measured value falls below or exceeds the set values. The binary signal channels can be set to start a recording on the rising or the falling edge of the binary signal or both.

By default, the binary channels are set to record external or internal IED signals, for example the pickup or trip signals of the IED stages, or external blocking or control signals. Binary IED signals such as a protection pickup or trip signal, or an external IED control signal over a binary input can be set to trigger the recording. The recorded information is stored in a non-volatile memory and can be uploaded for subsequent fault analysis.

9.1.1.1 Recorded analog inputs

The user can map any analog signal type of the IED to each analog channel of the digital fault recorder by setting the *Channel selection* parameter of the corresponding analog channel. In addition, the user can enable or disable each analog channel of the digital fault recorder by setting the *Operation* parameter of the corresponding analog channel to Enable or Disable.

All analog channels of the digital fault recorder that are enabled and have a valid signal type mapped are included in the recording.

9.1.1.2 Triggering alternatives

The recording can be triggered by any or several of the following alternatives:

- Triggering according to the state change of any or several of the binary channels of the digital fault recorder. The user can set the level sensitivity with the *Level trigger mode* parameter of the corresponding binary channel.
- Triggering on limit violations of the analog channels of the digital fault recorder (high and low limit)
- Manual triggering via the *Trig recording* parameter (LHMI or communication)
- Periodic triggering.

Regardless of the triggering type, each recording generates events through state changes of the *Recording started*, *Recording made* and *Recording stored* status parameters. The *Recording stored* parameter indicates that the recording has been stored to the non-volatile memory. In addition, every analog channel and binary channel of the digital fault recorder has its own *Channel triggered* parameter. Manual trigger has the *Manual triggering* parameter and periodic trigger has the *Periodic triggering* parameter. A state change in any of these parameters also generates an event that gives individual information about the reason of the triggering. COMTRADE files provide unambiguous information about the reason of the triggering, usually only for the binary channels but in some cases also for the analog channels.

Triggering by binary channels

Input signals for the binary channels of the digital fault recorder can be formed from any of the digital signals that can be dynamically mapped. A change in the status of a monitored signal triggers the recorder according to the configuration and settings. Triggering on the rising edge of a digital input signal means that the recording sequence starts when the input signal is activated. Correspondingly, triggering on the falling edge means that the recording sequence starts when the active input signal resets. It is also possible to trigger from both edges. In addition, if preferred, the monitored signal can be non-triggering. The trigger setting can be set individually for each binary channel of the digital fault recorder with the *Level trigger mode* parameter of the corresponding binary channel.

Triggering by analog channels

The trigger level can be set for triggering in a limit violation situation. The user can set the limit values with the *High trigger level* and *Low trigger level* parameters of the corresponding analog channel. Both high level and low level violation triggering can be active simultaneously for the same analog channel. If the duration of the limit violation condition exceeds the filter time of approximately 50 ms, the recorder triggers. In case of a low level limit violation, if the measured value falls below approximately 0.05 during the filter time, the situation is considered to be a circuit-breaker operation and therefore, the recorder does not trigger. This is useful especially in undervoltage situations. The filter time of approximately 50 ms is common to all the analog channel triggers of the digital fault recorder. The value used for triggering is the calculated peak-to-peak value.

Manual triggering

The recorder can be triggered manually via the LHMI or via communication by setting the *Trig recording* parameter to TRUE.

Periodic triggering

Periodic triggering means that the recorder automatically makes a recording at certain time intervals. The user can adjust the interval with the *Periodic trig time* parameter. If the value of the parameter is changed, the new setting takes effect when the next periodic triggering occurs. Setting the parameter to zero disables the triggering alternative and the setting becomes valid immediately. If a new non-zero setting needs to be valid immediately, the user should first set the *Periodic trig time* parameter to zero and then to the new value. The user can monitor the time remaining to the next triggering with the `Time to trigger` monitored data which counts downwards.

9.1.1.3 Length of recordings

The user can define the length of a recording with the *Record length* parameter. The length is given as the number of fundamental cycles.

According to the memory available and the number of analog channels used, the digital fault recorder automatically calculates the remaining amount of recordings that fit into the available recording memory. The user can see this information with the `Rem. amount of rec` monitored data. The fixed memory size allocated for the recorder can fit in two recordings that are ten seconds long. The recordings contain data from all analog and binary channels of the digital fault recorder, at the sample rate of 32 samples per fundamental cycle.

The user can view the number of recordings currently in memory with the `Number of recordings` monitored data. The currently used memory space can be viewed with the `Rec. memory used` monitored data. It is shown as a percentage value.

The maximum number of recordings is 100.

9.1.1.4 Sampling frequencies

The sampling frequency of the digital fault recorder analog channels depends on the set rated frequency. One fundamental cycle always contains the amount of samples set with the *Storage rate* parameter. Since the states of the binary channels are sampled once per task execution of the digital fault recorder, the sampling frequency of binary channels is 400 Hz at the rated frequency of 50 Hz and 480 Hz at the rated frequency of 60 Hz.

Table 508: Sampling frequencies of the digital fault recorder analog channels

Storage rate (samples per fundamental cycle)	Recording length	Sampling frequency of analog channels, when the rated frequency is 50 Hz	Sampling frequency of binary channels, when the rated frequency is 50 Hz	Sampling frequency of analog channels, when the rated frequency is 60 Hz	Sampling frequency of binary channels, when the rated frequency is 60 Hz
32	1* Record length	1600 Hz	400 Hz	1920 Hz	480 Hz
16	2* Record length	800 Hz	400 Hz	960 Hz	480 Hz
8	4 * Record length	400 Hz	400 Hz	480 Hz	480 Hz

9.1.1.5 Uploading of recordings

The IED stores COMTRADE files to the `C:\COMTRADE\` folder. The files can be uploaded with the PCM tool or FTP software that can access the `C:\COMTRADE\` folder.

One complete digital fault recorder consists of two COMTRADE file types: the configuration file and the data file. The file name is the same for both file types. The configuration file has .CFG and the data file .DAT as the file extension.

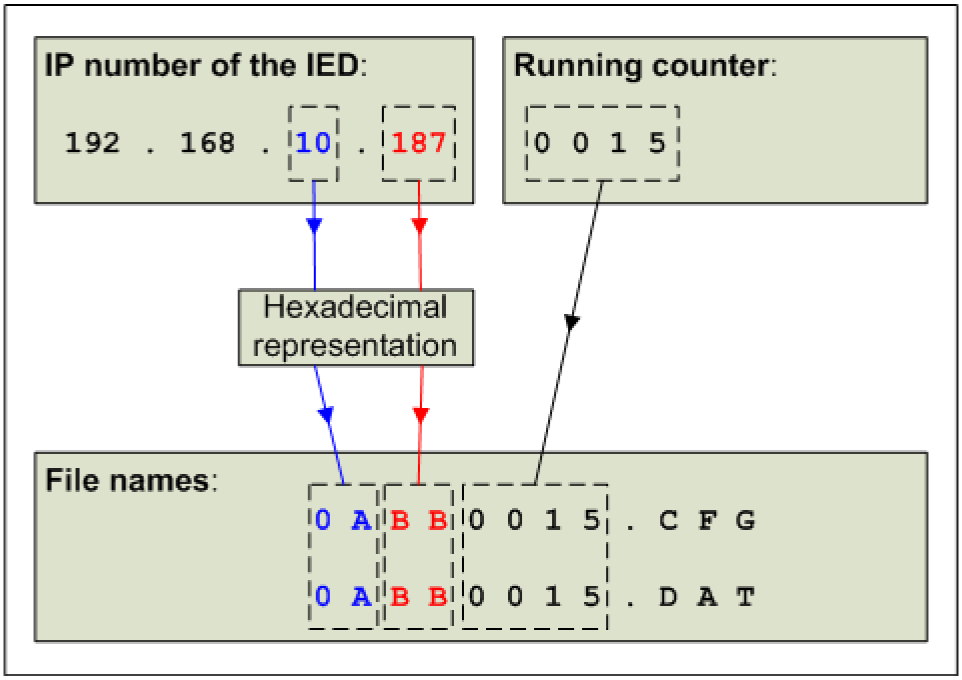

Figure 322: Digital fault recorder file naming

The naming convention of 8+3 characters is used in COMTRADE file naming. The file name is composed of the last two octets of the IED's IP number and a running counter, which has a range of 1...9999. A hexadecimal representation is used for the IP number octets. The appropriate file extension is added to the end of the file name.

9.1.1.6 Deletion of recordings

There are several ways to delete digital fault records. The recordings can be deleted individually or all at once.

Individual digital fault recorder can be deleted with the PCM tool or any appropriate computer software, which can access the IED's `C:\COMTRADE` folder. The digital fault recorder is not removed from the IED memory until both of the corresponding COMTRADE files, .CFG and .DAT, are deleted. The user may have to delete both of the files types separately, depending on the software used.

Deleting all digital fault records at once is done either with the PCM tool or any appropriate computer software, or from the LHMI via the **Clear/Digital fault recorder** menu. Deleting all digital fault recorders at once also clears the pre-trigger recording in progress.

9.1.1.7 Storage mode

The digital fault recorder can capture data in two modes: waveform and trend mode. The user can set the storage mode individually for each trigger source with the *Storage mode* parameter of the corresponding analog channel or binary channel, the *Stor. mode manual* parameter for manual trigger and the *Stor. mode periodic* parameter for periodic trigger.

In the waveform mode, the samples are captured according to the *Storage rate* and *Pre-trg length* parameters.

In the trend mode, one RMS value is recorded for each enabled analog channel, once per fundamental cycle. The binary channels of the digital fault recorder are also recorded once per fundamental cycle in the trend mode.

Only post-trigger data is captured in trend mode.

The trend mode enables recording times of 32 * *Record length*.

9.1.1.8 Pre-trigger and post-trigger data

The waveforms of the digital fault recorder analog channels and the states of the digital fault recorder binary channels are constantly recorded into the history memory of the recorder. The user can adjust the percentage of the data duration preceding the triggering, that is, the so-called pre-trigger time, with the *Pre-trg length* parameter. The duration of the data following the triggering, that is, the so-called post-trigger time, is the difference between the recording length and the pre-trigger time. Changing the pre-trigger time resets the history data and the current recording under collection.

9.1.1.9 Operation modes

Digital fault recorder has two operation modes: saturation and overwrite mode. The user can change the operation mode of the digital fault recorder with the *Operation mode* parameter.

Saturation mode

In saturation mode, the captured recordings cannot be overwritten with new recordings. Capturing the data is stopped when the recording memory is full, that is, when the maximum number of recordings is reached. In this case, the event is sent via the state change (TRUE) of the *Memory full* parameter. When there is memory available again, another event is generated via the state change (FALSE) of the *Memory full* parameter.

Overwrite mode

When the operation mode is "Overwrite" and the recording memory is full, the oldest recording is overwritten with the pre-trigger data collected for the next recording. Each time a recording is overwritten, the event is generated via the state change of the *Overwrite of rec.* parameter. The overwrite mode is recommended, if it is more important to have the latest recordings in the memory. The saturation mode is preferred, when the oldest recordings are more important.

New triggerings are blocked in both the saturation and the overwrite mode until the previous recording is completed. On the other hand, a new triggering can be accepted before all pre-trigger samples are collected for the new recording. In such a case, the recording is as much shorter as there were pre-trigger samples lacking.

9.1.1.10 Exclusion mode

Exclusion mode is on, when the value set with the *Exclusion time* parameter is higher than zero. During the exclusion mode, new triggerings are ignored if the triggering reason is the same as in the previous recording. The *Exclusion time* parameter controls how long the exclusion of triggerings of same type is active after a triggering. The exclusion mode only applies to the analog and binary channel triggerings, not to periodic and manual triggerings.

When the value set with the *Exclusion time* parameter is zero, the exclusion mode is disabled and there are no restrictions on the triggering types of the successive recordings.

The exclusion time setting is global for all inputs, but there is an individual counter for each analog and binary channel of the digital fault recorder, counting the remaining exclusion time. The user can monitor the remaining exclusion time with the *Exclusion time rem* parameter of the corresponding analog or binary channel. The *Exclusion time rem* parameter counts downwards.

9.1.2 Configuration

The user can configure the digital fault recorder with the PCM600 tool or any tool supporting the IEC 61850 standard.

The user can enable or disable the digital fault recorder with the *Operation* parameter under the **Configuration/Digital fault recorder/General** menu.

Analog channels are fixed except channel 4 which is selectable based on the Ground CT option. The name of the analog channel is user-configurable. The user can modify it by writing the new name to the *Channel id text* parameter of the corresponding analog channel.

Any external or internal digital signal of the IED which can be dynamically mapped can be connected to the binary channels of the digital fault recorder.These signals can be, for example, the pickup and trip signals from protection function blocks or the external digital inputs of the IED. The connection is made with dynamic mapping to the binary channel of the digital fault recorder using SMT of PCM600. It is also possible to connect several digital signals to one binary channel of the digital fault recorder. In that case, the signals can be combined with logical functions, for example AND and OR. The user can configure the name of the binary channel and modify it by writing the new name to the *Channel id text* parameter of the corresponding binary channel.

Note that the *Channel id text* parameter is used in COMTRADE configuration files as a channel identifier.

The recording always contains all binary channels of the digital fault recorder. If one of the binary channels is disabled, the recorded state of the channel is continuously FALSE and the state changes of the corresponding channel are not recorded. The corresponding channel name for disabled binary channels in the COMTRADE configuration file is Unused BI.

To enable or disable a binary channel of the digital fault recorder, the user can set the *Operation* parameter of the corresponding binary channel to the values Enable or Disable.

The states of manual triggering and periodic triggering are not included in the recording, but they create a state change to the *Periodic triggering* and *Manual triggering* status parameters, which in turn create events.

The *Recording started* parameter can be used to control the indication LEDs of the IED. The output of the *Recording started* parameter is TRUE due to the triggering of the digital fault recorder, until all the data for the corresponding recording is recorded.

The IP number of the IED and the content of the *Bay name* parameter are both included in the COMTRADE configuration file for identification purposes.

9.1.3 Application

The digital fault recorder is used for post-fault analysis and for verifying the correct operation of protection IEDs and circuit breakers. It can record both analog and binary signal information. The analog inputs are recorded as instantaneous values and converted to primary peak value units when the IED converts the recordings to the COMTRADE format.

COMTRADE is the general standard format used in storing disturbance recordings.

The binary channels are sampled once per task execution of the digital fault recorder. The task execution interval for the digital fault recorder is the same as for the protection functions. During the COMTRADE conversion, the digital status values are repeated so that the sampling frequencies of the analog and binary channels correspond to each other. This is required by the COMTRADE standard.

The digital fault recorder follows the 1999 version of the COMTRADE standard and uses the binary data file format.

9.1.4 Settings

Table 509: Non-group general settings for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable		1	1=Enable	DFR Enabled / Disabled
Record length	10...500	fundamental cycles	1	50	Size of the recording in fundamental cycles
Pre-trg length	5...95	%	1	10	Length of the recording preceding the triggering
Operation mode	1=Saturation 2=Overwrite		1	1	Operation mode of the recorder
Exclusion time	0...1 000 000	ms	1	0	The time during which triggerings of same type are ignored
Storage rate	32, 16, 8	samples per fundamental cycle		32	Storage rate of the waveform recording
Periodic trig time	0...604 800	s	10	0	Time between periodic triggerings
Stor. mode periodic	0=Waveform 1=Trend / cycle		1	0	Storage mode for periodic triggering
Stor. mode manual	0=Waveform 1=Trend / cycle		1	0	Storage mode for manual triggering

Table 510: Non-group analog channel settings for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable		1	1=Enable for Channels 1 - 4 5=Disable for channels 5 - 8	Analog channel is enabled or disabled
Channel selection	[1]		0		Select the signal to be recorded by this channel
Channel id text	0 to 64 characters, alphanumeric			DR analog channel X	Identification text for the analog channel used in the COMTRADE format
High trigger level	0.00...60.00	pu	0.01	10.00	High trigger level for the analog channel
Low trigger level	0.00...2.00	pu	0.01	0.00	Low trigger level for the analog channel
Storage mode	0=Waveform 1=Trend / cycle		1	0	Storage mode for the analog channel

1. Refer to the application manual for channel allocation for each configuration.

Table 511: Non-group binary channel settings for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable		1	5=Disable	Binary channel is enabled or disabled
Level trigger mode	1=Positive or Rising 2=Negative or Falling 3=Both 4=Level trigger off		1	1=Rising	Level trigger mode for the binary channel
Storage mode	0=Waveform 1=Trend / cycle		1	0	Storage mode for the binary channel
Channel id text	0 to 64 characters, alphanumeric			DR binary channel X	Identification text for the analog channel used in the COMTRADE format

Table 512: Control data for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Trig recording	0=Cancel 1=Trig				Trigger the disturbance recording
Clear recordings	0=Cancel 1=Clear				Clear all recordings currently in memory

9.1.5 Monitored data

Table 513: Monitored data for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Number of recordings	0...100				Number of recordings currently in memory
Rem. amount of rec.	0...100				Remaining amount of recordings that fit into the available recording memory, when current settings are used
Rec. memory used	0...100	%			Storage mode for the binary channel
Time to trigger	0...604 800	s			Time remaining to the next periodic triggering

9.1.6 Technical revision history

Table 514: RDRE Technical revision history

Technical revision	Change
B	ChNum changed to EChNum (RADR's). RADR9...12 added (Analog channel 9 -12). RBDR33...64 added (Binary channel 33 - 64).
C	Enum update for Channel selection parameters (DR.RADRx.EChNum.setVal) Std. enum changes to Clear and Manual Trig

9.2 Fault locator FLOC

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Synchronism and energizing check	SECRSYN	SYNC	25

9.2.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fault locator	DRFLO	FLO	FLO

9.2.2 Function block

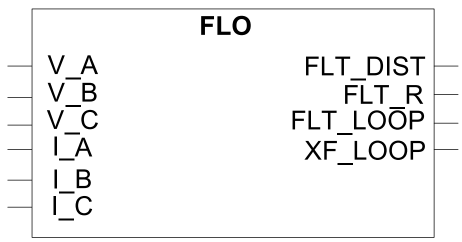

Figure 323: Function block

9.2.3 Functionality

The fault locator function performs the estimation of apparent distance to fault and fault resistance. The calculation is performed by comparing the pre-fault current and voltage phasor by fault current and voltage phasor along with line parameters.

The fault loop is determined and the respective voltage and current phasor are selected for the fault location algorithm. The pre fault current and voltage phasor are used to calculate the pre fault load impedance and fault current and voltage phasor are used to calculate the apparent impedance during the fault. The load impedance, apparent impedance and line parameters are used to estimate the fault resistance and distance to fault.

9.2.4 Operation principle

The *Operation* setting is used to enable or disable the function. When selected “On” the function is enabled and respectively “Off” means function is disabled.

The operation of FLO can be described by using a module diagram (see Figure 324). All the modules in the diagram are explained in the next sections.

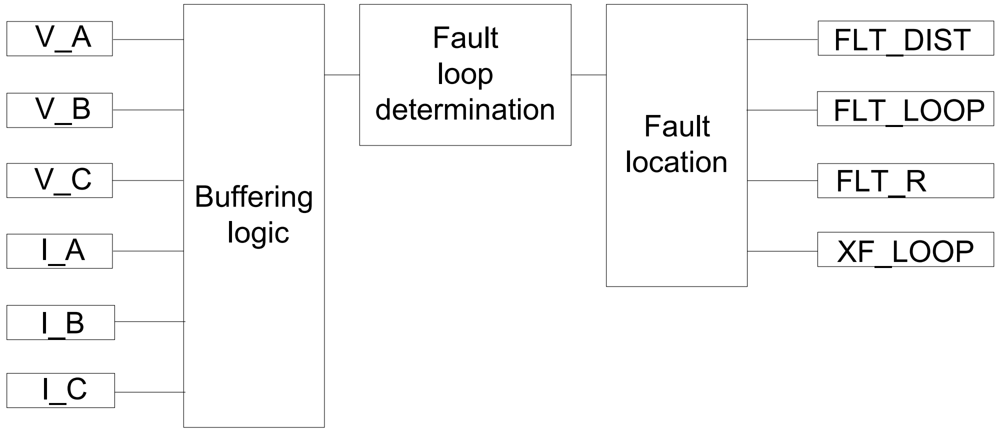

Figure 324: Functional module diagram

Buffering logic

This module buffers the three phase voltage and current phasor input values (DFT values of V_A, V_B, V_C, I_A, I_B, I_C). Once the phase current magnitude is more than the *Phase Level* setting the pre-fault buffer will freeze and updating of fault buffer will be started. The fault buffer will freeze once the buffer is updated fully. The fault location algorithm will be started only if Relay Trip signal is detected.

Fault loop determination

Any fault can be categorized as either a phase to phase fault or a phase to ground fault.

The fault loop determination algorithm determines whether the fault is a phase to ground fault or phase to phase fault by comparing the phase currents with zero sequence current.

This module determines the fault loop from pre-fault and fault phasor stored in the respective buffers. The fault typing is the procedure to identify the type of fault and therefore the respective voltage and current phasor can be selected from the pre-fault and fault buffers, for the fault location algorithm.

Once the fault has been classified as either a phase to ground or phase to phase fault, then the specific fault loop is determined by comparing all phase currents with the setting *Phase Level*. Fault loop determination is done in accordance with Table 515.

Table 515: Fault identification

Fault in phase A	Fault in phase B	Fault in phase C	Fault in ground (Io)	FLTLOOP	FLTLOOP
1	0	0	1	AG Fault	1
0	1	0	1	BG Fault	2
0	0	1	1	CG Fault	3
1	1	0	0	AB Fault	4
0	1	1	0	BC Fault	5
1	0	1	0	CA Fault	6
1	1	1	0	ABC Fault	7
1	1	0	1	ABG Fault	-1
0	1	1	1	BCG Fault	-2
1	0	1	1	CAG Fault	-3
1	1	1	1	ABCG Fault	-4
0	0	0	0	No Fault	0

Once the specific fault type is determined, the respective fault loop voltage and current phasor are taken for fault location algorithm.

If the fault is any single phase to ground fault, then the respective phase current should be ground compensated.

The procedure for the ground compensation is given below,

For ground fault cases, the current measured at the relay is ground compensated by employing the following formula:

$$I^{*}_{rly} = I_{rly} + k * I_0 * (ZL_{zero} - ZL_{pos}) / ZL_{pos}$$

Equation (76)

where

$$I_0 = (I\_A + I\_B + I\_C)/3$$

Equation (77)

k = 1.0 (scaling factor)

ZL_{pos} and ZL_{zero} refer to positive and zero sequence line impedances.

$ZL_{pos} = RL_{pos} + j*XL_{pos}$

$ZL_{zero} = RL_{zero} + j*XL_{zero}$

RL_{pos} = *PosSeqR* * *LinLen*

XL_{pos} = *PosSeqX* * *LinLen*

RL_{zero} = *ZeroSeqR* * *LinLen*

XL_{zero} = *ZeroSeqX* * *LinLen*

I^{*}_{rly} = Ground compensated phase current

I_{rly} = Non-compensated phase current

R1 is positive sequence line resistance in ohm/ (miles or kms) and is provided as a setting

X1 is positive sequence line reactance in ohm/ (miles or kms) and is provided as a setting

R0 is zero sequence line resistance in ohm/ (miles or kms) and is provided as a setting

X0 is zero sequence line reactance in ohm/ (miles or kms) and is provided as a setting

Line Length is the length of the line in the units of kilometers (Km) or miles and is provided as a setting.

If *R1*, *X1*, *R0*, *X0* are given in ohm/mile then the length of the line *Line Length* should be given in the unit of miles

If *R1*, *X1*, *R0*, *X0* are given in ohm/Km then the length of the line *Line Length* should be given in the unit of Km's.

Table 516 describes what will be the voltage phasor and current phasor under different fault types.

Table 516: Relay voltage and current phasor identification

FLTLOOP	Current phasor	Voltage phasor
AG Fault	I_A*	V_A
BG Fault	I_B*	V_B
CG Fault	I_C*	V_C
ABG Fault	(I_A - I_B)	(V_A - V_B)
BCG Fault	(I_B - I_C)	(V_B - V_C)
CAG Fault	(I_C - I_A)	(V_C - V_A)
ABCG Fault	I_A	V_A
AB Fault	(I_A - I_B)	(V_A - V_B)
BC Fault	(I_B - I_C)	(V_B - V_C)
CA Fault	(I_C - I_A)	(V_C - V_A)
ABC Fault	I_A	V_A

* indicates the respective current is ground compensated

Fault location

This module calculates the distance to fault and fault resistance from the voltage phasor and current phasor selected based on type of the fault (see Table 516).

The algorithm uses the fundamental frequency phasor voltages and currents measured at the relay terminal before and during the fault.

The algorithm basically is an iterative technique, performs a comparison of the pre fault load impedance and apparent impedance during the fault, to estimate the distance to fault.

Estimated values of fault resistance, pre fault load impedance and line impedance are then modified using the correction factors. And the corrected values are used to estimate the final FLT_DIST and FLT_R.

During the auto-re-closure sequences the fault location is done with initial fault conditions.

9.2.5 Application

Electrical power system has grown rapidly over the last few decades. This resulted in a large increase of the number of lines in operation and their total length. These lines experience faults which are caused by storms, lightning, snow, freezing rain, insulation breakdown and short circuits caused by birds and other external objects. In most cases, electrical faults manifest in mechanical damage, which must be repaired before returning the line to service. The restoration can be expedited if the location of the fault is either known or can be expedited with reasonable accuracy.

Fault locators provide estimate for both sustained and transient faults. Generally transient faults cause minor damage that is not easily visible on inspection. Fault locators help identify those locations for early repairs to prevent recurrence and consequent major damage.

The fault location algorithm is most applicable for radial feeder. The algorithm is based on the system model shown in Figure 325. The algorithm was designed to be used on a homogeneous radial distribution line. Therefore the unit is not intended to be used on a distribution line with many different types of conductors because the algorithm will not be as accurate. Fault locator algorithm may not be accurate for switch on to fault condition.

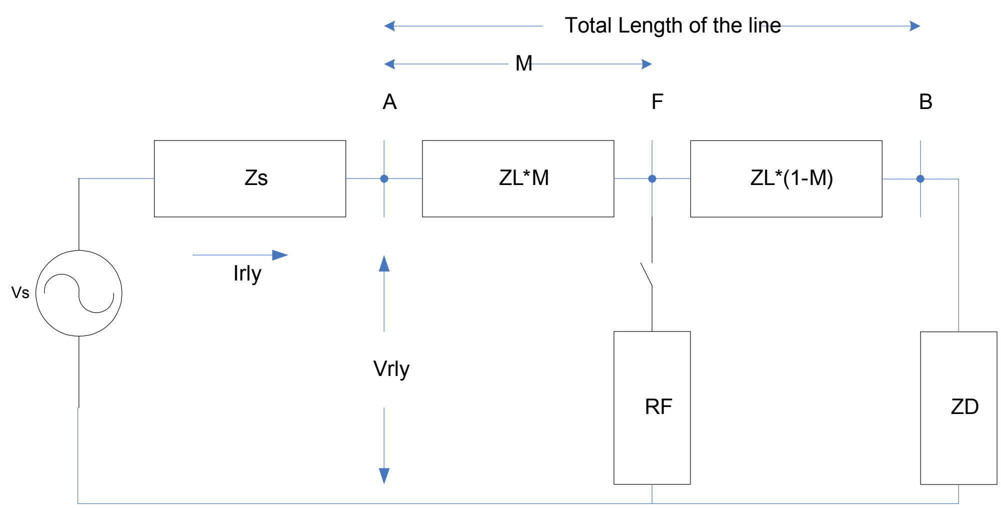

Figure 325: System model considered for fault location

Where,

Vs = Source Voltage

Vrly = Voltage at the relay location

Irly = Current in the transmission line at the relay location

Zs = Source impedance

ZL = Transmission line impedance in ohm/unit length

ZD = Load impedance

RF = Fault resistance

M = Distance to point of fault from relay location

9.2.6 Signals

Table 517: FLO input signals

Name	Type	Default	Description
V_A	SIGNAL	0	Phase A Voltage
V_B	SIGNAL	0	Phase B Voltage
V_C	SIGNAL	0	Phase C Voltage
I_A	SIGNAL	0	Phase A Current
I_B	SIGNAL	0	Phase B Current
I_C	SIGNAL	0	Phase C Current

9.2.7 Settings

Table 518: FLO group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	ON/OFF			ON	Operation
Line Length	0.00…300.00	Miles/Kms		100.00	Length of the transmission or distribution line in miles
R1	0.000...20.000	Ohm/(Mile or Km)		1.000	Positive sequence resistance of line in primary Ohm/(Mile or Km)
X1	0.000...30.000	Ohm/(Mile or Km)		2.000	Positive sequence reactance of line in primary Ohm/(Mile or Km)
R0	0.000...20.000	Ohm/(Mile or Km)		0.010	Zero sequence resistance of line in primary Ohm/(Mile or Km)
X0	0.000...30.000	Ohm/(Mile or Km)		1.000	Zero sequence reactance of line in primary Ohm/(Mile or Km)
Phase Level	0.00...40.00	%In		0.10	Threshold magnitude of phase current in the per-unit of primary rated current

9.2.8 Monitored data

Table 519: FLO monitored data

Name	Type	Description
FLT_DIST	FLOAT32	Estimated distance to fault in Miles or Kms depending on Line parameter units
FLT_R	FLOAT32	Estimated fault resistance in ohms
XF_LOOP	FLOAT32	Estimated reactance in the fault loop in ohms
FLT_LOOP	-1=ABG Fault -2=BCG Fault -3=CAG Fault -4=ABCG Fault 0=No Fault 1=AG Fault 2=BG Fault 3=CG Fault 4=AB Fault 5=BC Fault 6=CA Fault 7=ABC Fault	Fault loop

Section 10 Other functions

10.1 Minimum pulse timer (2pcs), TP

10.2 Mimimum pulse timer (2pcs, second/minute resolution), 62CLD

10.3 Pulse timer (8pcs), PT

10.3.1 Function block

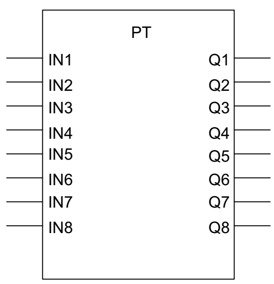

Figure 326: Function block

10.3.2 Functionality

The pulse timer function block PT contains eight independent timers. The function has a settable pulse length. Once the input is activated, the output is set for a specific duration using the *Pulse delay time* setting.

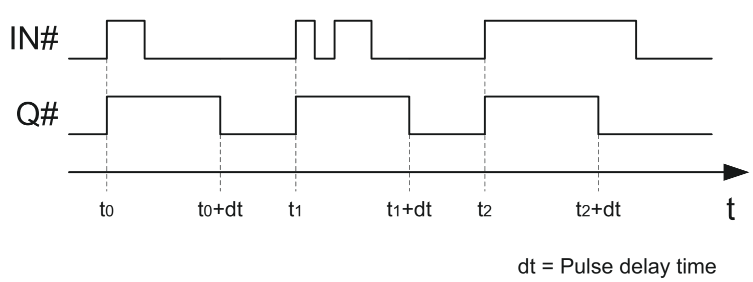

Figure 327: Timer operation

10.3.3 Signals

Table 520: PT Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status
IN3	BOOLEAN	0=False	Input 3 status
IN4	BOOLEAN	0=False	Input 4 status
IN5	BOOLEAN	0=False	Input 5 status
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 521: PT Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1 status
Q2	BOOLEAN	Output 2 status
Q3	BOOLEAN	Output 3 status
Q4	BOOLEAN	Output 4 status
Q5	BOOLEAN	Output 5 status
Q6	BOOLEAN	Output 6 status
Q7	BOOLEAN	Output 7 status
Q8	BOOLEAN	Output 8 status

10.3.4 Settings

Table 522: PT Non group settings

Pulse delay time 1	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 2	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 3	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 4	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 5	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 6	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 7	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 8	0...3600000	ms	10	0	Pulse delay time

Table 523: Generic timers, TPGAPC1...4

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...60000	ms	1	150	Minimum pulse time

Table 524: Generic timers, TPSGAPC1

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	s	1	0	Minimum pulse time, range in seconds

Table 525: Generic timers, TPMGAPC1

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	min	1	0	Minimum pulse time, range in minutes

10.3.5 Technical data

Table 526: PT Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

10.4 Time delay off timers, TOF

10.4.1 Function block

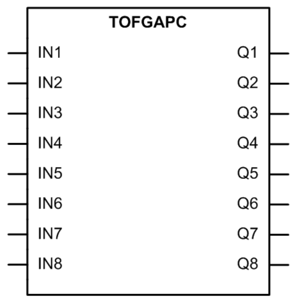

Figure 328: Function block

10.4.2 Functionality

The time-delay-off function block TOFGAPC can be used, for example, for a drop-off-delayed output related to the input signal. TOFGAPC contains eight independent timers. There is a settable delay in the timer. Once the input is activated, the output is set immediately. When the input is cleared, the output stays on until the time set with the *Off delay time* setting has elapsed.

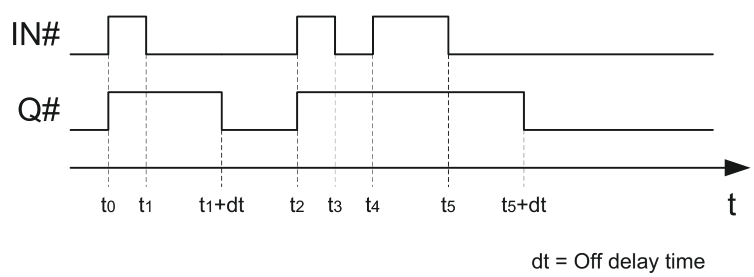

Figure 329: Timer operation

10.4.3 Signals

Table 527: TOFGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status
IN3	BOOLEAN	0=False	Input 3 status
IN4	BOOLEAN	0=False	Input 4 status
IN5	BOOLEAN	0=False	Input 5 status
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 528: TOFGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1 status
Q2	BOOLEAN	Output 2 status
Q3	BOOLEAN	Output 3 status
Q4	BOOLEAN	Output 4 status
Q5	BOOLEAN	Output 5 status
Q6	BOOLEAN	Output 6 status
Q7	BOOLEAN	Output 7 status
Q8	BOOLEAN	Output 8 status

10.4.4 Settings

Table 529: TOFGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Off delay time 1	0...3600000	ms	10	0	Off delay time
Off delay time 2	0...3600000	ms	10	0	Off delay time
Off delay time 3	0...3600000	ms	10	0	Off delay time
Off delay time 4	0...3600000	ms	10	0	Off delay time
Off delay time 5	0...3600000	ms	10	0	Off delay time
Off delay time 6	0...3600000	ms	10	0	Off delay time
Off delay time 7	0...3600000	ms	10	0	Off delay time
Off delay time 8	0...3600000	ms	10	0	Off delay time

10.4.5 Technical data

Table 530: TOFGAPC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

10.5 Time delay on timers, TON

10.5.1 Function block

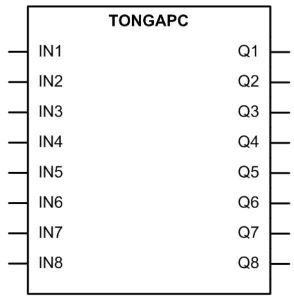

Figure 330: Function block

10.5.2 Functionality

The time-delay-on function block TONGAPC can be used, for example, for time-delaying the output related to the input signal. TONGAPC contains eight independent timers. The timer has a settable time delay. Once the input is activated, the output is set after the time set by the *On delay time* setting has elapsed.

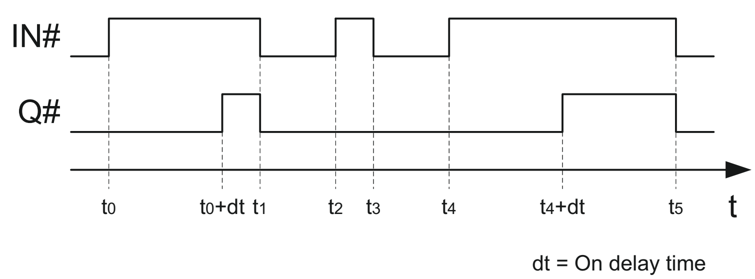

Figure 331: Timer operation

10.5.3 Signals

Table 531: TONGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2
IN3	BOOLEAN	0=False	Input 3
IN4	BOOLEAN	0=False	Input 4
IN5	BOOLEAN	0=False	Input 5
IN6	BOOLEAN	0=False	Input 6
IN7	BOOLEAN	0=False	Input 7
IN8	BOOLEAN	0=False	Input 8

Table 532: TONGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1
Q2	BOOLEAN	Output 2
Q3	BOOLEAN	Output 3
Q4	BOOLEAN	Output 4
Q5	BOOLEAN	Output 5
Q6	BOOLEAN	Output 6
Q7	BOOLEAN	Output 7
Q8	BOOLEAN	Output 8

10.5.4 Settings

Table 533: TONGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
On delay time 1	0...3600000	ms	10	0	On delay time
On delay time 2	0...3600000	ms	10	0	On delay time
On delay time 3	0...3600000	ms	10	0	On delay time
On delay time 4	0...3600000	ms	10	0	On delay time
On delay time 5	0...3600000	ms	10	0	On delay time
On delay time 6	0...3600000	ms	10	0	On delay time
On delay time 7	0...3600000	ms	10	0	On delay time
On delay time 8	0...3600000	ms	10	0	On delay time

10.5.5 Technical data

Table 534: TONGAPC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

10.6 Set reset flip flops, SR

10.6.1 Function block

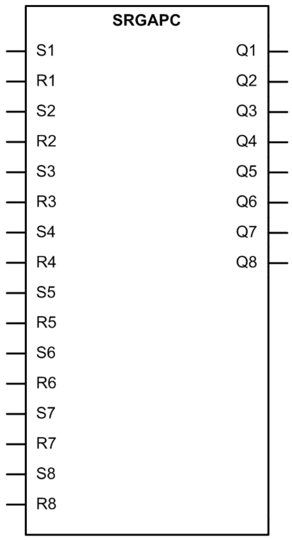

Figure 332: Function block

10.6.2 Functionality

The SRGAPC function block is a simple SR flip-flop with a memory that can be set or that can reset an output from the `S#` or `R#` inputs, respectively. SRGAPC contains eight independent set-reset flip-flop latches where the `SET` input has the higher priority over the `RESET` input. The status of each `Q#` output is retained in the nonvolatile memory. The individual reset for each `Q#` output is available on the LHMI or through tool via communication.

Table 535: Truth table for SRGAPC

S#	R#	Q#
0	0	0[1]
0	1	0
1	0	1
1	1	1

1. Keep state/no change

10.6.3 Signals

Table 536: SRGAPC Input signals

Name	Type	Default	Description
S1	BOOLEAN	0=False	Set Q1 output when set
R1	BOOLEAN	0=False	Resets Q1 output when set
S2	BOOLEAN	0=False	Set Q2 output when set
R2	BOOLEAN	0=False	Resets Q2 output when set
S3	BOOLEAN	0=False	Set Q3 output when set
R3	BOOLEAN	0=False	Resets Q3 output when set
S4	BOOLEAN	0=False	Set Q4 output when set
R4	BOOLEAN	0=False	Resets Q4 output when set
S5	BOOLEAN	0=False	Set Q5 output when set
R5	BOOLEAN	0=False	Resets Q5 output when set
S6	BOOLEAN	0=False	Set Q6 output when set
R6	BOOLEAN	0=False	Resets Q6 output when set
S7	BOOLEAN	0=False	Set Q7 output when set
R7	BOOLEAN	0=False	Resets Q7 output when set
S8	BOOLEAN	0=False	Set Q8 output when set
R8	BOOLEAN	0=False	Resets Q8 output when set

Table 537: SRGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Q1 status
Q2	BOOLEAN	Q2 status
Q3	BOOLEAN	Q3 status
Q4	BOOLEAN	Q4 status
Q5	BOOLEAN	Q5 status
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

10.6.4 Settings

Table 538: SRGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Reset Q1	0=Cancel 1=Reset			0=Cancel	Resets Q1 output when set
Reset Q2	0=Cancel 1=Reset			0=Cancel	Resets Q2 output when set
Reset Q3	0=Cancel 1=Reset			0=Cancel	Resets Q3 output when set
Reset Q4	0=Cancel 1=Reset			0=Cancel	Resets Q4 output when set
Reset Q5	0=Cancel 1=Reset			0=Cancel	Resets Q5 output when set
Reset Q6	0=Cancel 1=Reset			0=Cancel	Resets Q6 output when set
Reset Q7	0=Cancel 1=Reset			0=Cancel	Resets Q7 output when set
Reset Q8	0=Cancel 1=Reset			0=Cancel	Resets Q8 output when set

10.7 Move blocks, MV

10.7.1 Function block

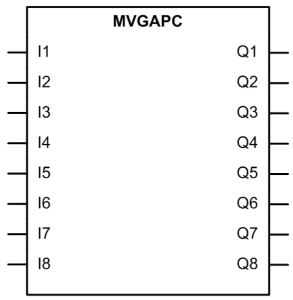

Figure 333: Function block

10.7.2 Functionality

The move function block MVGAPC is used for user logic bits. Each input state is directly copied to the output state. This allows the creating of events from advanced logic combinations.

10.7.3 Signals

Table 539: MVGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Q1 status
Q2	BOOLEAN	Q2 status
Q3	BOOLEAN	Q3 status
Q4	BOOLEAN	Q4 status
Q5	BOOLEAN	Q5 status
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

Section 11 General function block features

11.1 Definite time characteristics

11.1.1 Definite time operation

The DT mode is enabled when the *Operating curve type* setting is selected either as "ANSI Def. Time" or "IEC Def. Time". In the DT mode, the `TRIP` output of the function is activated when the time calculation exceeds the set *Trip delay time*.

The user can determine the reset in the DT mode with the *Reset delay time* setting, which provides the delayed reset property when needed.

The *Type of reset curve* setting has no effect on the reset method when the DT mode is selected, but the reset is determined solely with the *Reset delay time* setting.

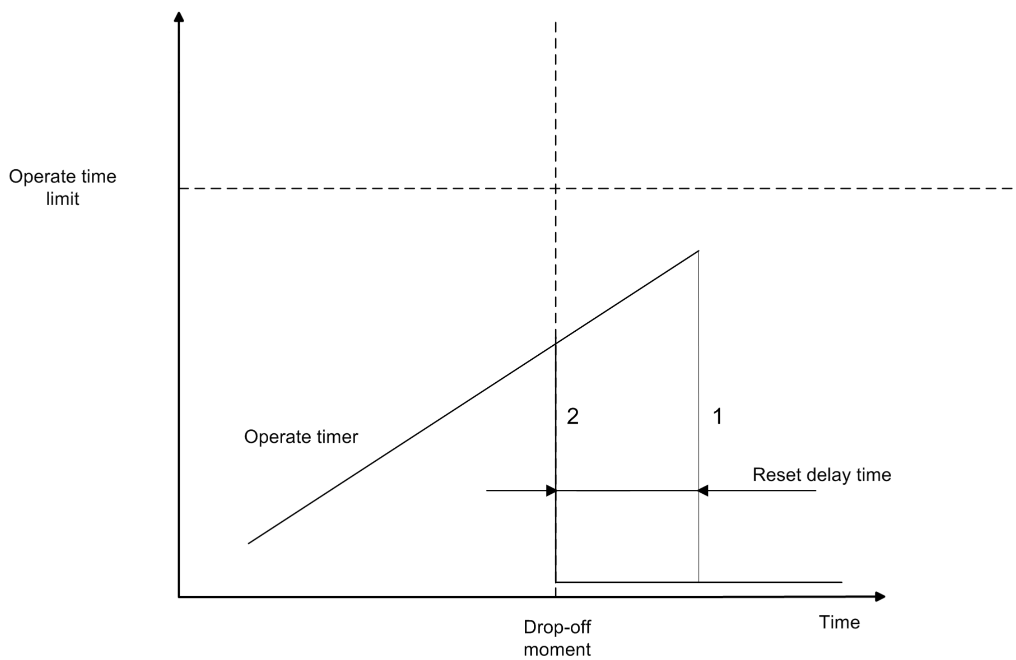

Figure 334: Operation of the counter in drop-off

In case 1, the reset is delayed with the *Reset delay time* setting and in case 2, the counter is reset immediately, because the *Reset delay time* setting is set to zero.

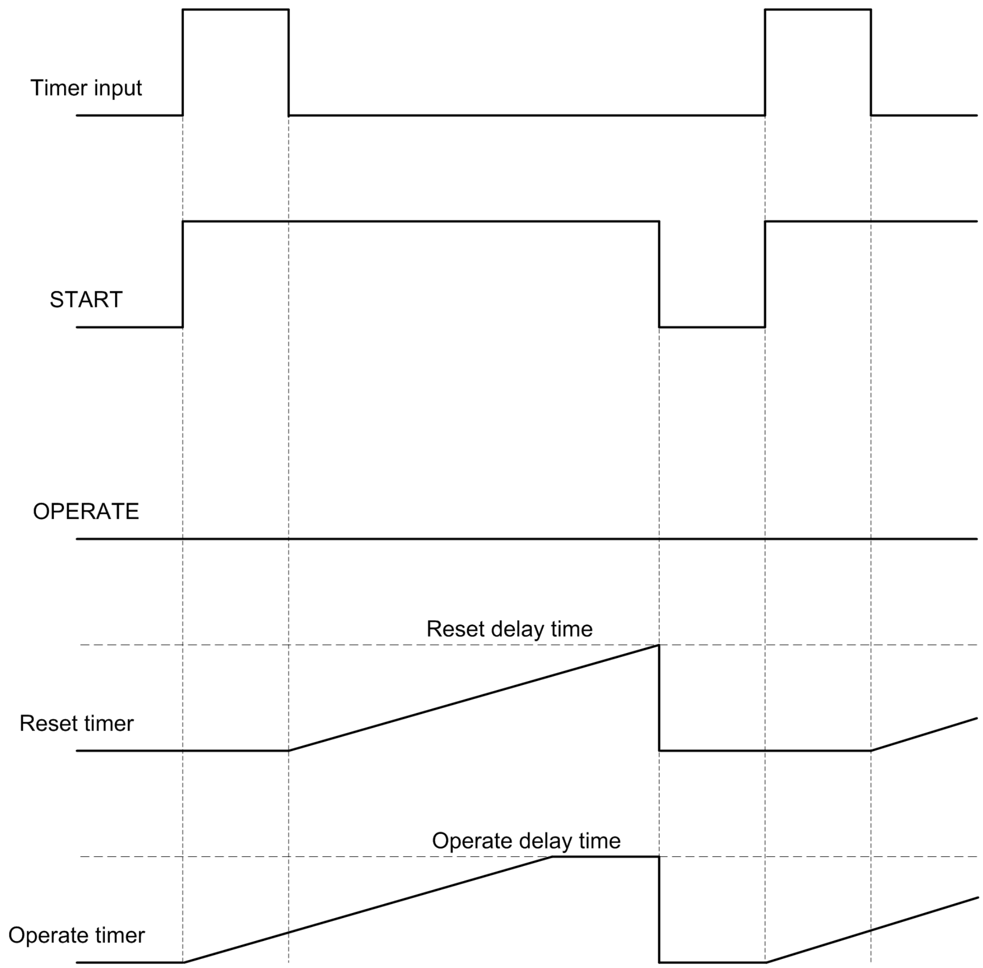

Figure 335: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 335, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Pickup value*. The input signal is inactive when the current is below the set *Pickup value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the `PICKUP` output and the trip timer starts elapsing. The reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. When the reset (drop-off) timer elapses, the trip timer is reset. Since this happens before another pickup occurs, the `TRIP` output is not activated.

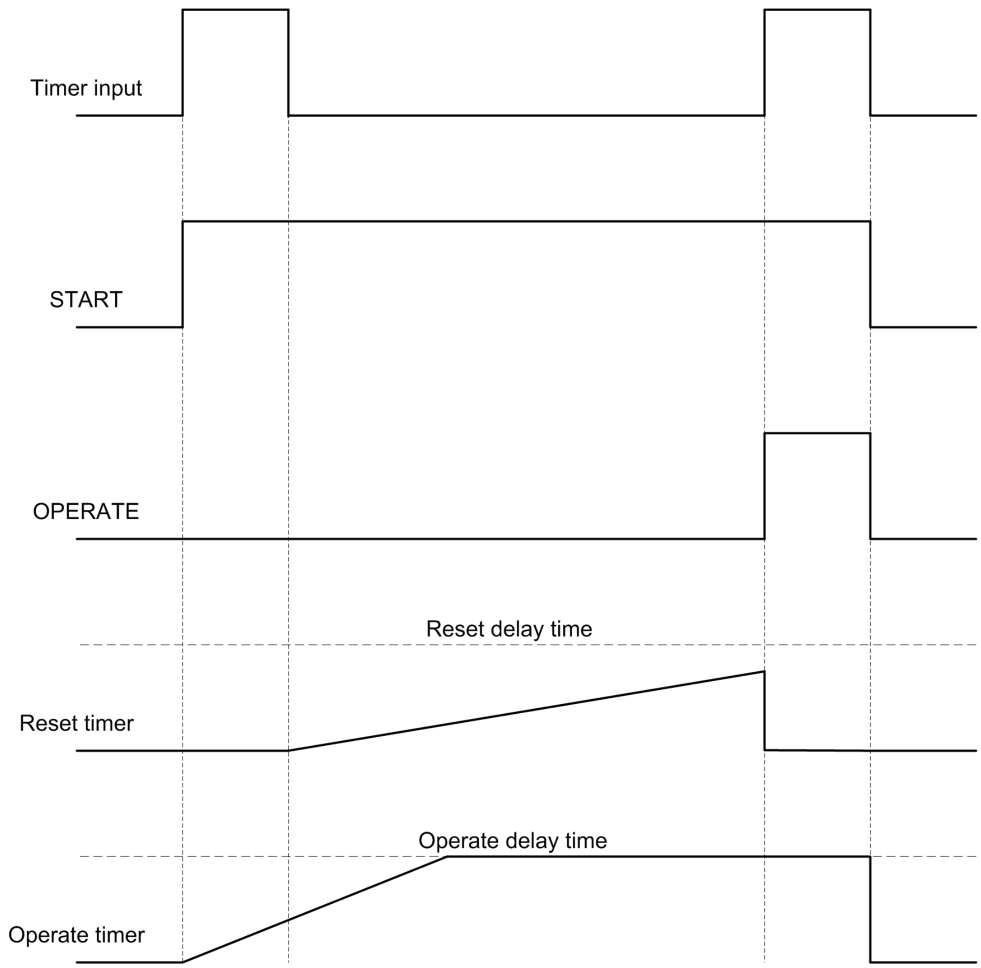

Figure 336: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 336 , the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Pickup value*. The input signal is inactive when the current is below the set *Pickup value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the `PICKUP` output and the trip timer starts elapsing. The reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. Another fault situation occurs before the reset (drop-off) timer has elapsed. This causes the activation of the `TRIP` output, since the trip timer already has elapsed.

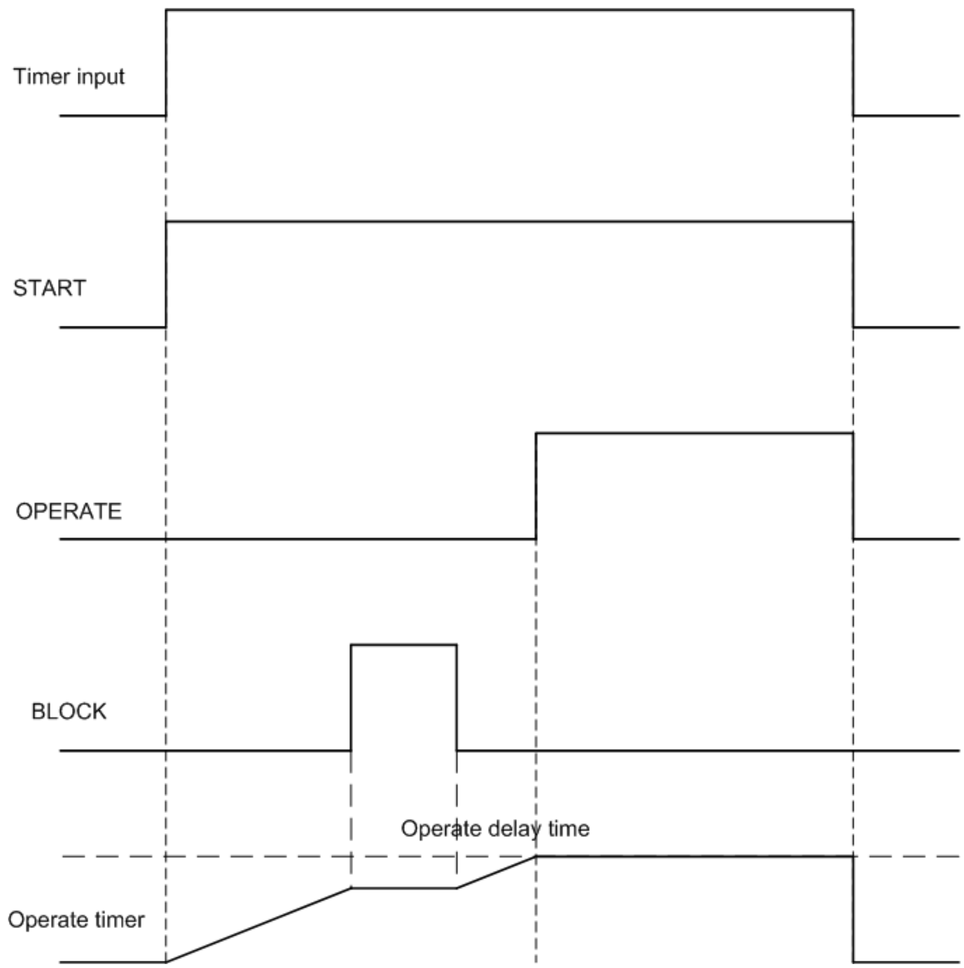

Figure 337: Operating effect of the BLOCK input when the selected blocking mode is "Freeze timer"

If the BLOCK input is activated when the trip timer is running, as described in Figure 337, the timer is frozen during the time BLOCK remains active. If the timer input is not active longer than specified by the *Reset delay time* setting, the trip timer is reset in the same way as described in Figure 335, regardless of the BLOCK input.

The selected blocking mode is "Freeze timer".

11.2 Current based inverse definite minimum time characteristics

11.2.1 IDMT curves for overcurrent protection

In inverse-time modes, the trip time depends on the momentary value of the current: the higher the current, the faster the trip time. The trip time calculation or integration starts immediately when the current exceeds the set *Pickup value* and the `PICKUP` output is activated.

The `TRIP` output of the component is activated when the cumulative sum of the integrator calculating the overcurrent situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time for the IDMT mode, that is, it is possible to limit the IDMT based trip time for not becoming too short. For example:

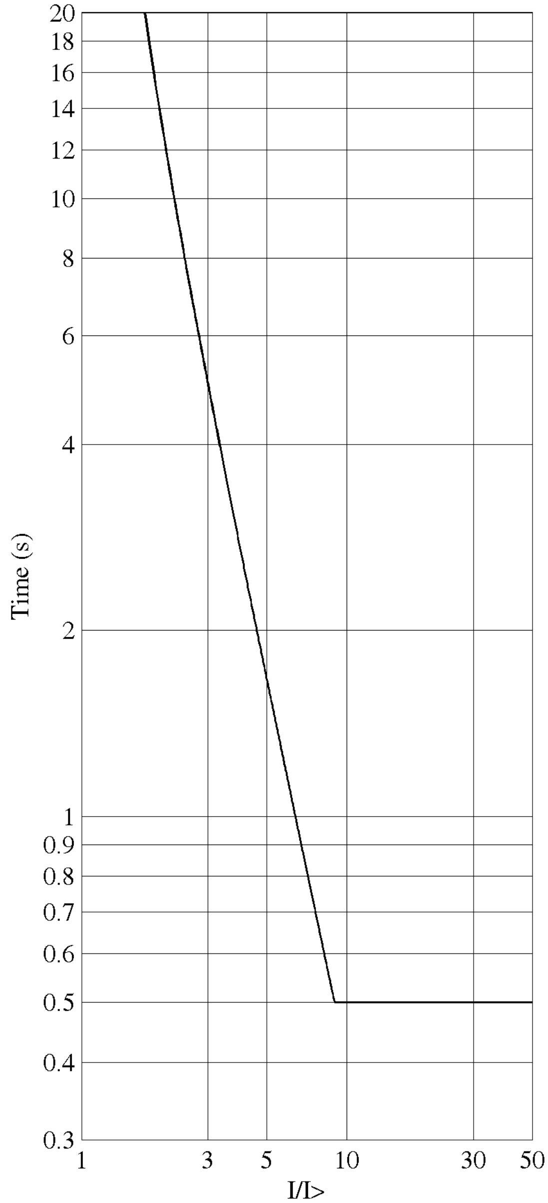

Figure 338: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 0.5 second

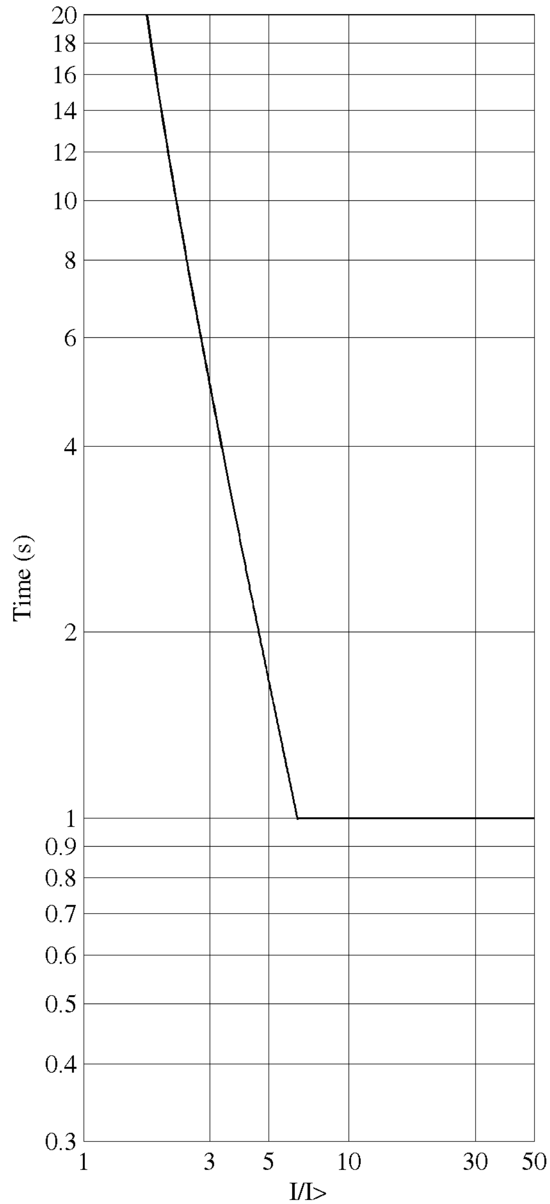

Figure 339: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 1 second

11.2.1.1 Standard inverse-time characteristics

For inverse-time operation, both IEC and ANSI/IEEE standardized inverse-time characteristics are supported.

The trip times for the ANSI and IEC IDMT curves are defined with the coefficients A, B and C.

The values of the coefficients can be calculated according to the formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>} \right)^{C} - 1} + B \right) \cdot k$$

(Equation 78)

t[s] t[s] = Trip time in seconds
I measured current
I> set *Pickup value*
k set *Time multiplier*

Table 540: Curve parameters for ANSI and IEC IDMT curves

Curve name	A	B	C
(1) ANSI Extremely Inverse	28.2	0.1217	2.0
(2) ANSI Very Inverse	19.61	0.491	2.0
(3) ANSI Normal Inverse	0.0086	0.0185	0.02
(4) ANSI Moderately Inverse	0.0515	0.1140	0.02
(6) Long Time Extremely Inverse	64.07	0.250	2.0
(7) Long Time Very Inverse	28.55	0.712	2.0
(8) Long Time Inverse	0.086	0.185	0.02
(9) IEC Normal Inverse	0.14	0.0	0.02
(10) IEC Very Inverse	13.5	0.0	1.0
(11) IEC Inverse	0.14	0.0	0.02
(12) IEC Extremely Inverse	80.0	0.0	2.0
(13) IEC Short Time Inverse	0.05	0.0	0.04
(14) IEC Long Time Inverse	120	0.0	1.0

The maximum guaranteed measured current is 50 x In for the current protection. When the set *Pickup value* exceeds 1.00 x In, the turn point where the theoretical IDMT characteristics are leveling out to the definite time can be calculated with the formula:

$$Turn\ point = \frac{50 \times In}{Pickup\,value}$$

(Equation 79)

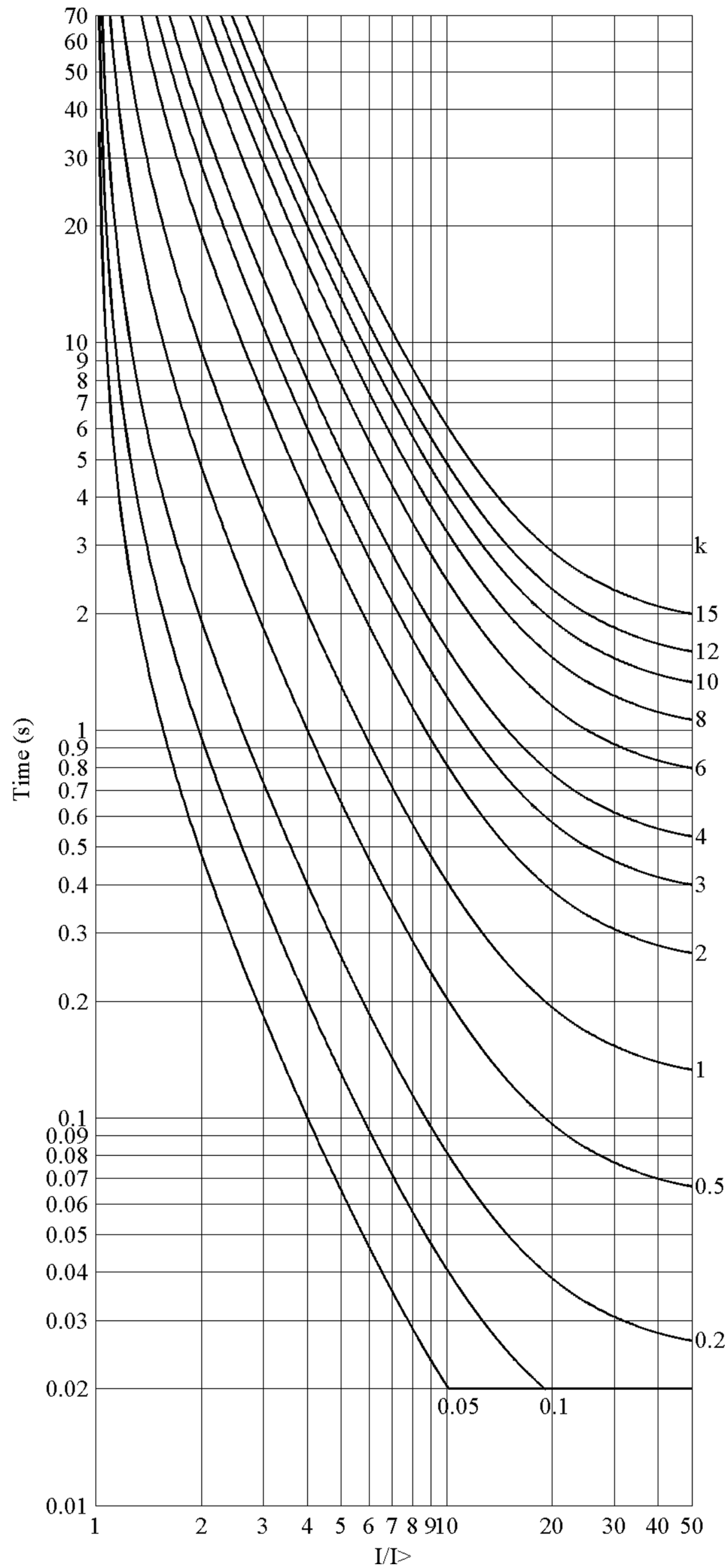

Figure 340: ANSI extremely inverse-time characteristics

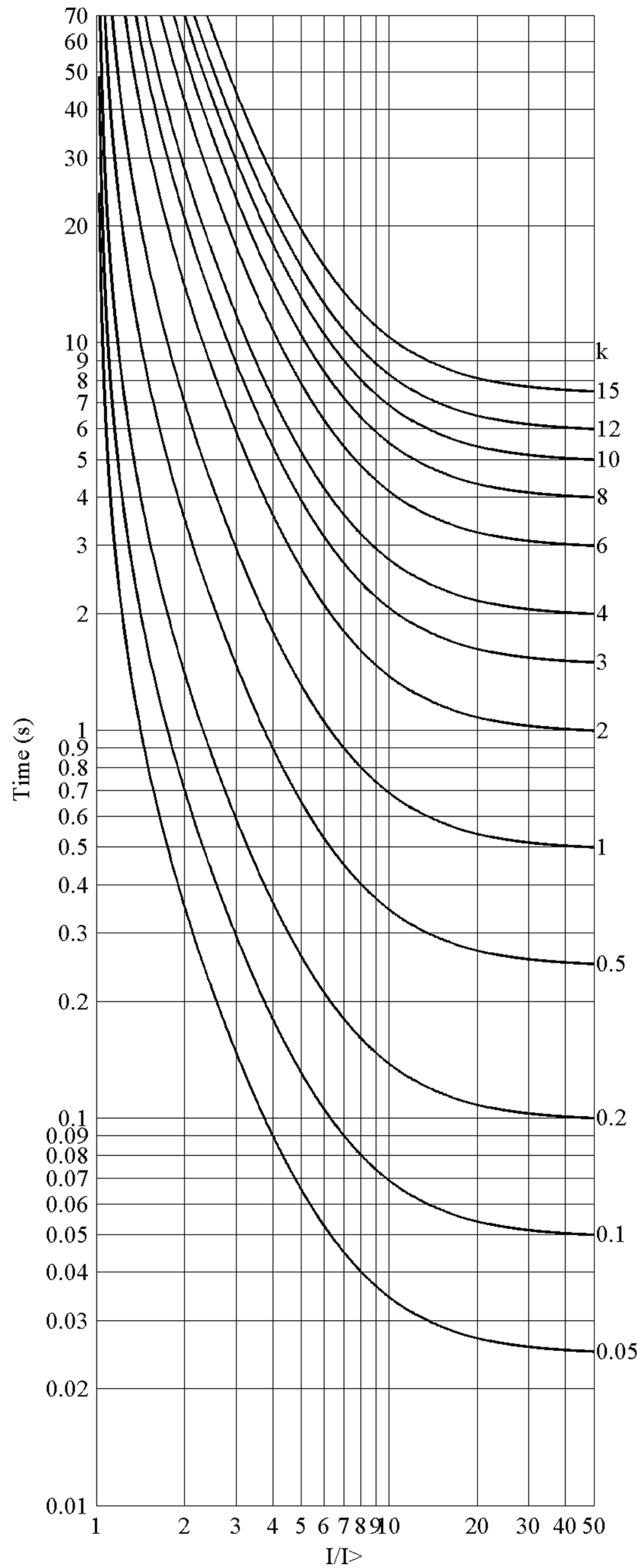

Figure 341: ANSI very inverse-time characteristics

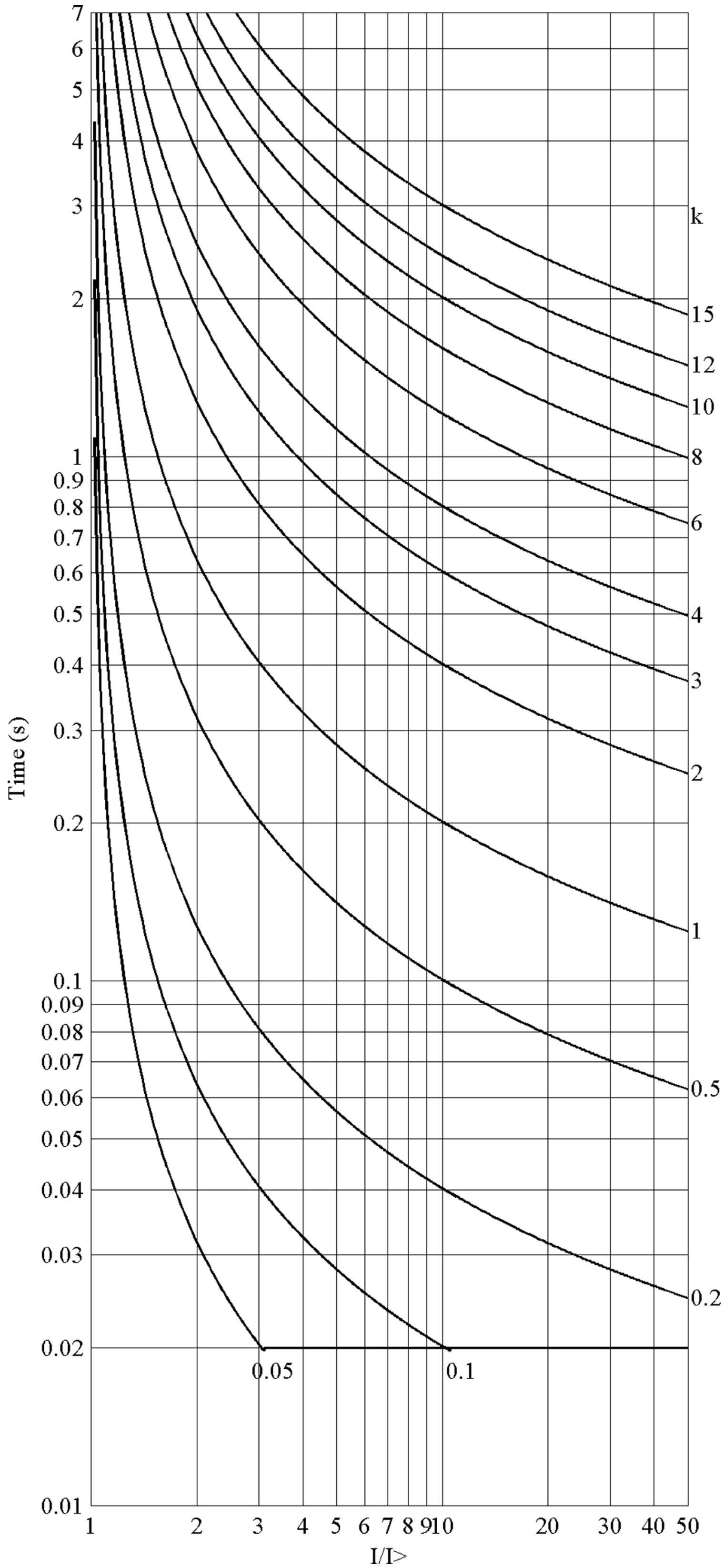

Figure 342: ANSI normal inverse-time characteristics

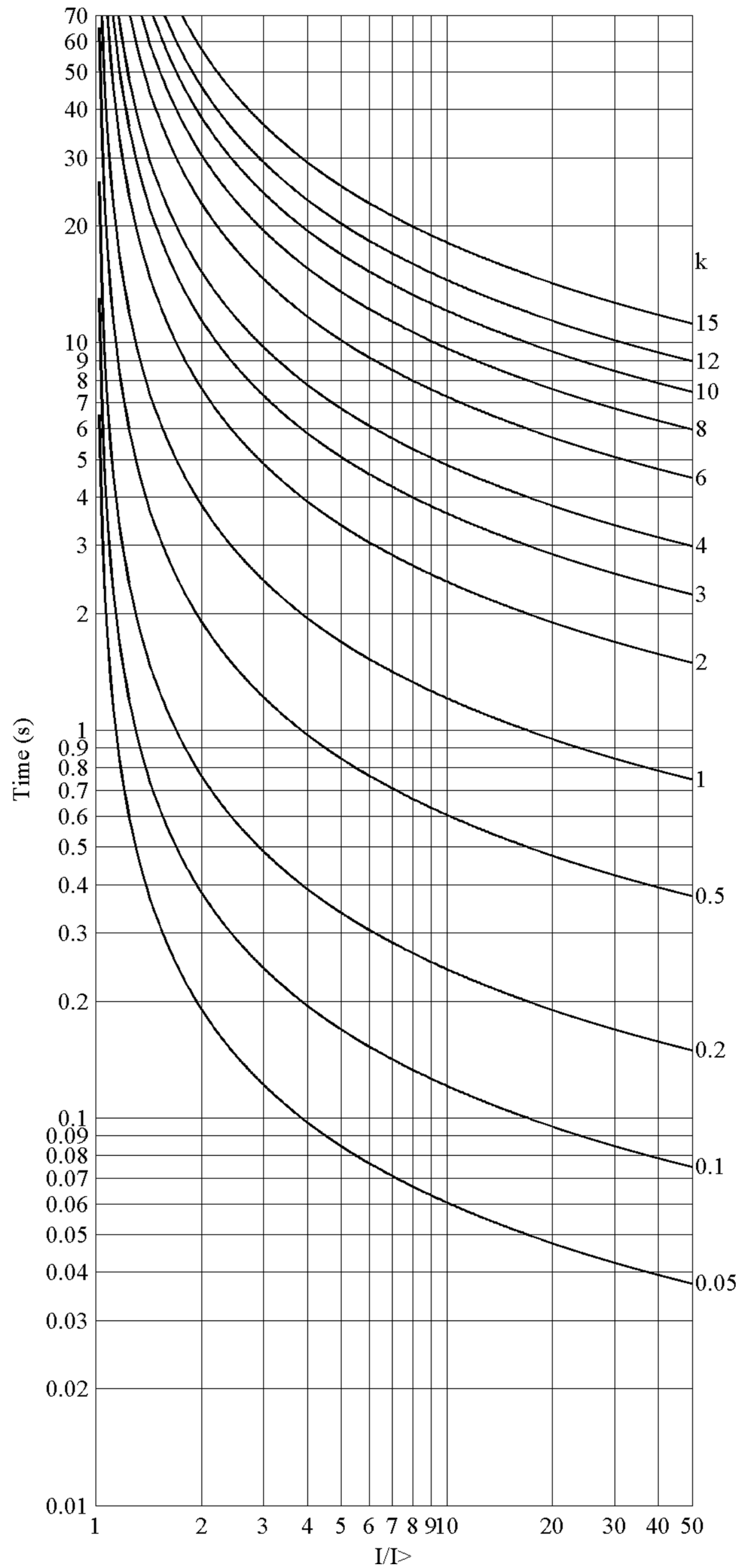

Figure 343: ANSI moderately inverse-time characteristics

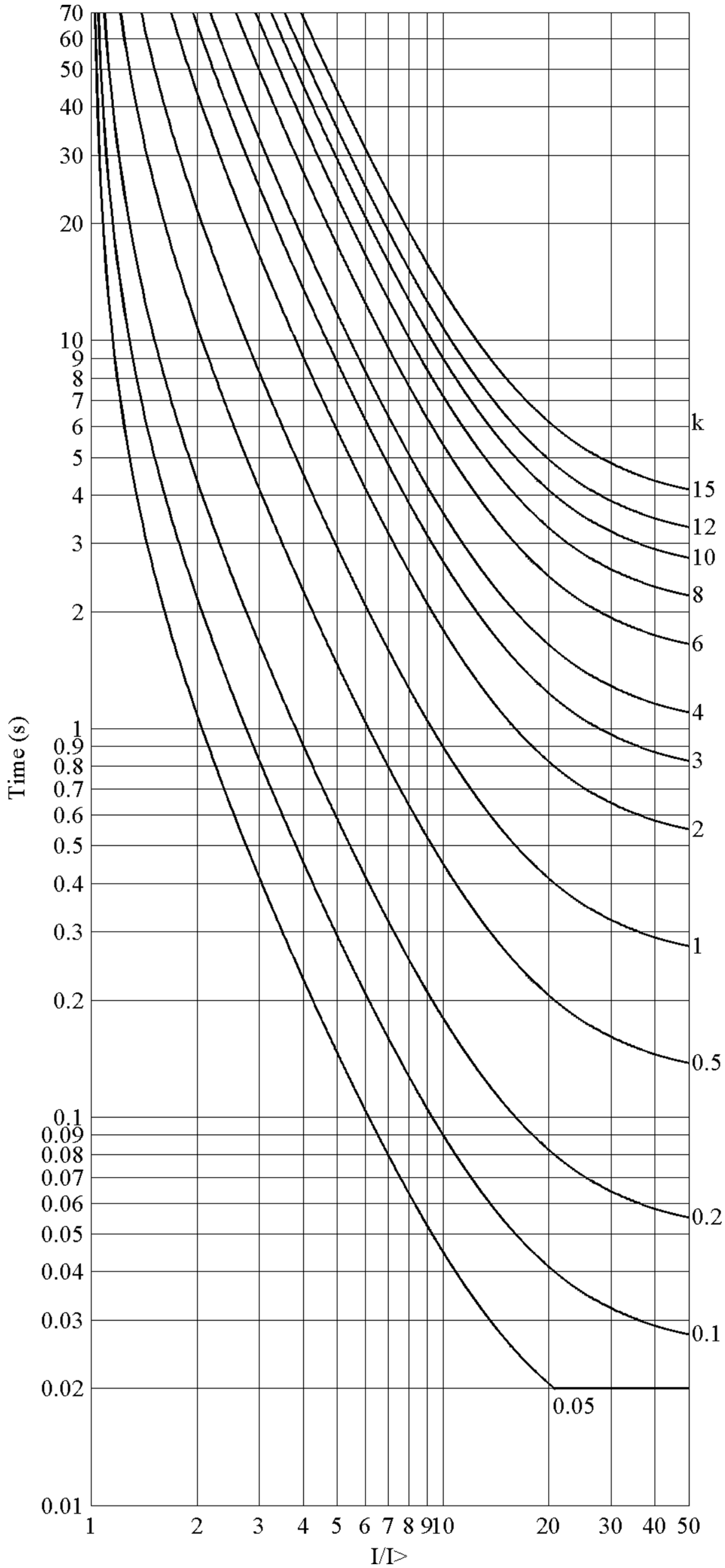

Figure 344: ANSI long-time extremely inverse-time characteristics

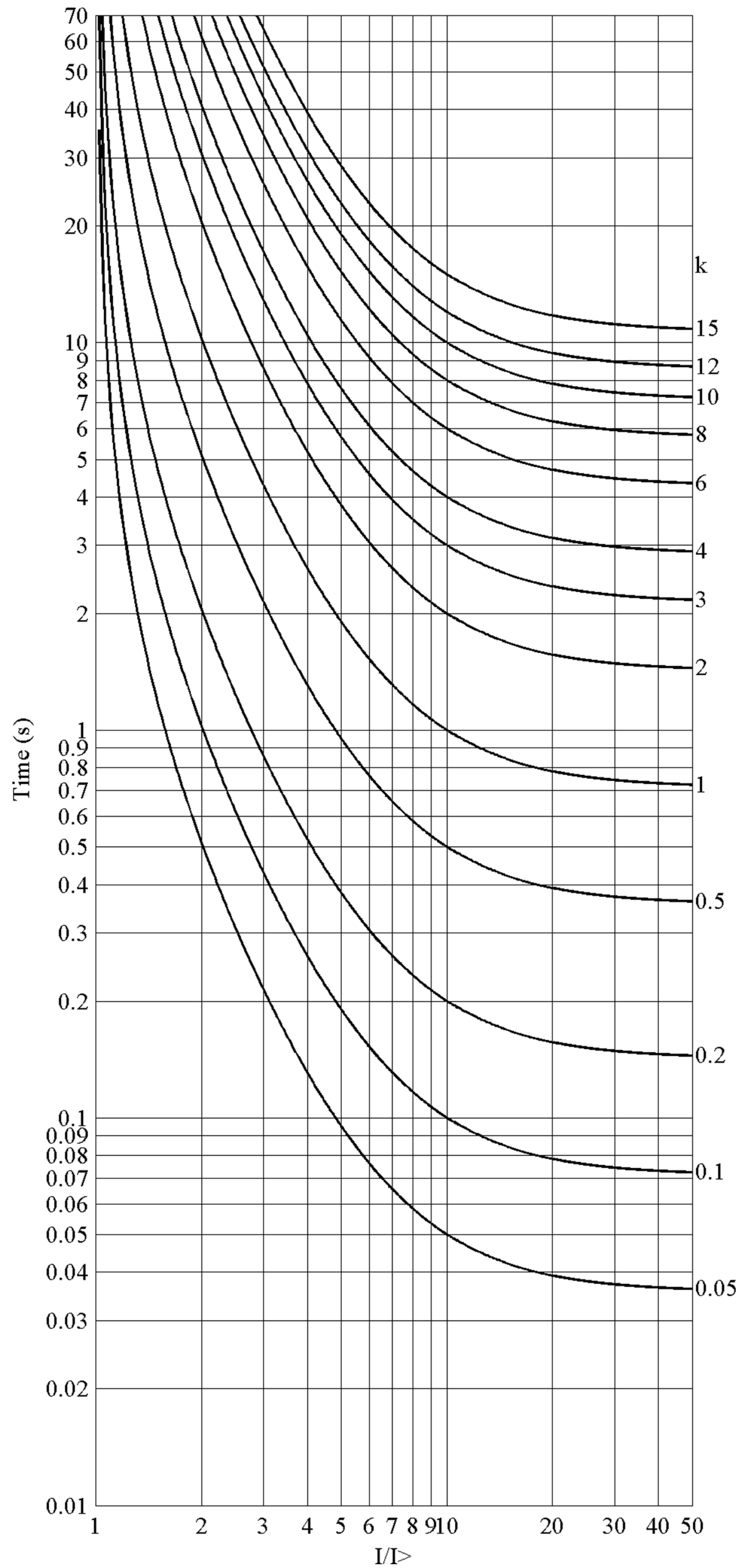

Figure 345: ANSI long-time very inverse-time characteristics

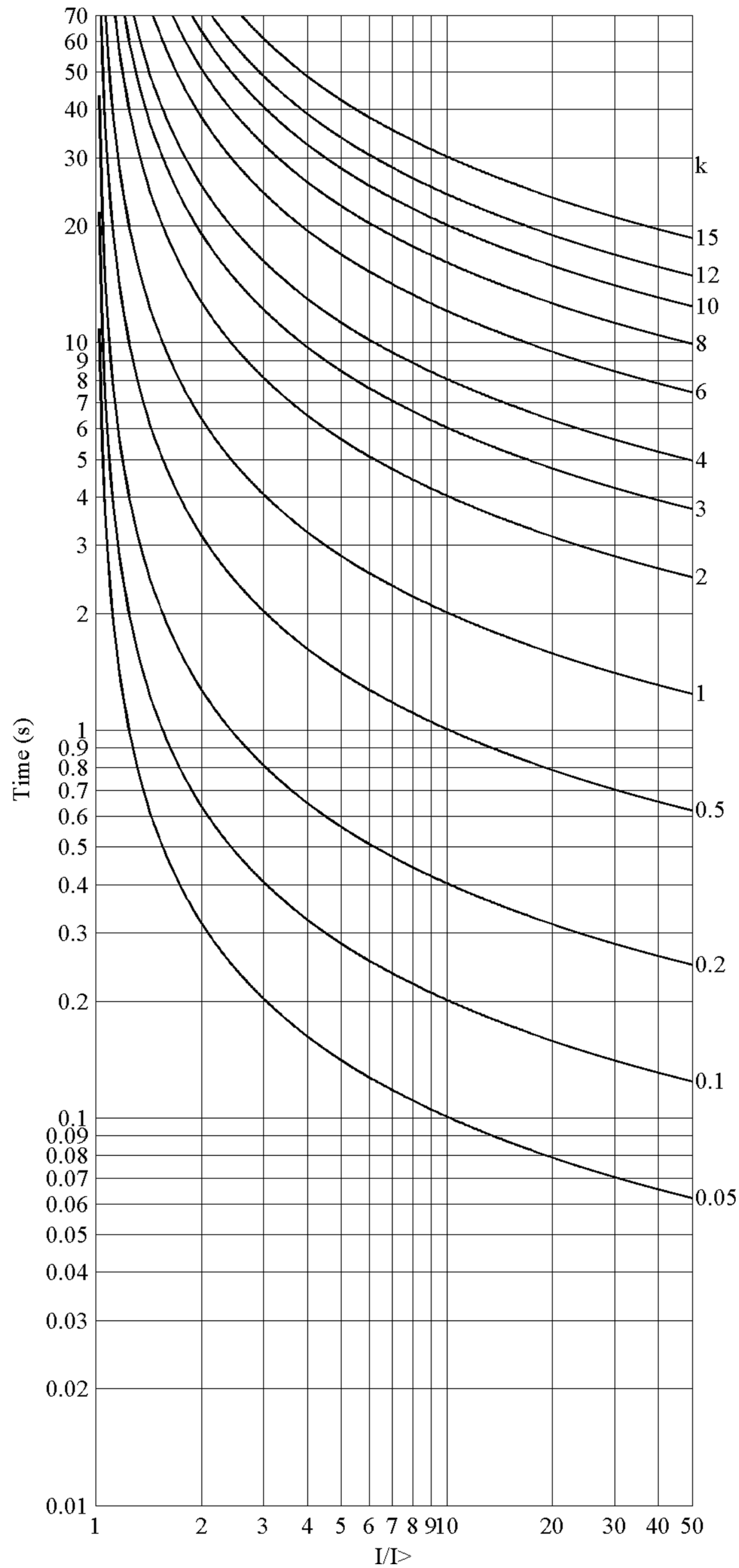

Figure 346: ANSI long-time inverse-time characteristics

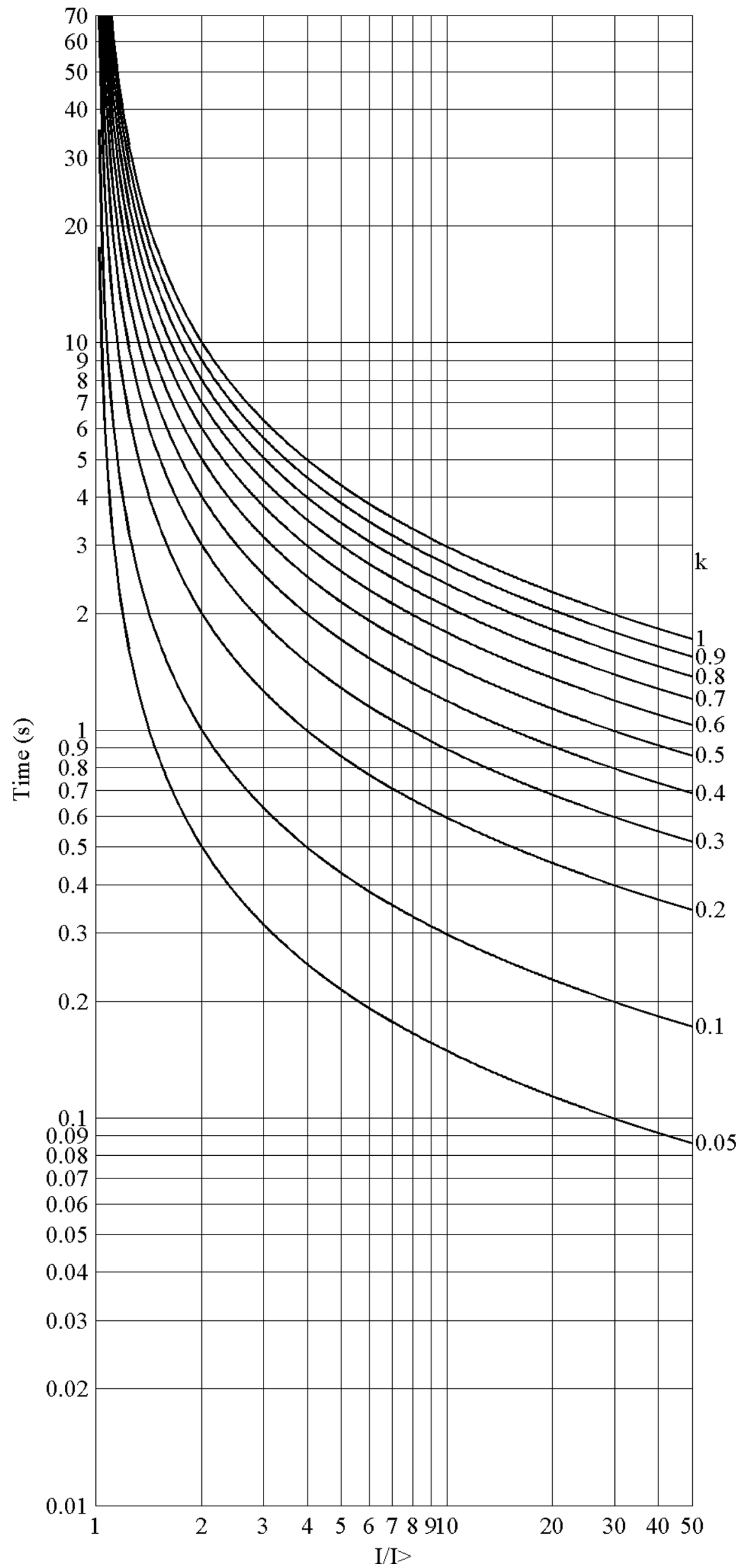

Figure 347: IEC normal inverse-time characteristics

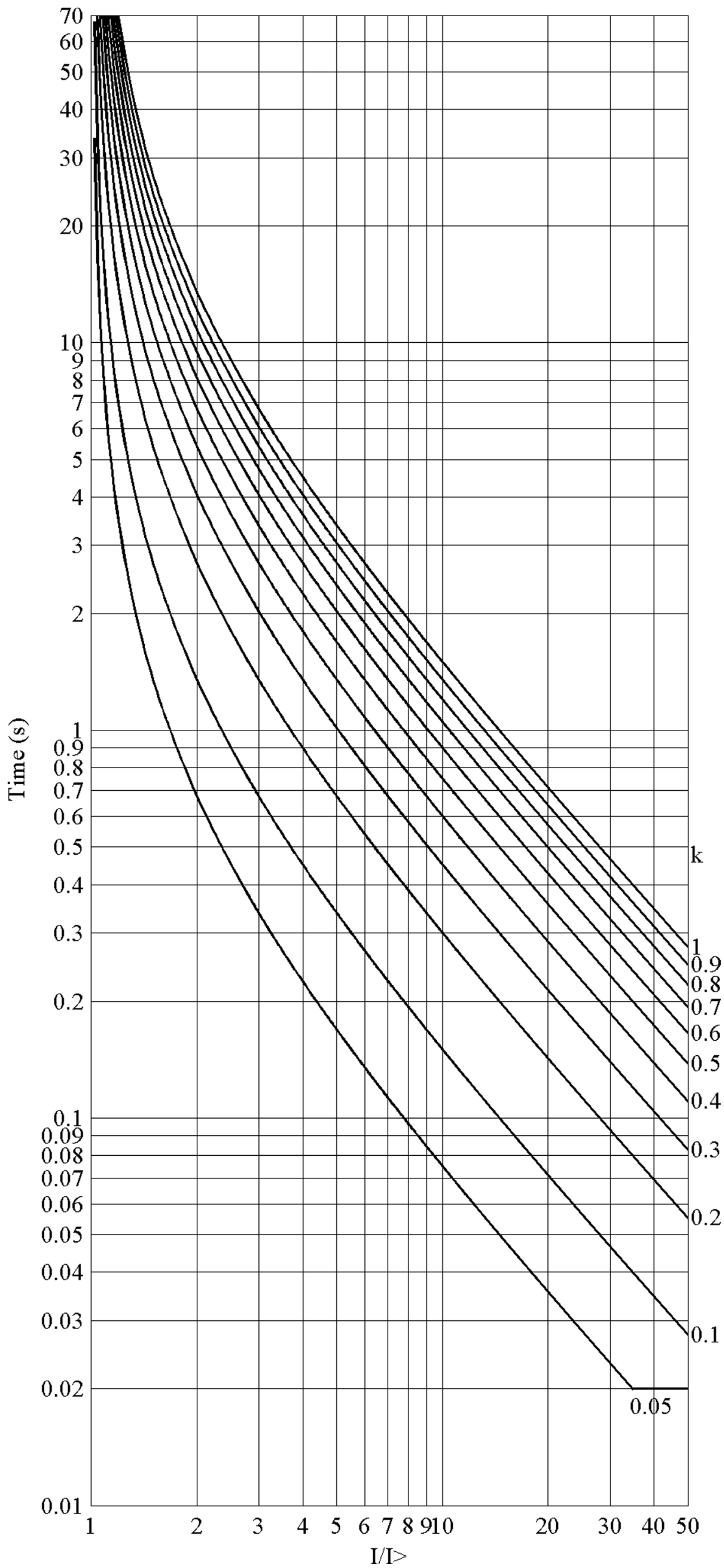

Figure 348: IEC very inverse-time characteristics

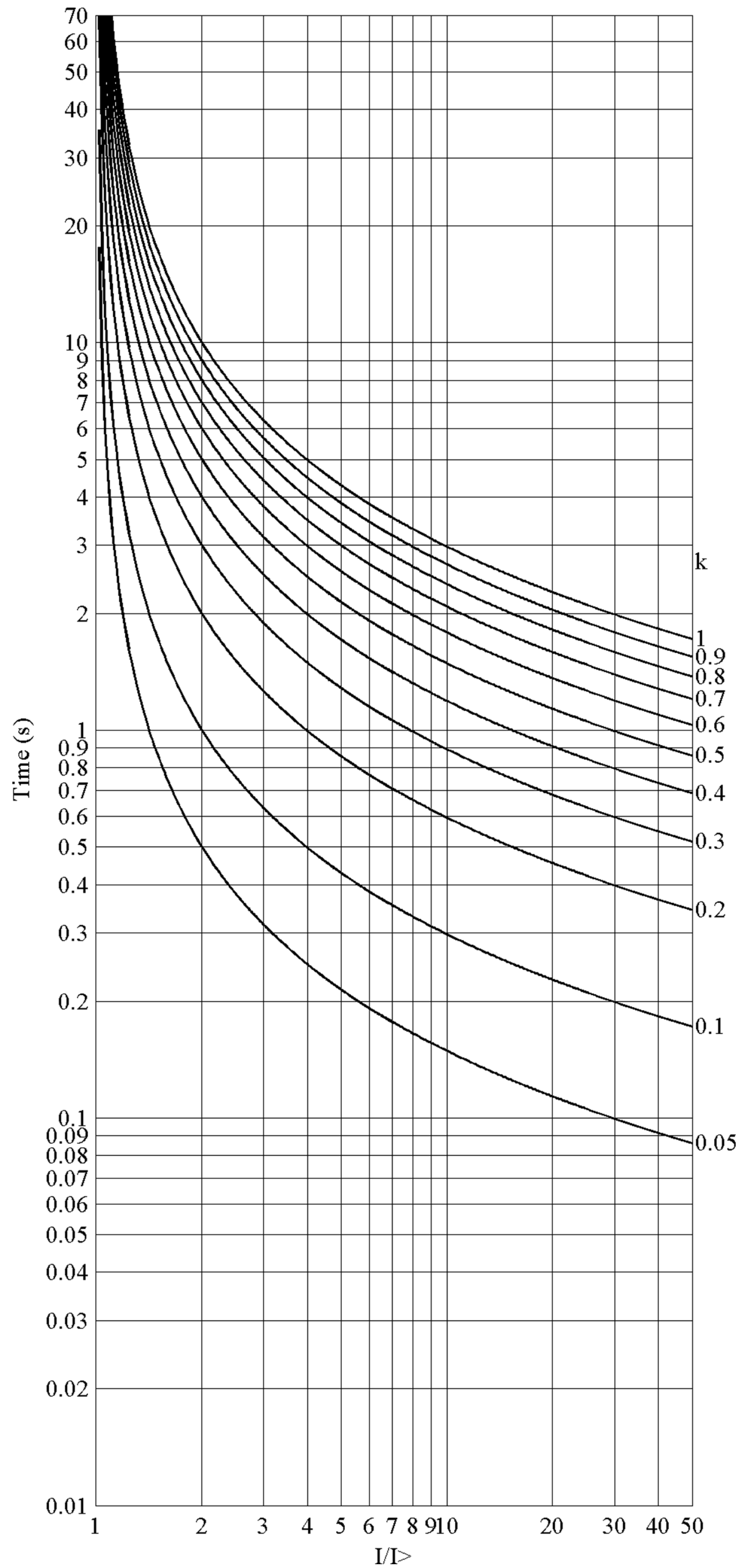

Figure 349: IEC inverse-time characteristics

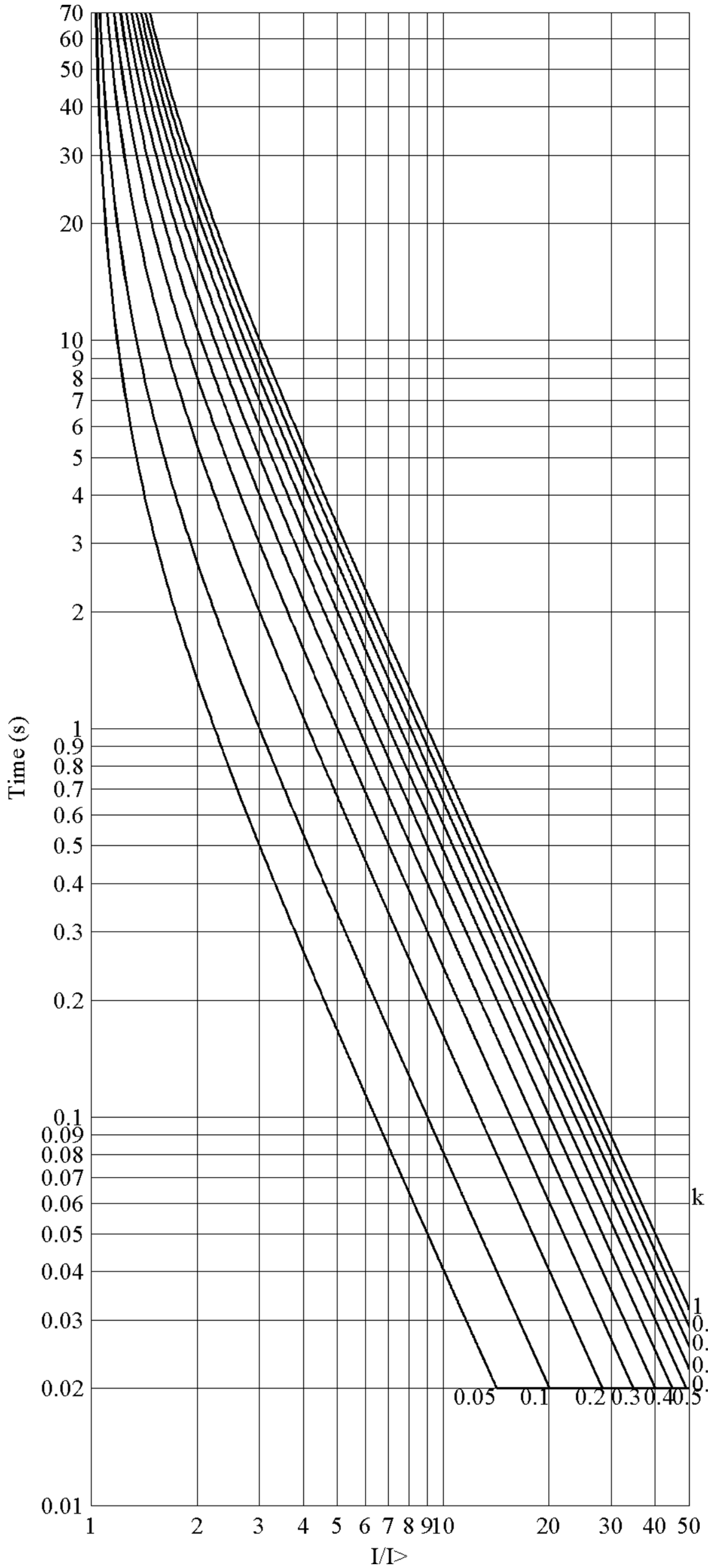

Figure 350: IEC extremely inverse-time characteristics

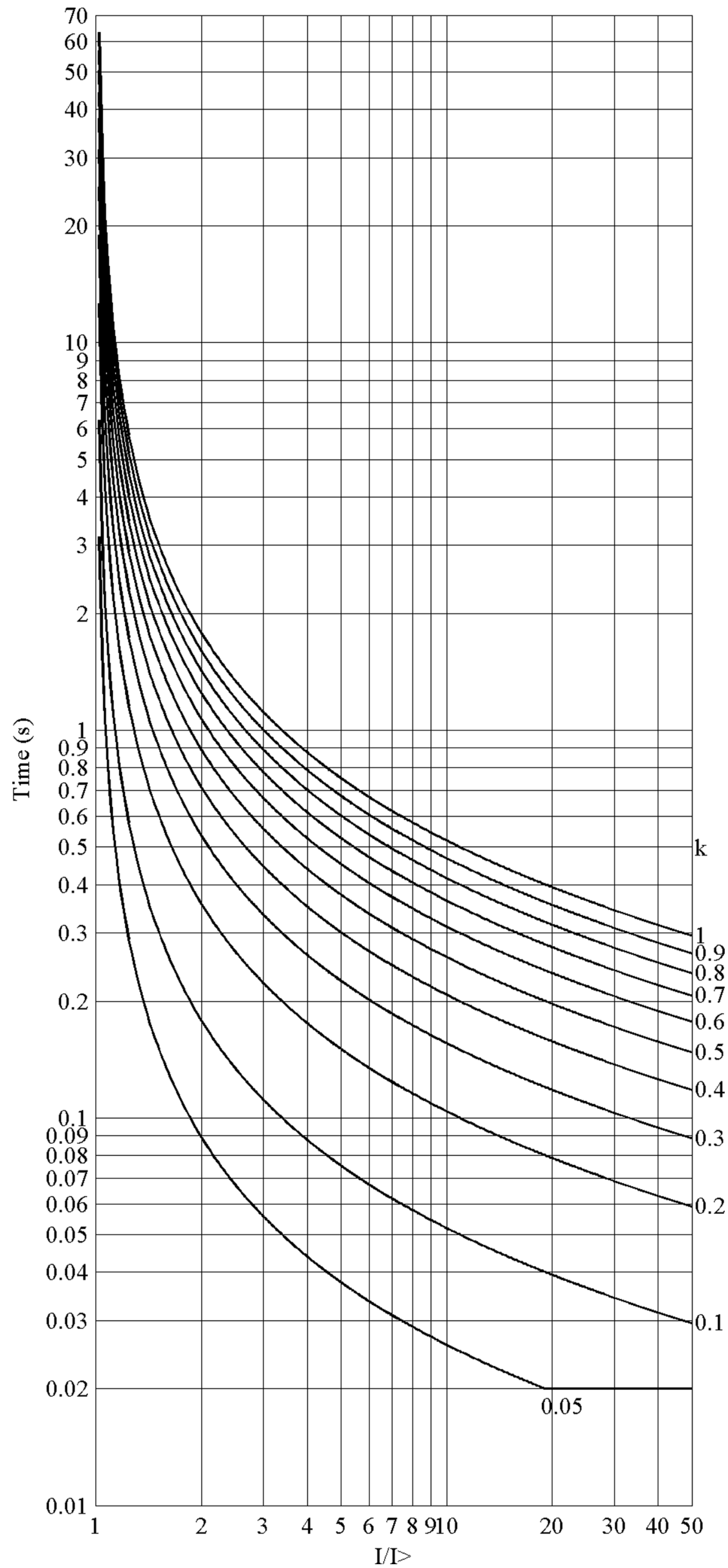

Figure 351: IEC short-time inverse-time characteristics

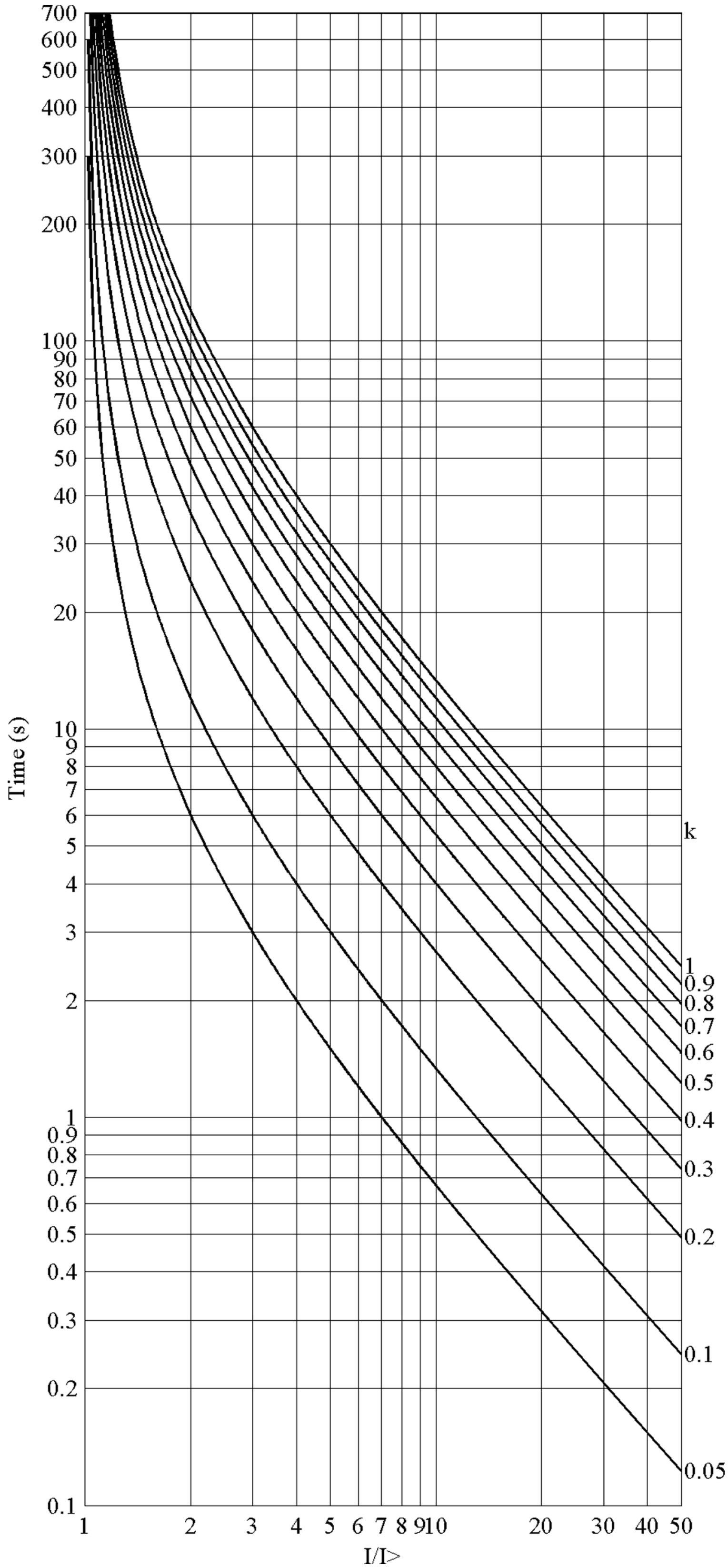

Figure 352: IEC long-time inverse-time characteristics

11.2.1.2 User-programmable inverse-time characteristics

The user can define curves by entering parameters into the following standard formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>} \right)^{c} - E} + B \right) \cdot k$$

(Equation 80)

t[s] Trip time (in seconds)
A set *Curve parameter A*
B set *Curve parameter B*
C set *Curve parameter C*
E set *Curve parameter E*
I Measured current
I> set *Pickup value*
k set *Time multiplier*

11.2.1.3 RI and RD-type inverse-time characteristics

The RI-type simulates the behavior of electromechanical relays. The RD-type is a ground-fault specific characteristic.

The RI-type is calculated using the formula

$$t[s] = \left(\frac{k}{0.339 - 0.236 \times \frac{I>}{I}} \right)$$

(Equation 81)

The RD-type is calculated using the formula

$$t[s] = 5.8 - 1.35 \times \text{In}\left(\frac{I}{k \times I>} \right)$$

(Equation 82)

t[s] Trip time (in seconds)
k set *Time multiplier*
I Measured current
I>set *Pickup value*

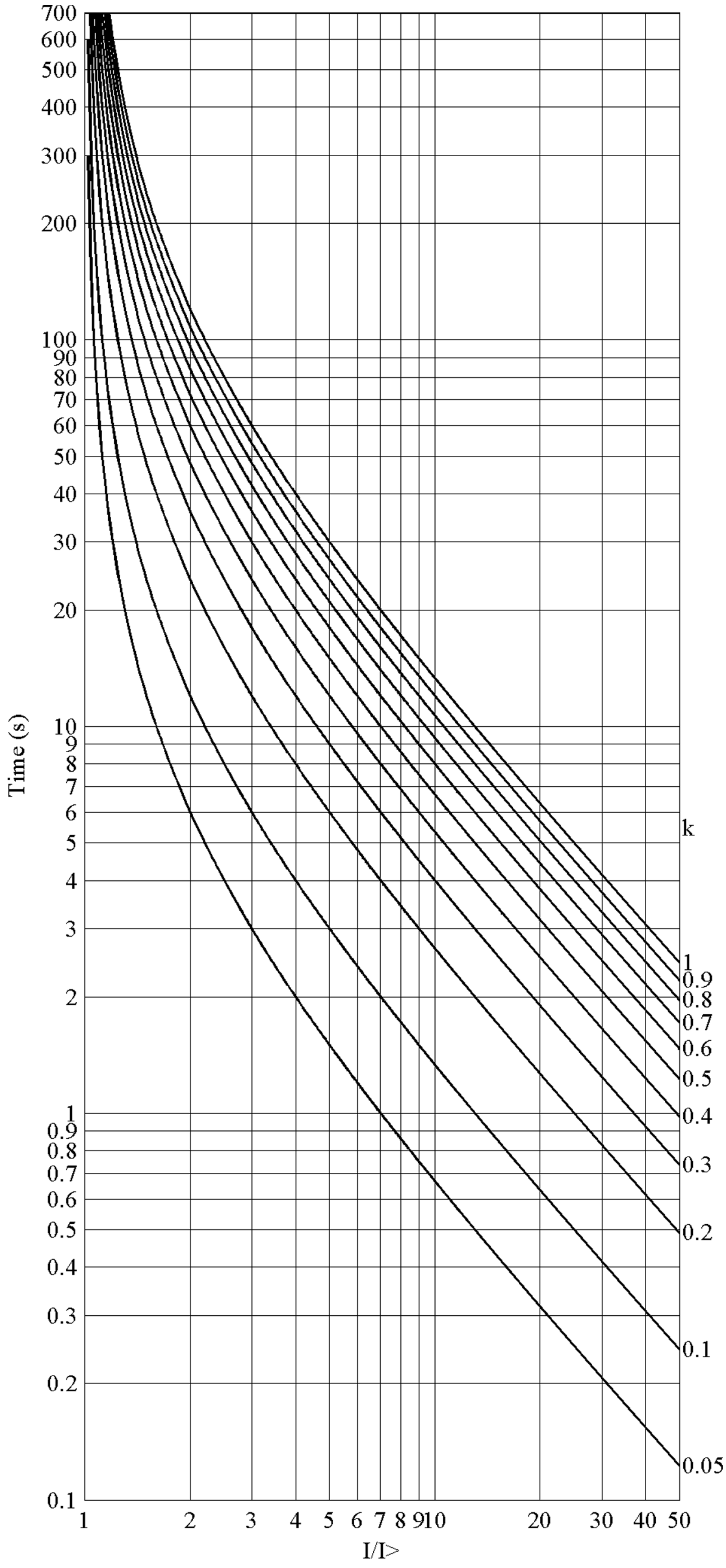

Figure 353: RI-type inverse-time characteristics

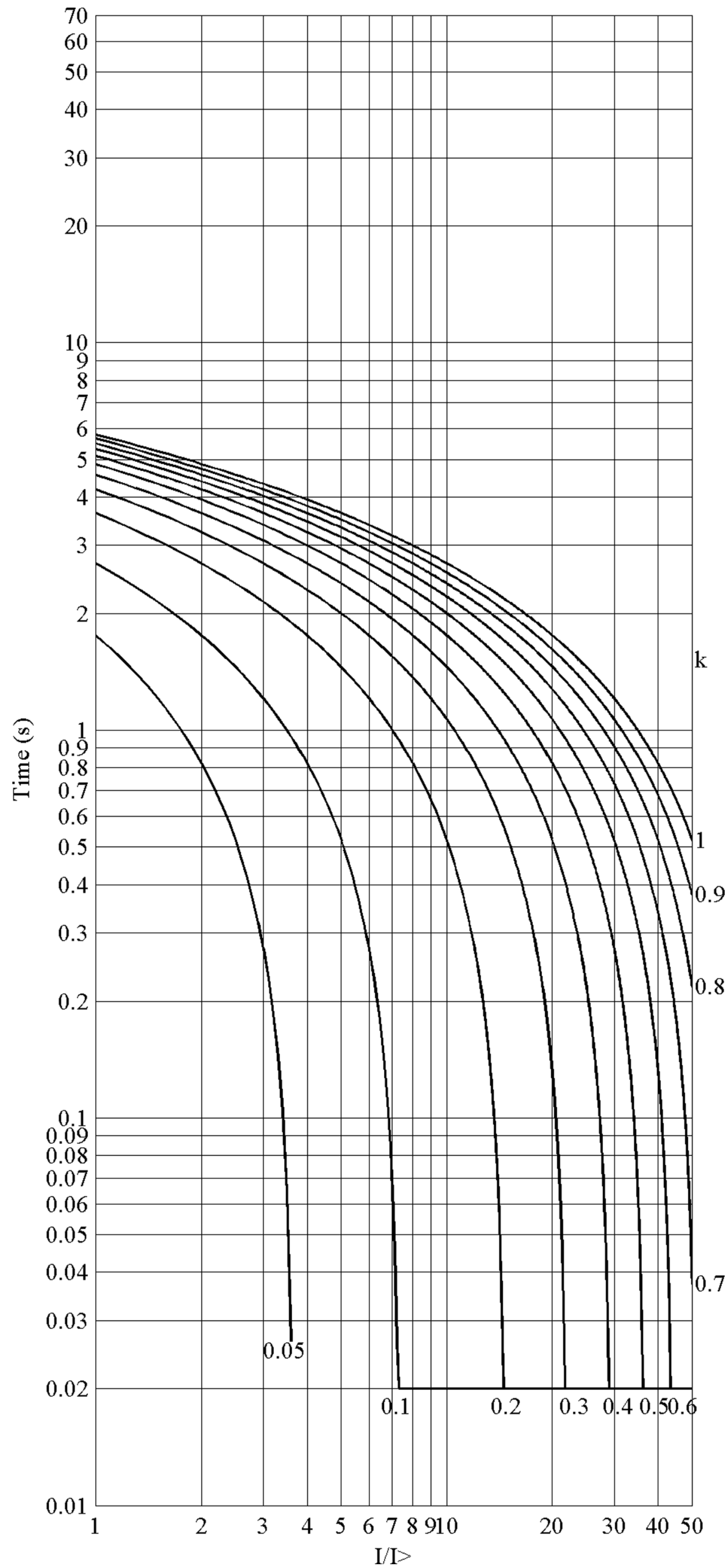

Figure 354: *RD-type inverse-time characteristics*

11.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting as follows:

Table 541: Values for reset mode

Setting name	Possible values
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset

Immediate reset

If the *Type of reset curve* setting in a drop-off case is selected as "Immediate", the inverse timer resets immediately.

Definite time reset

The definite type of reset in the inverse-time mode can be achieved by setting the *Type of reset curve* parameter to “Def time reset”. As a result, the trip inverse-time counter is frozen for the time determined with the *Reset delay time* setting after the current drops below the set *Pickup value*, including hysteresis.The integral sum of the inverse-time counter is reset, if another pickup does not occur during the reset delay.

If the *Type of reset curve* setting is selected as “Def time reset”, the current level has no influence on the reset characteristic.

Inverse reset

Inverse reset curves are available only for ANSI and user-programmable curves. If you use other curve types, immediate reset occurs.

Standard delayed inverse reset

The reset characteristic required in ANSI (IEEE) inverse-time modes is provided by setting the *Type of reset curve* parameter to “Inverse reset”. In this mode, the time delay for reset is given with the following formula using the coefficient D, which has its values defined in the table below.

$$t[s] = \left(\frac{D}{\left(\frac{I}{I>} \right)^2 - 1} \right) \cdot k$$

(Equation 83)

t[s]	Reset time (in seconds)
kset	*Time multiplier*
I	Measured current
I>	set *Pickup value*

Table 542: Coefficients for ANSI delayed inverse reset curves

Curve name	D
(1) ANSI Extremely Inverse	29.1
(2) ANSI Very Inverse	21.6
(3) ANSI Normal Inverse	0.46
(4) ANSI Moderately Inverse	4.85
(6) Long Time Extremely Inverse	30
(7) Long Time Very Inverse	13.46
(8) Long Time Inverse	4.6

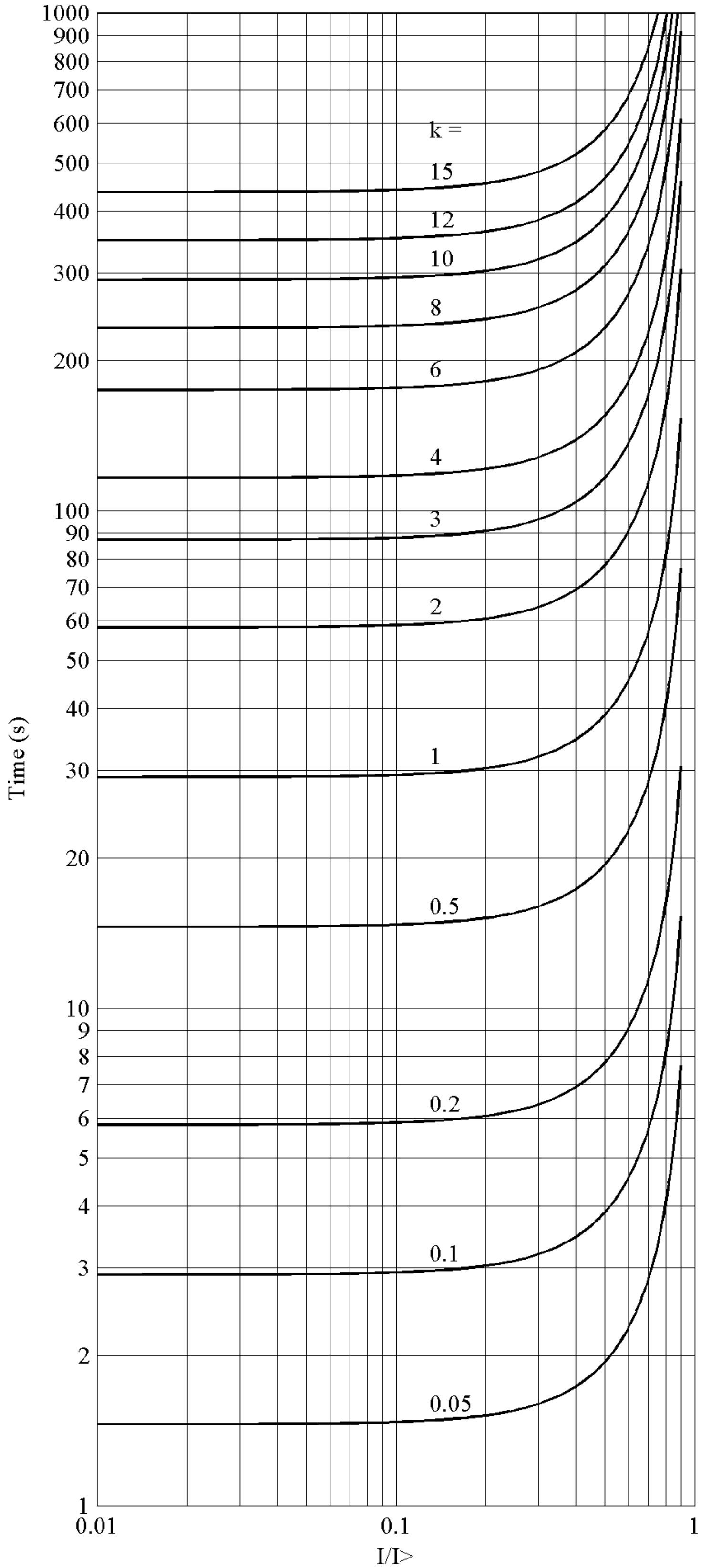

Figure 355: ANSI extremely inverse reset time characteristics

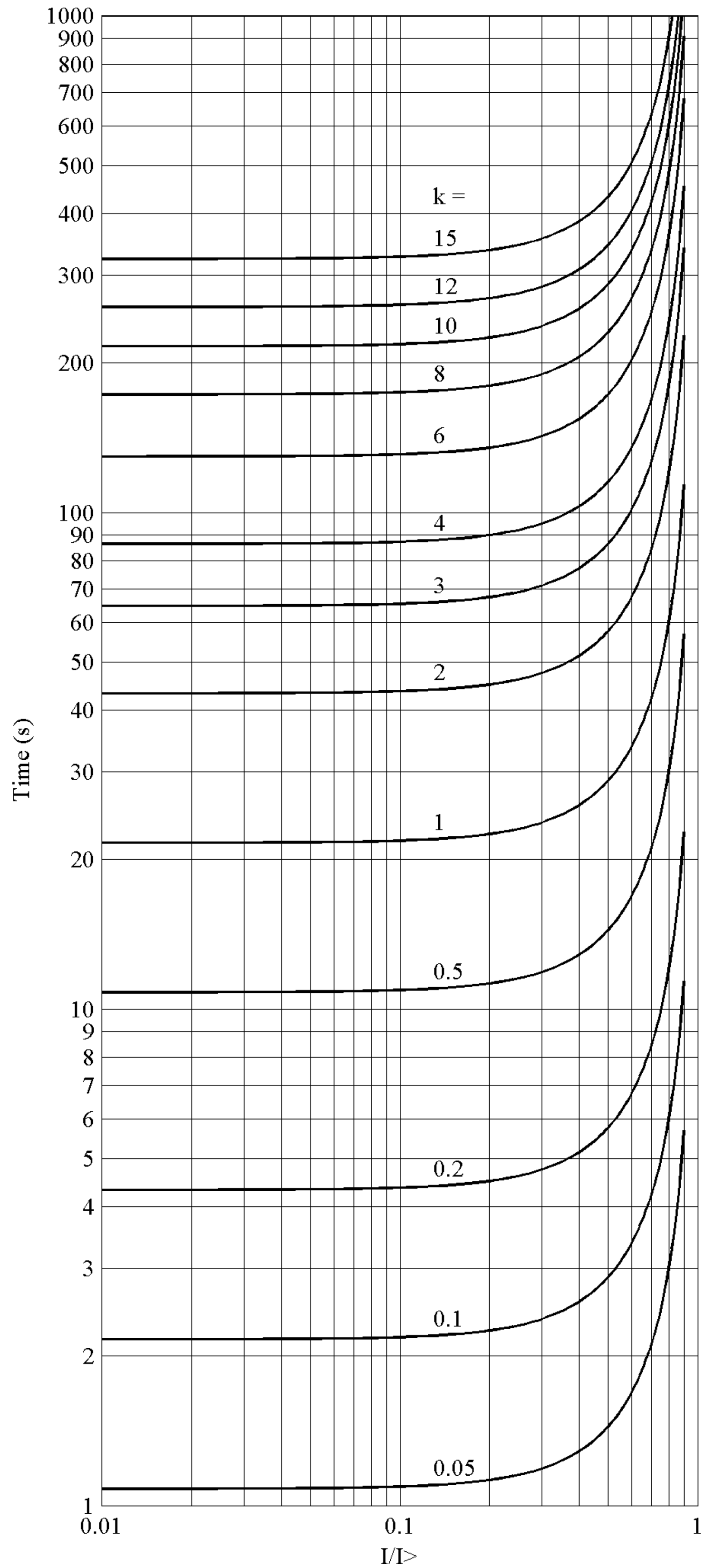

Figure 356: ANSI very inverse reset time characteristics

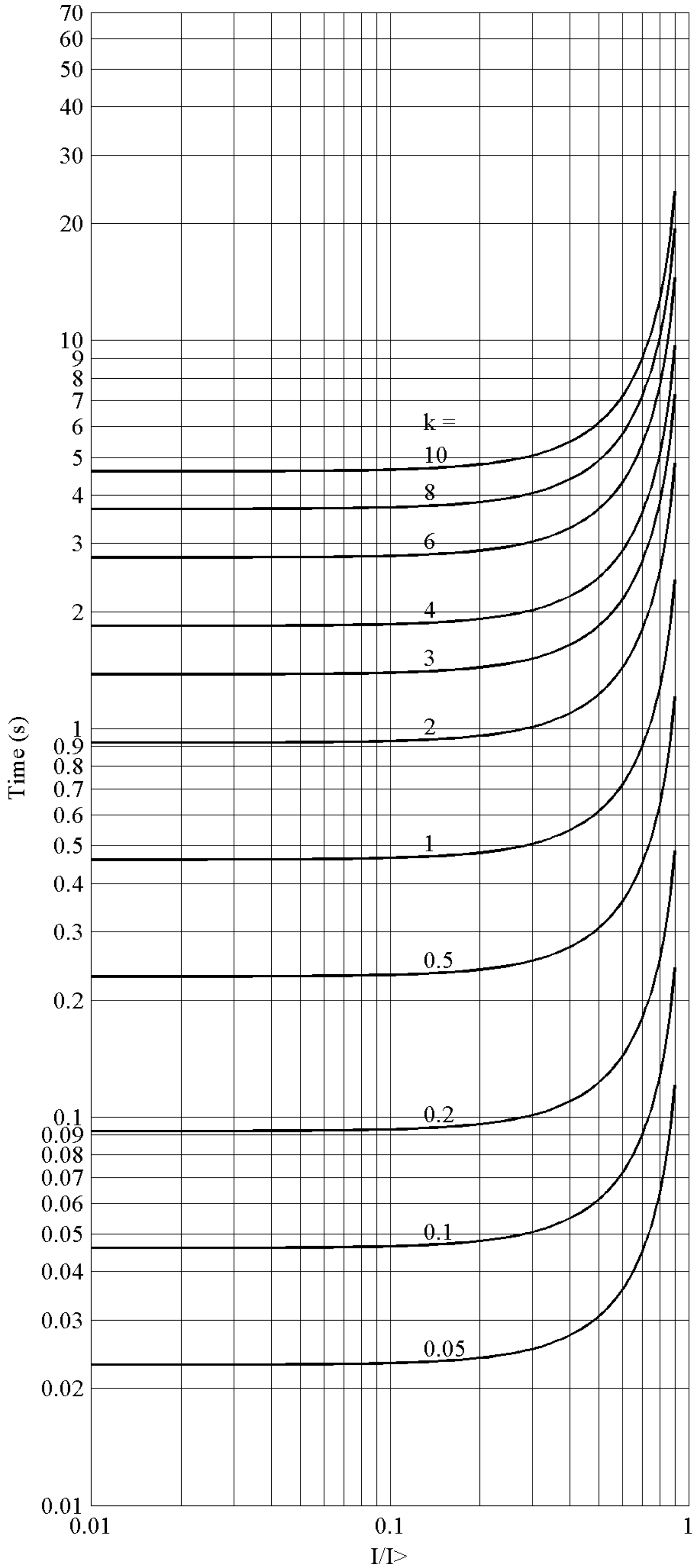

Figure 357: ANSI normal inverse reset time characteristics

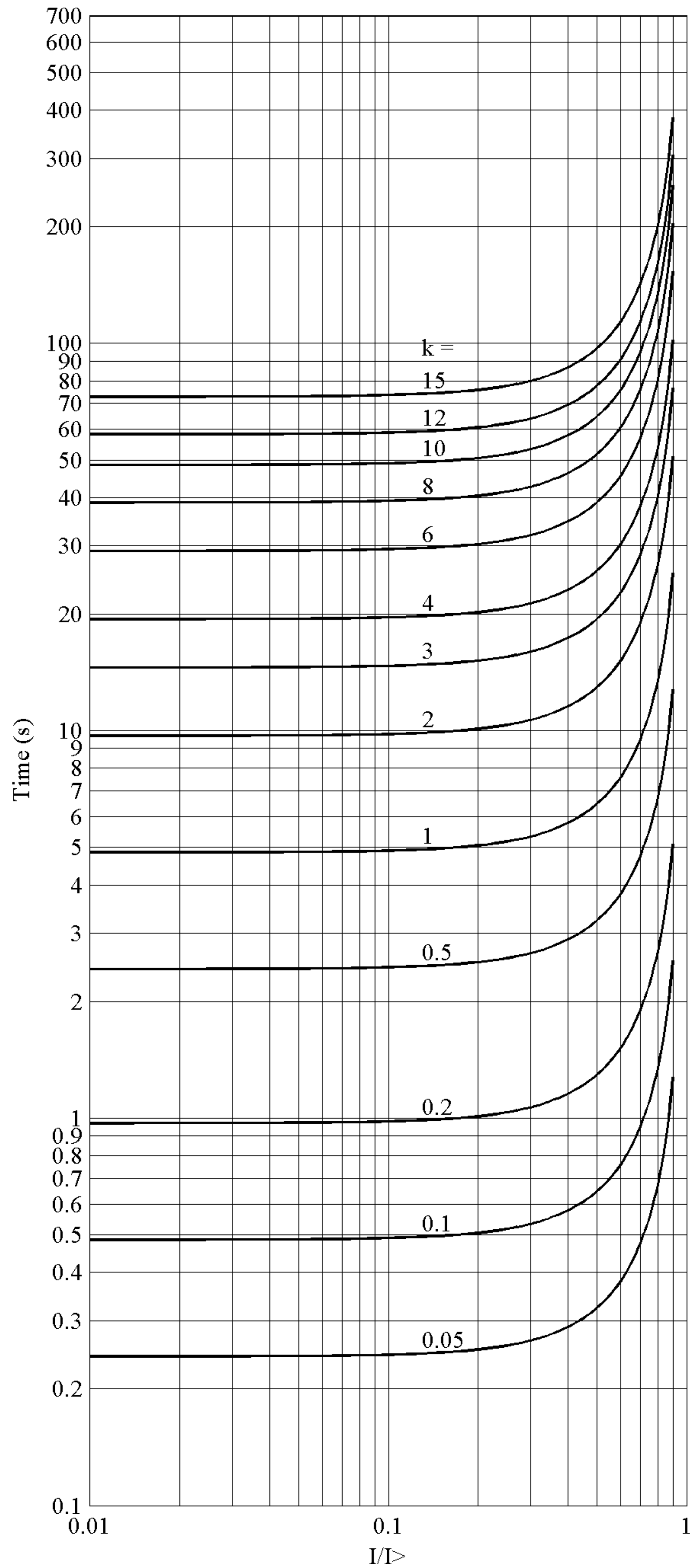

Figure 358: ANSI moderately inverse reset time characteristics

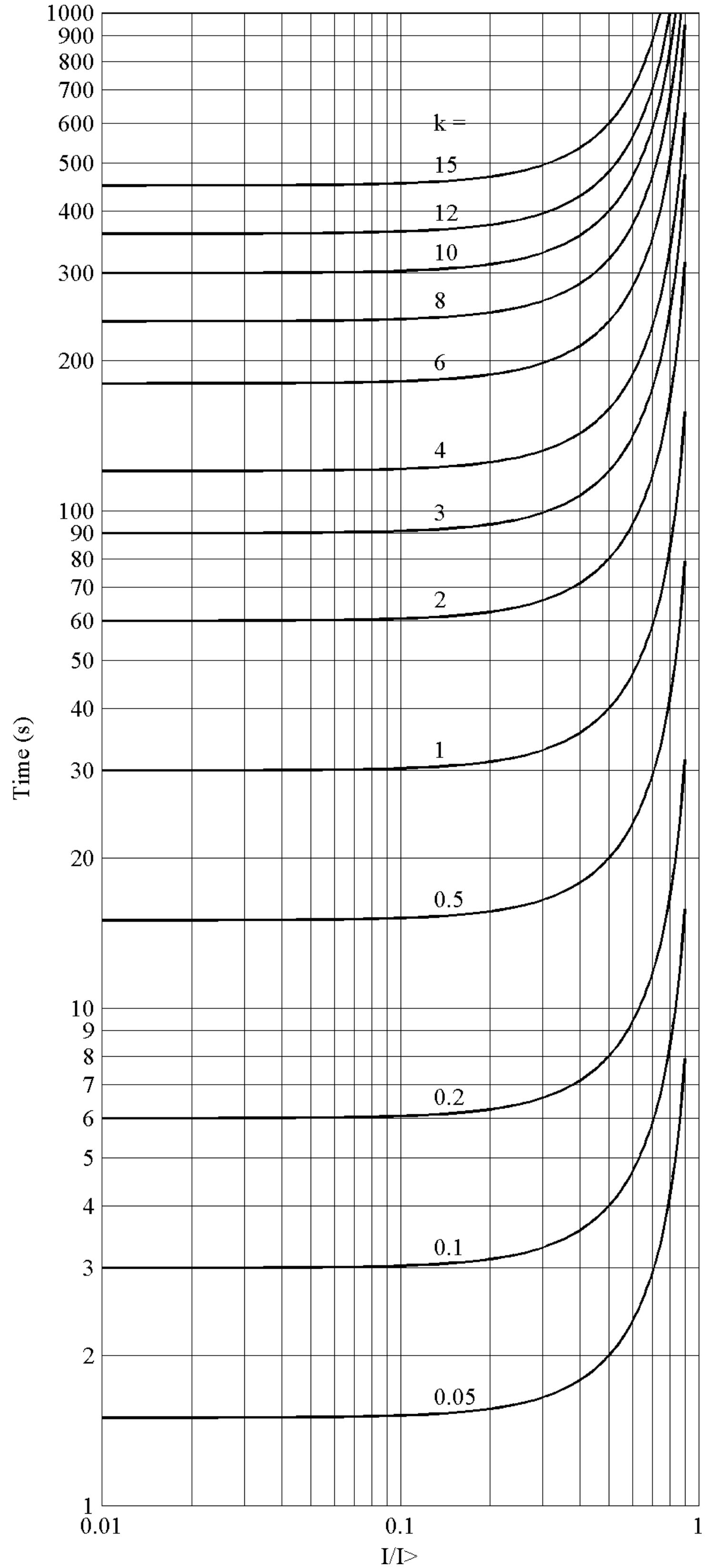

Figure 359: ANSI long-time extremely inverse reset time characteristics

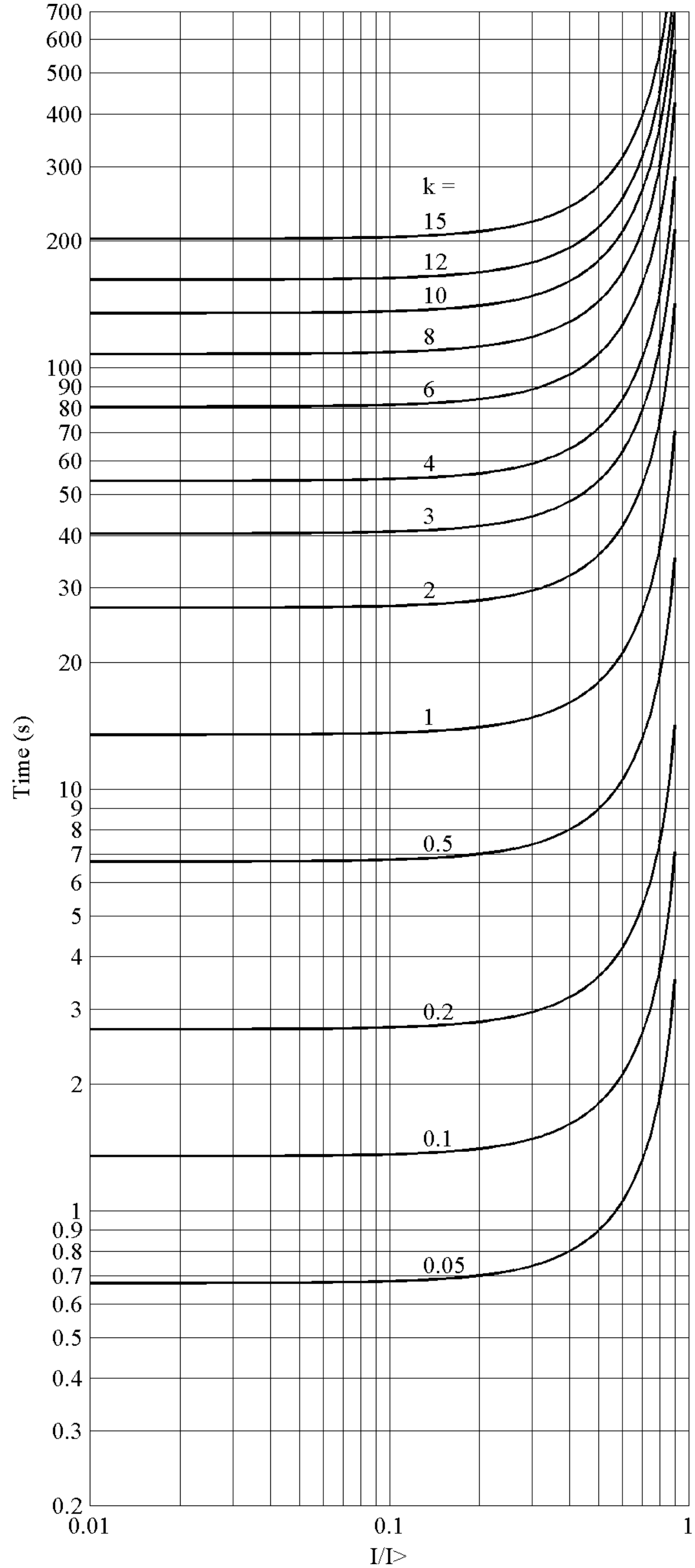

Figure 360: ANSI long-time very inverse reset time characteristics

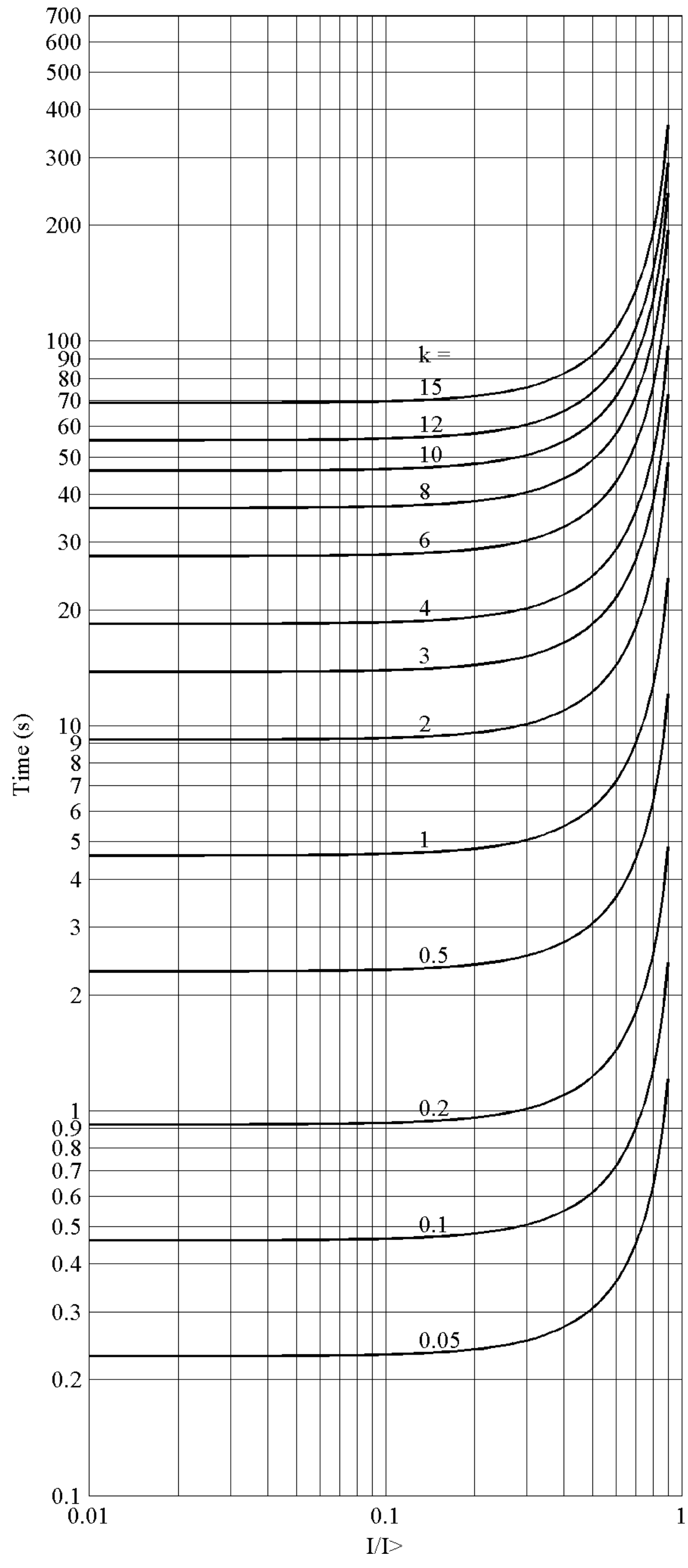

Figure 361: ANSI long-time inverse reset time characteristics

The delayed inverse-time reset is not available for IEC-type inverse time curves.

User-programmable delayed inverse reset

The user can define the delayed inverse reset time characteristics with the following formula using the set *Curve parameter D*.

$$t[s] = \left(\frac{D}{\left(\frac{I}{I>} \right)^2 - 1} \right) \cdot k$$

(Equation 84)

t[s]	Reset time (in seconds)
k	set *Time multiplier*
D	set *Curve parameter D*
I	Measured current
I>	set *Pickup value*

11.2.3 Inverse-timer freezing

When the BLOCK input is active, the internal value of the time counter is frozen at the value of the moment just before the freezing. Freezing of the counter value is chosen when the user does not wish the counter value to count upwards or to be reset. This may be the case, for example, when the inverse-time function of an IED needs to be blocked to enable the definite-time operation of another IED for selectivity reasons, especially if different relaying techniques (old and modern relays) are applied.

The selected blocking mode is "Freeze timer".

The activation of the BLOCK input also lengthens the minimum delay value of the timer.

Activating the BLOCK input alone does not affect the operation of the PICKUP output. It still becomes active when the current exceeds the set *Pickup value*, and inactive when the current falls below the set *Pickup value* and the set *Reset delay time* has expired.

11.3 Voltage based inverse definite minimum time characteristics

11.3.1 IDMT curves for overvoltage protection

In inverse-time modes, the trip time depends on the momentary value of the voltage, the higher the voltage, the faster the trip time. The trip time calculation or integration starts immediately when the voltage exceeds the set value of the *Pickup value* setting and the `PICKUP` output is activated.

The `TRIP` output of the component is activated when the cumulative sum of the integrator calculating the overvoltage situation exceeds the value set by the inverse time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time for the IDMT mode, that is, it is possible to limit the IDMT based trip time for not becoming too short. For example:

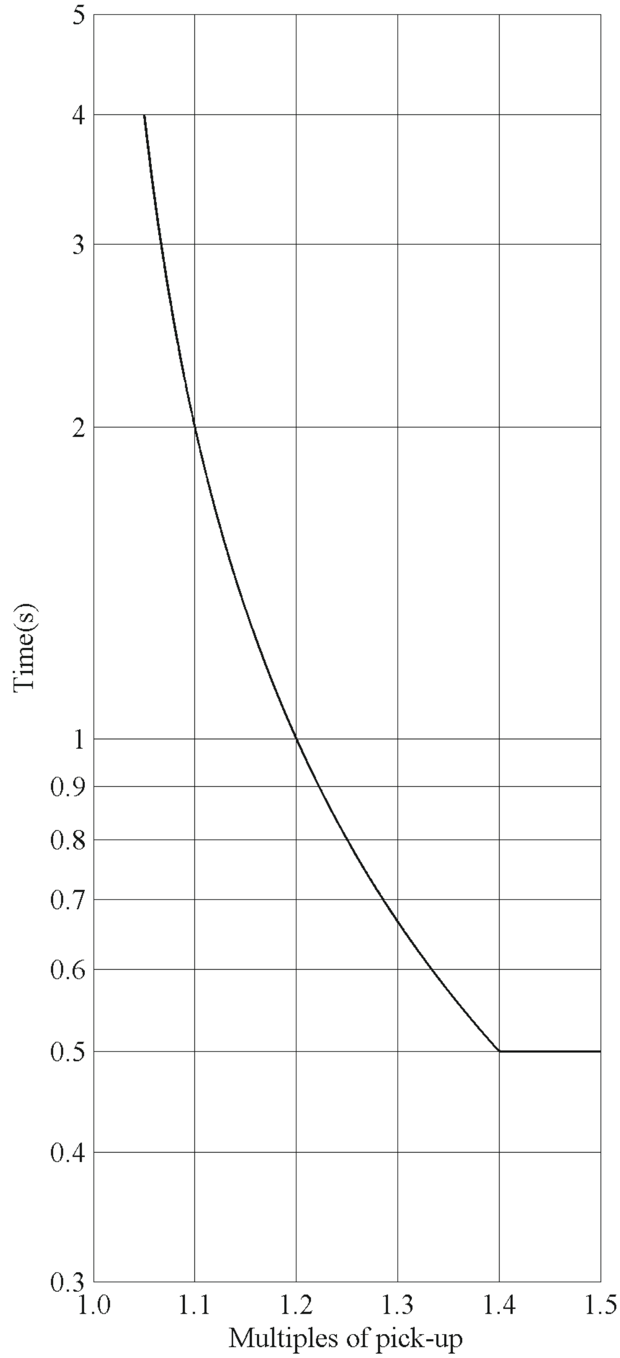

Figure 362: Trip time curve based on IDMT characteristic with Minimum trip time *set to 0.5 second*

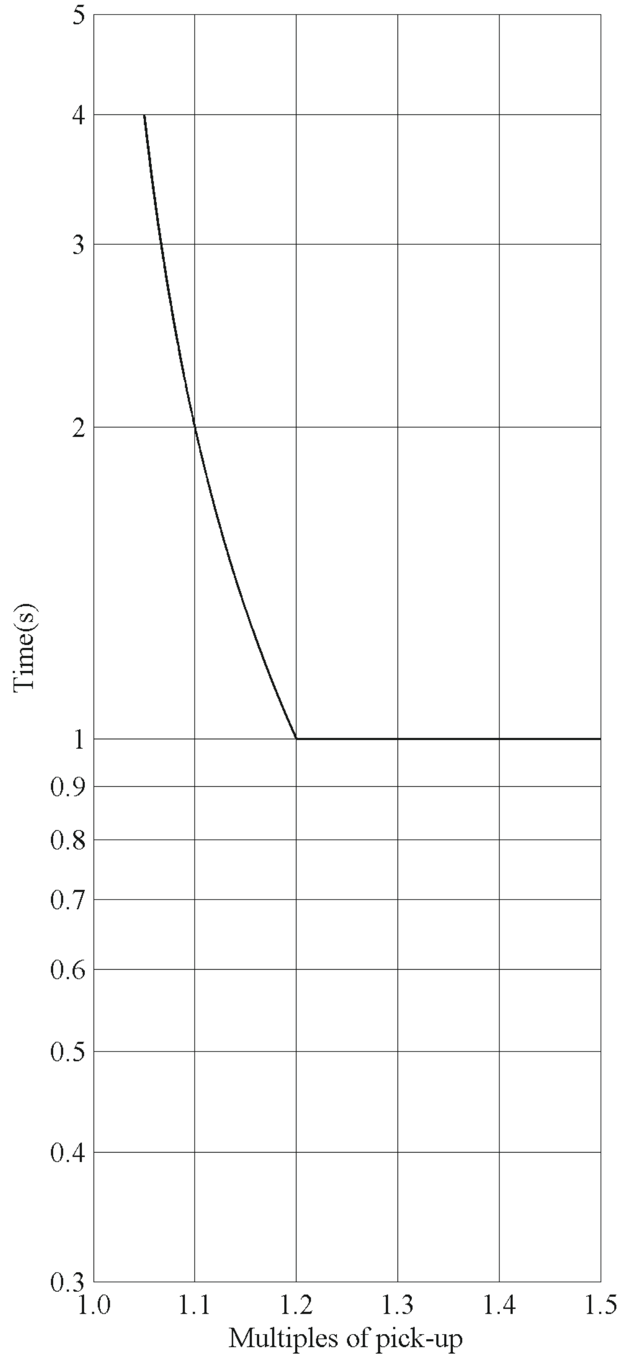

Figure 363: Trip time curve based on IDMT characteristic with Minimum trip time set to 1 second

11.3.1.1 Standard inverse-time characteristics for overvoltage protection

The trip times for the standard overvoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse trip time can be calculated with the formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V - V>}{V>} - C\right)^{E}} + D$$

(Equation 85)

t [s] trip time in seconds
V measured voltage
V> the set value of *Pickup value*
k the set value of *Time multiplier*

Table 543: Curve coefficients for the standard overvoltage IDMT curves

Curve name	A	B	C	D	E
(17) Inverse Curve A	1	1	0	0	1
(18) Inverse Curve B	480	32	0.5	0.035	2
(19) Inverse Curve C	480	32	0.5	0.035	3

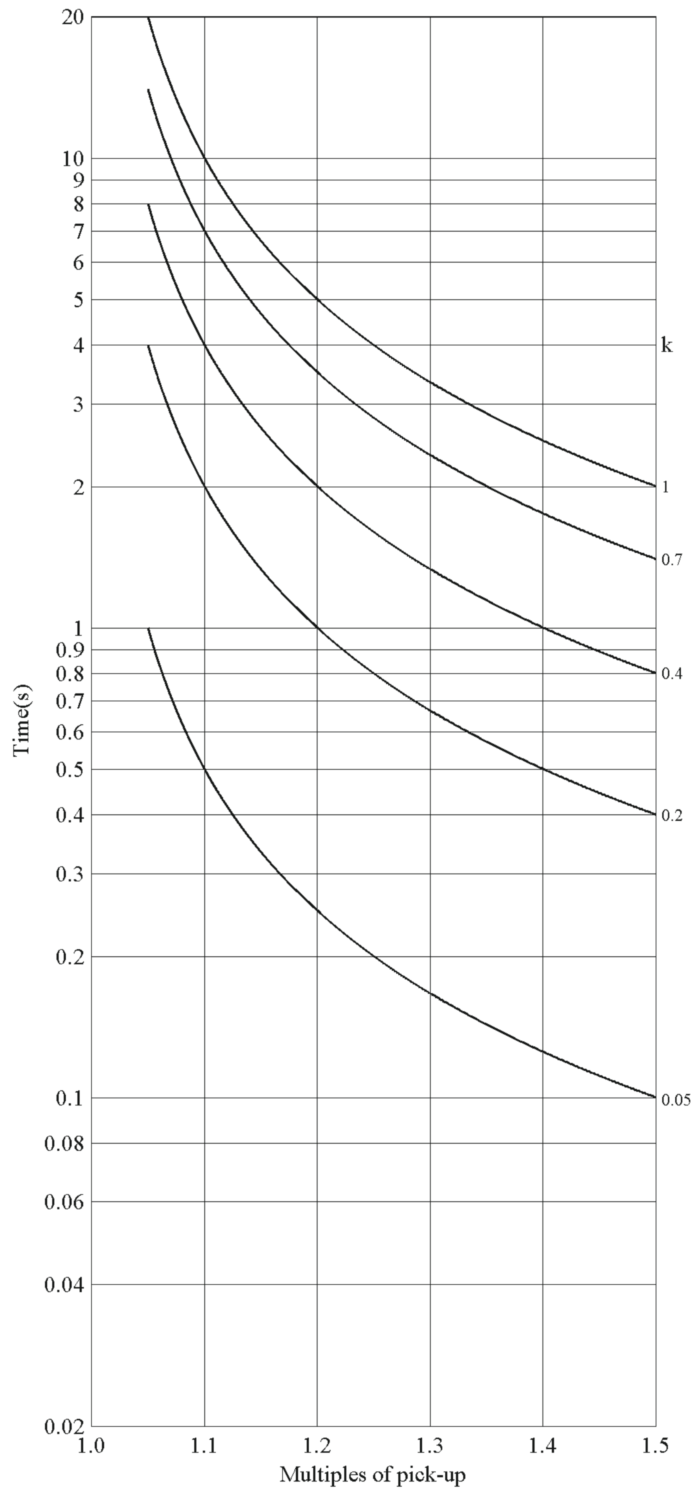

Figure 364: Inverse curve A characteristic of overvoltage protection

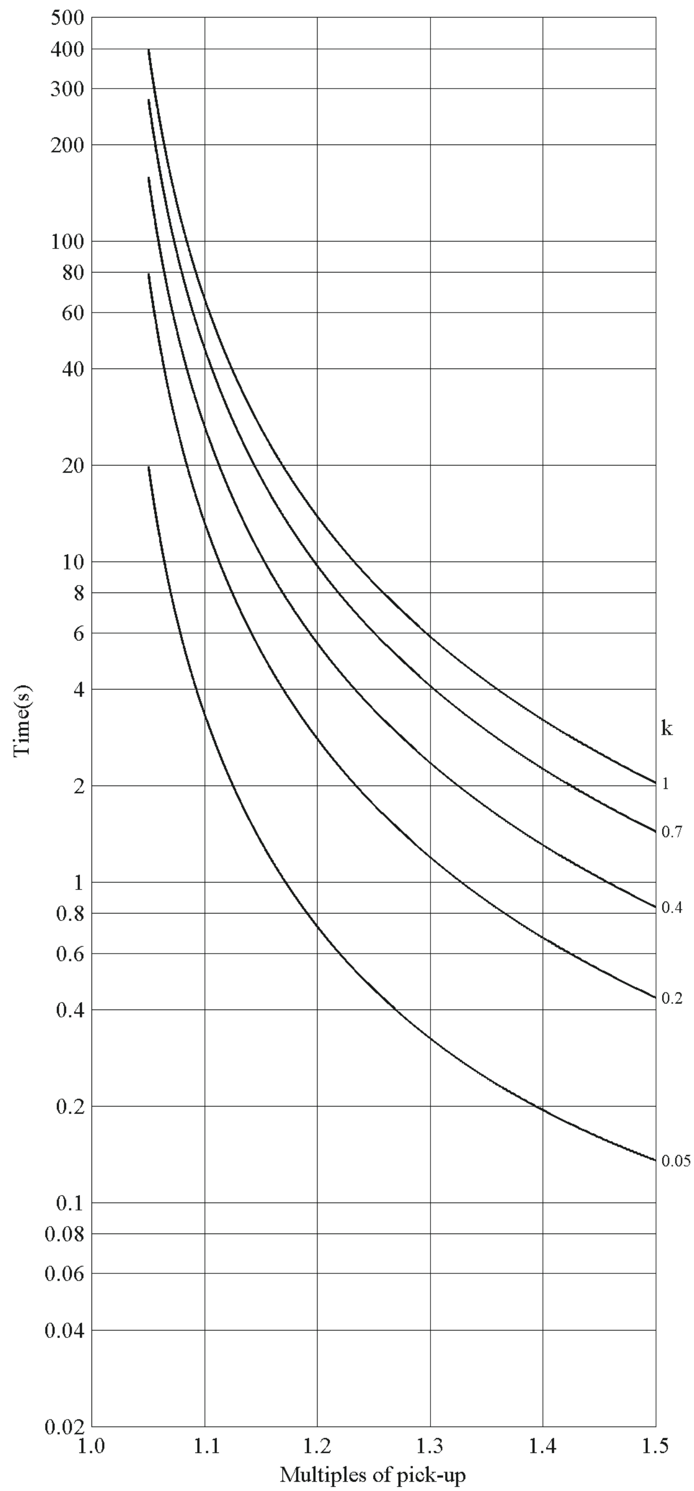

Figure 365: Inverse curve B characteristic of overvoltage protection

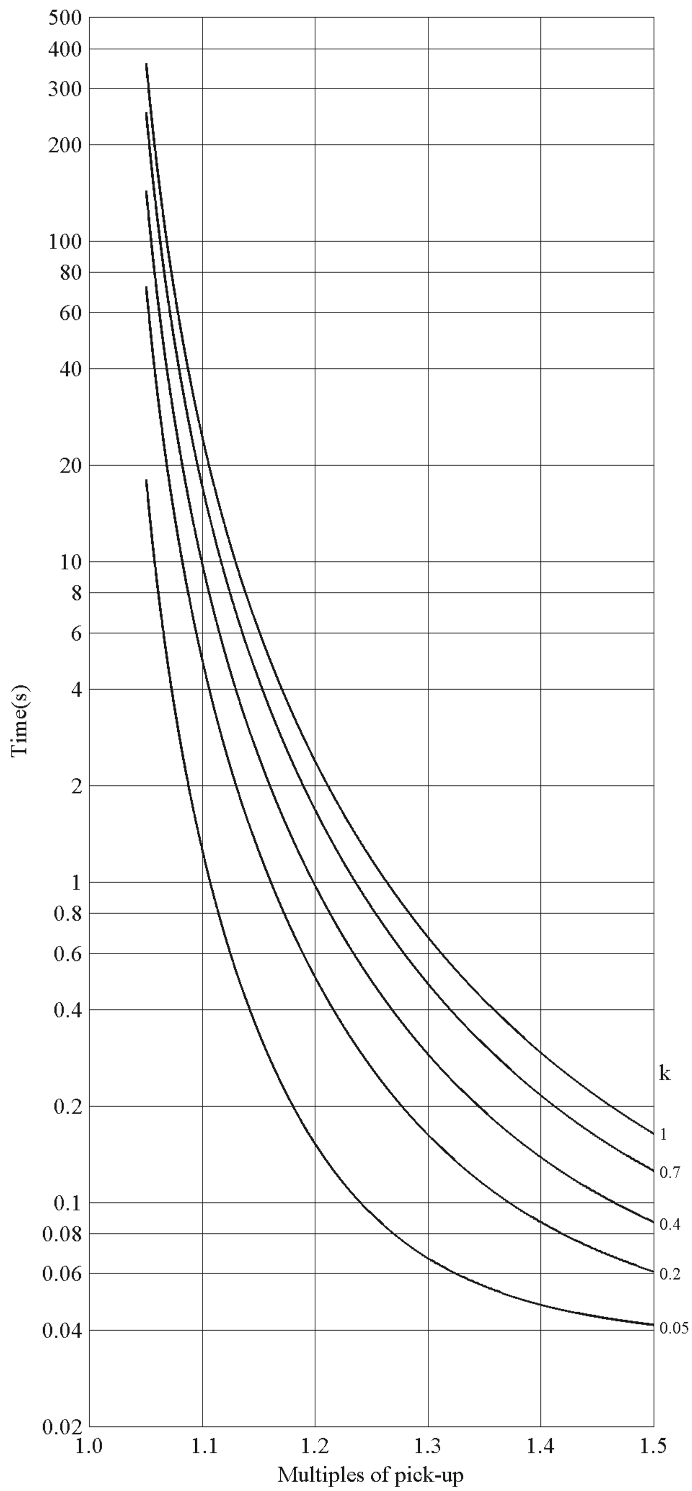

Figure 366: Inverse curve C characteristic of overvoltage protection

11.3.1.2 User programmable inverse-time characteristics for overvoltage protection

The user can define the curves by entering the parameters using the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V - V>}{V>} - C\right)^{E}} + D$$

(Equation 86)

t[s] trip time in seconds
A the set value of *Curve parameter A*
B the set value of *Curve parameter B*
C the set value of *Curve parameter C*
D the set value of *Curve parameter D*
E the set value of *Curve parameter E*
V measured voltage
V> the set value of *Pickup value*
k the set value of *Time multiplier*

11.3.1.3 IDMT curve saturation of overvoltage protection

For the overvoltage IDMT mode of operation, the integration of the trip time does not start until the voltage exceeds the value of *Pickup value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared to *Pickup value*. For example, due to the curve equation B and C, the characteristics equation output is saturated in such a way that when the input voltages are in the range of *Pickup value* to *Curve Sat Relative* in percent over *Pickup value*, the equation uses *Pickup value* * (1.0 + *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio V/V> exceeds the unity, *Curve Sat Relative* is also set for it. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning the discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum trip time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

11.3.2 IDMT curves for undervoltage protection

In the inverse-time modes, the trip time depends on the momentary value of the voltage, the lower the voltage, the faster the trip time. The trip time calculation or integration starts immediately when the voltage goes below the set value of the *Pickup value* setting and the `PICKUP` output is activated.

The `TRIP` output of the component is activated when the cumulative sum of the integrator calculating the undervoltage situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time possible for the IDMT mode. For setting a value for this parameter, the user should carefully study the particular IDMT curve.

11.3.2.1 Standard inverse-time characteristics for undervoltage protection

The trip times for the standard undervoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse trip time can be calculated with the formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V< - V}{V<} - C\right)^{E}} + D$$

(Equation 87)

t [s]	trip time in seconds
V	measured voltage
V<	the set value of the *Pickup value* setting
k	the set value of the *Time multiplier* setting

Table 544: Curve coefficients for standard undervoltage IDMT curves

Curve name	A	B	C	D	E
(21) Inverse Curve A	1	1	0	0	1
(22) Inverse Curve B	480	32	0.5	0.055	2

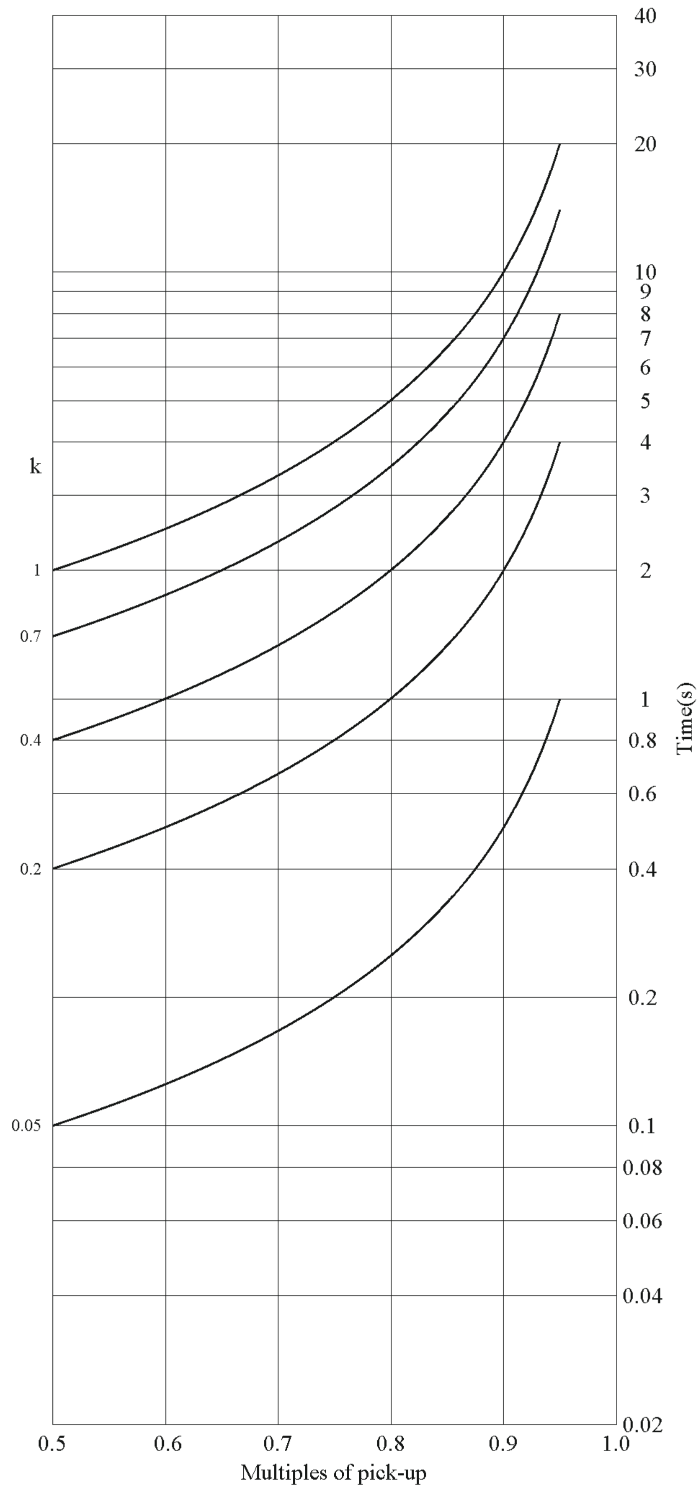

Figure 367: Inverse curve A characteristic of undervoltage protection

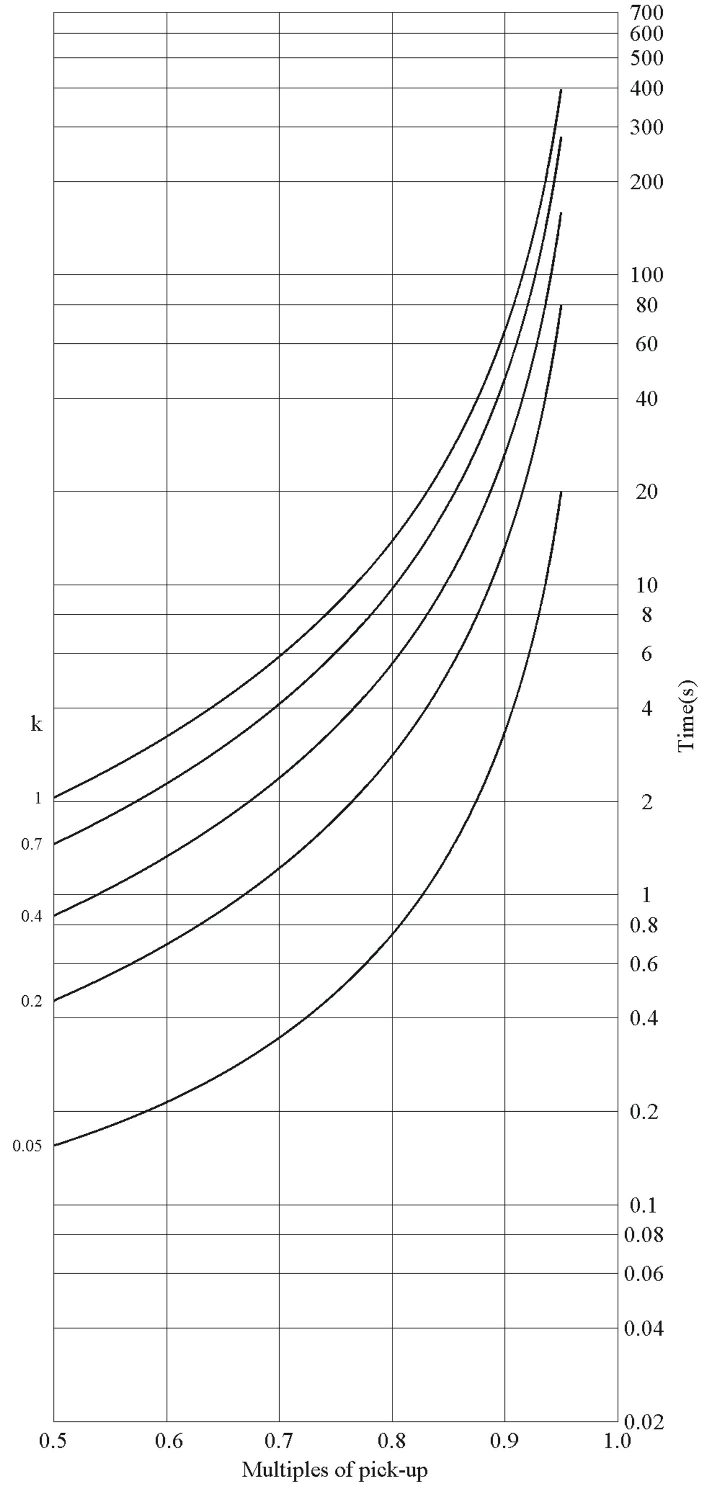

Figure 368: Inverse curve B characteristic of undervoltage protection

11.3.2.2 User-programmable inverse-time characteristics for undervoltage protection

The user can define curves by entering parameters into the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V< - V}{V<} - C\right)^{E}} + D$$

(Equation 88)

t[s]	trip time in seconds
A	the set value of *Curve parameter A*
B	the set value of *Curve parameter B*
C	the set value of *Curve parameter C*
D	the set value of *Curve parameter D*
E	the set value of *Curve parameter E*
V	measured voltage
V<	the set value of *Pickup value*
k	the set value of *Time multiplier*

11.3.2.3 IDMT curve saturation of undervoltage protection

For the undervoltage IDMT mode of operation, the integration of the trip time does not start until the voltage falls below the value of *Pickup value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared with *Pickup value*. For example, due to the curve equation B, the characteristics equation output is saturated in such a way that when input voltages are in the range from *Pickup value* to *Curve Sat Relative* in percents under *Pickup value*, the equation uses *Pickup value* * (1.0 - *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio V/V> exceeds the unity, *Curve Sat Relative* is set for it as well. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning also discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum trip time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

11.4 Measurement modes

In many current or voltage dependent function blocks, there are four alternative measuring principles:

- RMS
- DFT which is a numerically calculated fundamental component of the signal
- Peak-to-peak

- Peak-to-peak with peak backup

Consequently, the measurement mode can be selected according to the application.

In extreme cases, for example with high overcurrent or harmonic content, the measurement modes function in a slightly different way. The Pickup accuracy is defined with the frequency range of f/fn=0.95...1.05. In peak-to-peak and RMS measurement modes, the harmonics of the phase currents are not suppressed, whereas in the fundamental frequency measurement the suppression of harmonics is at least -50 dB at the frequency range of f= n x fn, where n = 2, 3, 4, 5,...

RMS

The RMS measurement principle is selected with the *Measurement mode* setting using the value "RMS". RMS consists of both AC and DC components. The AC component is the effective mean value of the positive and negative peak values. RMS is used in applications where the effect of the DC component must be taken into account.

RMS is calculated according to the formula:

$$I_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_i^2} \quad \text{(Equation 89)}$$

n the number of samples in a calculation cycle

I_i the current sample value

DFT

The DFT measurement principle is selected with the *Measurement mode* setting using the value "DFT". In the DFT mode, the fundamental frequency component of the measured signal is numerically calculated from the samples. In some applications, for example, it can be difficult to accomplish sufficiently sensitive settings and accurate operation of the low stage, which may be due to a considerable amount of harmonics on the primary side currents. In such a case, the operation can be based solely on the fundamental frequency component of the current. In addition, the DFT mode has slightly higher CT requirements than the peak-to-peak mode, if used with high and instantaneous stages.

Peak-to-peak

The peak-to-peak measurement principle is selected with the *Measurement mode* setting using the value "Peak-to-Peak". It is the fastest measurement mode, in which the measurement quantity is made by calculating the average from the positive and negative peak values. The DC component is not included. The retardation time is short. The damping of the harmonics is quite low and practically determined by the characteristics of the anti-aliasing filter of the IED inputs. Consequently, this mode is usually used in conjunction with high and instantaneous stages, where the suppression of harmonics is not so important. In addition, the peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.

Peak-to-peak with peak backup

The peak-to-peak with peak backup measurement principle is selected with the *Measurement mode* setting using the value "P-to-P+backup". It is similar to the peak-to-peak mode, with the exception that it has been enhanced with the peak backup. In the peak-to-peak with peak backup mode, the function starts with two conditions: the peak-to-peak value is above the set pickup current or the peak value is above two times the set *Pickup value*. The peak backup is enabled only when the function is used in the DT mode in high and instantaneous stages for faster operation.

Section 12 IED physical connections

All external circuits are connected to the terminals on the rear panel of the IED.

- Connect each signal connector (X100 and X110) terminal with one 14 or 16 Gauge wire. Use 12 or 14 Gauge wire for CB trip circuit.
- Connect each ring-lug terminal for signal connector X120 with one of maximum 14 or 16 Gauge wire.
- Connect each ring-lug terminal for CTs/VTs with one 12 Gauge wire.

12.1 Protective ground connections

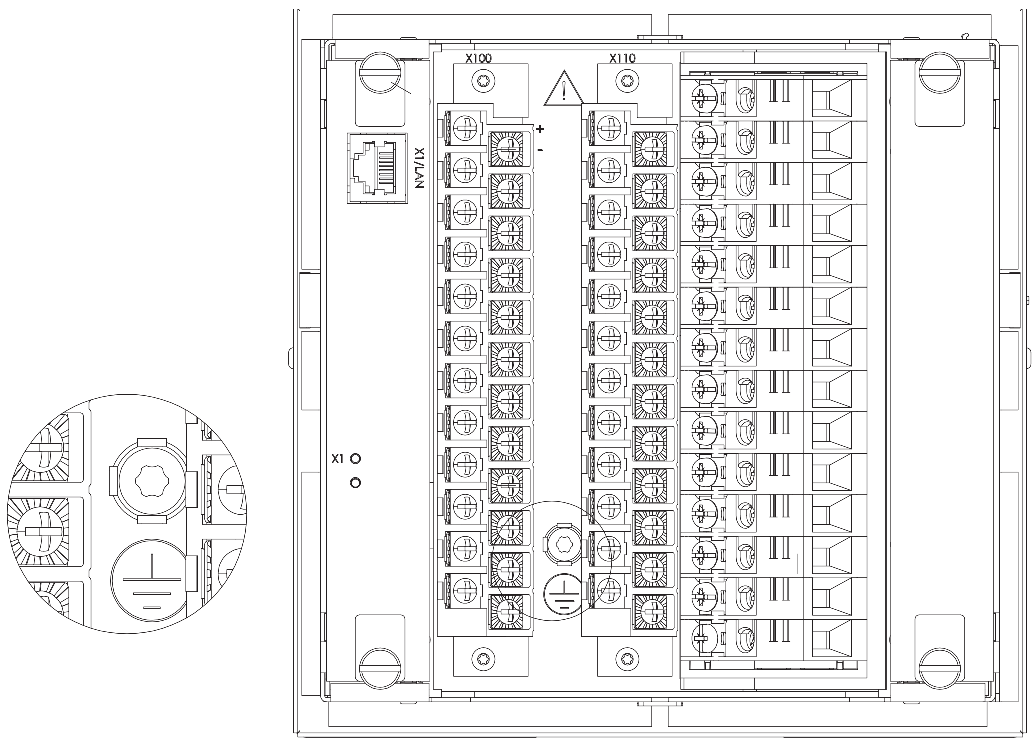

Figure 369: The protective ground screw is located between connectors X100 and X110

The ground lead must be at least 4.0 mm^2 and as short as possible.

All binary and analog connections are described in the product specific application manuals."

12.2 Communication connections

The front communication connection is an RJ-45 type connector used mainly for configuration and setting.

Depending on order code, several rear port communication connections are available.

- Galvanic RJ-45 Ethernet connection
- Optical LC Ethernet connection
- ST-type glass fibre serial connection
- EIA-485 serial connection
- EIA-232 serial connection

12.2.1 Ethernet RJ-45 front connection

The IED is provided with an RJ-45 connector on the LHMI. The connector is mainly for configuration and setting purposes. The interface on the PC side has to be configured in a way that it obtains the IP address automatically. There is a DHCP server inside IED for the front interface only.

The events and setting values and all input data such as memorized values and disturbance records can be read via the front communication port.

Only one of the possible clients can be used for parametrization at a time.

- PCM600
- LHMI
- WHMI

The default IP address of the IED through this port is 192.168.0.254.

The front port supports TCP/IP protocol. A standard Ethernet CAT 5 crossover cable is used with the front port.

The speed of the front connector interface is limited to 10 Mbps.

12.2.2 Ethernet rear connections

The Ethernet communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection depending on the product variant and selected communication interface option. A shielded twisted-pair cable CAT 5e is used with RJ-45, and an optical cable ($\leq$2 km) with LC type connections.

The IED's default IP address through this port is 192.168.2.10 with the TCP/IP protocol. The data transfer rate is 100 Mbps.

12.2.3 EIA-232 serial rear connection

The EIA-232 connection follows the TIA/EIA-232 standard and is intended to be used with a point-to-point connection. The connection supports hardware flow control (RTS, CTS, DTR, DSR), full-duplex and half-duplex communication.

12.2.4 EIA-485 serial rear connection

The EIA-485 communication module follows the TIA/EIA-485 standard and is intended to be used in a daisy-chain bus wiring scheme with 2-wire half-duplex or 4-wire full-duplex, multi-point communication.

The maximum number of devices (nodes) connected to the bus where the IED is used is 32, and the maximum length of the bus is 1200 meters.

12.2.5 Optical ST serial rear connection

Serial communication can be used optionally through an optical connection either in loop or star topology. The connection idle state is light on or light off.

12.2.6 Communication interfaces and protocols

The communication protocols supported depend on the optional rear communication module.

Table 545: Supported communication interfaces and protocols

	100BASE-TX RJ-45	100BASE-FX LC	RS-485 + IRIG-B
IEC 61850	●	●	-
DNP3 over LAN/WAN	●	●	-
DNP3, RS485	-	-	●
MODBUS RTU/ASCII	-	-	●
MODBUS TCP/IP	●	●	-

12.2.7 Rear communication modules

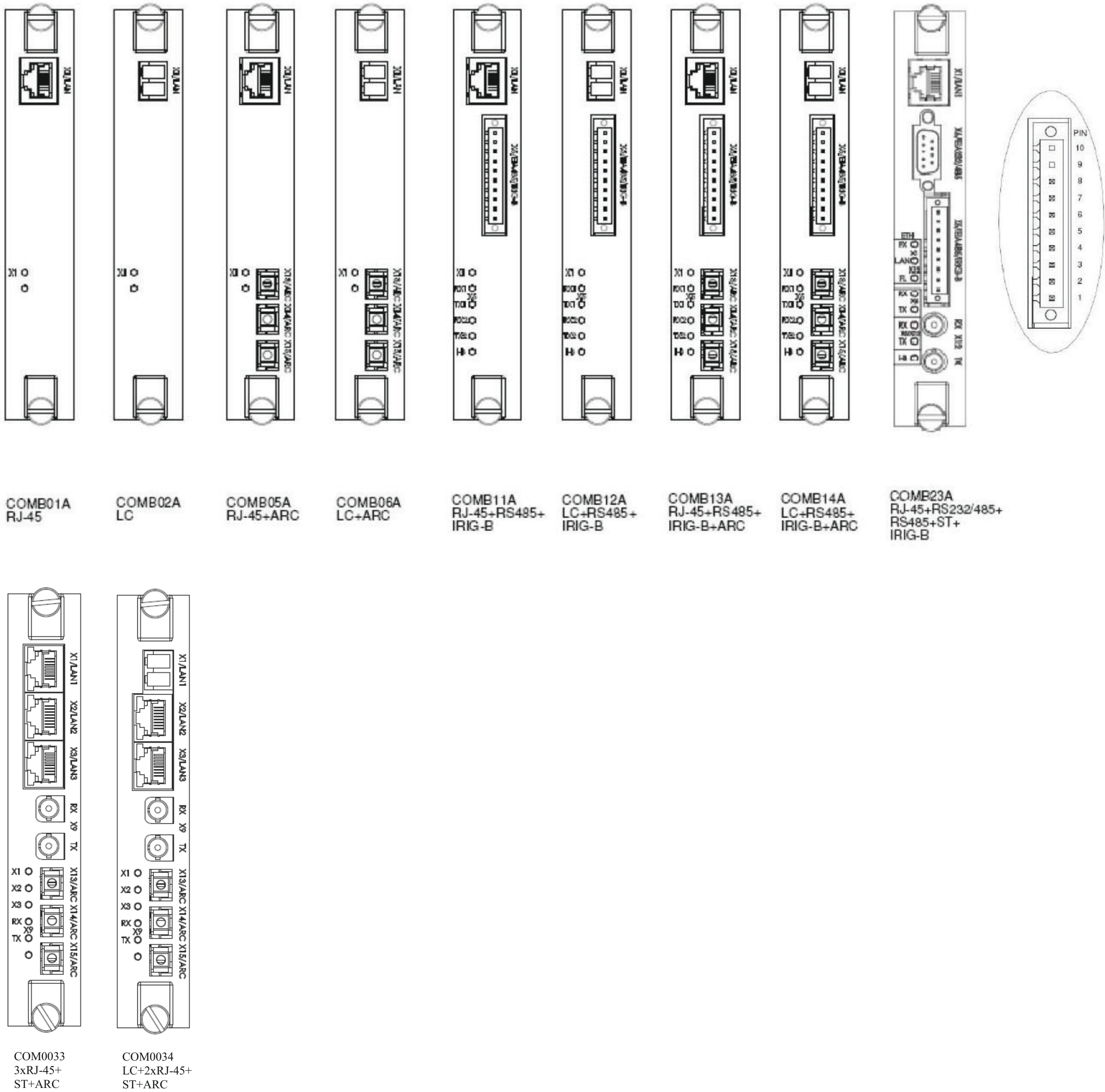

Figure 370: Communication module options

Table 546: Communication interfaces included in communication modules

Module ID	RJ-45	LC	EIA-485	EIA-232	ST
COMB01A	●	-	-	-	-
COMB02A	-	●	-	-	-
COMB05A	●	-	-	-	-
COMB06A	-	●	-	-	-
COMB11A	●	-	●	-	-
COMB12A	-	●	●	-	-
COMB13A	●	-	●	-	-
COMB14A	-	●	●	-	-
COMB23A	●	-	●	●	●
COM0033	●	-	-	-	●
COM0034	●	●	-	-	●

Table 547: LED descriptions for COMB01A-COMB14A

LED	Connector	Description[1]
LAN	X1	LAN link status and activity (RJ-45 and LC)
RX1	X5	COM2 2-wire/4-wire receive activity
TX1	X5	COM2 2-wire/4-wire transmit activity
RX2	X5	COM1 2-wire receive activity
TX2	X5	COM1 2-wire transmit activity
I-B	X5	IRIG-B signal activity

1. Depending on the COM module and jumper configuration

Table 548: LED descriptions for COMB23A

LED	Connector	Description[1]
FX	X12	Not used by COMB23A
LAN	X1	LAN Link status and activity (RJ-45 and LC)
FL	X12	Not used by COMB23A
RX	X6	COM1 2-wire / 4-wire receive activity
TX	X6	COM1 2-wire / 4-wire transmit activity
RX	X5 / X12	COM2 2-wire / 4-wire or fiber-optic receive activity
TX	X5 / X12	COM2 2-wire / 4-wire or fiber-optic transmit activity
I-B	X5	IRIG-B Signal activity

1. Depending on the jumper configuration

Table 549: LED descriptions for COM0033 and COM0034

LED	Connector	Description
X1	X1	X1/LAN1 link status and activity
X2	X2	X2/LAN2 link status and activity
X3	X3	X3/LAN3 link status and activity
RX	X9	COM1 fiber-optic receive activity
TX	X9	COM1 fiber-optic transmit activity

12.2.7.1 COMB01A-COMB014A jumper locations and connections

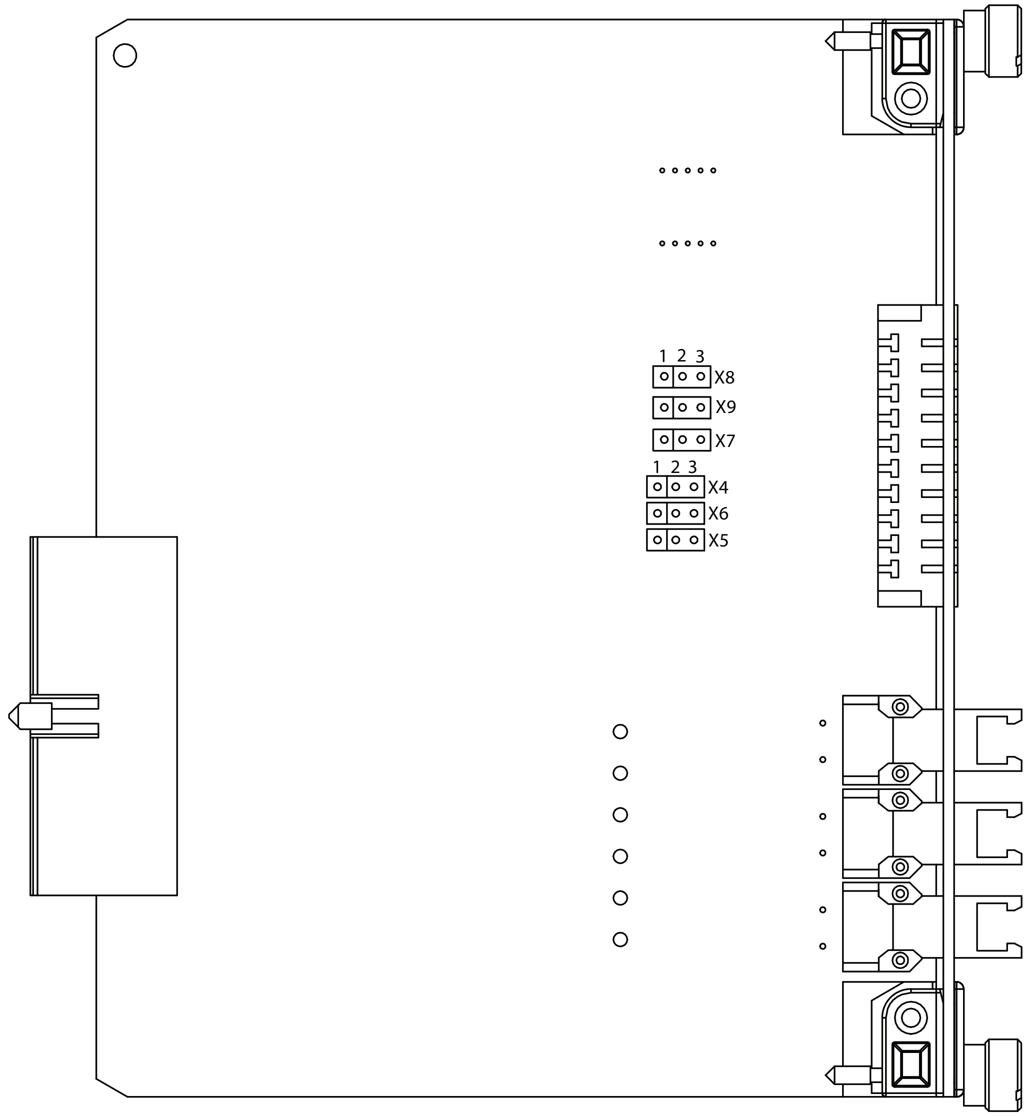

Figure 371: Jumper connectors on communication module

Table 550: 2-wire EIA-485 jumper connectors

Group	Jumper connection	Description	Notes
X4	1-2	A+ bias enabled	COM2 2-wire connection
	2-3	A+ bias disabled	
X5	1-2	B- bias enabled	
	2-3	B- bias disabled	
X6	1-2	Bus termination enabled	
	2-3	Bus termination disabled	
X7	1-2	B- bias enabled	COM1 2-wire connection
	2-3	B- bias disabled	
X8	1-2	A+ bias enabled	
	2-3	A+ bias disabled	
X9	1-2	Bus termination enabled	
	2-3	Bus termination disabled	

The bus is to be biased at one end to ensure fail-safe operation, which can be done using the pull-up and pull-down resistors on the communication module. In 4-wire connection the pull-up and pull-down resistors are selected by setting jumpers X4, X5, X7 and X8 to enabled position. The bus termination is selected by setting jumpers X6 and X9 to enabled position.

The jumpers have been set to no termination and no biasing as default.

Table 551: 4-wire EIA-485 jumper connectors for COM2

Group	Jumper connection	Description	Notes
X4	1-2	A+ bias enabled	COM2 4-wire TX channel
	2-3	A+ bias disabled [1]	
X5	1-2	B- bias enabled	
	2-3	B- bias disabled	
X6	1-2	Bus termination enabled	
	2-3	Bus termination disabled	
X7	1-2	B- bias enabled	COM2 4-wire RX channel
	2-3	B- bias disabled	
X8	1-2	A+ bias enabled	
	2-3	A+ bias disabled	
X9	1-2	Bus termination enabled	
	2-3	Bus termination disabled	

1. Default setting

It is recommended to enable biasing only at one end of the bus.

Termination is enabled at each end of the bus.

It is recommended to ground the signal directly to ground from one node and through capacitor from other nodes.

The two 2-wire ports are called COM1 and COM2. Alternatively, if there is only one 4-wire port configured, the port is called COM2. The fibre-optic ST connection uses the COM1 port.

Collision detection in serial communication is supported on 2-wire mode, in the following cards/ports: COMB23A: COM1, COMB11-14A: COM2.

Table 552: EIA-485 connections for COMB01A-COMB014A

Pin	2-wire mode		4-wire mode	
10	COM1	A/+	COM2	Rx/+
9		B/-		Rx/-
8	COM2	A/+		Tx/+
7		B/-		Tx/-
6	AGND (isolated ground)			
5	IRIG-B +			
4	IRIG-B -			
3	-			
2	GNDC (case via capacitor)			
1	GND (case)			

12.2.7.2 COMB023A jumper locations and connections

The optional communication module supports EIA-232/EIA-485 serial communication (X6 connector), EIA-485 serial communication (X5 connector) and optical ST serial communication (X12 connector).

Two independent communication ports are supported. The two 2-wire-ports are calIed. COM1 and COM2. Alternatively, if only one 4-wire-port is configured, the port is called COM2. The fibre-optic ST connection uses the COM1 port.

Table 553: Configuration options of the two independent communication ports

COM1 connector X6	COM2 connector X5 or X12
EIA-232	Optical ST (X12)
EIA-485 2-wire	EIA-485 2-wire (X5)
EIA-485 4-wire	EIA-485 4-wire (X5)

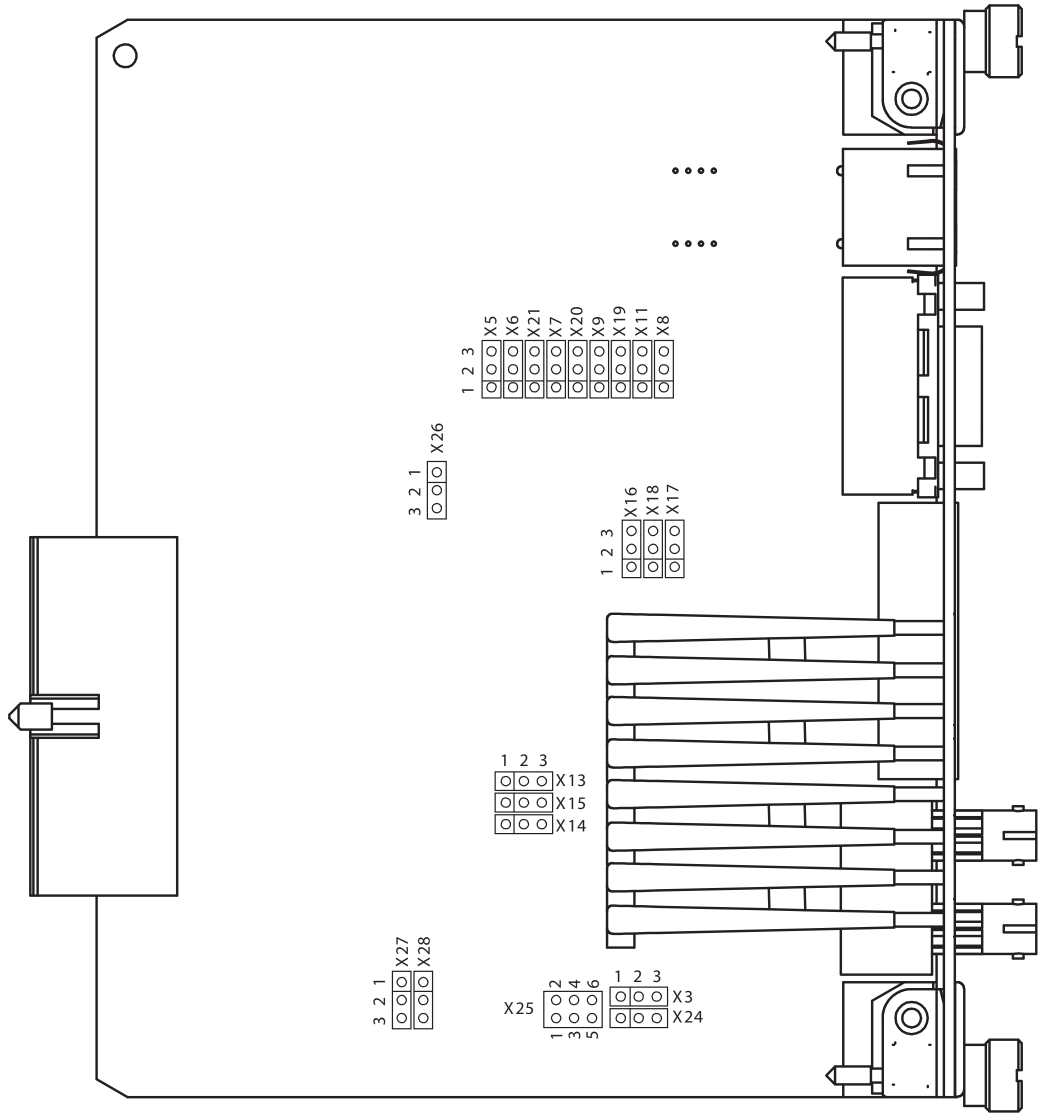

Figure 372: Jumper connections on communication module COMB023A

COM1 port connection type can be either EIA-232 or EIA-485. Type is selected by setting jumpers X19, X20, X21, X26.

The jumpers are set to EIA-232 by default.

Table 554: EIA-232 and EIA-485 jumper connectors for COM1

Group	Jumper connection	Description
X19	1-2 2-3	EIA-485 EIA-232
X20	1-2 2-3	EIA-485 EIA-232
X21	1-2 2-3	EIA-485 EIA-232
X26	1-2 2-3	EIA-485 EIA-232

To ensure fail-safe operation, the bus is to be biased at one end using the pull-up and pull-down resistors on the communication module. In the 4-wire connection, the pull-up and pull-down resistors are selected by setting jumpers X5, X6, X8, X9 to enabled position. The bus termination is selected by setting jumpers X7, X11 to enabled position.

The jumpers have been set to no termination and no biasing as default.

Table 555: 2-wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1-2 2-3	A+ bias enabled A+ bias disabled[1]	COM1 Rear connector X6 2-wire connection
X6	1-2 2-3	B- bias enabled B- bias disabled	
X7	1-2 2-3	Bus termination enabled Bus termination disabled	

1. Default setting

Table 556: 4–wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1-2 2-3	A+ bias enabled A+ bias disabled[1]	COM1 Rear connector X6 4-wire TX channel
X6	1-2 2-3	B- bias enabled B- bias disabled	
X7	1-2 2-3	Bus termination enabled Bus termination disabled	
X9	1-2 2-3	A+ bias enabled A+ bias disabled	4-wire RX channel
X8	1-2 2-3	B- bias enabled B- bias disabled	
X11	1-2 2-3	Bus termination enabled Bus termination disabled	

1. Default setting

COM2 port connection can be either EIA-485 or optical ST. Connection type is selected by setting jumpers X27 and X28.

Table 557: COM2 serial connection X5 EIA-485/ X12 Optical ST

Group	Jumper connection	Description
X27	1-2 2-3	EIA-485 Optical ST
X28	1-2 2-3	EIA-485 Optical ST

Table 558: 2-wire EIA-485 jumper connectors for COM2

Group	Jumper connection	Description
X13	1-2 2-3	A+ bias enabled A+ bias disabled
X14	1-2 2-3	B- bias enabled B- bias disabled
X15	1-2 2-3	Bus termination enabled Bus termination disabled

Table 559: 2-wire EIA-485 jumper connectors for COM2

Group	Jumper connection	Description	Notes
X13	1-2 2-3	A+ bias enabled A+ bias disabled	COM2 4-wire TX channel
X14	1-2 2-3	B- bias enabled B- bias disabled	
X15	1-2 2-3	Bus termination enabled Bus termination disabled	
X17	1-2 2-3	A+ bias enabled A+ bias disabled	4-wire RX channel
X18	1-2 2-3	B- bias enabled B- bias disabled	
X19	1-2 2-3	Bus termination enabled Bus termination disabled	

Table 560: X12 Optical ST connection

Group	Jumper connection	Description
X3	1-2 2-3	Star topology Loop topology
X24	1-2 2-3	Idle state = Light on Idle state = Light off

Table 561: EIA-232 connections for COMB023A (X6)

Pin	EIA-232
1	DCD
2	RxD
3	TxD
4	DTR
5	AGND
6	-
7	RTS
8	CTS

Table 562: EIA-485 connections for COMB023A (X6)

Pin	2-wire mode	4-wire mode
1	-	Rx/+
6	-	Rx/-
7	B/-	Tx/-
8	A/+	Tx/+

Table 563: EIA-485 connections for COMB023A (X5)

Pin	2-wire mode	4-wire mode
9	-	Rx/+
8	-	Rx/-
7	A/+	Tx/+
6	B/-	Tx/-
5	AGND (isolated ground)	
4	IRIG-B +	
3	IRIG-B -	
2	-	
1	GND (case)	

12.2.7.3 COM0033 and COM0034 jumper locations and connections

The optional communication modules include support for optical ST serial communication (X9 connector). The fiber-optic ST connection uses the COM1 port.

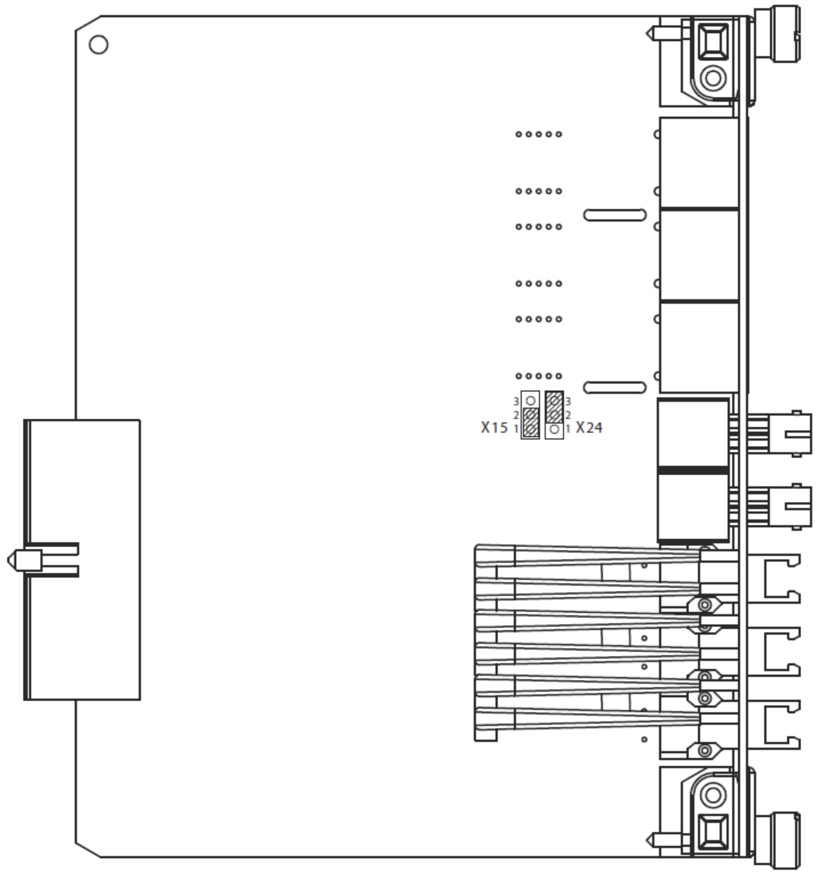

Figure 373: Jumper connections on communication module COM0033

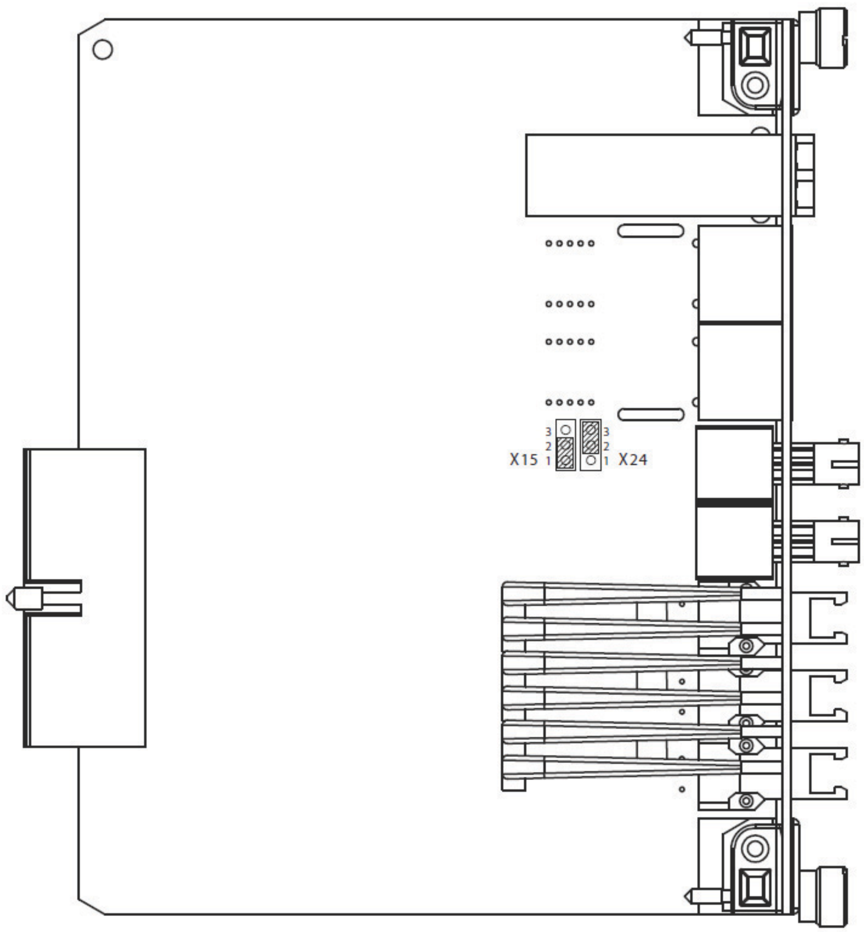

Figure 374: Jumper connections on communication module COM0034

Table 564: X9 Optical ST jumper connectors

Group	Jumper Connection	Description
X15	1-2	Star Topology
	2-3	Loop Topology
X24	1-2	Idle state = Light on
	2-3	Idle state = Light off

12.2.8 Recommended industrial Ethernet switches

ABB recommends three third-party industrial Ethernet switches.

- RuggedCom RS900
- RuggedCom RS1600
- RuggedCom RSG2100

Section 13 Technical data

Table 565: Dimensions

Description	Value	
Width	frame	7.08 inches (179.8 mm)
	case	6.46 inches (164 mm)
Height	frame	6.97 inches (177 mm), 4U
	case	6.30 inches (160 mm)
Depth		7.64 inches (194 mm)
Weight	complete IED	7.7 lbs (3.5 kg)
	plug-in unit only	4.0 lbs (1.8 kg)

Table 566: Power supply

Description	Type 1	Type 2
V_{aux}	100, 110, 120, 220, 240 V AC, 50 and 60 Hz	24, 30, 48, 60 V DC
	48, 60, 110, 125, 220, 250 V DC	
Maximum interruption time in the auxiliary DC voltage without resetting the IED	50 ms at V_{aux}rated	
V_{aux} variation	38...110% of V_n (38...264 V AC)	50...120% of V_n (12...72 V DC)
	80...120% of V_n (38.4...300 V DC)	
Start-up threshold		19.2 V DC (24 V DC * 80%)
Burden of auxiliary voltage supply under quiescent (P_q)/ operating condition	DC < 12.0 W (nominal)/< 18.0 W (max) AC< 16.0 W (nominal)/< 21.0W (max)	DC < 12.0 W (nominal)/< 18.0 W (max)
Ripple in the DC auxiliary voltage	Max 15% of the DC value (at frequency of 100 Hz)	
Fuse type	T4A/250 V	

Table 567: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz	
Current inputs	Rated current, I_n	0.2/1 A 1)2)	1/5 A 3)
	Thermal withstand capability: • Continuously • For 1 s	 4 A 100 A	 20 A 500 A
	Dynamic current withstand: • Half-wave value	250 A	1250 A
	Input impedance	<100 mΩ	<20 mΩ
Voltage inputs	Rated voltage, V_n	60...210 V AC	
	Voltage withstand: • Continuous • For 10 s	 2 x V_n (240 V AC) 3 x V_n (360 V AC)	
	Burden at rated voltage	<0.05 VA	

1) Ordering option for ground current input
2) Not available for RET615
3) Ground current and/or phase current

Table 568: Binary inputs

Description	Value
Operating range	±20% of the rated voltage
Rated voltage	24...250 V DC
Current drain	1.6...1.9 mA
Power consumption	31.0...570.0 mW
Threshold voltage	18...176 V DC
Reaction time	3 ms

Table 569: RTD/mA inputs

Description	Value		
RTD inputs	Supported RTD sensors	100 Ω platinum 250 Ω platinum 100 Ω nickel 120 Ω nickel 250 Ω nickel 10 Ω copper	TCR 0.00385 (DIN 43760) TCR 0.00385 TCR 0.00618 (DIN 43760) TCR 0.00618 TCR 0.00618 TCR 0.00427
	Supported resistance range	0...2 kΩ	
	Maximum lead resistance (threewire measurement)	25 Ω per lead	
	Isolation	2 kV (inputs to protective groundgroundground)	
	Response time	<4 s	
	RTD/resistance sensing current	Maximum 0.33 mA rms	
	Operation accuracy	Resistance	Temperature
		± 2.0% or ±1 Ω	±1°C 10 Ω copper: ±2°C
mA inputs	Supported current range	0…20 mA	
	Current input impedance	44 Ω ± 0.1%	
	Operation accuracy	±0.5% or ±0.01 mA	

Table 570: Signal output X100: SO1

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 571: Signal outputs and IRF output

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A
Make and carry for 0.5 s	15 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	10 mA at 5 V AC/DC

Table 572: Double-pole power output relays with TCM function

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC (two contacts connected in series)	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC
Trip-circuit monitoring (TCM): • Control voltage range • Current drain through the monitoring circuit • Minimum voltage over the TCM contact	 20...250 V AC/DC ~1.5 mA 20 V AC/DC (15...20 V)

Table 573: Single-pole power output relays

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC

Table 574: High-speed output HSO

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	6 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	5 A/3 A/1 A
Pickup	1ms
Dropout	20 ms, resistive load

Table 575: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front	TCP/IP protocol	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s
Rear	TCP/IP protocol	Shielded twisted pair CAT 5e cable with RJ-45 connector or fibre-optic cable with LC connector	100 MBits/s

Table 576: Serial rear interface

Type	Counter connector
Serial port (X5)	10-pin counter connector Weidmuller BL 3.5/10/180F AU OR BEDR or 9-pin counter connector Weidmuller BL 3.5/9/180F AU OR BEDR1)
Serial port (X16)	9-pin D-sub connector DE-9
Serial port (X12)	Optical ST-connector

1) Depending on the optional communication module

Table 577: Fibre-optic communication link

Connector	Fibre type	Wave length	Max. distance	Permitted path attenuation1)
LC	MM 62.5/125 μm glass fibre core	1300 nm	2 km	<8 dB
ST	MM 62.5/125 μm glass fibre core	820-900 nm	1 km	<11 dB

1) Maximum allowed attenuation caused by connectors and cable together

Table 578: IRIG-B

Description	Value
IRIG time code format	B004, B0051)
Isolation	500V 1 min.
Modulation	Unmodulated
Logic level	TTL Level
Current consumption	2...4 mA
Power consumption	10...20 mW

1) According to 200-04 IRIG -standard

Table 579: Lens sensor and optical fiber for arc flash detector

Description	Value
Fiber-optic cable including lens	1.5 m, 3.0 m or 5.0 m
Normal service temperature range of the lens	-40...+100°C
Maximum service temperature range of the lens, max 1 h	+140°C
Minimum permissible bending radius of the connection fiber	3.94 inches (100 mm)

Table 580: Degree of protection of flush-mounted IED

Description	Value
Front side	IP 54

Table 581: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)
Short-time service temperature range	• REF615, REM615 and RET615: -40...+85ºC (<16 h)[1)2)]
Relative humidity	<93%, non-condensing
Atmospheric pressure	12.47...15.37 psi (86...106 kPa)
Altitude	Up to 6561.66 feet (2000 m)
Transport and storage temperature range	-40...+85ºC

1) Degradation in MTBF and HMI performance outside the temperature range of -25...+55 ºC
2) For IEDs with an LC communication interface the maximum operating temperature is +70 ºC

Section 14 IED and Functionality tests

Table 582: Electromagnetic compatibility tests

Test Description	Test level	Reference
1 MHz/100 kHz burst disturbance test	±2.5 kV differential mode ±2.5 kV common mode	IEEE C37.90.1-2002
Electrostatic discharge test	±8 kV contact discharge ±15 kV air discharge	IEEE C37.90.3.-2001
Radio frequency interference tests	20 V/m (prior to modulation) f = 80...1000 MHz (sweep and keying test)	IEEE C37.90.2-2004
Fast transient disturbance test	All ports • ±4 kV common mode/ differential mode	IEEE C37.90.1-2002

Table 583: Mechanical tests

Test Description	Requirement	Reference
Vibration tests (sinusoidal)	Class 2	IEC 60255-21-1
Shock and bump tests	Class 2	IEC 60255-21-2
Mechanical durability	• 200 withdrawals and insertions of the plug-in unit • 200 adjustments of IED setting controls	IEEE C37.90-2005 and IEC 60255-6

Table 584: Insulation tests

Test Description	Requirement	Reference
Dielectric test	2.8 kV DC, 1 min 700 V, DC, 1 min for communication	IEEE C37.90-2005
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J	IEEE C37.90-2005

Table 585: Environmental tests

Test Description	Requirement	Reference
Dry heat test	+85°C 12h[1) 2)]	IEEE C37.90-2005
	• 96 h at +55°C • 16 h at +85° C[1)2)]	IEC 60068-2-2
Dry cold test	-40°C 12h[2) 3)]	IEEE C37.90-2005
	• 96 h at -25ºC • 6 h at -40ºC	IEC 60068-2-1
Damp heat test	+25°C, Rh = 95%, 96h	IEEE C37.90-2005
	• 6 cycles (12 h + 12 h) at +25°C…+55°C, humidity >93%	IEC 60068-2-30
Storage test	+85°C 96h -40°C 96h	IEEE C37.90-2005

1. For IED’s with an LC communication interface, the maximum operating temperature +70 ˚ C.
2. LCD may be unreadable, but IED is operational.

Section 15 Applicable standards and regulations

EMC council directive 2004/108/EC

EU directive 2002/96/EC/175

IEC 60255

IEEE C37.90.1-2002

IEEE C37.90.2-2004

IEEE C37.90.3-2001

IEEE C37.90-2005

Low-voltage directive 2006/95/EC

Section 16 Glossary

100BASE-FX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fibre-optic cabling
100BASE-TX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
ANSI	American National Standards Institute
CAT 5	A twisted pair cable type designed for high signal integrity
CAT 5e	An enhanced version of CAT 5 that adds specifications for far end crosstalk
CB	Circuit breaker
CBB	Cycle building block
CPU	Central processing unit
CT	Current transformer
CTS	Clear to send
DFR	Digital fault recorder
DFT	Discrete Fourier transform
DHCP	Dynamic Host Configuration Protocol
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DSR	Data set ready
DT	Definite time
DTR	Data terminal ready
EEPROM	Electrically erasable programmable read-only memory
EIA-232	Serial communication standard according to Electronics Industries Association
EIA-485	Serial communication standard according to Electronics Industries Association
EMC	Electromagnetic compatibility
FPGA	Field programmable gate array
GOOSE	Generic Object Oriented Substation Event

HMI	Human-machine interface
HW	Hardware
IDMT	Inverse definite minimum time
IEC 61850	International standard for substation communication and modelling
IED	Intelligent electronic device
IP	Internet protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
PC	Personal computer; Polycarbonate
PCM600	Protection and Control IED Manager
Peak-to-peak	The amplitude of a waveform between its maximum positive value and its maximum negative value; A measurement principle, where the measurement quantity is made by calculating the average from the positive and negative peak values without including the DC component. The peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.
Peak-to-peak with peak backup	A measurement principle similar to the peak-to-peak mode but with the function picking up on two conditions: the peak-to-peak value is above the set pickup current or the peak value is above two times the set pickup value
RAM	Random access memory
RCA	Also known as MTA or base angle. Characteristic angle.
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)

ROM	Read-only memory
RTC	Real-time clock
RTS	Ready to send
SBO	Select-before-operate
SCL	Substation configuration language
SMT	Signal Matrix Tool in PCM600
SNTP	Simple Network Time Protocol
SOTF	Switch on to fault
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
TRMS	True root-mean-square (value)
UTC	Coordinated universal time
WAN	Wide area network
WHMI	Web human-machine interface

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