RELION® PROTECTION AND CONTROL

REF615R

Technical Manual

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Table of contents

Section 1 Introduction

1.1 This manual

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

1.2 Intended audience

This manual addresses system engineers and installation and commissioning personnel, who use technical data during engineering, installation and commissioning, and in normal service.

The system engineer must have a thorough knowledge of protection systems, protection equipment, protection functions and the configured functional logic in the protection relays. The installation and commissioning personnel must have a basic knowledge in handling electronic equipment.

1.3 Product documentation

1.3.1 Product documentation set

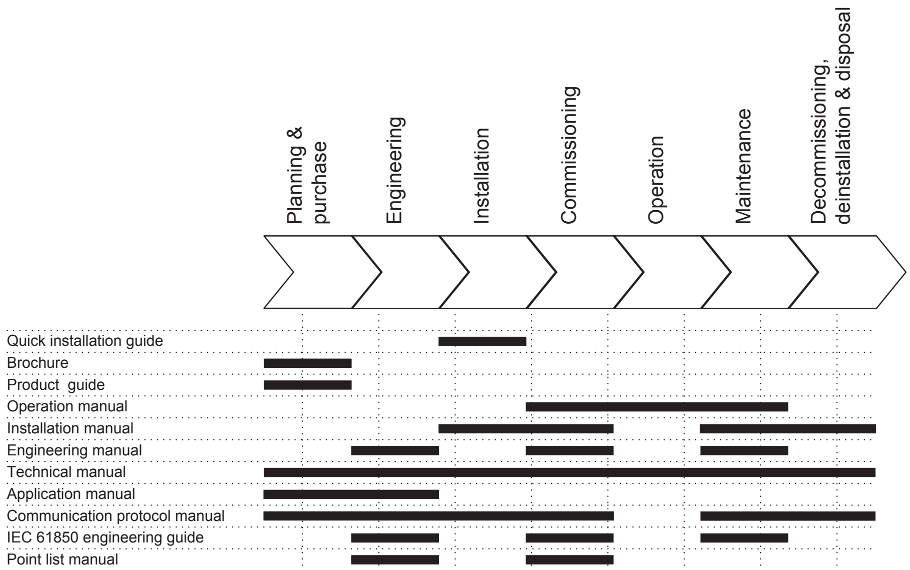


Figure 1: The intended use of documents during the product life cycle

1.3.2 Document revision history

Document revision/date	Product version	History
A/2013-11-22	4.0	First release
B/2016-10-24	4.1	Content updated to correspond to the product version
C/2019-07-02	4.1	Content updated

Download the latest documents from the ABB Web site http://www.abb.com/substationautomation.

1.3.3 Related documentation

Product series- and product-specific manuals can be downloaded from the ABB Web site http://www.abb.com/substationautomation.

1.4 Symbols and conventions

1.4.1 Symbols

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.
  To navigate between the options, use and .
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- WHMI menu names are presented in bold.
  Click **Information** in the WHMI menu structure.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile memory, select `Yes` and press .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "Enabled" and "Disabled".
- Input/output messages and monitored data names are shown in Courier font.
  When the function picks up, the `PICKUP` output is set to TRUE.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned, the dimension is in mm.

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to a specific configuration.

Table 1: Functions included in the protection relay

Function	IEC 61850	IEC 60617	REF615R
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	50P-1
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	50P-2
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P-3
Three-phase non-directional long time overcurrent protection, low stage, instance 1	PHLTPTOC1	3I> (3)	51LT
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67/51P
Three-phase directional overcurrent protection, high stage, instance 1	DPHHPDOC1	3I>> -> (1)	67/50P-1
Three-phase directional overcurrent protection, high stage, instance 2	DPHHPDOC2	3I>> -> (2)	67/50P-2
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51G
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1
Non-directional earth-fault protection, low stage, instance 4	EFLPTOC4	Io> (4)	50SEF
Table continues on next page			

Function	IEC 61850	IEC 60617	REF615R
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	50G-1
Non-directional earth-fault protection, high stage, instance 2	EFHPTOC2	Io>> (2)	50G-2
Non-directional earth-fault protection, high stage, instance 3	EFHPTOC3	Io>> (3)	50N-1
Non-directional earth-fault protection, high stage, instance 4	EFHPTOC4	Io>> (4)	50N-2
Non-directional earth-fault protection, instantaneous stage, instance 1	EFIPTOC1	Io>>> (1)	50G-3
Non-directional earth-fault protection, instantaneous stage, instance 2	EFIPTOC2	Io>>> (2)	50N-3
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67/51N
Directional earth-fault protection, high stage, instance 1	DEFHPDEF1	Io>> -> (1)	67/50N-1
Directional earth-fault protection, high stage, instance 2	DEFHPDEF2	Io>> -> (2)	67/50N-2
Three phase directional power protection, instance 1	DPSRDIR1	I1-> (1)	32P-1
Ground directional power protection, instance 1	DNZSRDIR1	I2 ->, Io-> (1)	32N-1
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46-1
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46-2
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59N-1
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27-1
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27-2
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59-1
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59-2
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47-1
Negative-sequence overvoltage protection, instance 2	NSPTOV2	U2> (2)	47-2
Frequency protection, instance 1	FRPFRQ1	f>/f<,df/dt (1)	81-1
Frequency protection, instance 2	FRPFRQ2	f>/f<,df/dt (2)	81-2
Voltage per hertz protection, instance 1	OEPVPH1	U/f> (1)	24
Three-phase thermal protection for feeders, cables and distribution transformers, Instance 1	T1PTTR1	3Ith>F (1)	49F-1
Numerical stabilized low impedance restricted earth-fault protection	LREFPNDF1	dIoLo>	87LOZREF
Circuit breaker failure protection, instance 1	CCBRBRF1	3I>/Io>BF (1)	50BF-1
Three-phase inrush detector, instance 1	INRPHAR1	3I2f> (1)	INR-1
Master trip, instance 1	TRPPTRC1	Master Trip (1)	86/94-1
Master trip, instance 2	TRPPTRC2	Master Trip (2)	86/94-2
Arc protection, instance 1	ARCSARC1	ARC (1)	AFD-1
Arc protection, instance 2	ARCSARC2	ARC (2)	AFD-2
Arc protection, instance 3	ARCSARC3	ARC (3)	AFD-3
High impedance fault detection	PHIZ1	PHIZ1	HIZ
Load shedding and restoration, instance 1	LSHDPFRQ1	UFLS/R (1)	81LSH-1

Table continues on next page

Function	IEC 61850	IEC 60617	REF615R
Load shedding and restoration, instance 2	LSHDPFRQ2	UFLS/R (2)	81LSH-2
Loss of phase, instance 1	PHPTUC1	3I< (1)	37-1
Control			
Circuit-breaker control, instance 1	CBXCBR1	I <-> O CB (1)	52-1
Auto-reclosing	DARREC1	O -> I	79
Synchronism and energizing check	SECRSYN1	SYNC	25
Condition monitoring			
Circuit-breaker condition monitoring, instance 1	SSCBR1	CBCM (1)	52CM-1
Current circuit supervision	CCRDIF1	MCS 3I	CCM
Fuse failure supervision, intance 1	SEQRFUF1	FUSEF (1)	60-1
Cable fault detection	RCFD1	RCFD	CFD
Measurement			
Three-phase current measurement, instance 1	CMMXU1	3I	IA, IB, IC
Sequence current measurement, instance 1	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	IG
Three-phase voltage measurement, instance 1	VMMXU1	3U	VA, VB, VC
Residual voltage measurement, instance 1	RESVMMXU1	Uo	VG
Sequence voltage measurement, instance 1	VSMSQI1	U1, U2, U0	V1, V2, V0
Single-phase power and energy measurement, instance 1	SPEMMXU1	SP, SE	SP, SE-1
Three-phase power and energy measurement, instance 1	PEMMXU1	P, E	P, E-1
Current total demand distortion, instance 1	CMHAI1	PQM3I	PQI-1
Voltage total harmonic distortion, instance 1	VMHAI1	PQM3U	PQVPH-1
Voltage variation, instance 1	PHQVVR1	PQ 3U<>	PQSS-1
Voltage unbalance, instance 1	VSQVUB1	PQMUBU(1)	PQVUB-1
Load profile	LDPMSTA1	-	LoadProf
Frequency measurement, instance 1	FMMXU1	f	f
Other			
Minimum pulse timer (2 pcs), instance 1	TPGAPC1	TP (1)	TP (1)
Minimum pulse timer (2 pcs), instance 2	TPGAPC2	TP (2)	TP (2)
Minimum pulse timer (2 pcs), instance 3	TPGAPC3	TP (3)	TP (3)
Minimum pulse timer (2 pcs), instance 4	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution), instance 1	TPSGAPC1	TPS (1)	62CLD-1
Minimum pulse timer (2 pcs, minute resolution), instance 1	TPMGAPC1	TPM (1)	62CLD-2
Pulse timer (8 pcs), instance 1	PTGAPC1	PT (1)	PT-1
Pulse timer (8 pcs), instance 2	PTGAPC2	PT (2)	PT-2
Time delay off (8 pcs), instance 1	TOFGAPC1	TOF (1)	TOF-1

Table continues on next page

Function	IEC 61850	IEC 60617	REF615R
Time delay off (8 pcs), instance 2	TOFGAPC2	TOF (2)	TOF-2
Time delay on (8 pcs), instance 1	TONGAPC1	TON (1)	TON -1
Time delay on (8 pcs), instance 2	TONGAPC2	TON (2)	TON -2
Set reset (8 pcs), instance 1	SRGAPC1	SR (1)	SR-1
Set reset (8 pcs), instance 2	SRGAPC2	SR (2)	SR-2
Set reset (8 pcs), instance 3	SRGAPC3	SR (3)	SR-3
Set reset (8 pcs), instance 4	SRGAPC4	SR (4)	SR-4
Move (8 pcs), instance 1	MVGAPC1	MV (1)	MV-1
Move (8 pcs), instance 2	MVGAPC2	MV (2)	MV-2
Move (8 pcs), instance 3	MVGAPC3	MV (3)	MV-3
Move (8 pcs), instance 4	MVGAPC4	MV (4)	MV-4
Move (8 pcs), instance 5	MVGAPC5	MV (5)	MV-5
Move (8 pcs), instance 6	MVGAPC6	MV (6)	MV-6
Move (8 pcs), instance 7	MVGAPC7	MV (7)	MV-7
Move (8 pcs), instance 8	MVGAPC8	MV (8)	MV-8
Generic control points, instance 1	SPCGGIO1	SPC(1)	CNTRL-1
Generic control points, instance 2	SPCGGIO2	SPC(2)	CNTRL-2
Generic control points, instance 3	SPCGGIO3	SPC(3)	CNTRL-3
Remote Generic control points, instance 1	SPCRGGIO1	SPCR(1)	RCNTRL-1
Local Generic control points, instance 1	SPCLGGIO1	SPCL(1)	LCNTRL-1
Programmable buttons(16 buttons), instance 1	FKEYGGIO1	FKEY	FKEY
Generic Up-Down Counters, instance 1	UDFCNT1	CTR(1)	CTR-1
Generic Up-Down Counters, instance 2	UDFCNT2	CTR(2)	CTR-2
Generic Up-Down Counters, instance 3	UDFCNT3	CTR(3)	CTR-3
Shift register, instance 1	SHFTGAPC1	SHFT(1)	SHFT-1
Shift register, instance 2	SHFTGAPC2	SHFT(2)	SHFT-2
Shift register, instance 2	SHFTGAPC3	SHFT(3)	SHFT-3
Logging functions			
Disturbance recorder	RDRE1	-	DFR
Fault recorder	FLTMSTA1	-	FR
Sequence event recorder	SER	-	SER
Fault location	DRFLO1	FLO	FLO

Section 2 REF615R overview

2.1 Overview

REF615R is a dedicated feeder protection relay designed for the protection, control, measurement and supervision of utility substations and industrial power systems. REF615R is a member of ABB's Relion® product family. The REF615R protection relays are characterized by their versatility of 19" rack mounting and withdrawable design.

Re-engineered from the ground up, REF615R has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices.

The protection relay provides main protection for overhead lines and cable feeders in distribution networks. The protection relay is also used as back-up protection in applications, where an independent and redundant protection system is required.

Depending on the chosen standard configuration, the protection relay is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance grounded, compensated and solidly-grounded networks. Once the standard configuration protection relay has been given the application-specific settings, it can directly be put into service.

REF615R supports a range of communication protocols including IEC 61850 with GOOSE messaging, Modbus® and DNP3.

REF615R is designed to be a wire-alike replacement of an existing DPU2000R installation. It is designed to match existing DPU2000R cutout and external wiring except communication cable connections.

2.1.1 Product version history

Product series version	Product series history
4.0	First release
4.1	DNP3 and Modbus controls' implementation updated

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.5 or later
- REF615R Connectivity Package Ver.4.0 or later

Download connectivity packages from the ABB Web site
http://www.abb.com/substationautomation

2.2 Local HMI

The LHMI is used for setting, monitoring and controlling the protection relay. The LHMI comprises the display, buttons, LED indicators and communication port.

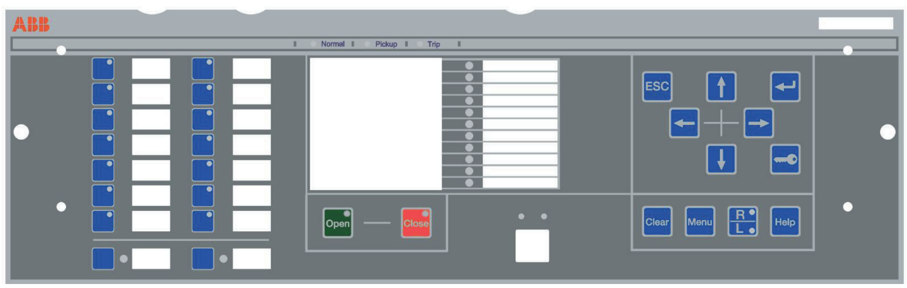


Figure 2: Example of the LHMI (ANSI OCI)

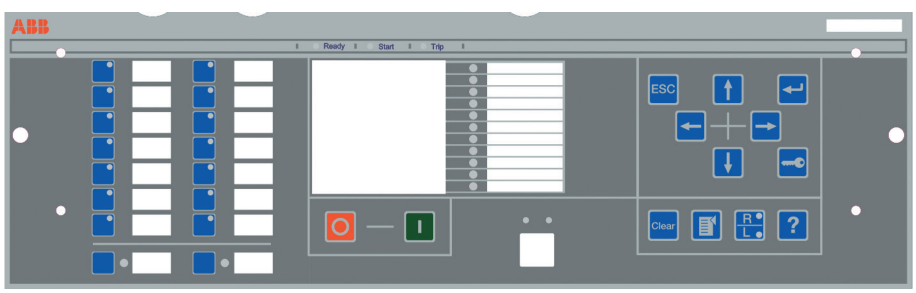


Figure 3: Example of the LHMI (IEC)

2.2.1 Display

The LHMI includes a graphical display that supports one character size.

Table 2: Large display

Character size	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20

The display view is divided into four basic areas.

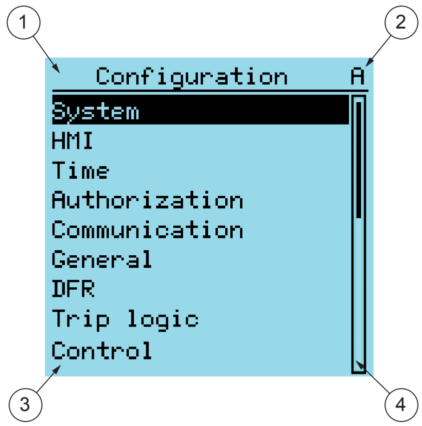


Figure 4: Display layout

1 Header

2 Icon

3 Content

4 Scroll bar (displayed when needed)

2.2.2 LEDs

The LHMI includes three protection indicators above the display: Normal, Pickup and Trip.

There are 11 matrix programmable LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

There are two additional LEDs which are embedded into the control buttons 

and 

. They represent the status of the selected breaker n (CBXCBRn).

2.2.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. Using the push buttons, open or close commands can be given to objects in the primary circuit, for example, a circuit breaker, a contactor or a disconnector. The push buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

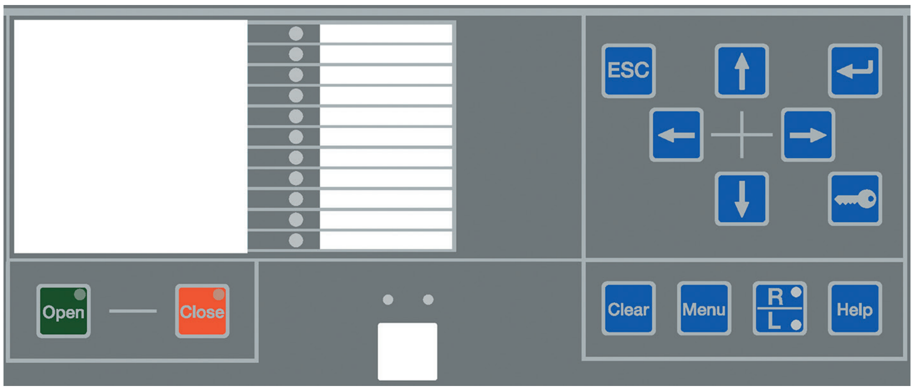


Figure 5: ANSI LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

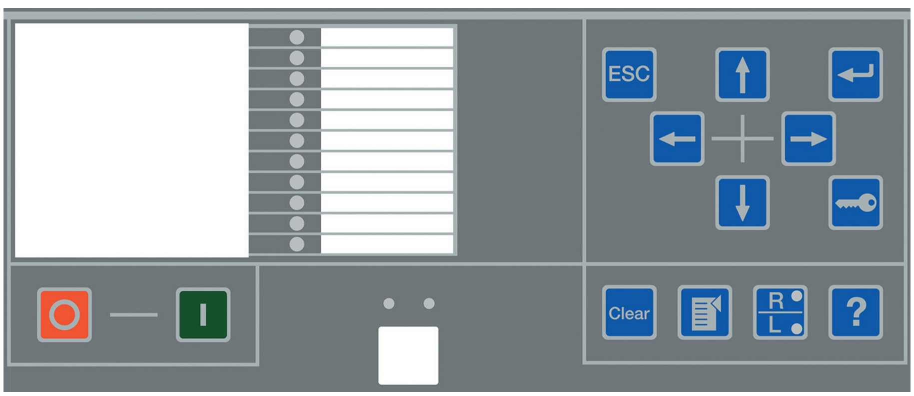


Figure 6: IEC LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.2.4 Programmable push buttons with LEDs

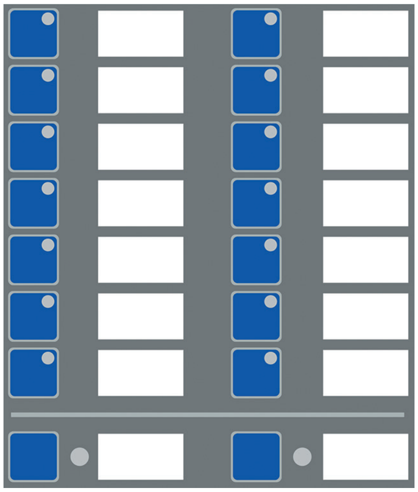


Figure 7: Programmable push buttons with LEDs

The LHMI keypad on the left side of the protection relay contains 16 programmable push buttons with red LEDs.

The buttons and LEDs are freely programmable, and they can be configured both for operation and acknowledgement purposes. That way, it is possible to get acknowledgements of the executed actions associated with the buttons. This combination can be useful, for example, for quickly selecting or changing a setting group, selecting or operating equipment, indicating field contact status or indicating or acknowledging individual alarms.

The push buttons are enabled in units ordered with the “Enhanced OCI” option. For ordering details, see the product guide. The push buttons are available for customer use though disabled by factory default for the LHMI options "A" and "C".

The LEDs can also be independently configured to bring general indications or important alarms to the operator's attention.

The lowest two buttons with LEDs on top are typically used for hot-line tag for the emergency operation of the circuit controlled by the protection relay.

To provide a description of the button function, it is possible to insert a paper sheet behind the transparent film next to the button.

2.3 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. The supported Web browser versions are Internet Explorer 7.0, 8.0 and 9.0.

WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- DFR records
- Phasor diagram
- Single-line diagram

The menu tree structure on the WHMI is almost identical to the one on the LHMI.

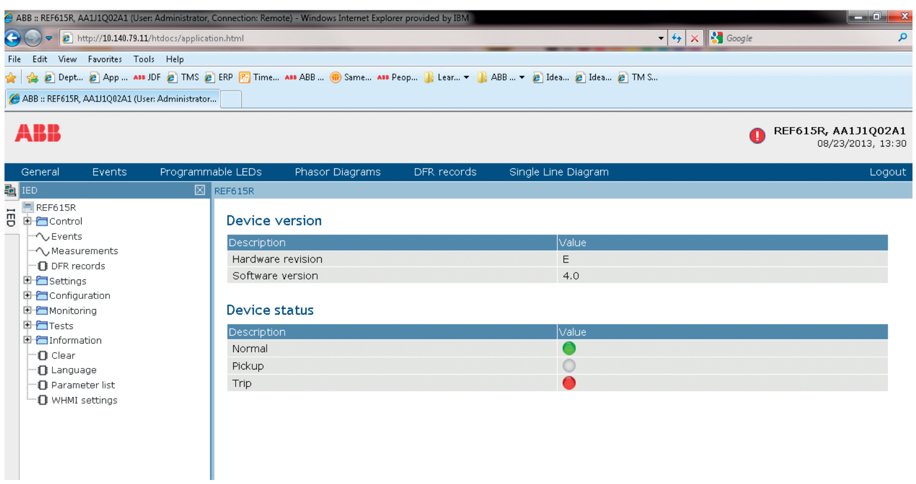


Figure 8: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting the laptop to the protection relay via the front communication port.
- Remotely over LAN/WAN.

2.4 Authorization

The user categories have been predefined for the LHMI and the WHMI, each with different rights and default passwords.

The default passwords can be changed with Administrator user rights.

User authorization is disabled by default for LHMI but WHMI always uses authorization.

Table 3: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with (only locally) • Changing setting groups • Controlling • Clearing indications
ENGINEER	• Changing settings • Clearing event list • Clearing DFRs and load profile record • Changing system settings such as IP address, serial baud rate or DFR settings • Setting the IED to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.5 Communication

The protection relay supports different communication protocols: IEC 61850, Modbus® and DNP3 Level 2 - all using TCP/IP. DNP3 and Modbus also support serial communication. Operational information and controls are available through these protocols.

The protection relay utilizes Ethernet communication extensively for different purposes. The exact services depend on the ordered product variant and enabled functionality.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and DFR records can be accessed using the IEC 61850 protocol. Oscillographic files are available to any Ethernet-based application in the standard COMTRADE format. The protection relay can send and receive binary signals from other protection relays (so called horizontal communication) using the IEC61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Further, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard. The protection relay can simultaneously report events to five different clients on the station bus.

The protection relay can support five simultaneous clients. If PCM600 reserves one client connection, only four client connections are left, for example, for IEC 61850, DNP3 and Modbus. Only one DNP3 client can be supported at a time.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber-optic LC connector (100Base-FX).

For the correct operation of redundant loop topology, it is essential that the external switches in the network support the RSTP protocol and that it is enabled in the switches. Otherwise, connecting the loop topology can cause problems to the network. The protection relay itself does not support link-down detection or RSTP. The ring recovery process is based on the aging of MAC addresses and link-up/link-down events can cause temporary breaks in communication. For better performance of the self-healing loop, it is recommended that the external switch furthest from the protection relay loop is assigned as the root switch (bridge priority = 0) and the bridge priority increases towards the protection relay loop. The end links of the protection relay loop can be attached to the same external switch or to two adjacent external switches. Self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all protection relays.

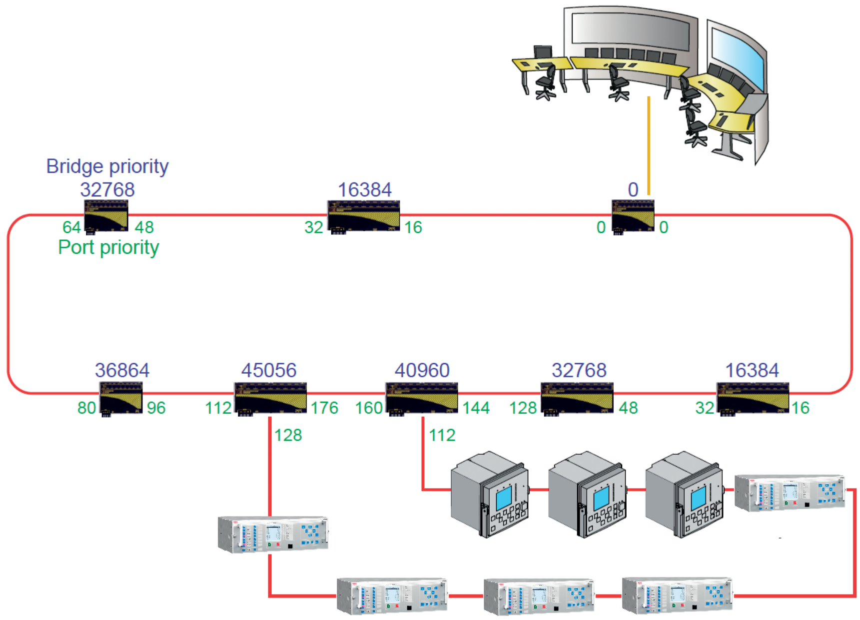


Figure 9: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to thirty REF615R protection relays. If more than 30 protection relays are to be connected, it is recommended that the network is split into several rings with no more than 30 protection relays per ring.

Section 3 Basic functions

3.1 General parameters

Table 4: Analog input settings, phase currents

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary current	1=0.2A 2=1A 3=5A			2=1A	Rated secondary current
Primary current	1.0...6000.0	A	0.1	100.0	Rated primary current
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A amplitude correction factor
Amplitude corr. B	0.900...1.100		0.001	1.000	Phase B amplitude correction factor
Amplitude corr. C	0.900...1.100		0.001	1.000	Phase C amplitude correction factor
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the phase CTs

Table 5: Analog input settings, residual current

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary current	1=0.2A 2=1A 3=5A			2=1A	Secondary current
Primary current	1.0...6000.0	A	0.1	100.0	Primary current
Amplitude corr.	0.900...1.100		0.001	1.000	Amplitude correction
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the residual CT

Table 6: Analog input settings, phase voltages

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.100...440.000	kV	0.001	20.000	Primary rated voltage
Secondary voltage	60...210	V	1	100	Secondary rated voltage
VT connection	1=Wye/Delta 2=Delta 3=VAB 4=VA			2=Delta	Wye or delta VT connection[1)]
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Amplitude corr. B	0.900...1.100		0.001	1.000	Phase B Voltage phasor magnitude correction of an external voltage transformer
Amplitude corr. C	0.900...1.100		0.001	1.000	Phase C Voltage phasor magnitude correction of an external voltage transformer
Voltage input type	1=Voltage trafo 3=CVD sensor			1=Voltage trafo	Type of the voltage input

1) VT connection depends on the external connection. For example, if VA, VB, VC and Vn are connected, there will be a wye connection; if only VA, VB and VC without Vn are connected, there will be a delta connection.

Table 7: Analog input settings, bus voltage for synchronization

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.100...440.000	kV	0.001	20.000	Primary rated voltage
Secondary voltage	60...210	V	1	100	Secondary rated voltage L-L
VT connection	3=VAB 4=VA			3=VAB	VAB or VA connection
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Voltage input type	1=Voltage trafo			1=Voltage trafo	Type of the voltage input

Table 8: Analog input settings, residual voltage

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary voltage	60...210	V	1	100	Secondary voltage
Primary voltage	0.100...440.000	kV	0.001	11.547	Primary voltage
Amplitude corr.	0.900...1.100		0.001	1.000	Amplitude correction

Table 9: Authorization settings

Parameter	Values (Range)	Unit	Step	Default	Description
Local override	0=False[1] 1=True[2]			1=True	Disable authority
Remote override	0=False[3] 1=True[4]			1=True	Disable authority
Local viewer (4-8 chars)				0	Set password (4-8 chars)
Local operator (4-8 chars)				0	Set password (4-8 chars)
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Local engineer (4-8 chars)				0	Set password (4-8 chars)
Local admin (4-8 chars)				0	Set password (4-8 chars)
Remote viewer (9-20 chars)				0	Set password (9-20 chars)
Remote operator (9-20 chars)				0	Set password (9-20 chars)
Remote engineer (9-20 chars)				0	Set password (9-20 chars)
Remote admin (9-20 chars)				0	Set password (9-20 chars)
Authority logging	1=None 2=Configuration change 3=Setting group 4=Setting group, control 5=Settings edit 6=All			4=Setting group, control	Authority logging level

1) Authorization override is disabled, LHMI password must be entered.
2) Authorization override is enabled, LHMI password is not asked.
3) Authorization override is disabled, communication tools ask password to enter the protection relay.
4) Authorization override is enabled, communication tools do not need password to enter the protection relay, except for WHMI which always requires it.

To avoid communication errors with PCM600 while authentication is enabled, ensure that appropriate credentials are used for the specific action. Confirm that the password in the protection relay properties is valid for the action attempted.

Table 10: Binary input settings

Parameter	Values (Range)	Unit	Step	Default	Description
Threshold voltage	18...176	Vdc	2	18	Digital input threshold voltage
Input osc. level	2...50	events/s	1	30	Digital input oscillation suppression threshold
Input osc. hyst	2...50	events/s	1	10	Digital input oscillation suppression hysteresis

Table 11: Ethernet front port settings

Parameter	Values (Range)	Unit	Step	Default	Description
IP address				192.168.0.254	IP address for front port (fixed)
Mac address				XX-XX-XX-XX-XX-XX	Mac address for front port

Table 12: Ethernet rear port settings

Parameter	Values (Range)	Unit	Step	Default	Description
IP address				192.168.2.10	IP address for rear port(s)
Subnet mask				255.255.255.0	Subnet mask for rear port(s)
Default gateway				192.168.2.1	Default gateway for rear port(s)
Mac address				XX-XX-XX-XX-XX-XX	Mac address for rear port(s)

Table 13: General system settings

Parameter	Values (Range)	Unit	Step	Default	Description
Rated frequency	1=50Hz 2=60Hz			1=50Hz	Rated frequency of the network
Phase rotation	1=ABC 2=ACB			1=ABC	Phase rotation order
Blocking mode	1=Freeze timer 2=Block all 3=Block TRIP output			1=Freeze timer	Behavior for function BLOCK inputs
Bay name[1)]				REF615R[2)]	Bay name in system
Phase order mode	1=ABC 2=BCA 3=CAB 4=ACB 5=CBA 6=BAC			1=ABC	Selection for phase connection order
IDMT Sat point	10...50	I/I>	1	50	Overcurrent IDMT saturation point

1) Used in the protection relay main menu header and as part of the disturbance recording identification
2) Depending on the product variant

Table 14: HMI settings

Parameter	Values (Range)	Unit	Step	Default	Description
FB naming convention	1=IEC61850 2=IEC60617 3=IEC-ANSI			1=IEC61850	FB naming convention used in protection relay
Default view	1=Measurements 2=Main menu			1=Measurements	LHMI default view
Backlight timeout	1...60	min	1	3	LHMI backlight timeout
Web HMI mode	1=Active read only 2=Active 3=Disabled			3=Disabled	Web HMI functionality
Web HMI timeout	1...60	min	1	3	Web HMI login timeout
Autoscroll delay	0...30	s	1	0	Autoscroll delay for Measurements view

Table 15: IEC 61850-8-1 MMS settings

Parameter	Values (Range)	Unit	Step	Default	Description
Unit mode	1=Primary 0=Nominal 2=Primary-Nominal			0=Nominal	IEC 61850-8-1 unit mode

Table 16: Modbus settings

Parameter	Values (Range)	Unit	Step	Default	Description
Serial port 1	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 1
Parity 1	0=none 1=odd 2=even			2=even	Parity for Serial interface 1
Address 1	1...255			1	Modbus unit address on Serial interface 1
Link mode 1	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 1
Start delay 1	0...20	char		4	Start frame delay in chars on Serial interface 1
End delay 1	0...20	char		3	End frame delay in chars on Serial interface 1
Serial port 2	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 2
Parity 2	0=none 1=odd 2=even			2=even	Parity for Serial interface 2
Address 2	1...255			2	Modbus unit address on Serial interface 2
Link mode 2	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 2
Start delay 2	0...20			4	Start frame delay in chars on Serial interface 2
End delay 2	0...20			3	End frame delay in chars on Serial interface 2
MaxTCPClients	0...5			5	Maximum number of Modbus TCP/IP clients
TCPWriteAuthority	0=No clients 1=Reg. clients 2=All clients			2=All clients	Write authority setting for Modbus TCP/IP clients
EventID	0=Address 1=UID			0=Address	Event ID selection
TimeFormat	0=UTC 1=Local			1=Local	Time format for Modbus time stamps
ClientIP1				000.000.000.000	Modbus Registered Client 1
ClientIP2				000.000.000.000	Modbus Registered Client 2
ClientIP3				000.000.000.000	Modbus Registered Client 3
ClientIP4				000.000.000.000	Modbus Registered Client 4
ClientIP5				000.000.000.000	Modbus Registered Client 5
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
CtlStructPWd1				****	Password for Modbus control struct 1
CtlStructPWd2				****	Password for Modbus control struct 2
CtlStructPWd3				****	Password for Modbus control struct 3
CtlStructPWd4				****	Password for Modbus control struct 4
CtlStructPWd5				****	Password for Modbus control struct 5
CtlStructPWd6				****	Password for Modbus control struct 6
CtlStructPWd7				****	Password for Modbus control struct 7
CtlStructPWd8				****	Password for Modbus control struct 8

Table 17: DNP3 settings

Parameter	Values (Range)	Unit	Step	Default	Description
DNP physical layer	1=Serial 2=TCP/IP			2=TCP/IP	DNP physical layer
Unit address	1...65519		1	1	DNP unit address
Master address	1...65519		1	3	DNP master and UR address
Serial port	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for serial interface, when physical layer is serial.
Need time interval	0...65535	min	1	30	Period to set IIN need time bit
Time format	0=UTC 1=Local			1=Local	UTC or local. Coordinate with master.
CROB select timeout	1...65535	sec	1	10	Control Relay Output Block select timeout
Data link confirm	0=Never 1=Only Multiframe 2=Always			0=Never	Data link confirm mode
Data link confirm TO	100...65535	ms	1	3000	Data link confirm timeout
Data link retries	0...65535		1	3	Data link retries count
Data link Rx to Tx delay	0...255	ms	1	0	Turnaround transmission delay
Data link inter char delay	0...20	char	1	4	Inter character delay for incoming messages
App layer confirm	1=Disable 2=Enable			1=Disable	Application layer confirm mode
App confirm TO	100...65535	ms	1	5000	Application layer confirm and UR timeout
App layer fragment	256...2048	bytes	1	2048	Application layer fragment size
UR mode	1=Disable 2=Enable			1=Disable	Unsolicited responses mode
UR retries	0...65535		1	3	Unsolicited retries before switching to UR offline mode
UR TO	0...65535	ms	1	5000	Unsolicited response timeout
UR offline interval	0...65535	min	1	15	Unsolicited offline interval
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
UR Class 1 Min events	0...999		1	2	Min number of class 1 events to generate UR
UR Class 1 TO	0...65535	ms	1	50	Max holding time for class 1 events to generate UR
UR Class 2 Min events	0...999		1	2	Min number of class 2 events to generate UR
UR Class 2 TO	0...65535	ms	1	50	Max holding time for class 2 events to generate UR
UR Class 3 Min events	0...999		1	2	Min number of class 3 events to generate UR
UR Class 3 TO	0...65535	ms	1	50	Max holding time for class 3 events to generate UR
Legacy master UR	1=Disable 2=Enable			1=Disable	Legacy DNP master unsolicited mode support. When enabled relay does not send initial unsolicited message.
Legacy master SBO	1=Disable 2=Enable			1=Disable	Legacy DNP Master SBO sequence number relax enable
Default Var Obj 01	1...2		1	1	1=BI; 2=BI with status.
Default Var Obj 02	1...2		1	2	1=BI event; 2=BI event with time.
Default Var Obj 30	1...4		1	2	1=32 bit AI; 2=16 bit AI; 3=32 bit AI without flag; 4=16 bit AI without flag.
Default Var Obj 32	1...4		1	4	1=32 bit AI event; 2=16 bit AI event; 3=32 bit AI event with time; 4=16 bit AI event with time.
Paired Mode	1=Disable 2=Enable			1=Disable	Backward compatibility to DPU2000R paired mode operation.

Table 18: COM1/COM2 serial communication settings

Parameter	Values (Range)	Unit	Step	Default	Description
Fiber mode	0=No fiber 2=Fiber light OFF loop			0=No fiber	Fiber mode for COM1
Serial mode	1=RS485 2Wire 2=RS485 4Wire 3=RS232 no handshake 4=RS232 with handshake			1=RS485 2Wire	Serial mode for COM1
CTS delay	0...60000			0	CTS delay for COM1

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
RTS delay	0...60000			0	RTS delay for COM1
Baudrate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baudrate for COM1
Parity	0=none 1=odd 2=even			2=even	Parity for COM1

If this protocol does not operate as expected, check that another serial protocol is not using the same COM port.

DNP3 protocol ignores any parity setting in the COM settings group; DNP3 is defined as an 8 bit/no parity protocol with a 16-bit CRC every 16 bytes. This provides better error detection than parity.

Table 19: Serial communication settings

Parameter	Values (Range)	Unit	Step	Default	Description
Fiber mode	0=No fiber 2=Fiber light OFF loop			0=No fiber	Fiber mode for COM2
Serial mode	1=RS485 2Wire 2=RS485 4Wire 3=RS232 no handshake 4=RS232 with handshake			1=RS485 2Wire	Serial mode for COM2
CTS delay	0...60000			0	CTS delay for COM2
RTS delay	0...60000			0	RTS delay for COM2
Baudrate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baudrate for COM2

Table 20: Time settings

Parameter	Values (Range)	Unit	Step	Default	Description
Date				0	Date
Time				0	Time
Time format	1=24H:MM:SS:MS 2=12H:MM:SS:MS			1=24H:MM:SS:MS	Time format
Date format	1=DD.MM.YYYY 2=DD/MM/YYYY 3=DD-MM-YYYY 4=MM.DD.YYYY 5=MM/DD/YYYY 6=YYYY-MM-DD 7=YYYY-DD-MM 8=YYYY/DD/MM			1=DD.MM.YYYY	Date format
Local time offset	-840...840	min		0	Local time offset in minutes
Synch source	0=None 1=SNTP 2=Modbus 5=IRIG-B 9=DNP 16=IEC60870-5-101			1=SNTP	Time synchronization source
IP SNTP primary				10.58.125.165	IP address for SNTP primary server
IP SNTP secondary				192.168.2.165	IP address for SNTP secondary server
DST on time				02:00	Daylight savings time on, time (hh:mm)
DST on date				01.05.	Daylight savings time on, date
DST on day	0=No in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			0=No in use	Daylight savings time on, day of week
DST offset	-720...720	min		60	Daylight savings time offset, in minutes
DST off time				02:00	Daylight savings time off, time (hh:mm)
DST off date				25.09.	Daylight savings time off, date
DST off day	0=No in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			0=No in use	Daylight savings time off, day of week

Table 21: Binary input signals in cards X110 and X130

Name	Type	Terminal	Protection relay type	
			Protection relays with normal BO contacts	Protection relays with high-speed contacts
X110-Input 1	BOOLEAN	4 3	IN1+ Common-	IN1+ Common-
X110-Input 2	BOOLEAN	5 3	IN2+ Common-	IN2+ Common-
X110-Input 3	BOOLEAN	6 3	IN3+ Common-	IN3+ Common-
X110-Input 4	BOOLEAN	7 3	IN4+ Common-	IN4+ Common-
X110-Input 5	BOOLEAN	8 3	IN5+ Common-	IN5+ Common-
X110-Input 6	BOOLEAN	9 3	IN6+ Common-	IN6+ Common-
X110-Input 7	BOOLEAN	10 11	IN7+ IN7-	IN7+ Common-
X110-Input 8	BOOLEAN	12 13	IN8+ IN8-	IN8+ Common-
X130-Input 9	BOOLEAN	39 40	IN9+ IN9-	IN9+ IN9-
X130-Input 10	BOOLEAN	41 42	IN10+ IN10-	IN10+ IN10-
X130-Input 11	BOOLEAN	43 44	IN11+ IN11-	IN11+ IN11-
Note: Binary inputs 1...8 in protection relays with high-speed output contacts have common negative terminals 3, 11 and 13.				

Table 22: Location of binary outputs hardware card (Xnnn)

Binary output	Protection relay with normal BO contacts	Protection relay with high-speed contacts
TRIP	X100	X100
OUT1	X110	X100
OUT2	X110	X100
OUT3	X100	X100
OUT4	X100	X110
OUT5	X100	X110
OUT6	X100	X110

Table 23: Binary output signals in power supply module or card X110

Name	Type	Default	Terminal number
TRIP	BOOLEAN	0=False	29, 30
OUT1	BOOLEAN	0=False	27, 28
OUT2	BOOLEAN	0=False	25, 26
OUT3	BOOLEAN	0=False	23, 24
OUT4	BOOLEAN	0=False	21, 22
OUT5	BOOLEAN	0=False	19, 20
OUT6	BOOLEAN	0=False	17, 18

Table 24: Binary input settings in card location Xnnn

Name 1)	Value	Unit	Step	Default
Input m2) filter time	5…1000	ms		5
Input m inversion	0= False 1-True			0=False

1) Xnnn = Slot ID, for example, X110 or X130, as applicable
2) m = For example, 1, 2, depending on the serial number of the binary input in a particular BIO card

3.2 Self-supervision

The protection relay's extensive self-supervision system continuously supervises the software and the electronics. It handles run-time fault situation and informs the user about a fault via the LHMI and through the communication channels.

There are two types of fault indications.

- Internal faults
- Warnings

3.2.1 Internal faults

When an internal relay fault is detected, the green Normal LED begins to flash and the self-supervision output contact is activated.

Internal fault indications have the highest priority on the LHMI. None of the other LHMI indications can override the internal fault indication.

An indication about the fault is shown as a message on the LHMI. The text `Internal Fault` with an additional text message, a code, date and time, is shown to indicate the fault type.

Different actions are taken depending on the severity of the fault. The protection relay tries to eliminate the fault by restarting. After the fault is found to be permanent, the protection relay stays in internal fault mode. All other output contacts are released and locked for the internal fault. The protection relay continues to perform internal tests during the fault situation.

If an internal fault disappears, the green Normal LED stops flashing and the protection relay returns to the normal service state. The fault indication message remains on the display until manually cleared.

The self-supervision signal output operates on the closed circuit principle. Under normal conditions, the relay is energized and the self-check contact (terminals 16-15) is closed. If the auxiliary power supply fails or an internal fault is detected, the self-check contact is opened.

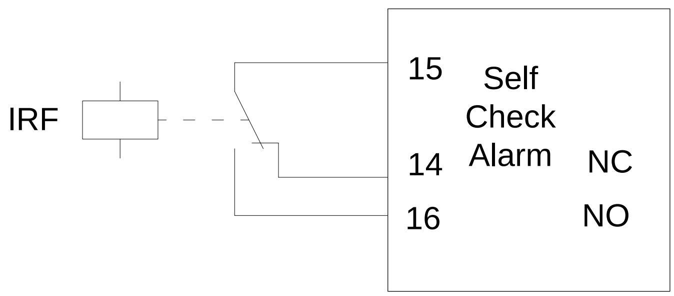


Figure 10: Output contact

The internal fault code indicates the type of internal relay fault. When a fault appears, record the code so that it can be reported to ABB customer service.

Table 25: Internal fault indications and codes

Fault indication	Fault code	Additional information
Internal Fault System error	2	An internal system error has occurred.
Internal Fault File system error	7	A file system error has occurred.
Internal Fault Test	8	Internal fault test activated manually by the user
Internal Fault SW watchdog error	10	Watchdog reset has occurred too many times within an hour.
Internal Fault SO-relay(s),X100	43	Faulty Signal Output relay(s) in card located in slot X100
Table continues on next page		

Fault indication	Fault code	Additional information
Internal Fault SO-relay(s),X110	44	Faulty Signal Output relay(s) in card located in slot X110
Internal Fault SO-relay(s),X120	45	Faulty Signal Output relay(s) in card located in slot X120
Internal Fault SO-relay(s),X130	46	Faulty Signal Output relay(s) in card located in slot X130
Internal Fault PO-relay(s),X100	53	Faulty Power Output relay(s) in card located in slot X100
Internal Fault PO-relay(s),X110	54	Faulty Power Output relay(s) in card located in slot X110
Internal Fault PO-relay(s),X120	55	Faulty Power Output relay(s) in card located in slot X120
Internal Fault PO-relay(s),X130	56	Faulty Power Output relay(s) in card located in slot X130
Internal Fault Light sensor error	57	Faulty ARC light sensor input(s)
Internal Fault Conf. error,X000	62	Card in slot X000 is wrong type
Internal Fault Conf. error,X100	63	Card in slot X100 is wrong type or does not belong to the original composition.
Internal Fault Conf. error,X110	64	Card in slot X110 is wrong type, is missing or does not belong to the original composition.
Internal Fault Conf. error,X120	65	Card in slot X120 is wrong type, is missing or does not belong to the original composition.
Internal Fault Conf.error,X130	66	Card in slot X130 is wrong type, is missing or does not belong to the original composition.
Internal Fault Card error,X000	72	Card in slot X000 is faulty.
Internal Fault Card error,X100	73	Card in slot X100 is faulty.
Internal Fault Card error,X110	74	Card in slot X110 is faulty.
Internal Fault Card error,X120	75	Card in slot X120 is faulty.
Internal Fault Card error,X130	76	Card in slot X130 is faulty.
Internal Fault LHMI module	79	LHMI module is faulty. The fault indication may not be seen on the LHMI during the fault.
Internal Fault RAM error	80	Error in the RAM memory on the CPU card.
Internal Fault ROM error	81	Error in the ROM memory on the CPU card.

Table continues on next page

Fault indication	Fault code	Additional information
Internal Fault EEPROM error	82	Error in the EEPROM memory on the CPU card.
Internal Fault FPGA error	83	Error in the FPGA on the CPU card.
Internal Fault RTC error	84	Error in the RTC on the CPU card.

For further information on internal fault indications, see the operation manual.

3.2.2 Warnings

In case of a warning, the protection relay continues to operate except for those protection functions possibly affected by the fault, and the green Normal LED remains lit as during normal operation.

Warnings are indicated with the text `Warning` additionally provided with the name of the warning, a numeric code, and the date and time on the LHMI. The warning indication message can be manually cleared.

If a warning appears, record the name and code so that it can be provided to ABB customer service.

Table 26: Warning indications and codes

Warning indication	Warning code	Additional information
Warning System warning	2	An internal system error has occurred.
Warning Watchdog reset	10	A watchdog reset has occurred.
Warning Power down det.	11	The auxiliary supply voltage has dropped too low.
Warning IEC61850 error	20	Error when building the IEC 61850 data model
Warning Modbus error	21	Error in the Modbus communication
Warning DNP3 error	22	Error in the DNP3 communication
Warning Dataset error	24	Error in the Data set(s)
Warning Report cont. error	25	Error in the Report control block(s)
Warning GOOSE contr. error	26	Error in the GOOSE control block(s)

Table continues on next page

Warning indication	Warning code	Additional information
Warning SCL config error	27	Error in the SCL configuration file or the file is missing
Warning Logic error	28	Too many connections in the configuration
Warning SMT logic error	29	Error in the SMT connections
Warning GOOSE input error	30	Error in the GOOSE connections
ACT error	31	Error in the ACT connections
Warning GOOSE Rx. error	32	Error in the GOOSE message receiving
Warning AFL error	33	Analog channel configuration error
Warning Unack card comp.	40	A new composition has not been acknowledged/accepted.
Warning Protection comm.	50	Error in protection communication
Warning ARC1 cont. light	85	A continuous light has been detected on the ARC light input 1.
Warning ARC2 cont. light	86	A continuous light has been detected on the ARC light input 2.
Warning ARC3 cont. light	87	A continuous light has been detected on the ARC light input 3.

For further information on warning indications, see the operation manual.

3.3 Programmable LEDs

3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE identification
Programmable LEDs	LED	LED	LED

3.3.2 Function block

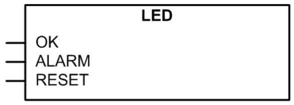


Figure 11: Function block

3.3.3 Functionality

The programmable LEDs reside on the right side of the display on the LHMI.

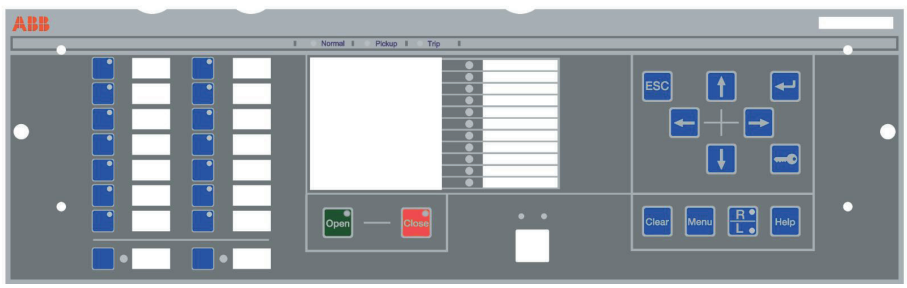


Figure 12: Programmable LEDs on the right side of the ANSI LHMI display

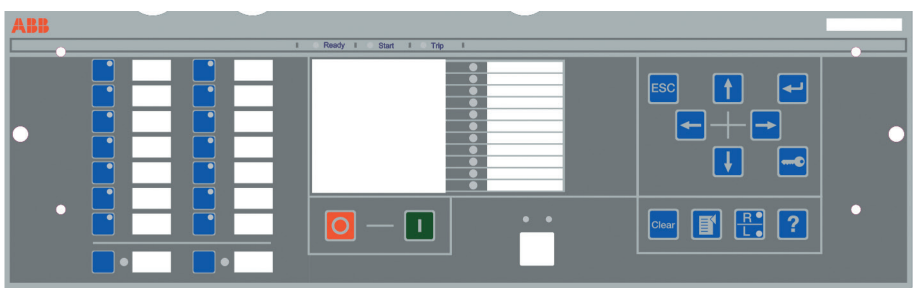


Figure 13: Programmable LEDs on the right side of the IEC LHMI display

All the programmable LEDs in the HMI of the protection relay have two colors, green and red. For each LED, the different colors are individually controllable.

Each LED is seen in the Application Configuration tool as an individual function block. Each LED has user-editable description text for event description. The state ("None", "OK", "Alarm") of each LED can also be read under a common monitored data view for programmable LEDs.

The LED status also provides a means for resetting the individual LED via communication. The LED can also be reset from configuration with the `RESET` input.

The red has the higher priority than the green.

The control of the LEDs is part of the SMT functionality. Each LED has two control inputs, one for each color. For the `ALARM` and `OK` inputs, the color is selectable as "Green" or "Red". The color for the `ALARM` input can be selected with the Alarm colour setting. The *Alarm colour* setting is common for all LEDs and has "Red" as default value. The `OK` input corresponds to the color that is available, with default being "Green".

The resetting and clearing function for all LEDs is under the **Clear** menu.

The menu structure for the programmable LEDs is presented in Figure 14. The common color selection setting *Alarm colour* for all `ALARM` inputs is in the **General** menu, while the LED-specific settings are under the LED-specific menu nodes.

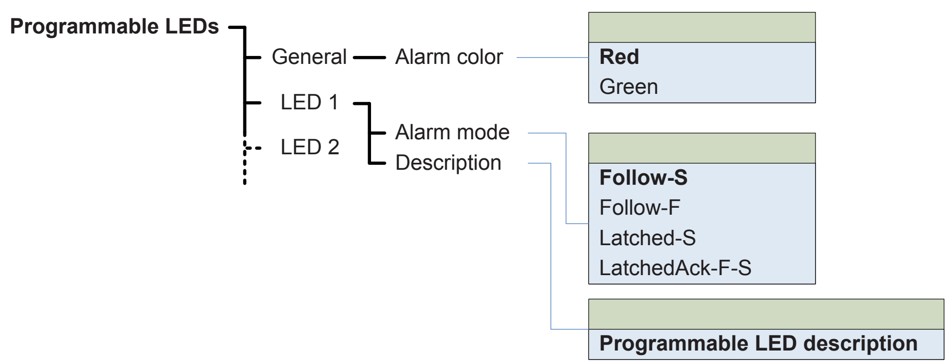


Figure 14: Menu structure

Alarm mode alternatives

The different alternatives for *Alarm mode* are "Follow-S", "Follow-F", "Latched-S" and "LatchedAck-F-S".

The *Alarm mode* setting applies only to the alarm-colored LED, which is red by default. When the LED color is of the `OK` input, it acts according to the "Follow-S" mode.

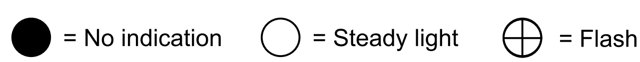


Figure 15: Symbols used in the sequence diagrams

"Follow-S": Follow Signal, ON

In this mode ALARM follows the input signal value, Non-latched.

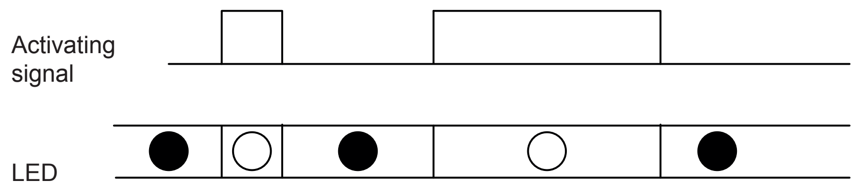


Figure 16: Operating sequence "Follow-S"

"Follow-F": Follow Signal, Flashing

Similar to "Follow-S", but instead the LED is flashing when the input is active, Non-latched.

"Latched-S": Latched, ON

This mode is a latched function. At the activation of the input signal, the alarm shows a steady light. After acknowledgement by the local operator pressing any key on the keypad, the alarm disappears.

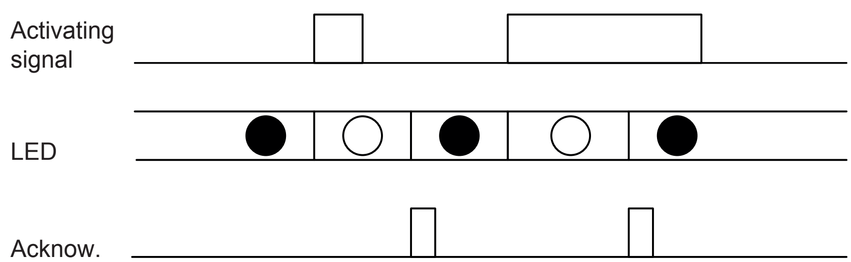


Figure 17: Operating sequence "Latched-S"

"LatchedAck-F-S": Latched, Flashing-ON

This mode is a latched function. At the activation of the input signal, the alarm starts flashing. After acknowledgement, the alarm disappears if the signal is not present and gives a steady light if the signal is present.

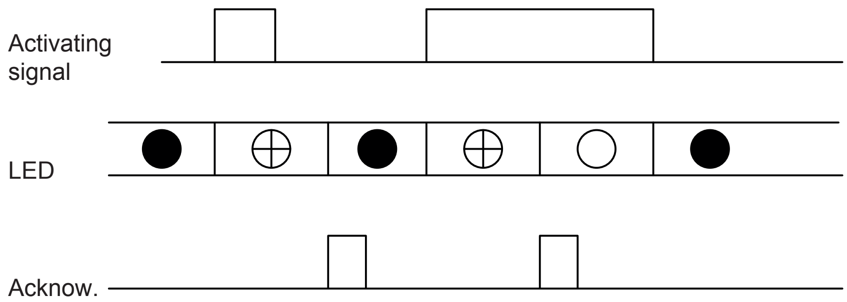


Figure 18: Operating sequence "LatchedAck-F-S"

3.3.4 Signals

Table 27: LED Input signals

Name	Type	Default	Description
OK	BOOLEAN	0=False	Ok input for LED 1
ALARM	BOOLEAN	0=False	Alarm input for LED 1
RESET	BOOLEAN	0=False	Reset input for LED 1
OK	BOOLEAN	0=False	Ok input for LED 2
ALARM	BOOLEAN	0=False	Alarm input for LED 2
RESET	BOOLEAN	0=False	Reset input for LED 2
OK	BOOLEAN	0=False	Ok input for LED 3
ALARM	BOOLEAN	0=False	Alarm input for LED 3
RESET	BOOLEAN	0=False	Reset input for LED 3
OK	BOOLEAN	0=False	Ok input for LED 4
ALARM	BOOLEAN	0=False	Alarm input for LED 4
RESET	BOOLEAN	0=False	Reset input for LED 4
OK	BOOLEAN	0=False	Ok input for LED 5
ALARM	BOOLEAN	0=False	Alarm input for LED 5
RESET	BOOLEAN	0=False	Reset input for LED 5
OK	BOOLEAN	0=False	Ok input for LED 6
ALARM	BOOLEAN	0=False	Alarm input for LED 6
RESET	BOOLEAN	0=False	Reset input for LED 6
OK	BOOLEAN	0=False	Ok input for LED 7
ALARM	BOOLEAN	0=False	Alarm input for LED 7
RESET	BOOLEAN	0=False	Reset input for LED 7
OK	BOOLEAN	0=False	Ok input for LED 8

Table continues on next page

Name	Type	Default	Description
ALARM	BOOLEAN	0=False	Alarm input for LED 8
RESET	BOOLEAN	0=False	Reset input for LED 8
OK	BOOLEAN	0=False	Ok input for LED 9
ALARM	BOOLEAN	0=False	Alarm input for LED 9
RESET	BOOLEAN	0=False	Reset input for LED 9
OK	BOOLEAN	0=False	Ok input for LED 10
ALARM	BOOLEAN	0=False	Alarm input for LED 10
RESET	BOOLEAN	0=False	Reset input for LED 10
OK	BOOLEAN	0=False	Ok input for LED 11
ALARM	BOOLEAN	0=False	Alarm input for LED 11
RESET	BOOLEAN	0=False	Reset input for LED 11

3.3.5 Settings

Table 28: LED Settings

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm color	1=Green 2=Red			2=Red	Color for the alarm state of the LED
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 1
Description				Programmable LEDs LED 1	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 2
Description				Programmable LEDs LED 2	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 3
Description				Programmable LEDs LED 3	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 4
Description				Programmable LEDs LED 4	Programmable LED description

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 5
Description				Programmable LEDs LED 5	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 6
Description				Programmable LEDs LED 6	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 7
Description				Programmable LEDs LED 7	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 8
Description				Programmable LEDs LED 8	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 9
Description				Programmable LEDs LED 9	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 10
Description				Programmable LEDs LED 10	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 11
Description				Programmable LEDs LED 11	Programmable LED description

3.3.6 Monitored data

Table 29: LED Monitored data

Name	Type	Values (Range)	Unit	Description
Programmable LED 1	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 1
Programmable LED 2	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 2
Programmable LED 3	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 3
Programmable LED 4	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 4
Programmable LED 5	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 5
Programmable LED 6	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 6
Programmable LED 7	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 7
Programmable LED 8	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 8
Programmable LED 9	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 9
Programmable LED 10	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 10
Programmable LED 11	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 11

3.4 LED indication control

3.4.1 Function block

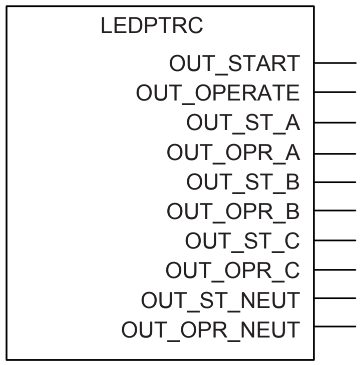


Figure 19: Function block

3.4.2 Functionality

The protection relay includes a global conditioning function LEDPTRC that is used with the protection indication LEDs.

LED indication control should never be used for tripping purposes. There is a separate trip logic function 86/94 available in the relay configuration.

LED indication control is preconfigured in a such way that all the protection function general pickup and trip signals are combined with this function (available as output signals `OUT_START` and `OUT_OPERATE`). These signals are always internally connected to Pickup and Trip LEDs. LEDPTRC collects and combines phase information from different protection functions (available as output signals `OUT_ST_A /_B /_C` and `OUT_OPR_A /_B /_C`). There is also combined ground fault information collected from all the ground-fault functions available in the relay configuration (available as output signals `OUT_ST_NEUT` and `OUT_OPR_NEUT`).

3.5 Time synchronization

3.5.1 Functionality

The protection relay has an internal real-time clock which can be either free-running or synchronized from an external source. The real-time clock is used for time stamping events, recorded data and disturbance recordings.

The protection relay is provided with a 48 hour capacitor backup that enables the real-time clock to keep time in case of an auxiliary power failure.

The setting *Synch source* determines the method to synchronize the real-time clock. If it is set to “None”, the clock is free-running and the settings *Date* and *Time* can be used to set the time manually. Other setting values activate a communication protocol that provides the time synchronization. Only one synchronization method can be active at a time but SNTP provides time master redundancy.

The protection relay supports SNTP, IRIG-B, DNP3 and Modbus to update the real-time clock. IRIG-B with GPS provides the best accuracy.

When Modbus TCP or DNP3 over TCP/IP is used, SNTP time synchronization should be used for better synchronization accuracy.

DNP3 can be used as a time synchronization source.

When the SNTP server IP setting is changed, the protection relay must be rebooted to activate the new IP address. The SNTP server IP settings are normally defined in the engineering phase via the SCL file.

The relay can use one of two SNTP servers, the primary or the secondary server. The primary server is mainly in use, whereas the secondary server is used if the primary server cannot be reached. While using the secondary SNTP server, the relay tries to switch back to the primary server on every third SNTP request attempt. If both the SNTP servers are offline, event time stamps have the time invalid status. The time is requested from the SNTP server every 60 seconds.

IRIG-B time synchronization requires the IRIG-B format B004/B005 according to the 200-04 IRIG-B standard. Older IRIG-B standards refer to these as B000/B001 with IEEE-1344 extensions. The synchronization time can be either UTC time or local time. As no reboot is necessary, the time synchronization starts immediately after the IRIG-B sync source is selected and the IRIG-B signal source is connected.

ABB has tested the IRIG-B with the following clock masters.

- Tekron TTM01 GPS clock with IRIG-B output
- Meinberg TCG511 controlled by GPS167
- Datum ET6000L
- Arbiter Systems 1088B

IRIG-B time synchronization requires a COM card with an IRIG-B input. Available only with some models.

3.6 Parameter setting groups

3.6.1 Function block

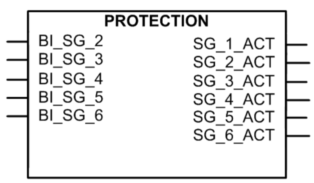


Figure 20: Function block

3.6.2 Functionality

The protection relay supports six setting groups. Each setting group contains parameters categorized as group settings inside application functions. The customer can change the active setting group at run time.

The active setting group can be changed by a parameter or via binary inputs depending on the mode selected with the **Configuration/Setting Group/SG operation mode** setting.

The default value of all inputs is FALSE, which makes it possible to use only the required number of inputs and leave the rest disconnected. The setting group selection is not dependent on the `SG_x_ACT` outputs.

Table 30: Optional operation modes for setting group selection

SG operation mode	Description
Operator (Default)	Setting group can be changed with the setting **Settings/Setting group/Active group**. Value of the `SG_LOGIC_SEL` output is FALSE.
Logic mode 1	Setting group can be changed with binary inputs (`BI_SG_2...BI_SG_6`). The highest `TRUE` binary input defines the active setting group. Value of the `SG_LOGIC_SEL` output is TRUE.
Logic mode 2	Setting group can be changed with binary inputs where `BI_SG_4` is used for selecting setting groups 1-3 or 4-6. When binary input `BI_SG_4` is `FALSE`, setting groups 1-3 are selected with binary inputs `BI_SG_2` and `BI_SG_3`. When binary input `BI_SG_4` is `TRUE`, setting groups 4-6 are selected with binary inputs `BI_SG_5` and `BI_SG_6`. Value of the `SG_LOGIC_SEL` output is TRUE.

The setting group (SG) is changed whenever switching the *SG operation mode* setting from "Operator" to either "Logic mode 1" or "Logic mode 2." Thus, it is recommended to select the preferred operation mode at the time of installation and commissioning and not change it throughout the protection relay's service. Changing the *SG operation mode* setting from "Logic mode 1" to "Logic mode 2" or from "Logic mode 2" to "Logic mode 1" does not affect the setting group (SG).

For example, six setting groups can be controlled with three binary inputs. The *SG operation mode* is set to “Logic mode 2” and inputs `BI_SG_2` and `BI_SG_5` are connected together the same way as inputs `BI_SG_3` and `BI_SG_6`.

Table 31: SG operation mode = “Logic mode 1”

Input					
BI_SG_2	BI_SG_3	BI_SG_4	BI_SG_5	BI_SG_6	Active group
FALSE	FALSE	FALSE	FALSE	FALSE	1
TRUE	FALSE	FALSE	FALSE	FALSE	2
any	TRUE	FALSE	FALSE	FALSE	3
any	any	TRUE	FALSE	FALSE	4
any	any	any	TRUE	FALSE	5
any	any	any	any	TRUE	6

Table 32: SG operation mode = “Logic mode 2”

Input					
BI_SG_2	BI_SG_3	BI_SG_4	BI_SG_5	BI_SG_6	Active group
FALSE	FALSE	FALSE	any	any	1
TRUE	FALSE	FALSE	any	any	2
any	TRUE	FALSE	any	any	3
any	any	TRUE	FALSE	FALSE	4
any	any	TRUE	TRUE	FALSE	5
any	any	TRUE	any	TRUE	6

The setting group 1 can be copied to any other or all groups from HMI (Copy group 1).

3.7 Fault records FLTMSTA

3.7.1 Functionality

The protection relay has the capacity to store the records of 128 latest fault events. Fault records include fundamental or RMS current values. The records enable the user to analyze recent power system events. Each fault record (FLTMSTA) is marked with an up-counting fault number and a time stamp that is taken from the beginning of the fault.

The fault recording period begins from the pickup event of any protection function and ends if any protection function trips or the pickup(s) is restored before the trip event. If a pickup is restored without a trip event, the pickup duration shows the protection function that has picked up first.

Pickup duration that has the value of 100% indicates that a protection function has tripped during the fault and if none of the protection functions has been tripped, Pickup duration shows always values less than 100%.

The Fault recorded data Protection and Pickup duration is from the same protection function. The Fault recorded data trip time shows the time of the actual fault period.

The Trip time in the fault record is calculated based on the pickup and trip time stamps. Pickup events may be delayed to avoid false positive reporting. Therefore, the Trip time may be shorter than expected.

If some functions in relay application are sensitive to start frequently it might be advisable to set the setting parameter *Trig mode* to “From trip”. Then only faults that cause an trip event trigger a new fault recording.

The fault-related current, voltage, frequency, angle values, shot pointer and the active setting group number are taken from the moment of the operate event, or from the beginning of the fault if only a pickup event occurs during the fault. The maximum current value collects the maximum fault currents during the fault. In case frequency cannot be measured, nominal frequency is used for frequency and zero for Frequency gradient and validity is set accordingly.

Measuring mode for phase current and residual current values can be selected with the *Measurement mode* setting parameter.

3.7.2 Settings

Table 33: FR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Trig mode	0=Trip or Pickup 1=Trip only 2=Pickup only			0=Trip or Pickup	Triggering mode
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

3.7.3 Monitored data

Table 34: FR Monitored data

Name	Type	Values (Range)	Unit	Description
Fault number	INT32	0...999999		Fault record number
Time and date	Timestamp			Fault record time stamp
Protection	Enum	0=Unknown 1=PHLPTOC1 2=PHLPTOC2 6=PHHPTOC1 7=PHHPTOC2 8=PHHPTOC3 9=PHHPTOC4 12=PHIPTOC1 13=PHIPTOC2 17=EFLPTOC1 18=EFLPTOC2 19=EFLPTOC3 22=EFHPTOC1 23=EFHPTOC2 24=EFHPTOC3 25=EFHPTOC4 30=EFIPTOC1 31=EFIPTOC2 32=EFIPTOC3 35=NSPTOC1 36=NSPTOC2 -7=INTRPTEF1 -5=STTPMSU1 -3=JAMPTOC1 41=PDNSPTOC1 44=T1PTTR1 46=T2PTTR1 48=MPTTR1 50=DEFLPDEF1 51=DEFLPDEF2 53=DEFHPDEF1 56=EFPADM1 57=EFPADM2 58=EFPADM3 59=FRPFRQ1 60=FRPFRQ2 61=FRPFRQ3 62=FRPFRQ4 63=FRPFRQ5 64=FRPFRQ6		Protection function

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		65=LSHDPFRQ1 66=LSHDPFRQ2 67=LSHDPFRQ3 68=LSHDPFRQ4 69=LSHDPFRQ5 71=DPHLPDOC1 72=DPHLPDOC2 74=DPHHPDOC1 77=MAPGAPC1 78=MAPGAPC2 79=MAPGAPC3 85=MNSPTOC1 86=MNSPTOC2 88=LOFLPTUC1 90=TR2PTDF1 91=LNPLDF1 92=LREFPNDF1 94=MPDIF1 96=HREFPDIF1 100=ROVPTOV1 101=ROVPTOV2 102=ROVPTOV3 104=PHPTOV1 105=PHPTOV2 106=PHPTOV3 108=PHPTUV1 109=PHPTUV2 110=PHPTUV3 112=NSPTOV1 113=NSPTOV2 116=PSPTUV1 118=ARCSARC1 119=ARCSARC2 120=ARCSARC3 -96=SPHIPTOC1		

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		-93=SPHLPTOC2 -92=SPHLPTOC1 -89=SPHHPTOC2 -88=SPHHPTOC1 -86=SPHPTUV3 -85=SPHPTUV2 -84=SPHPTUV1 -82=SPHPTOV3 -81=SPHPTOV2 -80=SPHPTOV1 -25=OEPVPH4 -24=OEPVPH3 -23=OEPVPH2 -22=OEPVPH1 -19=PSPTOV2 -18=PSPTOV1 -15=PREVPTOC1 -12=PHPTUC2 -11=PHPTUC1 -9=PHIZ1 5=PHLTPTOC1 20=EFLPTOC4 26=EFHPTOC5 27=EFHPTOC6 37=NSPTOC3 38=NSPTOC4 45=T1PTTR2 54=DEFHPDEF2 75=DPHHPDOC2 89=LOFLPTUC2 103=ROVPTOV4 117=PSPTUV2		
Pickup duration	FLOAT32	0.00...100.00	%	Maximum pickup duration of all stages during the fault
Trip time	FLOAT32	0.000...999999.999	s	Trip time
Fault distance	FLOAT32	0.00...9999.99	pu	Distance to fault measured in pu
Fault resistance	FLOAT32	0.00...999.99	ohm	Fault resistance
Setting group	INT32	1...6		Active setting group
Shot pointer	INT32	0...7		Autoreclosing shot pointer value
Max diff current IA	FLOAT32	0.000...80.000	pu	Maximum phase A differential current
Max diff current IB	FLOAT32	0.000...80.000	pu	Maximum phase B differential current

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Max diff current IC	FLOAT32	0.000...80.000	pu	Maximum phase C differential current
Diff current IA	FLOAT32	0.000...80.000	pu	Differential current phase A
Diff current IB	FLOAT32	0.000...80.000	pu	Differential current phase B
Diff current IC	FLOAT32	0.000...80.000	pu	Differential current phase C
Max bias current IA	FLOAT32	0.000...50.000	pu	Maximum phase A bias current
Max bias current IB	FLOAT32	0.000...50.000	pu	Maximum phase B bias current
Max bias current IC	FLOAT32	0.000...50.000	pu	Maximum phase C bias current
Bias current IA	FLOAT32	0.000...50.000	pu	Bias current phase A
Bias current IB	FLOAT32	0.000...50.000	pu	Bias current phase B
Bias current IC	FLOAT32	0.000...50.000	pu	Bias current phase C
Diff current IG	FLOAT32	0.000...80.000	pu	Differential current residual
Bias current IG	FLOAT32	0.000...50.000	pu	Bias current residual
Max current IA	FLOAT32	0.000...50.000	xIn	Maximum phase A current
Max current IB	FLOAT32	0.000...50.000	xIn	Maximum phase B current
Max current IC	FLOAT32	0.000...50.000	xIn	Maximum phase C current
Max current IG	FLOAT32	0.000...50.000	xIn	Maximum residual current
Current IA	FLOAT32	0.000...50.000	xIn	Phase A current
Current IB	FLOAT32	0.000...50.000	xIn	Phase B current
Current IC	FLOAT32	0.000...50.000	xIn	Phase C current
Current IG	FLOAT32	0.000...50.000	xIn	Residual current
Current IN	FLOAT32	0.000...50.000	xIn	Calculated residual current
Current I1	FLOAT32	0.000...50.000	xIn	Positive sequence current
Current I2	FLOAT32	0.000...50.000	xIn	Negative sequence current
Max current IA2	FLOAT32	0.000...50.000	xIn	Maximum phase A current (b)
Max current IB2	FLOAT32	0.000...50.000	xIn	Maximum phase B current (b)
Max current IC2	FLOAT32	0.000...50.000	xIn	Maximum phase C current (b)
Max current IG2	FLOAT32	0.000...50.000	xIn	Maximum residual current (b)
Current IA2	FLOAT32	0.000...50.000	xIn	Maximum phase A current (b)
Current IB2	FLOAT32	0.000...50.000	xIn	Maximum phase B current (b)
Current IC2	FLOAT32	0.000...50.000	xIn	Maximum phase C current (b)
Current IG2	FLOAT32	0.000...50.000	xIn	Residual current (b)
Current I0B	FLOAT32	0.000...50.000	xIn	Calculated residual current (b)
Current I1B	FLOAT32	0.000...50.000	xIn	Positive sequence current (b)
Current I2B	FLOAT32	0.000...50.000	xIn	Negative sequence current (b)

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Max current IA3	FLOAT32	0.000...50.000		Maximum phase A current (c)
Max current IB3	FLOAT32	0.000...50.000		Maximum phase B current (c)
Max current IC3	FLOAT32	0.000...50.000		Maximum phase C current (c)
Max current IG3	FLOAT32	0.000...50.000		Maximum residual current (c)
Current IA3	FLOAT32	0.000...50.000		Phase A current (c)
Current IB3	FLOAT32	0.000...50.000		Phase B current (c)
Current IC3	FLOAT32	0.000...50.000		Phase C current (c)
Current IG3	FLOAT32	0.000...50.000		Residual current (c)
Current I0C	FLOAT32	0.000...50.000		Calculated residual current (c)
Current I1C	FLOAT32	0.000...50.000		Positive sequence current (c)
Current I2C	FLOAT32	0.000...50.000		Negative sequence current (c)
Voltage VA	FLOAT32	0.000...4.000	xUn	Phase A voltage
Voltage VB	FLOAT32	0.000...4.000	xUn	Phase B voltage
Voltage VC	FLOAT32	0.000...4.000	xUn	Phase C voltage
Voltage VAB	FLOAT32	0.000...4.000	xUn	Phase A to phase B voltage
Voltage VBC	FLOAT32	0.000...4.000	xUn	Phase B to phase C voltage
Voltage VCA	FLOAT32	0.000...4.000	xUn	Phase C to phase A voltage
Voltage VG	FLOAT32	0.000...4.000	xUn	Residual voltage
Voltage V0	FLOAT32	0.000...4.000	xUn	Zero sequence voltage
Voltage V1	FLOAT32	0.000...4.000	xUn	Positive sequence voltage
Voltage V2	FLOAT32	0.000...4.000	xUn	Negative sequence voltage
Voltage VA2	FLOAT32	0.000...4.000	xUn	Phase A voltage (b)
Voltage VB2	FLOAT32	0.000...4.000	xUn	Phase B voltage (b)
Voltage VC2	FLOAT32	0.000...4.000	xUn	Phase B voltage (b)
Voltage VAB2	FLOAT32	0.000...4.000	xUn	Phase A to phase B voltage (b)
VoltageVBC2	FLOAT32	0.000...4.000	xUn	Phase B to phase C voltage (b)
Voltage VCA2	FLOAT32	0.000...4.000	xUn	Phase C to phase A voltage (b)
Voltage VG2	FLOAT32	0.000...4.000	xUn	Residual voltage (b)
Voltage Zro-SeqB	FLOAT32	0.000...4.000	xUn	Zero sequence voltage (b)
Voltage Ps-SeqB	FLOAT32	0.000...4.000	xUn	Positive sequence voltage (b)
Voltage Ng-SeqB	FLOAT32	0.000...4.000	xUn	Negative sequence voltage (b)
49 thermal level	FLOAT32	0.00...99.99		49 calculated temperature of the protected object relative to the trip level
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
PDNSPTOC1 rat. I2/I1	FLOAT32	0.00...999.99	%	46PD ratio I2/I1
Frequency	FLOAT32	30.00...80.00	Hz	Frequency
Frequency gradient	FLOAT32	-10.00...10.00	Hz/s	Frequency gradient
Conductance Yo	FLOAT32	-1000.00...1000.00	mS	Conductance Yo
Susceptance Yo	FLOAT32	-1000.00...1000.00	mS	Susceptance Yo
Angle VG - IG	FLOAT32	-180.00...180.00	deg	Angle residual voltage - residual current
Angle VBC - IA	FLOAT32	-180.00...180.00	deg	Angle phase B to phase C voltage - phase A current
Angle VCA - IB	FLOAT32	-180.00...180.00	deg	Angle phase C to phase A voltage - phase B current
Angle VAB - IC	FLOAT32	-180.00...180.00	deg	Angle phase A to phase B voltage - phase C current
Angle VG2 - IG2	FLOAT32	-180.00...180.00	deg	Angle residual voltage - residual current (b)
Angle VBC2 - IA2	FLOAT32	-180.00...180.00	deg	Angle phase B to phase C voltage - phase A current (b)
Angle VCA2 - IB2	FLOAT32	-180.00...180.00	deg	Angle phase C to phase A voltage - phase B current (b)
Angle VAB2 - IC2	FLOAT32	-180.00...180.00	deg	Angle phase A to phase B voltage - phase C current (b)

3.8 Nonvolatile memory

In addition to the setting values, the protection relay can store some data in the nonvolatile memory.

- Up to 1024 events are stored. The stored events are visible in LHMI and WHMI only
- Recorded data
    - Fault records (up to 128)
    - Maximum demands
- Circuit breaker condition monitoring
- Latched alarm and trip LEDs' statuses
- Trip circuit lockout
- Counter values
- Load profile

3.9 Binary input

3.9.1 Binary input filter time

The filter time eliminates debounces and short disturbances on a binary input. The filter time is set for each binary input of the protection relay.

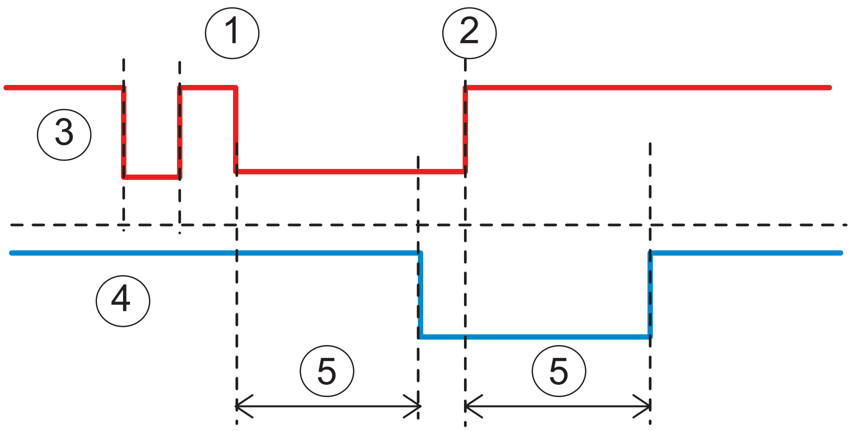


Figure 21: Binary input filtering

1 t_0

2 t_1

3 Input signal

4 Filtered input signal

5 Filter time

At the beginning, the input signal is at the high state, the short low state is filtered and no input state change is detected. The low state starting from the time t_0 exceeds the filter time, which means that the change in the input state is detected and the time tag attached to the input change is t_0. The high state starting from t_1 is detected and the time tag t_1 is attached.

Each binary input has a filter time parameter "Input # filter", where # is the number of the binary input of the module in question (for example "Input 1 filter").

Table 35: Input filter parameter values

Parameter	Values	Default
Input # filter time	5...1000 ms	5 ms

3.9.2 Binary input inversion

The parameter *Input # invert* is used to invert a binary input.

Table 36: Binary input states

Control voltage	Input # invert	State of binary input
No	0	FALSE (0)
Yes	0	TRUE (1)
No	1	TRUE (1)
Yes	1	FALSE (0)

When a binary input is inverted, the state of the input is TRUE (1) when no control voltage is applied to its terminals. Accordingly, the input state is FALSE (0) when a control voltage is applied to the terminals of the binary input.

3.9.3 Oscillation suppression

Oscillation suppression is used to reduce the load from the system when a binary input starts oscillating. A binary input is regarded as oscillating if the number of valid state changes (= number of events after filtering) during one second is equal to or greater than the set oscillation level value. During oscillation, the binary input is blocked (the status is invalid) and an event is generated. The state of the input will not change when it is blocked, that is, its state depends on the condition before blocking.

The binary input is regarded as non-oscillating if the number of valid state changes during one second is less than the set oscillation level value minus the set oscillation hysteresis value. Note that the oscillation hysteresis must be set lower than the oscillation level to enable the input to be restored from oscillation. When the input returns to a non-oscillating state, the binary input is deblocked (the status is valid) and an event is generated.

Table 37: Oscillation parameter values

Parameter	Values	Default
Input osc. level	2...50 events/s	30 events/s
Input osc. hyst	2...50 events/s	10 events/s

3.10 Binary outputs

The protection relay provides a number of binary outputs used for tripping, executing local or remote control actions of a breaker or a disconnector, and for connecting the protection relay to external annunciation equipment for indicating, signalling and recording.

All output contacts, except IRF output, are trip duty rated (Trip Output) and are designated as TRIP, OUT1, OUT2...OUT6. There are two types of these trip output contacts either marked as TO for normal binary output contacts or HSTO for high-speed output contacts. They can be used for controlling a breaker, such as, energizing the breaker trip and closing coils.

The contacts can also be used for external signalling, recording and indicating functions, but they can require a minimum current (burden) to ensure a guaranteed operation.

All contacts are freely programmable, except the internal fault output IRF.

3.10.1 Trip output contacts

Trip output contacts are normally used for energizing the breaker closing coil and trip coil, external high burden lockout or trip relays.

3.10.1.1 Trip outputs TO

Trip output contacts are either dual NO contacts in series (Form A) or dual change-over contacts (Form C) in parallel. When the latter is provided, typically provision is made within the protection relay to change the connection to either NO (Form A) or NC (Form B). See a typical connection diagram of some of the inputs in Figure 22.

Figure 22: Typical connection of trip output contacts

3.10.1.2 Dual single-pole high-speed trip outputs HSTO1, HSTO2 and HSTO3

HSO1, HSO2 and HSO3 are dual parallel connected, single-pole, normally open/form A high-speed power outputs. The high-speed power outputs are hybrid contacts which are wired to outputs OUT4, OUT5 and OUT6 if the protection relay is ordered with the high-speed output contact option.

The outputs are normally used in applications that require fast protection relay output contact activation time to achieve fast opening of a breaker, such as, arc-protection or breaker failure protection, where fast operation is required either to minimize fault effects to the equipment or to avoid a fault to expand to a larger area. With the high-speed outputs, the total time from the application to the protection relay output contact activation is 5-6 ms shorter than when using output contacts with conventional mechanical output relays.

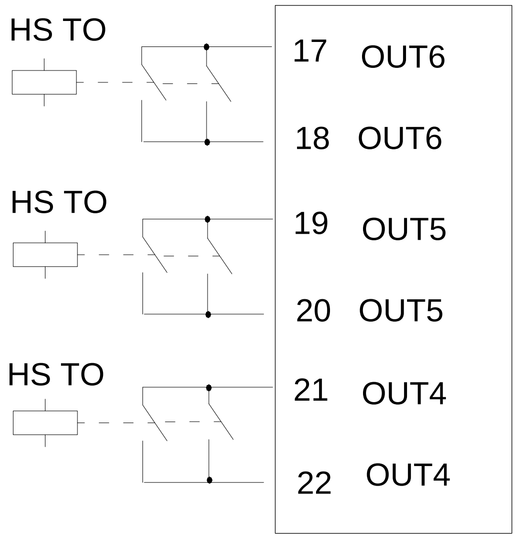


Figure 23: High-speed power outputs HSTO1, HSTO2 and HSTO3, when the protection relay is ordered with high-speed outputs

The reset time of the high-speed output contacts is longer than that of the conventional output contacts.

3.10.2 Internal fault signal output IRF

The internal fault signal output (change-over/form C) IRF is a single contact included in the power supply module of the protection relay.

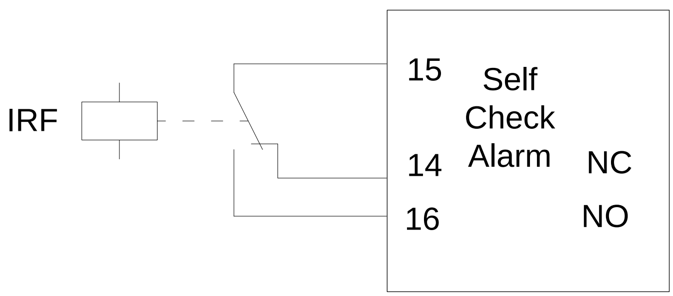


Figure 24: Internal fault signal output IRF

3.11 GOOSE function blocks

GOOSE function blocks are used for connecting incoming GOOSE data to application. They support BOOLEAN, Dbpos, Enum, FLOAT32, INT8 and INT32 data types.

Common signals

The VALID output indicates the validity of received GOOSE data, which means in case of valid, that the GOOSE communication is working and received data quality bits (if configured) indicate good process data. Invalid status is caused either by bad data quality bits or GOOSE communication failure. See IEC 61850 engineering guide for details.

The OUT output passes the received GOOSE value for the application. Default value (0) is used if VALID output indicates invalid status. The IN input is defined in the GOOSE configuration and can always be seen in SMT sheet.

Settings

The GOOSE function blocks do not have any parameters available in LHMI or PCM600.

3.11.1 GOOSERCV_BIN function block

3.11.1.1 Function block

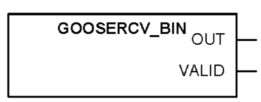


Figure 25: Function block

3.11.1.2 Functionality

The GOOSERCV_BIN function is used to connect the GOOSE binary inputs to the application.

3.11.1.3 Signals

Table 38: GOOSERCV_BIN Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
VALID	BOOLEAN	Output signal

3.11.2 GOOSERCV_DP function block

3.11.2.1 Function block

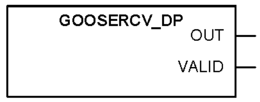


Figure 26: Function block

3.11.2.2 Functionality

The GOOSERCV_DP function is used to connect the GOOSE double binary inputs to the application.

3.11.2.3 Signals

Table 39: GOOSERCV_DP Output signals

Name	Type	Description
OUT	Dbpos	Output signal
VALID	BOOLEAN	Output signal

3.11.3 GOOSERCV_MV function block

3.11.3.1 Function block

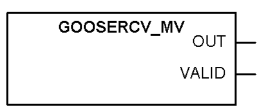


Figure 27: Function block

3.11.3.2 Functionality

The GOOSERCV_MV function is used to connect the GOOSE measured value inputs to the application.

3.11.3.3 Signals

Table 40: GOOSERCV_MV Output signals

Name	Type	Description
OUT	FLOAT32	Output signal
VALID	BOOLEAN	Output signal

3.11.4 GOOSERCV_INT8 function block

3.11.4.1 Function block

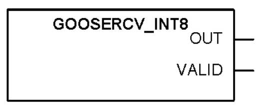


Figure 28: Function block

3.11.4.2 Functionality

The GOOSERCV_INT8 function is used to connect the GOOSE 8 bit integer inputs to the application.

3.11.4.3 Signals

Table 41: GOOSERCV_INT8 Output signals

Name	Type	Description
OUT	INT8	Output signal
VALID	BOOLEAN	Output signal

3.11.5 GOOSERCV_INTL function block

3.11.5.1 Function block

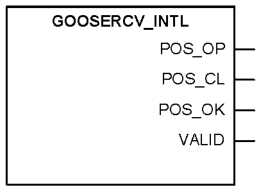


Figure 29: Function block

3.11.5.2 Functionality

The GOOSERCV_INTL function is used to connect the GOOSE double binary input to the application and extracting single binary position signals from the double binary position signal.

The OP output signal indicates that the position is open. Default value (0) is used if VALID output indicates invalid status.

The CL output signal indicates that the position is closed. Default value (0) is used if VALID output indicates invalid status.

The OK output signal indicates that the position is neither in faulty or intermediate state. The default value (0) is used if VALID output indicates invalid status.

3.11.5.3 Signals

Table 42: GOOSERCV_INTL Output signals

Name	Type	Description
POS_OP	BOOLEAN	Position open output signal
POS_CL	BOOLEAN	Position closed output signal
POS_OK	BOOLEAN	Position OK output signal
VALID	BOOLEAN	Output signal

3.11.6 GOOSERCV_CMV function block

3.11.6.1 Function block

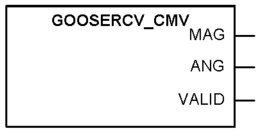


Figure 30: Function block

3.11.6.2 Functionality

The GOOSERCV_CMV function is used to connect GOOSE measured value inputs to the application. The MAG_IN (amplitude) and ANG_IN (angle) inputs are defined in the GOOSE configuration (PCM600).

The MAG output passes the received GOOSE (amplitude) value for the application. Default value (0) is used if VALID output indicates invalid status.

The ANG output passes the received GOOSE (angle) value for the application. Default value (0) is used if VALID output indicates invalid status.

3.11.6.3 Signals

Table 43: GOOSERCV_CMV Output signals

Name	Type	Description
MAG	FLOAT32	Output signal (amplitude)
ANG	FLOAT32	Output signal (angle)
VALID	BOOLEAN	Output signal

3.11.7 GOOSERCV_ENUM function block

3.11.7.1 Function block

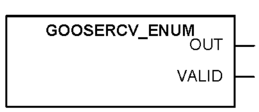


Figure 31: Function block

3.11.7.2 Functionality

The GOOSERCV_ENUM function block is used to connect GOOSE enumerator inputs to the application.

3.11.7.3 Signals

Table 44: GOOSERCV_ENUM Output signals

Name	Type	Description
OUT	Enum	Output signal
VALID	BOOLEAN	Output signal

3.11.8 GOOSERCV_INT32 function block

3.11.8.1 Function block

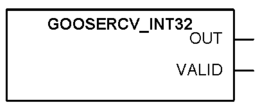


Figure 32: Function block

3.11.8.2 Functionality

The GOOSERCV_INT32 function block is used to connect GOOSE 32 bit integer inputs to the application.

3.11.8.3 Signals

Table 45: GOOSERCV_INT32 Output signals

Name	Type	Description
OUT	INT32	Output signal
VALID	BOOLEAN	Output signal

3.12 Type conversion function blocks

3.12.1 QTY_GOOD function block

3.12.1.1 Functionality

The QTY_GOOD function block evaluates the quality bits of the input signal and passes it as a Boolean signal for the application.

The IN input can be connected to any logic application signal (logic function output, binary input, application function output or received GOOSE signal). Due to application logic quality bit propagation, each (simple and even combined) signal has quality which can be evaluated.

The OUT output indicates quality good of the input signal. Input signals that have no quality bits set or only test bit is set, will indicate quality good status.

3.12.1.2 Signals

Table 46: QTY_GOOD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 47: QTY_GOOD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.12.2 QTY_BAD function block

3.12.2.1 Functionality

The QTY_BAD function block evaluates the quality bits of the input signal and passes it as a Boolean signal for the application.

The IN input can be connected to any logic application signal (logic function output, binary input, application function output or received GOOSE signal). Due to application logic quality bit propagation, each (simple and even combined) signal has quality which can be evaluated.

The OUT output indicates quality bad of the input signal. Input signals that have any other than test bit set, will indicate quality bad status.

3.12.2.2 Signals

Table 48: QTY_BAD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 49: QTY_BAD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.12.3 T_HEALTH function block

3.12.3.1 Functionality

The T_HEALTH function evaluates enumerated data of “Health” data attribute. This function block can only be used with GOOSE.

The IN input can be connected to GOOSERCV_ENUM function block, which is receiving the LD0.LLN0.Health.stVal data attribute sent by another device.

The outputs OK, WARNING and ALARM are extracted from the enumerated input value. Only one of the outputs can be active at a time. In case the GOOSERCV_ENUM function block does not receive the value from the sending device or it is invalid, the default value (0) is used and the ALARM is activated in the T_HEALTH function block.

3.12.3.2 Signals

Table 50: T_HEALTH Input signals

Name	Type	Default	Description
IN1	Any	0	Input signal

Table 51: T_HEALTH Output signals

Name	Type	Description
OK	BOOLEAN	Output signal
WARNING	BOOLEAN	Output signal
ALARM	BOOLEAN	Output signal

3.12.4 T_F32_INT8 function block

3.12.4.1 Functionality

The T_F32_INT8 function is used to convert 32-bit floating type values to 8-bit integer type. The rounding operation is included. Output value saturates if the input value is below the minimum or above the maximum value. .

3.12.4.2 Function block

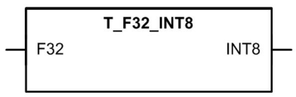


Figure 33: Function block

3.12.4.3 Settings

The function does not have any parameters available in LHMI or Protection and Control IED Manager (PCM600).

3.13 Configurable logic blocks

3.13.1 Shift register SHFT

3.13.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Shift register	SHFTGAPC	SHFT	SHFT

3.13.1.2 Function block

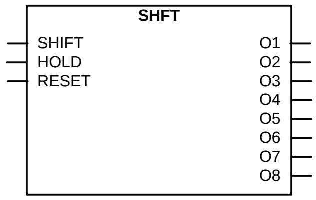


Figure 34: Function block

3.13.1.3 Functionality

The generic select shifter function SHFT turns off the present output and turns on the next consecutive enabled output for each positive edge of the shift input. The shifter output can be reset to the first output or held in place, if required.

The shifter function has eight outputs, only one of which can be active at a time. An event is generated each time the output changes. The present active output is stored in non-volatile memory and is restored at initialization.

3.13.1.4 Operation principle

The *Operation* setting is used to enable or disable the function. When "On" is selected, the function is enabled, and when "Off" is selected, the function is disabled. The operation of SHFT can be described by using a module diagram.

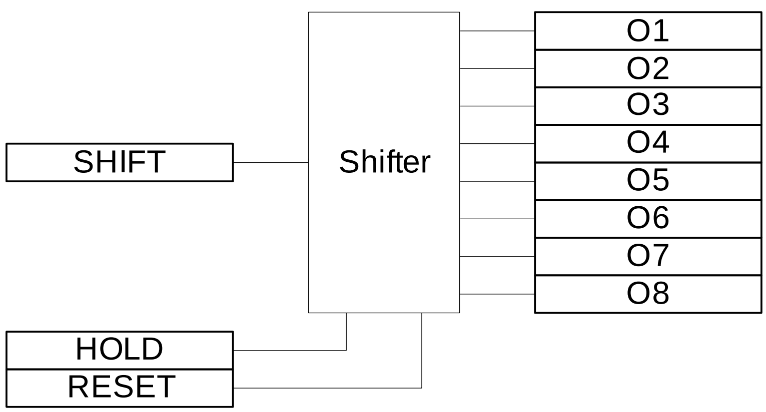


Figure 35: Functional module diagram

Shift selector

When the function is first enabled, `O1` is set to TRUE.

Each rising edge of the `SHIFT` input turns the presently asserted output `Ox` (x = 1...8) to FALSE and turns the next higher enabled output to TRUE. Figure 36 shows a logic diagram with all outputs enabled. If there is no higher enabled output, `O1` is set to TRUE. Figure 37 shows a logic diagram with outputs O2, O7, and O8 disabled.

Only one output can be set to TRUE at a time. An internal variable, ASSRTD_OUT, is updated to store the number of the asserted output. The range of ASSRTD_OUT is 1...8 and is available through the Monitored data view. Each time a rising edge on the SHIFT input causes the output to change, an event is generated that includes the number of the new asserted output.

The value ASSRTD_OUT is stored in a non-volatile memory. The value is used to set the corresponding output to TRUE at initialization. If the *Operation* setting is set from "Off" to "On", the value of ASSRTD_OUT is initialized to 1 and `O1` is set TRUE.

The outputs `O2`...`O8` can be disabled by setting the corresponding *Ox enable* (x = 2 to 8) setting from "Enable" to "Disable". Output `O1` has no corresponding setting and is always enabled.

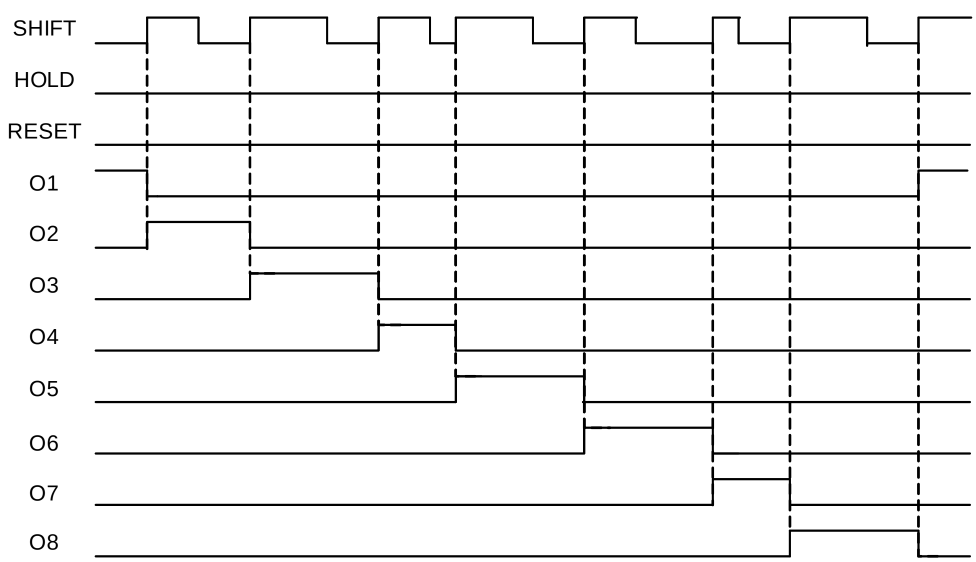


Figure 36: Logic diagram with all outputs enabled

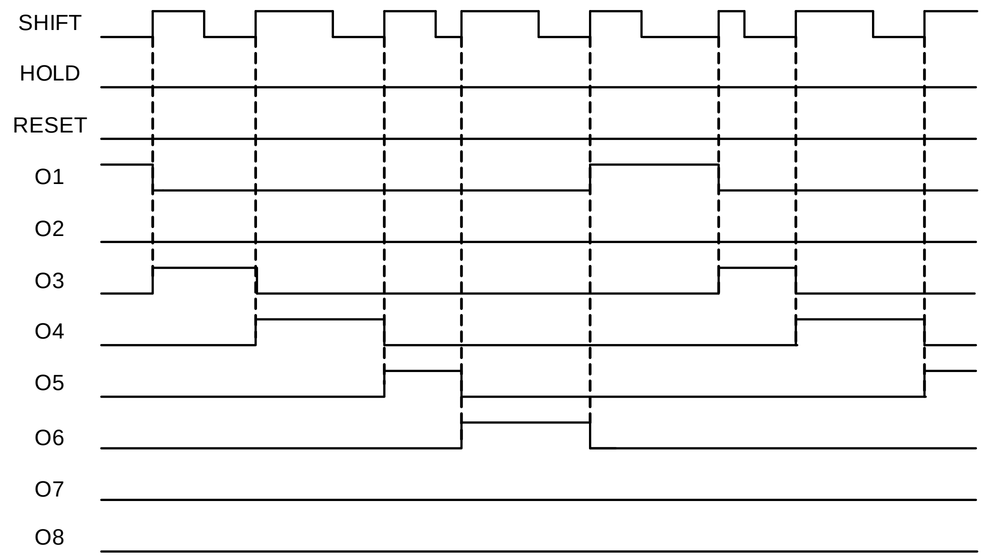


Figure 37: Logic diagram with O2, O7 and O8 disabled

If the HOLD input is set to TRUE and the *Hold mode* setting is "Freeze", rising edges on the SHIFT input are ignored and the present output is unchanged. When the HOLD input returns to FALSE, the SHIFT input recognizes rising edges again. Figure 38 shows the operation of the HOLD input with *Hold mode* setting set to "Freeze". Note that the RESET input overrides the HOLD input by immediately changing the asserted output to O1.

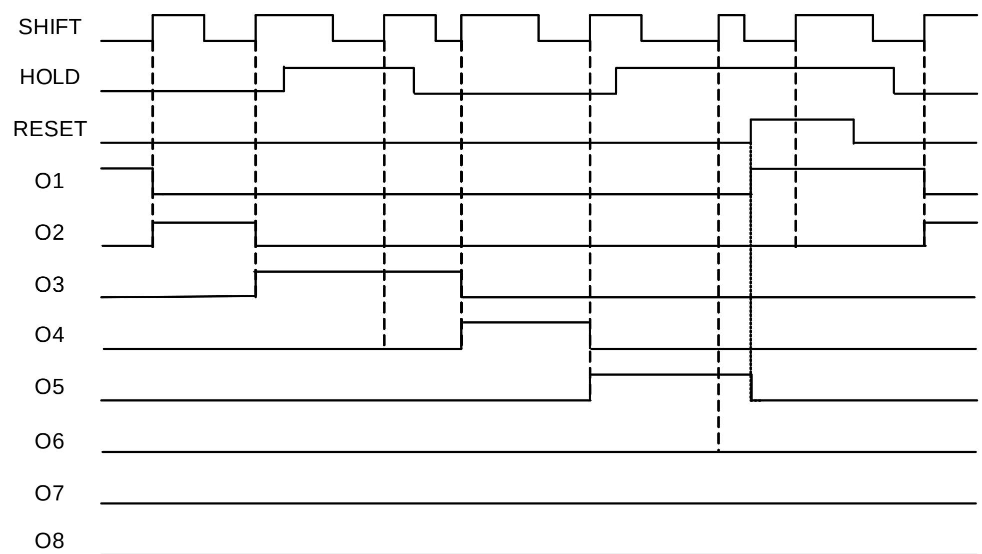


Figure 38: Logic diagram with HOLD mode set to "Freeze"

If the HOLD input is set to TRUE and the *Hold mode* setting is “Disable”, rising edges on the SHIFT input are ignored and all outputs are set to FALSE. When the HOLD input returns to FALSE, the original output that was TRUE when HOLD was activated returnes to TRUE unless the RESET input had been set TRUE or the *Operation* setting was set to “Off”. The SHIFT input can again recognize rising edges. Figure 39 shows the operation of the HOLD input with *Hold mode* setting set to “Disable”. Note that the RESET input overrides the HOLD input by returning O1 to TRUE after the HOLD input returns to FALSE. The RESET input does not, however, override the ability of the *Hold mode* setting in “Disable” to keep all outputs set to FALSE while the HOLD input is TRUE.

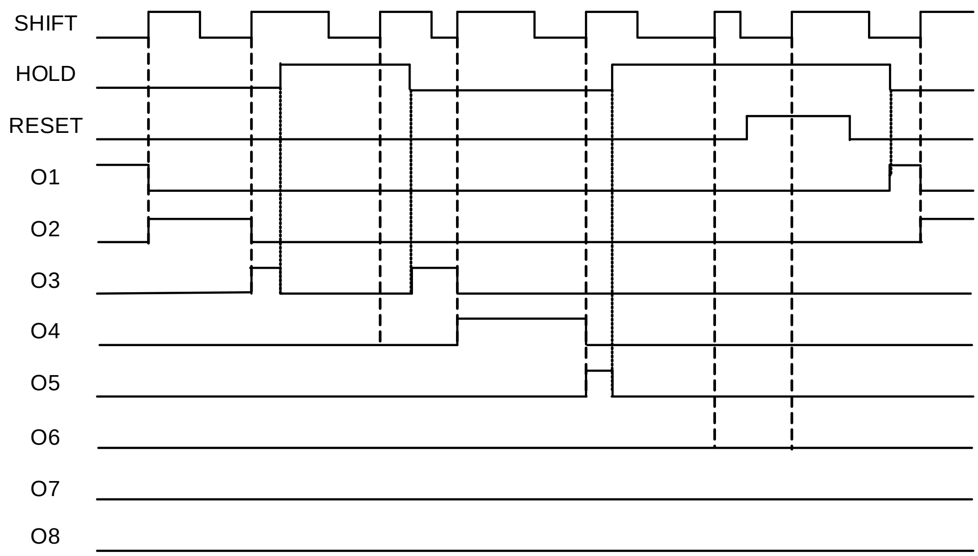


Figure 39: Logic diagram with HOLD mode set to “Disable”

The RESET input is used for resetting the function. When this input is set to TRUE, the presently asserted output Ox is set to FALSE and output O1 is set to TRUE. Figure 40 shows the operation of the RESET input. When both inputs are TRUE, the RESET input overrides the HOLD input (see Figure 38 and Figure 39).

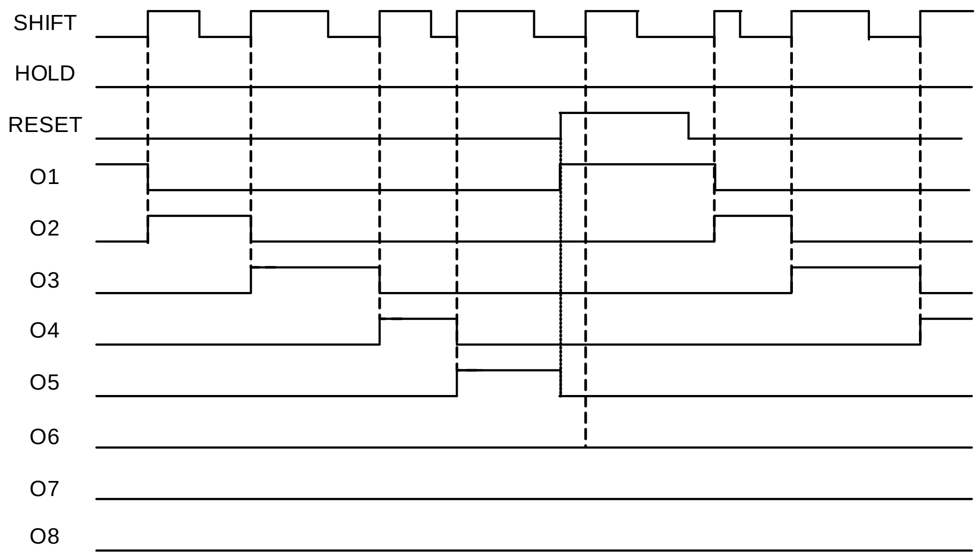


Figure 40: Logic diagram with RESET input

3.13.1.5 Application

The shift selector function can be used in any application where it is desired to select among exclusive modes of operation using a momentary push-button as user input. In the example in Figure , the shifter outputs can be connected to the setting group inputs of the protection function block. A push-button on the front panel can be configured as an input to the shifter and multiple presses configure the protection relay to use the next setting group.

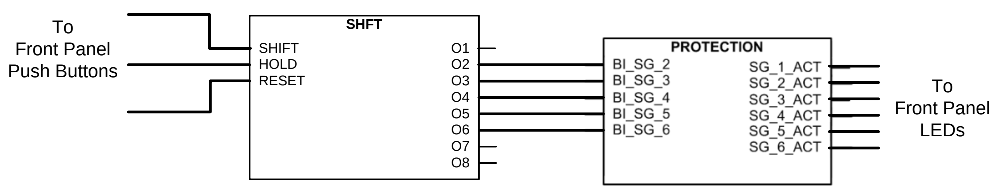


Figure 41: Using SHFT with a protection function to select a setting group

The *Ox enable* settings on SHFT must be used to disable outputs `O7` and `O8` since they are not used. Specific setting groups can optionally be disabled also by setting the corresponding output to “Disable”. Note that output `O1` requires no connection since the protection function defaults to SG_1 when no inputs are TRUE.

The protection function must have the *SG operation mode* setting set to “Logic mode 1”. The highest asserted input then determines the active setting group.

3.13.1.6 Signals

Table 52: SHFT input signals

Name	Type	Default	Description
SHIFT	BOOLEAN	0=False	Shift Input
HOLD	BOOLEAN	0=False	Hold present output
RESET	BOOLEAN	0=False	Reset to output 1

Table 53: SHFT output signals

Name	Type	Description
O1	BOOLEAN	Status of output 1
O2	BOOLEAN	Status of output 2
O3	BOOLEAN	Status of output 3
O4	BOOLEAN	Status of output 4
O5	BOOLEAN	Status of output 5
O6	BOOLEAN	Status of output 6
O7	BOOLEAN	Status of output 7
O8	BOOLEAN	Status of output 8

3.13.1.7 Settings

Table 54: SHFT Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Hold mode	1=Freeze 2=Disable			1=Freeze	Determine how outputs affected by HOLD input
Description				SHFTGAPC1 Status of Output 1	Description of output 1
Enable	0=False 1=True			1=True	Allow output 2 to be asserted
Description				SHFTGAPC1 Status of Output 2	Description of output 2
Enable	0=False 1=True			1=True	Allow output 3 to be asserted
Description				SHFTGAPC1 Status of Output 3	Description of output 3
Enable	0=False 1=True			1=True	Allow output 4 to be asserted
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Description				SHFTGAPC1 Status of Output 4	Description of output 4
Enable	0=False 1=True			1=True	Allow output 5 to be asserted
Description				SHFTGAPC1 Status of Output 5	Description of output 5
Enable	0=False 1=True			1=True	Allow output 6 to be asserted
Description				SHFTGAPC1 Status of Output 6	Description of output 6
Enable	0=False 1=True			1=True	Allow output 7 to be asserted
Description				SHFTGAPC1 Status of Output 7	Description of output 7
Enable	0=False 1=True			1=True	Allow output 8 to be asserted
Description				SHFTGAPC1 Status of Output 8	Description of output 8

3.13.1.8 Monitored data

Table 55: SHFT Monitored data

Name	Type	Values (Range)	Unit	Description
SHIFT	BOOLEAN	0=False 1=True		Shift Input
HOLD	BOOLEAN	0=False 1=True		Hold present output
RESET	BOOLEAN	0=False 1=True		Reset to output 1
O1	BOOLEAN	0=False 1=True		Status of output 1
O2	BOOLEAN	0=False 1=True		Status of output 2
O3	BOOLEAN	0=False 1=True		Status of output 3
O4	BOOLEAN	0=False 1=True		Status of output 4
O5	BOOLEAN	0=False 1=True		Status of output 5
O6	BOOLEAN	0=False 1=True		Status of output 6

Table continues on next page

Name	Type	Values (Range)	Unit	Description
O7	BOOLEAN	0=False 1=True		Status of output 7
O8	BOOLEAN	0=False 1=True		Status of output 8
ASSRTD_OUT	INT32	1...8		Present output position

3.13.2 Standard configurable logic blocks

3.13.2.1 OR function block

Functionality

OR and OR6 are used to form general combinatory expressions with Boolean variables.

The O output is activated when at least one input has the value TRUE. The default value of all inputs is FALSE, which makes it possible to use only the required number of inputs and leave the rest disconnected.

OR has two inputs and OR6 has six inputs.

Function block

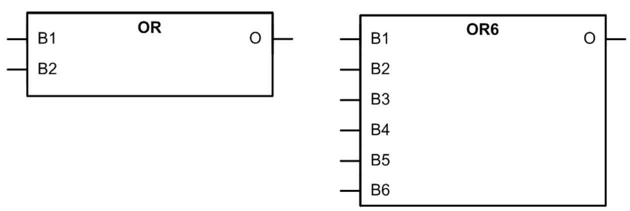


Figure 42: Function blocks

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.2 AND function block

Functionality

AND and AND6 are used to form general combinatory expressions with Boolean variables.

The default value in all inputs is logical true, which makes it possible to use only the required number of inputs and leave the rest disconnected.

AND has two inputs and AND6 has six inputs.

Function block

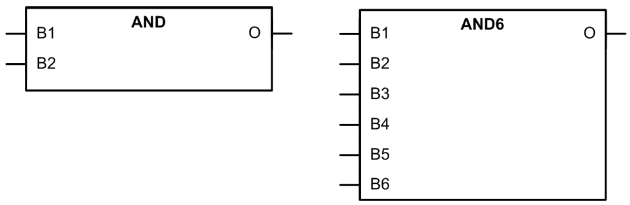


Figure 43: Function blocks

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.3 XOR function block

Functionality

The exclusive OR function XOR is used to generate combinatory expressions with Boolean variables.

The output signal is TRUE if the input signals are different and FALSE if they are equal.

Function block

Figure 44: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.4 NOT function block

Functionality

NOT is used to generate combinatory expressions with Boolean variables.

NOT inverts the input signal.

Function block

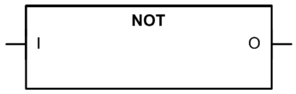


Figure 45: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.5 MAX3 function block

Functionality

The maximum function MAX3 selects the maximum value from three analog values. The disconnected inputs have the value 0.

Function block

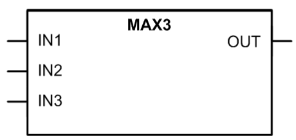


Figure 46: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.6 MIN3 function block

Functionality

The minimum function MIN3 selects the minimum value from three analog values.

If the minimum value is to be selected from two signals, connecting one of the inputs to two in MIN3 makes all the inputs to be connected.

Function block

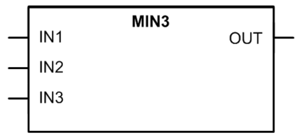


Figure 47: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.7 R_TRIG function block

Functionality

R_TRIG is used as a rising edge detector.

R_TRIG detects the transition from FALSE to TRUE at the `CLK` input. When the rising edge is detected, the element assigns the output to TRUE. At the next execution round, the output is returned to FALSE despite the state of the input.

Function block

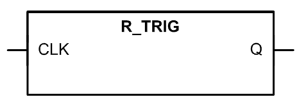


Figure 48: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.8 F_TRIG function block

Functionality

F_TRIG is used as a falling edge detector.

The function detects the transition from TRUE to FALSE at the `CLK` input. When the falling edge is detected, the element assigns the `Q` output to TRUE. At the next execution round, the output is returned to FALSE despite the state of the input.

Function block

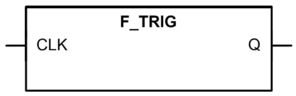


Figure 49: Function block

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.2.9 T_POS_XX function blocks

Functionality

The circuit breaker position information can be communicated with the IEC 61850 GOOSE messages. The position information is a double binary data type which is fed to the POS input.

T_POS_CL and T_POS_OP are used for extracting the circuit breaker status information. Respectively, T_POS_OK is used to validate the intermediate or faulty breaker position.

Table 56: Cross reference between circuit breaker position and the output of the function block

Circuit breaker position	Output of the function block		
	T_POS_CL	T_POS_OP	T_POS_OK
Intermediate '00'	FALSE	FALSE	FALSE
Close '01'	TRUE	FALSE	TRUE
Open '10'	FALSE	TRUE	TRUE
Faulty '11'	TRUE	TRUE	FALSE

Function block

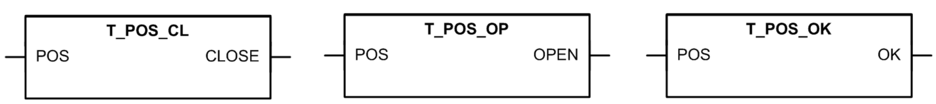


Figure 50: Function blocks

Settings

The function does not have any parameters available in LHMI or PCM600.

3.13.3 Local/remote control function block CONTROL

3.13.3.1 Function block

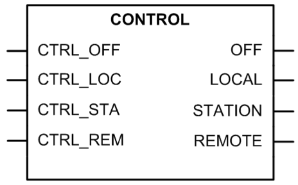


Figure 51: Function block

3.13.3.2 Functionality

Local/Remote control is by default realized through the R/L button on the front panel. The control via binary input can be enabled by setting the value of the *LR control* setting to "Binary input".

The actual Local/Remote control state is evaluated by the priority scheme on the function block inputs. If more than one input is active, the input with the highest priority is selected.

The actual state is reflected on the CONTROL function outputs. Only one output is active at a time.

Table 57: Truth table for CONTROL

Input				Output
CTRL_OFF	CTRL_LOC	CTRL_STA [1)]	CTRL_REM	
TRUE	any	any	any	OFF = TRUE
FALSE	TRUE	any	any	LOCAL = TRUE
FALSE	FALSE	TRUE	any	STATION = TRUE
FALSE	FALSE	FALSE	TRUE	REMOTE = TRUE
FALSE	FALSE	FALSE	FALSE	OFF = TRUE

1) If station authority is not in use, the `CTRL_STA` input is interpreted as `CTRL_REM`.

The station authority check based on the IEC 61850 command originator category in control command can be enabled by setting the value of the *Station authority* setting to "Station, Remote" (The command originator validation is performed only if the *LR control* setting is set to "Binary input"). The station authority check is not in use by default.

3.13.3.3 Signals

Table 58: CONTROL input signals

Name	Type	Default	Description
CTRL_OFF	BOOLEAN	0	Control input OFF
CTRL_LOC	BOOLEAN	0	Control input Local
CTRL_STA	BOOLEAN	0	Control input Station
CTRL_REM	BOOLEAN	0	Control input Remote

Table 59: CONTROL output signals

Name	Type	Description
OFF	BOOLEAN	Control output OFF
LOCAL	BOOLEAN	Control output Local
STATION	BOOLEAN	Control output Station
REMOTE	BOOLEAN	Control output Remote

3.13.3.4 Settings

Table 60: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
LR control	1=LR key 2=Binary input			1=LR key	LR control through LR key or binary input
Station authority	1=Not used 2=Station, Remote			1=Not used	Control command originator category usage

3.13.3.5 Monitored data

Table 61: Monitored data

Name	Type	Values (Range)	Unit	Description
Command response	Enum	0=No commands 1=Select open 2=Select close 3=Trip open 4=Trip close 5=Direct open 6=Direct close 7=Cancel 8=Position reached 9=Position timeout 10=Object status only 11=Object direct 12=Object select 13=RL local allowed 14=RL remote allowed 15=RL off 16=Function off 17=Function blocked 18=Command progress 19=Select timeout 20=Missing authority 21=Close not enabled 22=Open not enabled 23=Device in IRF 24=Already close 25=Wrong client 26=RL station allowed 27=RL change		Latest command response
LR state	Enum	0=Off 1=Local 2=Remote 3=Station		LR state monitoring for PCM

3.14 Factory settings restoration

In case of configuration data loss or any other file system error that prevents the protection relay from working properly, the whole file system can be restored to the original factory state. All default settings and configuration files stored in the factory are restored. For further information on restoring factory settings, see the operation manual.

3.15 Load profile record LoadProf

3.15.1 Functionality

The protection relay is provided with a load profile recorder. The load profile feature stores the historical load data captured at a periodical time interval (demand interval). Up to 12 load quantities can be selected for recording and storing in a nonvolatile memory. The value range for the recorded load quantities is about eight times the nominal value, and values larger than that saturate. The recording time depends on a settable demand interval parameter and the amount of quantities selected. The record output is in the COMTRADE format.

3.15.1.1 Quantities

Selectable quantities are product-dependent.

Table 62: Quantity Description

Disabled	Quantity not selected
IA	Phase A current, instance 1
IB	Phase B current, instance 1
IC	Phase C current, instance 1
IG	Neutral/ground/residual current, instance 1
VAB	Phase-to-phase AB voltage, instance 1
VBC	Phase-to-phase BC voltage, instance 1
VCA	Phase-to-phase CA voltage, instance 1
VA	Phase-to-ground A voltage, instance 1
VB	Phase-to-ground B voltage, instance 1
VC	Phase-to-ground C voltage, instance 1
S	Apparent power, instance 1
P	Real power, instance 1
Q	Reactive power, instance 1

Table continues on next page

Disabled	Quantity not selected
PF	Power factor, instance 1
SA	Phase A apparent power, instance 1
SB	Phase B apparent power, instance 1
SC	Phase C apparent power, instance 1
PA	Phase A real power, instance 1
PB	Phase B real power, instance 1
PC	Phase C real power, instance 1
QA	Phase A reactive power, instance 1
QB	Phase B reactive power, instance 1
QC	Phase C reactive power, instance 1
PFA	Phase A power factor, instance 1
PFB	Phase B power factor, instance 1
PFC	Phase C power factor, instance 1

If the data source for the selected quantity is removed, for example, with Application Configuration in PCM600, the load profile recorder stops recording it and the previously collected data are cleared.

3.15.1.2 Length of record

The recording capability is about 7.4 years when one quantity is recorded and the demand interval is set to 180 minutes. The recording time scales down proportionally when a shorter demand time is selected or more quantities are recorded. The recording lengths in days with different settings used are presented in Table 63. When the recording buffer is fully occupied, the oldest data are overwritten by the newest data.

Table 63: Recording capability in days with different settings

	Demand interval						
	1 minute	5 minutes	10 minutes	15 minutes	30 minutes	60 minutes	180 minutes
Amount of quantities	Recording capability in days						
1	15.2	75.8	151.6	227.4	454.9	909.7	2729.2
2	11.4	56.9	113.7	170.6	341.1	682.3	2046.9
3	9.1	45.5	91.0	136.5	272.9	545.8	1637.5
4	7.6	37.9	75.8	113.7	227.4	454.9	1364.6
5	6.5	32.5	65.0	97.5	194.9	389.9	1169.6

Table continues on next page

	Demand interval						
6	5.7	28.4	56.9	85.3	170.6	341.1	1023.4
7	5.1	25.3	50.5	75.8	151.6	303.2	909.7
8	4.5	22.7	45.5	68.2	136.5	272.9	818.8
9	4.1	20.7	41.4	62.0	124.1	248.1	744.3
10	3.8	19.0	37.9	56.9	113.7	227.4	682.3
11	3.5	17.5	35.0	52.5	105.0	209.9	629.8
12	3.2	16.2	32.5	48.7	97.5	194.9	584.8

3.15.1.3 Uploading of record

The protection relay stores the load profile COMTRADE files to the C:\LDP \COMTRADE folder. The files can be uploaded with the PCM600 tool or any appropriate computer software that can access the C:\LDP\COMTRADE folder.

The load profile record consists of two COMTRADE file types: the configuration file (.CFG) and the data file (.DAT). The file name is same for both file types.

To ensure that both the uploaded file types are generated from the same data content, the files need to be uploaded successively. Once either of the files is uploaded, the recording buffer is halted to give time to upload the other file.

Data content of the load profile record is sequentially updated. Therefore, the size attribute for both COMTRADE files is "0".

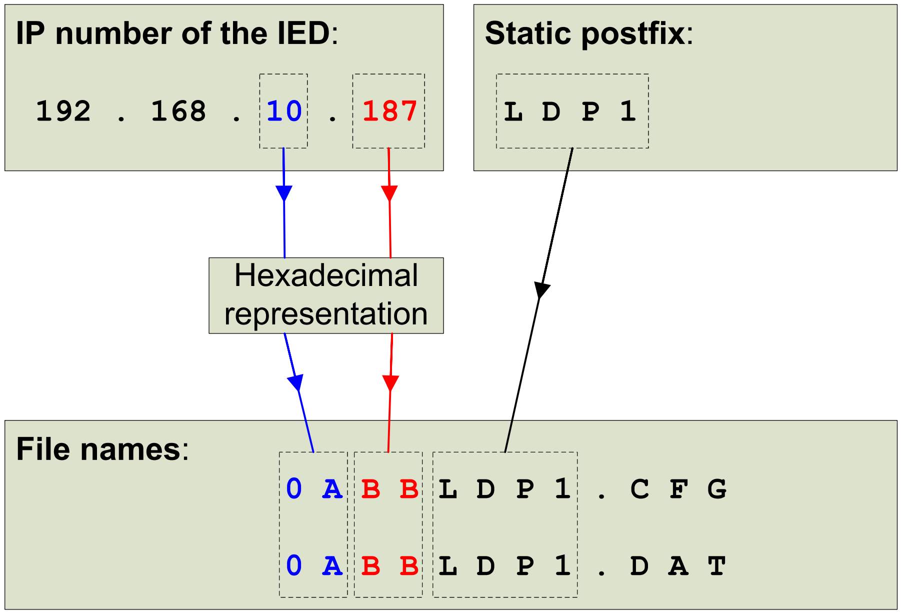


Figure 52: Load profile record file naming

3.15.1.4 Clearing of record

The load profile record can be cleared with *Reset load profile rec* via HMI, communication or the ACT input in PCM600. Clearing of the record is allowed only on the engineer and administrator authorization levels.

The load profile record is automatically cleared if the quantity selection parameters are changed or any other parameter which affects the content of the COMTRADE configuration file is changed. Also, if data source for selected quantity is removed, for example, with ACT, the load profile recorder stops recording and previously collected data are cleared.

3.15.2 Configuration

The load profile record can be configured with the PCM600 tool or any tool supporting the IEC 61850 standard.

The load profile record can be enabled or disabled with the *Operation* setting under the **Configuration/Load Profile Record** menu.

The recording buffer is filled in FIFO manner, meaning that oldest data is overwritten by newest data. If oldest data is considered important, *Mem. warning level* and *Mem. alarm* *level* parameters can be set to get notification about memory consumption reaching a certain level. Therefore the data can be uploaded before the oldest data gets overwritten. To re-enable notifications via *Mem. warning level* and *Mem. alarm level* parameters, the load profile record should be cleared after uploading. State change of *Mem. warning level* or *Mem. alarm level* parameters generates an event.

The IP number of the protection relay and the content of the *Bay name* setting are both included in the COMTRADE configuration file for identification purposes.

3.15.3 Signals

Table 64: LoadProf Output signals

Name	Type	Description
MEM_WARN	BOOLEAN	Recording memory warning status
MEM_ALARM	BOOLEAN	Recording memory alarm status

3.15.4 Settings

Table 65: LoadProf Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Quantity Sel 1...12	0=Disabled 1=IA 2=IB 3=IC 4=IG 5=IA2 6=IB2 7=IC2 8=IG2 9=VAB 10=VBC 11=VCA 12=VA 13=VB 14=VC 15=VAB2 16=VBC2 17=VCA2 18=VA2 19=VB2 20=VC2 21=S 22=P 23=Q 24=PF 25=S2 26=P2 27=Q2 28=PF2 29=SA 30=SB 31=SC 32=PA 33=PB 34=PC 35=QA 36=QB 37=QC 38=PFA 39=PFB 40=PFC 41=SA2 42=SB2 43=SC2 44=PA2 45=PB2 46=PC2 47=QA2 48=QB2 49=QC2 50=PFA2 51=PFB2 52=PFC2			0=Disabled	Select quantity to be recorded
Mem. warning level	0...100	%	1	0	Set memory warning level

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Mem. alarm level	0...100	%	1	0	Set memory alarm level

3.15.5 Monitored data

Table 66: LoadProf Monitored data

Name	Type	Values (Range)	Unit	Description
Rec. memory used	INT32	0...100	%	How much recording memory is currently used

Section 4 Protection functions

4.1 Current protection

4.1.1 Three-phase non-directional overcurrent protection 51P/50P

4.1.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	3I>	51P
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	3I>>	50P-1/2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	3I>>>	50P-3

4.1.1.2 Function block

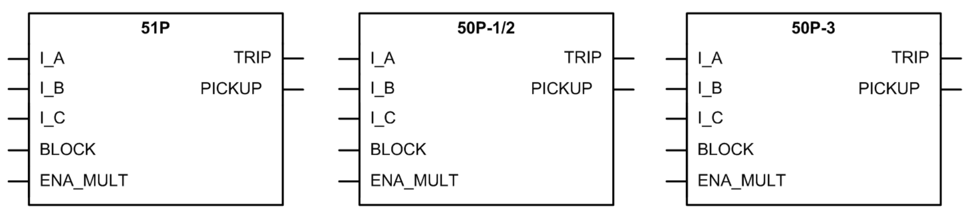


Figure 53: Function block

4.1.1.3 Functionality

The three-phase overcurrent protection function 51P/50P is used as one-phase, two-phase or three-phase non-directional overcurrent and short-circuit protection.

The function picks up when the current exceeds the set limit. The trip time characteristics for low stage 51P and high stage 50P-1/2 can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage 50P-3 always trips with the DT characteristic.

In the DT mode, the function trips after a predefined trip time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

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

4.1.1.4 Operation principle

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

The operation of 51P/50P can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

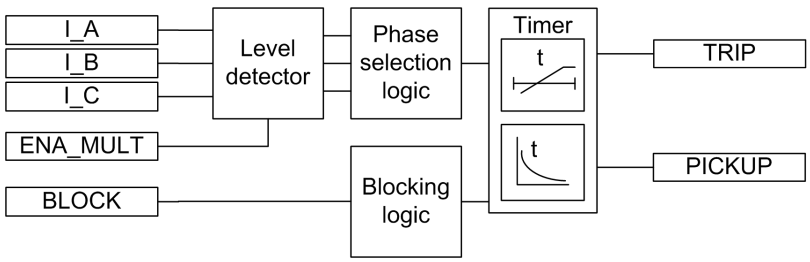


Figure 54: Functional module diagram

Level detector

The measured phase currents are compared phasewise to the set *Pickup value*. If the measured value exceeds the set *Pickup value*, the level detector reports the exceeding of the value to the phase selection logic. If the `ENA_MULT` input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

Do not set the multiplier setting *Pickup value Mult* higher than necessary. If the value is too high, the function may not trip at all during an inrush followed by a fault, no matter how severe the fault is.

The pickup value multiplication is normally done when the inrush detection function (INR) is connected to the `ENA_MULT` input.

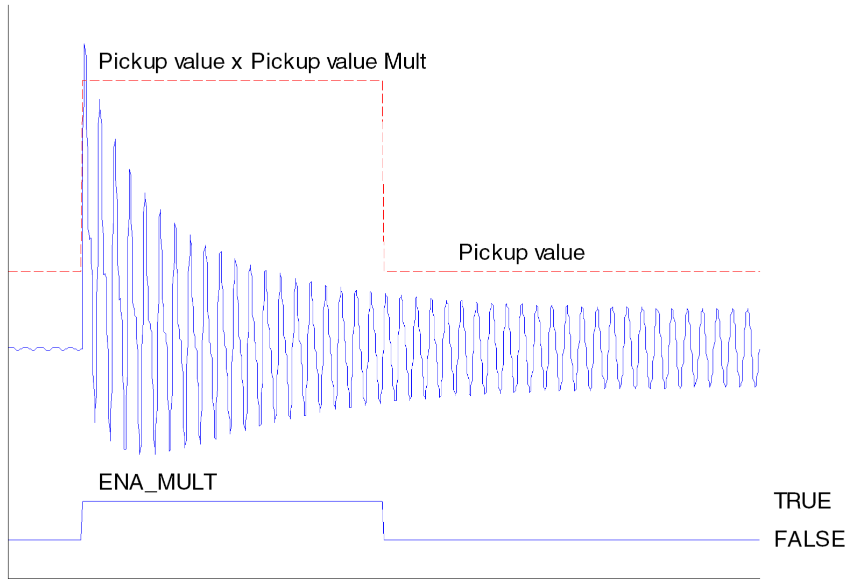


Figure 55: Pickup value behavior with `ENA_MULT` *input activated*

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of pickup phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the `TRIP` output is activated.

When the user-programmable IDMT curve is selected, the operation time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set

Reset delay time value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT trip and reset times.

The setting parameter *Minimum trip time* defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.1.1.5 Measurement modes

The function operates on four alternative measurement modes: "RMS", "DFT", "Peak-to-Peak" and "P-to-P + backup". The measurement mode is selected with the setting *Measurement mode*.

Table 67: Measurement modes supported by 51P/50P stages

Measurement mode	51P	50P-1/2	50P-3
RMS	x	x	
DFT	x	x	
Peak-to-Peak	x	x	
P-to-P + backup			x

For a detailed description of the measurement modes, see the Measurement modes section in this manual.

4.1.1.6 Timer characteristics

51P/50P supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* and *Type of reset curve* settings. When the DT characteristic is selected, it is only affected by the *Trip delay time* and *Reset delay time* settings.

The protection relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The DT characteristics can be chosen by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The timer characteristics supported by different stages comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages:

Table 68: Timer characteristics supported by different stages

Operating curve type	51P	50P-1/2
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
Table continues on next page		

Operating curve type	51P	50P-1/2
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	x
(10) IEC Very Inverse	x	x
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	x
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable	x	x
(18) RI type	x	
(19) RD type	x	

50P-3 supports only definite time characteristic.

For a detailed description of timers, see the General function block features section in this manual.

Table 69: Reset time characteristics supported by different stages

Reset curve type	51P	50P-1/2	Note
(1) Immediate	x	x	Available for all reset time curves
(2) Def time reset	x	x	Available for all reset time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

The *Type of reset curve* setting does not apply to 50P-3 or when the DT operation is selected. The reset is purely defined by the *Reset delay time* setting.

4.1.1.7 Application

51P/50P is used in several applications in the power system. The applications include but are not limited to:

- Selective overcurrent and short-circuit protection of feeders in distribution and subtransmission systems
- Backup overcurrent and short-circuit protection of power transformers and generators
- Overcurrent and short-circuit protection of various devices connected to the power system, for example shunt capacitor banks, shunt reactors and motors
- General backup protection

51P/50P is used for single-phase, two-phase and three-phase non-directional overcurrent and short-circuit protection. Typically, overcurrent protection is used for clearing two and three-phase short circuits. Therefore, the user can choose how many phases, at minimum, must have currents above the pickup level for the function to trip. When the number of pickup-phase settings is set to "1 out of 3", the operation of 51P/50P is enabled with the presence of high current in one-phase.

When the setting is "2 out of 3" or "3 out of 3", single-phase faults are not detected. The setting "3 out of 3" requires the fault to be present in all three phases.

Many applications require several steps using different current pickup levels and time delays. 51P/50P consists of three protection stages:

- Low 51P
- High 50P-1/2
- Instantaneous 50P-3

51P is used for overcurrent protection. The function contains several types of time-delay characteristics. 50P-1/2 and 50P-3 are used for fast clearance of very high overcurrent situations.

Transformer overcurrent protection

The purpose of transformer overcurrent protection is to operate as main protection, when differential protection is not used. It can also be used as coarse back-up protection for differential protection in faults inside the zone of protection, that is, faults occurring in incoming or outgoing feeders, in the region of transformer terminals and tank cover. This means that the magnitude range of the fault current can be very wide. The range varies from $6xI_n$ to several hundred times I_n, depending on the impedance of the transformer and the source impedance of the feeding network. From this point of view, it is clear that the operation must be both very fast and selective, which is usually achieved by using coarse current settings.

The purpose is also to protect the transformer from short circuits occurring outside the protection zone, that is through-faults. Transformer overcurrent protection also provides protection for the LV-side busbars. In this case the magnitude of the fault current is typically lower than $12xI_n$ depending on the fault location and transformer impedance. Consequently, the protection must operate as fast as possible taking into account the selectivity requirements, switching-in currents, and the thermal and mechanical withstand of the transformer and outgoing feeders.

Traditionally, overcurrent protection of the transformer has been arranged as shown in Figure 56. The low-set stage 51P operates time-selectively both in transformer and LV-side busbar faults. The high-set stage 50P-1/2 operates instantaneously making use of current selectivity only in transformer HV-side faults. If there is a possibility, that the fault current can also be fed from the LV-side up to the HV-side, the transformer must also be equipped with LV-side overcurrent protection. Inrush current detectors are used in start-up situations to multiply the current pickup value setting in each particular protection relay where the inrush current can occur. The overcurrent and contact based circuit breaker failure protection 50BF is used to confirm the protection scheme in case of circuit breaker malfunction.

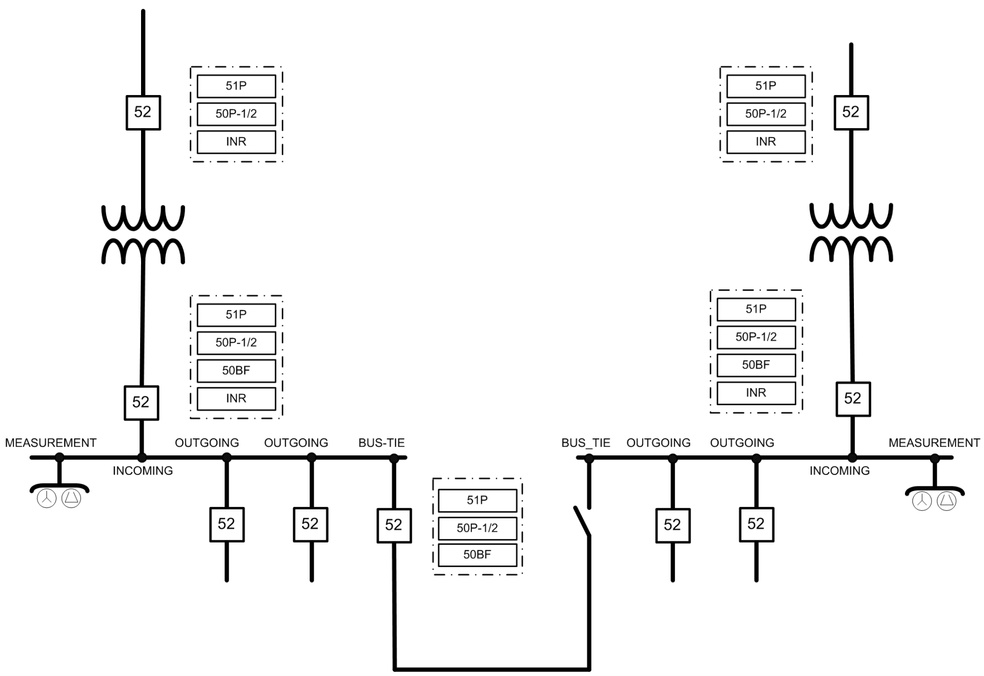


Figure 56: Example of traditional time selective transformer overcurrent protection

The operating times of the main and backup overcurrent protection of the above scheme become quite long, this applies especially in the busbar faults and also in the transformer LV-terminal faults. In order to improve the performance of the above scheme, a multiple-stage overcurrent protection with reverse blocking is proposed. Figure 57 shows this arrangement.

Transformer and busbar overcurrent protection with reverse blocking principle

By implementing a full set of overcurrent protection stages and blocking channels between the protection stages of the incoming feeders, bus-tie and outgoing feeders, it is possible to speed up the operation of overcurrent protection in the busbar and transformer LV-side faults without impairing the selectivity. Also, the security degree of busbar protection is increased, because there is now a dedicated, selective and fast busbar protection functionality which is based on the blockable overcurrent protection principle. The additional time selective stages on the transformer HV and LV-sides provide increased security of backup protection for the transformer, busbar and also for the outgoing feeders.

Depending on the overcurrent stage in question, the selectivity of the scheme in Figure 57 is based on the operating current, operating time or blockings between successive overcurrent stages. With blocking channels, the operating time of the protection can be drastically shortened if compared to the simple time selective protection. In addition to the busbar protection, this blocking principle is applicable for the protection of transformer LV terminals and short lines. The functionality and performance of the proposed overcurrent protections can be summarized as seen in the table.

Table 70: Proposed functionality of numerical transformer and busbar overcurrent protection. DT = definite time, IDMT = inverse definite minimum time

O/C-stage	Operating char.	Selectivity mode	Operation speed	Sensitivity
HV/51P	DT/IDMT	time selective	low	very high
HV/50P-1/2	DT	blockable/time selective	high/low	high
HV/50P-3	DT	current selective	very high	low
LV/51P	DT/IDMT	time selective	low	very high
LV/50P-1/2	DT	time selective	low	high
LV/50P-3	DT	blockable	high	high

In case the bus-tie breaker is open, the operating time of the blockable overcurrent protection is approximately 100 ms (relaying time). When the bus-tie breaker is closed, that is, the fault current flows to the faulted section of the busbar from two directions, the operation time becomes as follows: first the bus-tie relay unit trips the tie breaker in the above 100 ms, which reduces the fault current to a half. After this the incoming feeder relay unit of the faulted bus section trips the breaker in approximately 250 ms (relaying time), which becomes the total fault clearing time in this case.

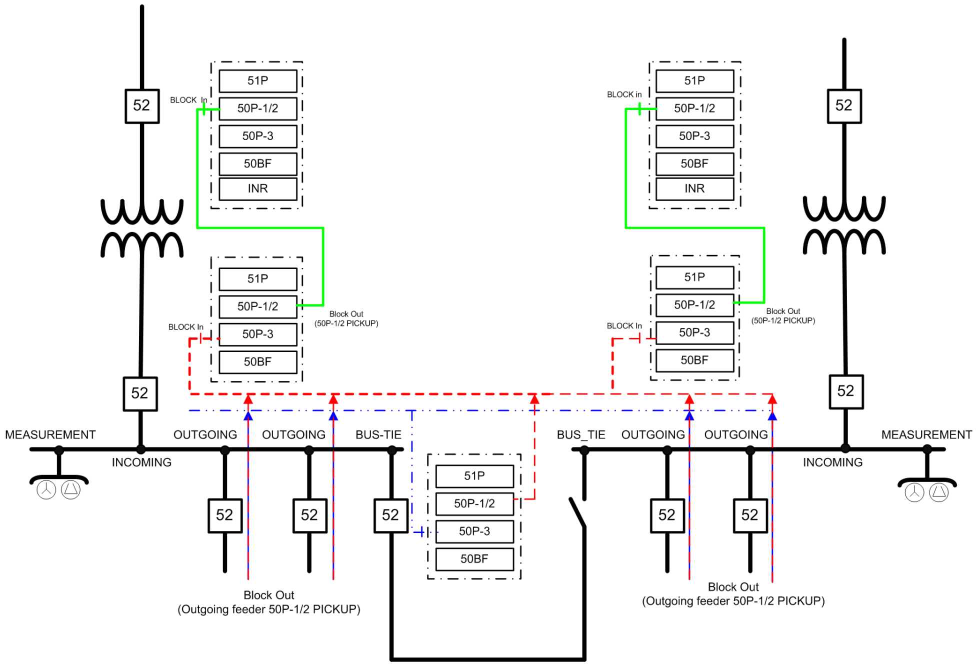


Figure 57: Numerical overcurrent protection functionality for a typical sub-transmission/distribution substation (feeder protection not shown).Blocking output = digital output signal from the pickup of a protection stage, Blocking in = digital input signal to block the operation of a protection stage

The operating times of the time selective stages are very short, because the grading margins between successive protection stages can be kept short. This is mainly due to the advanced measuring principle allowing a certain degree of CT saturation, good operating accuracy and short retardation times of the numerical units. So, for example, a grading margin of 150 ms in the DT mode of operation can be used, provided that the circuit breaker interrupting time is shorter than 60 ms.

The sensitivity and speed of the current-selective stages become as good as possible due to the fact that the transient overreach is very low. Also, the effects of switching inrush currents on the setting values can be reduced by using the protection relay's logic, which recognizes the transformer energizing inrush current and blocks the operation or multiplies the current pickup value setting of the selected overcurrent stage with a predefined multiplier setting.

Finally, a dependable trip of the overcurrent protection is secured by both a proper selection of the settings and an adequate ability of the measuring transformers to reproduce the fault current. This is important in order to maintain selectivity and also for the protection to operate without additional time delays. For additional information about available measuring modes and current transformer requirements, see the Measurement modes chapter in this manual.

Radial outgoing feeder overcurrent protection

The basic requirements for feeder overcurrent protection are adequate sensitivity and operation speed taking into account the minimum and maximum fault current levels along the protected line, selectivity requirements, inrush currents and the thermal and mechanical withstand of the lines to be protected.

In many cases the above requirements can be best fulfilled by using multiple-stage overcurrent units. Figure 58 shows an example of this. A brief coordination study has been carried out between the incoming and outgoing feeders.

The protection scheme is implemented with three-stage numerical overcurrent protection where the low-set stage 51P operates in IDMT-mode and the two higher stages 50P-1/2 and 50P-3 in DT-mode. Also the thermal withstand of the line types along the feeder and maximum expected inrush currents of the feeders are shown. Faults occurring near the station, where the fault current levels are the highest, are cleared rapidly by the instantaneous stage in order to minimize the effects of severe short circuit faults. The influence of the inrush current is taken into consideration by connecting the inrush current detector to the pickup value multiplying input of the instantaneous stage. In this way, the pickup value is multiplied with a predefined setting during the inrush situation and nuisance tripping can be avoided.

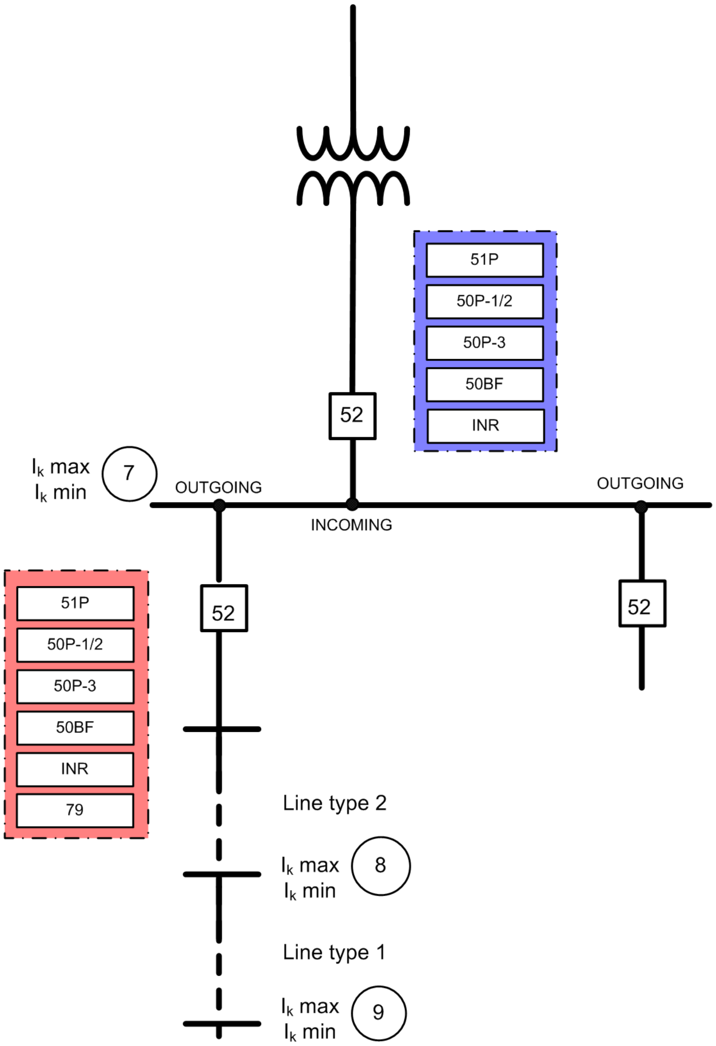


Figure 58: Functionality of numerical multiple-stage overcurrent protection

The coordination plan is an effective tool to study the operation of time selective operation characteristics. All the points mentioned earlier, required to define the overcurrent protection parameters, can be expressed simultaneously in a coordination plan. In Figure 59, the coordination plan shows an example of operation characteristics in the LV-side incoming feeder and radial outgoing feeder.

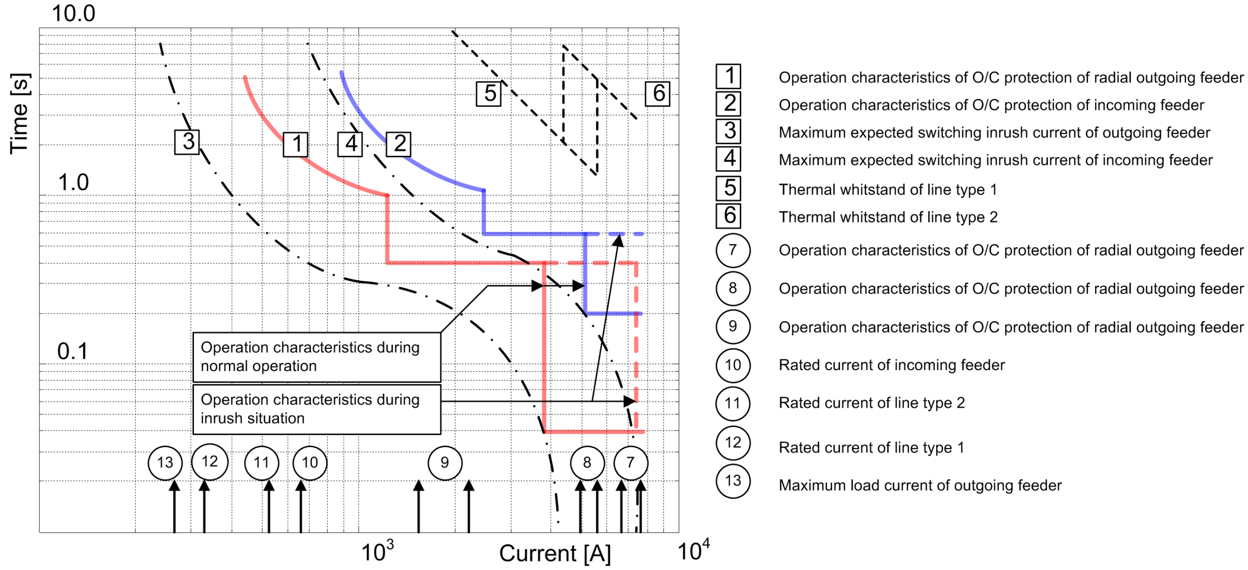


Figure 59: Example coordination of numerical multiple-stage overcurrent protection

4.1.1.8 Signals

Table 71: 51P 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
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 72: 50P-1/2 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
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 73: 50P-3 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
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 74: 51P Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 75: 50P-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 76: 50P-3 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.1.9 Settings

Table 77: 51P Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...5.00	xIn	0.01	0.05	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 78: 51P Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

Table 79: 50P-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 80: 50P-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

Table 81: 50P-3 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	1.00...40.00	xIn	0.01	1.00	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Trip delay time	20...200000	ms	10	20	Trip delay time

Table 82: 50P-3 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.1.10 Monitored data

Table 83: 51P Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
51P	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 84: 50P-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
50P-1/2	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 85: 50P-3 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
50P-3	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.1.1.11 Technical data

Table 86: 51P/50P Technical data

Characteristic		Value		
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz			
	51P	±1.5% of the set value or ±0.002 × I_n		
	50P-1/2 and 50P-3	±1.5% of set value or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n)		
Pickup time 1)2)		Minimum	Typical	Maximum
	50P-3: I_{Fault} = 2 × set *Pickup value* I_{Fault} = 10 × set *Pickup value*	15 ms 12 ms	16 ms 13 ms	17 ms 14 ms
	51P and 50P-1/2: I_{Fault} = 2 × set *Pickup value*	23 ms	25 ms	28 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<30 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms 3)		
Suppression of harmonics		RMS: No suppression DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression P-to-P+backup: No suppression		

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 × I_n, f_n = 60 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 2.5 x I_n, *Pickup value* multiples in range of 1.5...20

4.1.2 Three-phase non-directional long-time overcurrent protection 51LT

4.1.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase non-directional long time overcurrent protection	PHLTPTOC	3I>	51LT

4.1.2.2 Function block

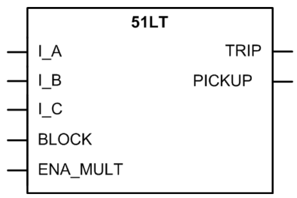


Figure 60: Function block

4.1.2.3 Functionality

The three-phase long-time overcurrent protection 51LT is used as one-phase, two-phase or three-phase non-directional overcurrent and short-circuit protection for feeders.

The operation of this function is very similar to the 51P function except that inverse curves operating times are 10 times that of 51P.

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

4.1.2.4 Operation principle

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

The operation of 51LT can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

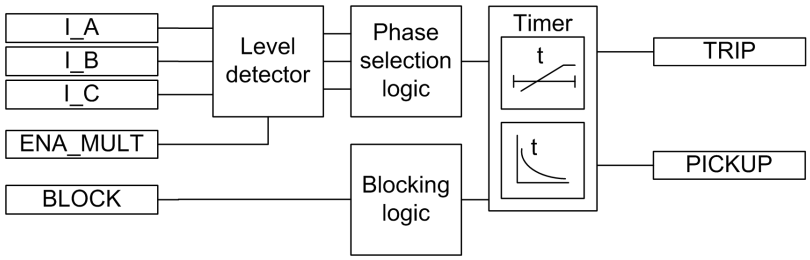


Figure 61: Functional module diagram. I_A, I_B and I_C represent phase currents.

Level detector

The measured phase currents are compared phasewise to the set *Pickup value*. If the measured value exceeds the set *Pickup value*, the level detector reports the exceeding of the value to the phase selection logic. If the `ENA_MULT` input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

The pickup value multiplication is normally done when the inrush detection function (INR) is connected to the `ENA_MULT` input.

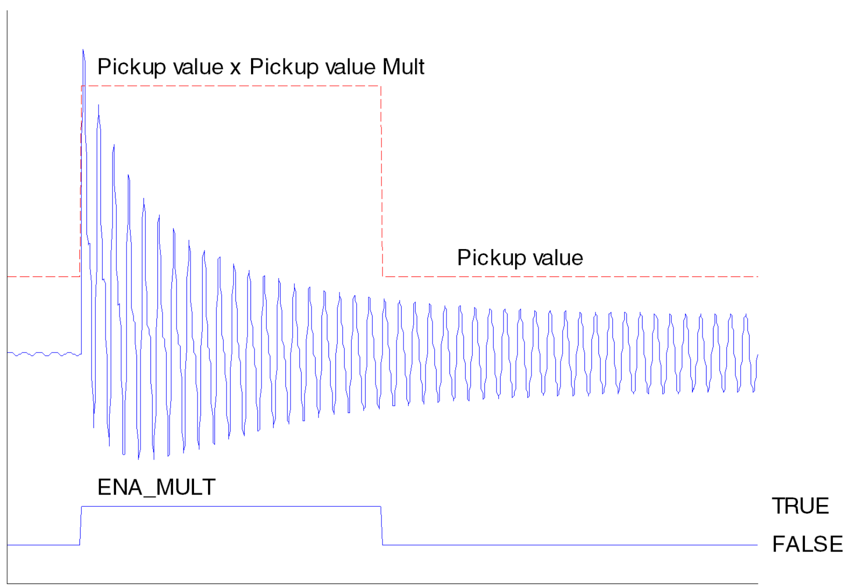


Figure 62: Pickup value behavior with `ENA_MULT` input activated

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of pickup phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the `TRIP` output is activated.

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 protection relay's 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.

4.1.2.5 Timer characteristics

51LT supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* and *Type of reset curve* settings. When the DT characteristic is selected, it is only affected by the *Trip delay time* and *Reset delay time* settings.

The relay provides 9 IDMT characteristics curves, of which eight comply with the IEEE C37.112 and one with the IEC 60255-3 standard. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* value "Long Definite Time".

Table 87: Timer characteristics supported

Operating curve type	51LT
(1) Long Time Extremely Inverse	x
(2) Long Time Very Inverse	x
(3) Long Time Inverse	x

Table continues on next page

Operating curve type	51LT
(4) Long Time Moderately Inverse	x
(5) Long Definite Time	x
(6) Very Long Time Extremely Inverse	x
(7) Very Long Time Very Inverse	x
(8) Very Long Time Inverse	x
(9) Long Time Normal Inverse	x
(14) IEC Long Time Inverse	x
(17) Programmable	x

For a detailed description of timers, refer to section General function block features in this manual.

Table 88: Reset time characteristics supported by different stages

Reset curve type	51LT
(1) Immediate	x
(2) Def time reset	x
(3) Inverse reset	x

4.1.2.6 Application

The long time overcurrent protection is used in special feeder protection application where operating time provided by 51P is not good enough for coordination purpose.

4.1.2.7 Signals

Table 89: 51LT 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
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 90: 51LT Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.2.8 Settings

Table 91: 51LT Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...5.00	xIn	0.01	0.05	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	1.0...15.0		0.1	1.0	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=LT Ext Inv 2=LT Very Inv 3=LT Inv 4=LT Mod Inv 5=Long DT 6=Very LT Ext Inv 7=Very LT Very Inv 8=Very LT Inv 9=LT Normal Inv 14=IEC LT Inv 17=Programmable			5=Long DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 92: 51LT Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

4.1.2.9 Monitored data

Table 93: 51LT Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
51LT	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 94: 51LT Technical data

Characteristic	Value		
Operation accuracy	Depending on the frequency of the current measured: f_n ±2 Hz		
	±1.5% of the set value or ±0.002 x In (at currents in the range of 0.1…5 x In)		
Pickup time 1)2)	Minimum	Typical	Maximum
I_{Fault} = 2 x set Pickup value	23 ms	25 ms	28 ms
Reset time	< 50 ms		
Reset ratio	Typical 0.96		
Retardation time	< 30 ms		
Trip time accuracy in definite time mode	±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms 3)		
Suppression of harmonics	RMS: No suppression DFT: -50 dB at f = n x fn, where n = 2, 3, 4, 5, … Peak-to-Peak: No suppression P-to-P+backup: No suppression		

1) Measurement mode = default (depends on stage), current before fault = 0.0 x In, fn = 60 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical
2) Includes the delay of the signal output contact
3) Maximum Pickup value = 2.5 x In, Pickup value multiples in range of 1.5 to 20

4.1.3 Three-phase directional overcurrent protection 67/51P and 67/50P

4.1.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67/51P
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> -> 3I>> ->	67/50P-1 67/50P-2

4.1.3.2 Function block

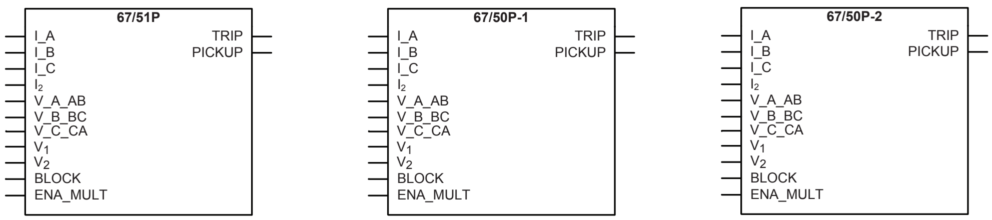


Figure 63: Function block

4.1.3.3 Functionality

The three-phase overcurrent protection function 67/51P and 67/50P is used as one-phase, two-phase or three-phase directional overcurrent and short-circuit protection.

67/51P and 67/50P pick up when the value of the current exceeds the set limit and directional criterion is fulfilled. The trip time characteristics for low stage 67/51P and high stages 67/50P-1 and 67/50P-2 can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

In the DT mode, the function trips after a predefined trip time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

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

4.1.3.4 Operation principle

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

The operation of 67/51P and 67/50P can be described using a module diagram. All the modules in the diagram are explained in the next sections.

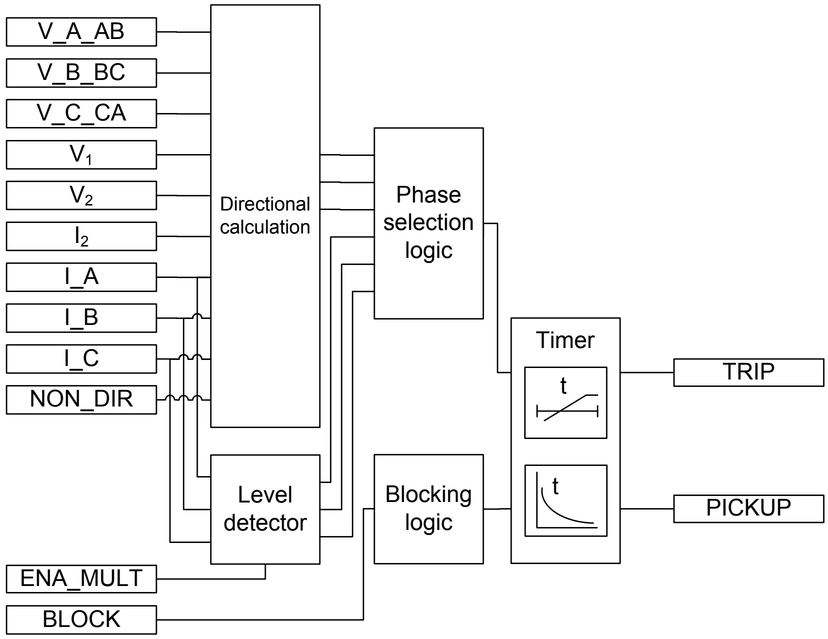


Figure 64: Functional module diagram

Directional calculation

The directional calculation compares the current phasors to the polarizing phasor. A suitable polarization quantity can be selected from the different polarization quantities, which are the positive sequence voltage, negative sequence voltage, self-polarizing (faulted) voltage and cross-polarizing voltages (healthy voltages). The polarizing method is defined with the *Pol quantity* setting.

Table 95: Polarizing quantities

Polarizing quantity	Description
Pos. seq. volt	Positive sequence voltage
Neg. seq. volt	Negative sequence voltage
Self pol	Self polarization
Cross pol	Cross polarization

The directional operation can be selected with the *Directional mode* setting. The user can select either "Non-directional", "Forward" or "Reverse" operation. By setting the value of

Allow Non Dir to "True", the non-directional operation is allowed when the directional information is invalid.

The *Characteristic angle* setting is used to turn the directional characteristic. The value of *Characteristic angle* should be chosen in such a way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the non-operating zone. The value of *Characteristic angle* depends on the network configuration.

Reliable operation requires both the operating and polarizing quantities to exceed certain minimum amplitude levels. The minimum amplitude level for the operating quantity (current) is set with the *Min trip current* setting. The minimum amplitude level for the polarizing quantity (voltage) is set with the *Min trip voltage* setting. If the amplitude level of the operating quantity or polarizing quantity is below the set level, the direction information of the corresponding phase is set to "Unknown".

The polarizing quantity validity can remain valid even if the amplitude of the polarizing quantity falls below the value of the *Min trip voltage* setting. In this case, the directional information is provided by a special memory function for a time defined with the *Voltage Mem time* setting.

67/51P and 67/50P is provided with a memory function to secure a reliable and correct directional protection relay operation in case of a close short circuit or a ground fault characterized by an extremely low voltage. At sudden loss of the polarization quantity, the angle difference is calculated on the basis of a fictive voltage. The fictive voltage is calculated using the positive phase sequence voltage measured before the fault occurred, assuming that the voltage is not affected by the fault. The memory function enables the function to trip up to a maximum of three seconds after a total loss of voltage. This time can be set with the *Voltage Mem time* setting. The voltage memory cannot be used for the "Negative sequence voltage" polarization because it is not possible to substitute the positive sequence voltage for negative sequence voltage without knowing the network unsymmetry level. This is the reason why the fictive voltage angle and corresponding direction information are frozen immediately for this polarization mode when the need for a voltage memory arises and these are kept frozen until the time set with *Voltage Mem time* elapses.

The value for the *Min trip voltage* setting should be carefully selected since the accuracy in low signal levels is strongly affected by the measuring device accuracy.

When the voltage falls below *Min trip voltage* at a close fault, the fictive voltage is used to determine the phase angle. The measured voltage is applied again as soon as the voltage rises above *Min trip voltage* and hysteresis. The fictive voltage is also discarded if the measured voltage stays below *Min trip voltage*and hysteresis for longer than *Voltage Mem* *time* or if the fault current disappears while the fictive voltage is in use. When the voltage is below *Min trip voltage* and hysteresis and the fictive voltage is unusable, the fault direction cannot be determined. The fictive voltage can be unusable for two reasons:

- The fictive voltage is discarded after *Voltage Mem time*
- The phase angle cannot be reliably measured before the fault situation.

67/51P and 67/50P can be forced to the non-directional operation with the `NON_DIR` input. When the `NON_DIR` input is active, 67/51P and 67/50P operate as a non-directional overcurrent protection, regardless of the *Directional mode* setting.

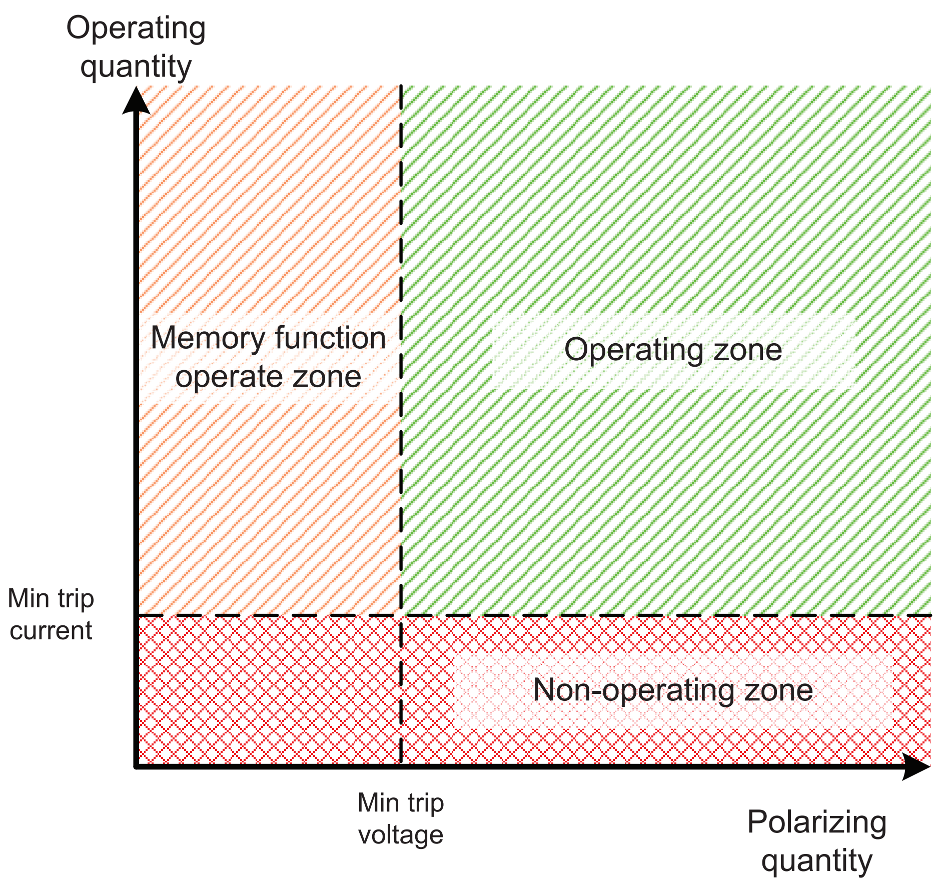


Figure 65: Operating zones at minimum magnitude levels

Level detector

The measured phase currents are compared phasewise to the set *Pickup value*. If the measured value exceeds the set *Pickup value*, the level detector reports the exceeding of the value to the phase selection logic. If the ENA_MULT input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

Do not set the multiplier setting *Pickup value Mult* higher than necessary. If the value is too high, the function may not trip at all during an inrush followed by a fault, no matter how severe the fault is.

The pickup value multiplication is normally done when the inrush detection function (INR) is connected to the ENA_MULT input.

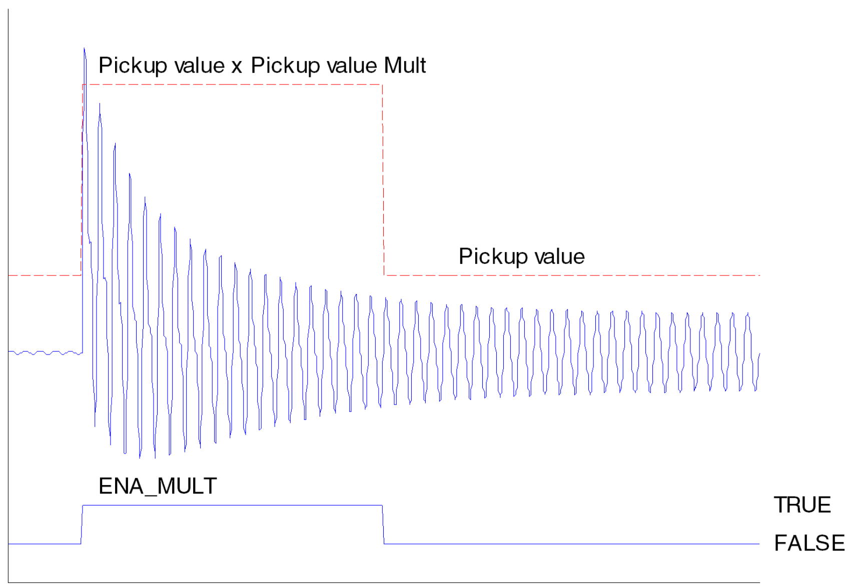


Figure 66: Pickup value behavior with ENA_MULT input activated

Phase selection logic

If the fault criteria are fulfilled in the level detector and the directional calculation, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of pickup phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the TRIP output is activated.

When the user-programmable IDMT curve is selected, the operation time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT trip and reset times.

The setting parameter *Minimum trip time* defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.1.3.5 Measurement modes

The function operates on three alternative measurement modes: “RMS”, “DFT” and “Peak-to-Peak” . The measurement mode is selected with the *Measurement mode* setting.

Table 96: Measurement modes supported by 67/51P and 67/50P stages

Measurement mode	67/51P	67/50P-1 and 67/50P-2
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

4.1.3.6 Directional overcurrent characteristics

The forward and reverse sectors are defined separately. The forward operation area is limited with the *Min forward angle* and *Max forward angle* settings. The reverse operation area is limited with the *Min reverse angle* and *Max reverse angle* settings.

The sector limits are always given as positive degree values.

In the forward operation area, the *Max forward angle* setting gives the counterclockwise sector and the *Min forward angle* setting gives the corresponding clockwise sector, measured from the *Characteristic angle* setting.

In the backward operation area, the *Max reverse angle* setting gives the counterclockwise sector and the *Min reverse angle* setting gives the corresponding clockwise sector, a measurement from the *Characteristic angle* setting that has been rotated 180 degrees.

Relay characteristic angle (RCA) is set positive if the operating current lags the polarizing quantity and negative if the operating current leads the polarizing quantity.

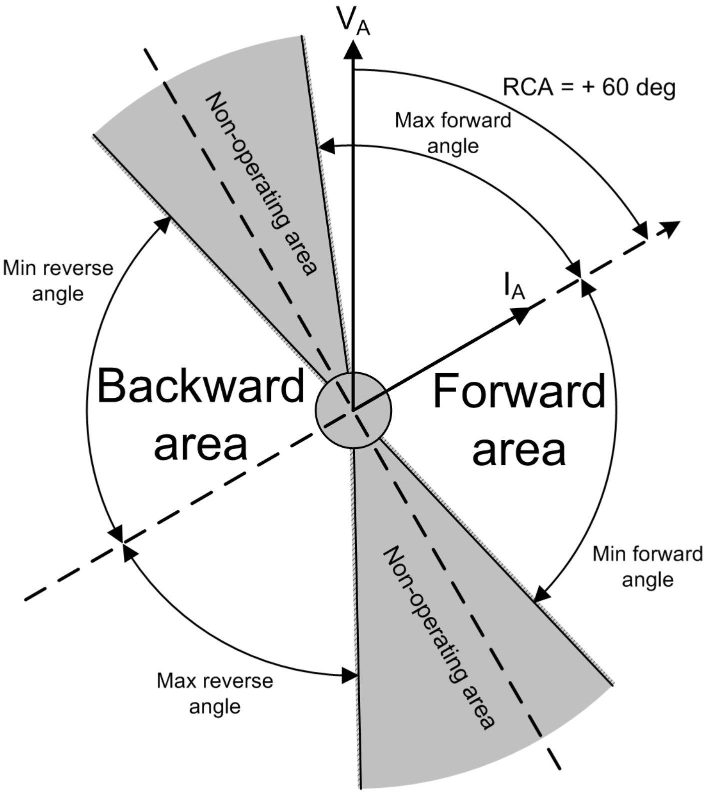


Figure 67: Configurable operating sectors

Table 97: Momentary per phase direction value for monitored data view

Criterion for per phase direction information	The value for DIR_A/_B/_C
The ANGLE_X is not in any of the defined sectors, or the direction cannot be defined due too low amplitude	0 = unknown
The ANGLE_X is in the forward sector	1 = forward
The ANGLE_X is in the reverse sector	2 = backward
(The ANGLE_X is in both forward and reverse sectors, that is, when the sectors are overlapping)	3 = both

Table 98: Momentary phase combined direction value for monitored data view

Criterion for phase combined direction information	The value for DIRECTION
The direction information (DIR_X) for all phases is unknown	0 = unknown
The direction information (DIR_X) for at least one phase is forward, none being in reverse	1 = forward
The direction information (DIR_X) for at least one phase is reverse, none being in forward	2 = backward
The direction information (DIR_X) for some phase is forward and for some phase is reverse	3 = both

FAULT_DIR gives the detected direction of the fault during fault situations, that is, when the PICKUP output is active.

Self-polarizing as polarizing method

Table 99: Equations for calculating angle difference for self-polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{V}_A$	$ANGLE\_A = \varphi(\underline{V}_A) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	$\underline{I}_B$	$\underline{V}_B$	$ANGLE\_B = \varphi(\underline{V}_B) - \varphi(\underline{I}_B) - \varphi_{RCA}$
C	$\underline{I}_C$	$\underline{V}_C$	$ANGLE\_C = \varphi(\underline{V}_C) - \varphi(\underline{I}_C) - \varphi_{RCA}$
A - B	$\underline{I}_A - \underline{I}_B$	$\underline{V}_{AB}$	$ANGLE\_A = \varphi(\underline{V}_{AB}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA}$
B - C	$\underline{I}_B - \underline{I}_C$	$\underline{V}_{BC}$	$ANGLE\_B = \varphi(\underline{V}_{BC}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA}$
C - A	$\underline{I}_C - \underline{I}_A$	$\underline{V}_{CA}$	$ANGLE\_C = \varphi(\underline{V}_{CA}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA}$

In an example case of the phasors in a single-phase ground fault where the faulted phase is phase A, the angle difference between the polarizing quantity V_A and operating quantity I_A is marked as φ. In the self-polarization method, there is no need to rotate the polarizing quantity.

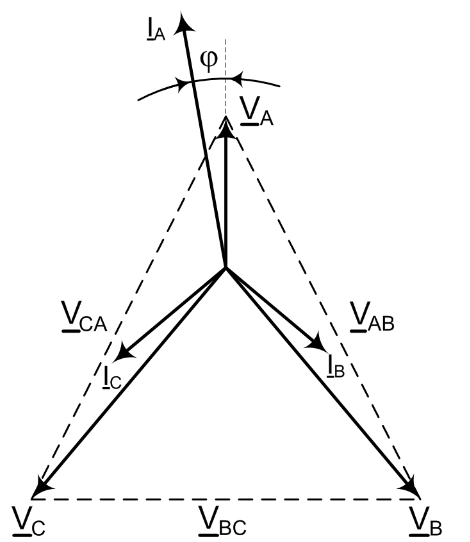


Figure 68: Single-phase ground fault, phase A

In an example case of a two-phase short-circuit failure where the fault is between phases B and C, the angle difference is measured between the polarizing quantity V_{BC} and operating quantity $\underline{I}_B$ - $\underline{I}_C$ in the self-polarizing method.

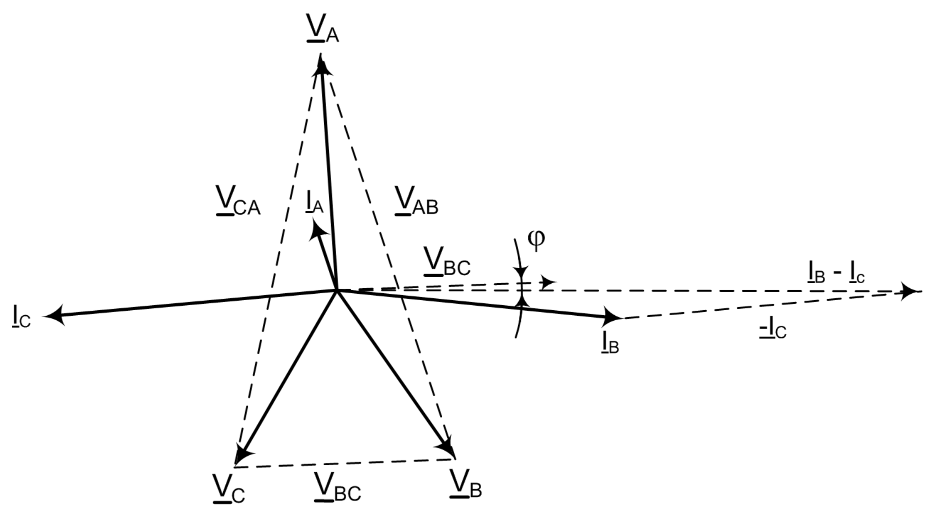


Figure 69: Two-phase short circuit, short circuit is between phases B and C

Cross-polarizing as polarizing quantity

Table 100: Equations for calculating angle difference for cross-polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{V}_{BC}$	$ANGLE\_A = \varphi(\underline{V}_{BC}) - \varphi(\underline{I}_A) - \varphi_{RCA} + 90^o$
B	$\underline{I}_B$	$\underline{V}_{CA}$	$ANGLE\_B = \varphi(\underline{V}_{CA}) - \varphi(\underline{I}_B) - \varphi_{RCA} + 90^o$
C	$\underline{I}_C$	$\underline{V}_{AB}$	$ANGLE\_C = \varphi(\underline{V}_{AB}) - \varphi(\underline{I}_C) - \varphi_{RCA} + 90^o$
A - B	$\underline{I}_A - \underline{I}_B$	$\underline{V}_{BC} - \underline{V}_{CA}$	$ANGLE\_A = \varphi(\underline{V}_{BC} - \underline{V}_{CA}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 90^o$
B - C	$\underline{I}_B - \underline{I}_C$	$\underline{V}_{CA} - \underline{V}_{AB}$	$ANGLE\_B = \varphi(\underline{V}_{CA} - \underline{V}_{AB}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} + 90^o$
C - A	$\underline{I}_C - \underline{I}_A$	$\underline{V}_{AB} - \underline{V}_{BC}$	$ANGLE\_C = \varphi(\underline{V}_{AB} - \underline{V}_{BC}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 90^o$

The polarizing quantity is rotated with 90 degrees. The characteristic angle is assumed to be ~ 0 degrees.

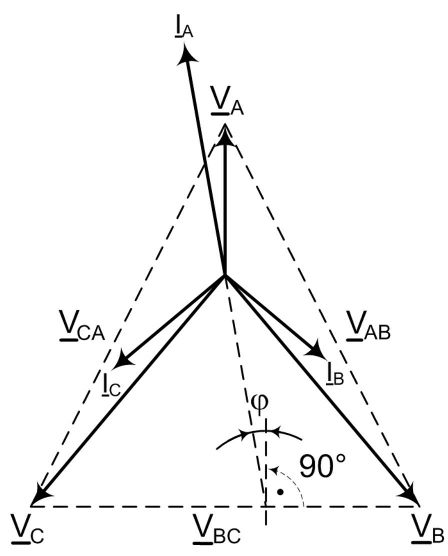


Figure 70: Single-phase ground fault, phase A

In an example of the phasors in a two-phase short-circuit failure where the fault is between the phases B and C, the angle difference is measured between the polarizing quantity $\underline{V}_{AB}$ and operating quantity $\underline{I}_B$ - $\underline{I}_C$ marked as φ.

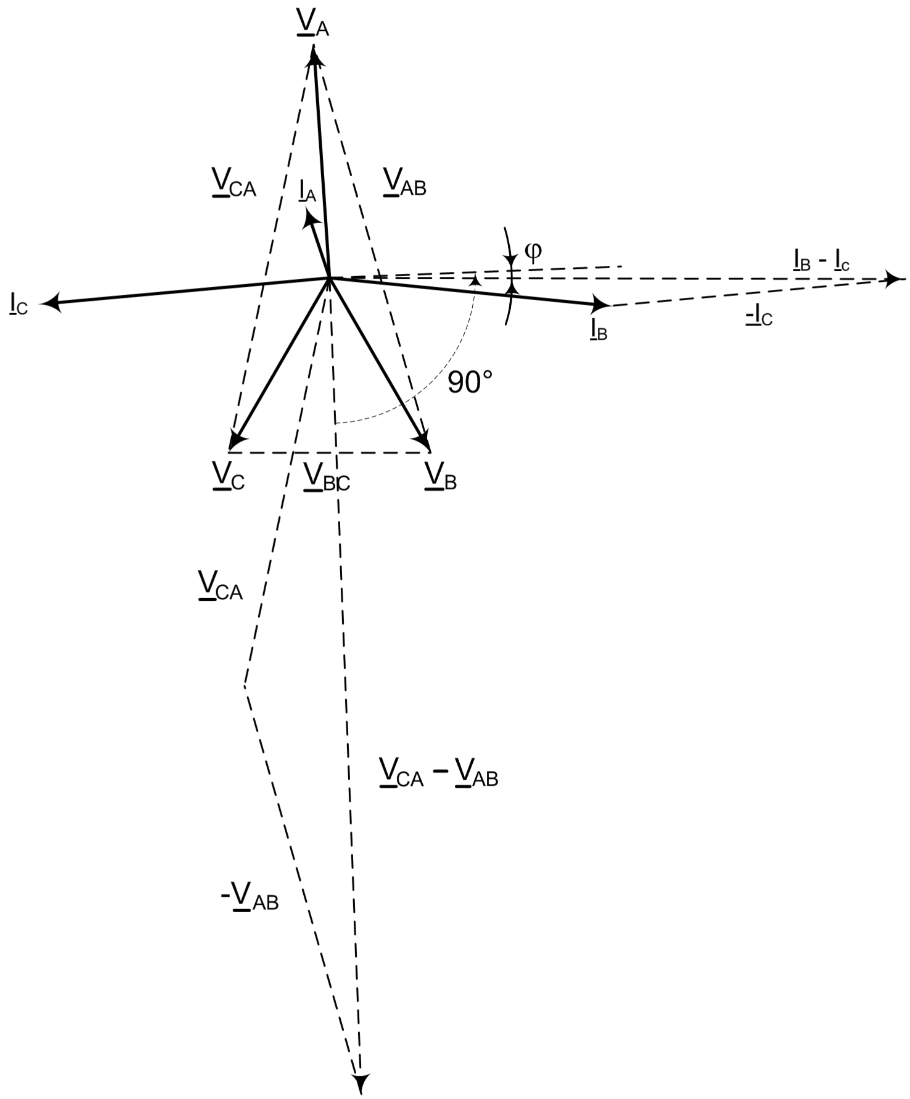


Figure 71: Two-phase short circuit, short circuit is between phases B and C

The equations are valid when network rotating direction is counter-clockwise, that is, ABC. If the network rotating direction is reversed, 180 degrees is added to the calculated angle difference. This is done automatically with a system parameter *Phase rotation*.

Negative sequence voltage as polarizing quantity

When the negative voltage is used as the polarizing quantity, the angle difference between the operating and polarizing quantity is calculated with the same formula for all fault types:

$$ANGLE\_X = \varphi(-\underline{V}2) - \varphi(\underline{I}2) - \varphi_{RCA}$$

(Equation 1)

This means that the actuating polarizing quantity is -V2.

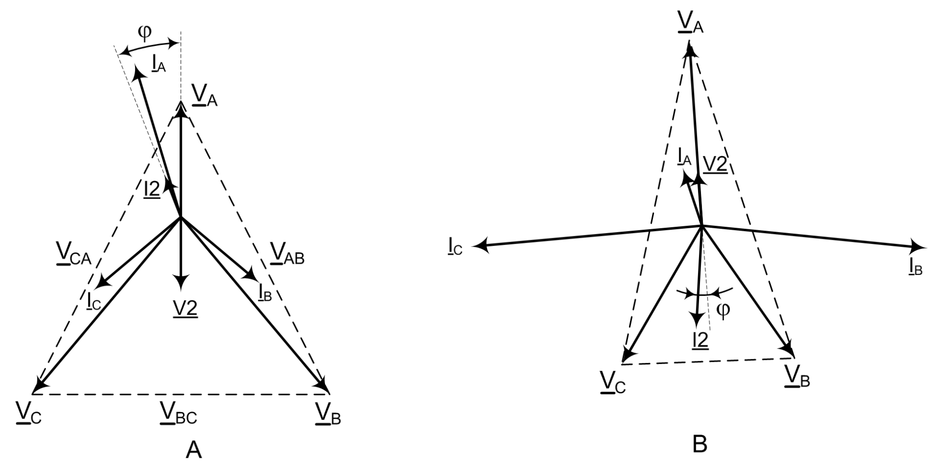


Figure 72: Phasors in a single-phase ground fault, phases A-N, and two-phase short circuit, phases B and C, when the actuating polarizing quantity is the negative-sequence voltage -V2

Positive sequence voltage as polarizing quantity

Table 101: Equations for calculating angle difference for positive-sequence quantity polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{V}1$	$ANGLE\_A = \varphi(\underline{V}1) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	$\underline{I}_B$	$\underline{V}1$	$ANGLE\_B = \varphi(\underline{V}1) - \varphi(\underline{I}_B) - \varphi_{RCA} - 120^{\circ}$
C	$\underline{I}_C$	$\underline{V}1$	$ANGLE\_C = \varphi(\underline{V}1) - \varphi(\underline{I}_C) - \varphi_{RCA} + 120^{\circ}$
Table continues on next page			

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A - B	$\underline{I}_A - \underline{I}_B$	$\underline{V1}$	$ANGLE\_A = \varphi(\underline{V1}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 30^\circ$
B - C	$\underline{I}_B - \underline{I}_C$	$\underline{V1}$	$ANGLE\_B = \varphi(\underline{V1}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} - 90^\circ$
C - A	$\underline{I}_C - \underline{I}_A$	$\underline{V1}$	$ANGLE\_C = \varphi(\underline{V1}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 150^\circ$

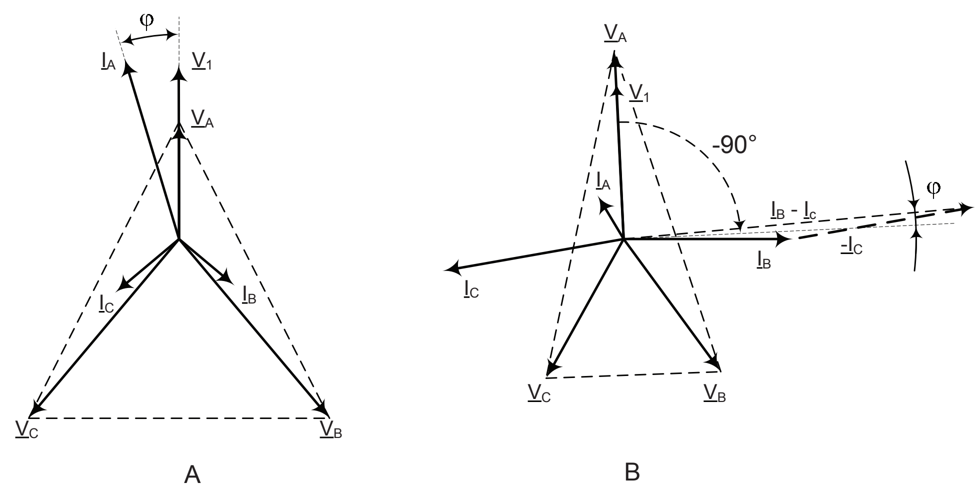


Figure 73: Phasors in a single-phase ground fault, phase A to ground, and a two-phase short circuit, phases B-C, are short-circuited when the polarizing quantity is the positive-sequence voltage V_1

Network rotation direction

Typically, the network rotating direction is counter-clockwise and defined as "ABC". If the network rotating direction is reversed, meaning clockwise, that is, "ACB", the equations for calculating the angle difference needs to be changed. The network rotating direction is defined with a system parameter *Phase rotation*. The change in the network rotating direction affects the phase-to-phase voltages polarization method where the calculated angle difference needs to be rotated 180 degrees. Also, when the sequence components are used, which are, the positive sequence voltage or negative sequence voltage components, the calculation of the components are affected but the angle difference calculation remains the same. When the phase-to-ground voltages are used as the polarizing method, the network rotating direction change has no effect on the direction calculation.

The network rotating direction is set in the protection relay using the parameter in the HMI menu **Configuration/System/Phase rotation**. The default parameter value is "ABC".

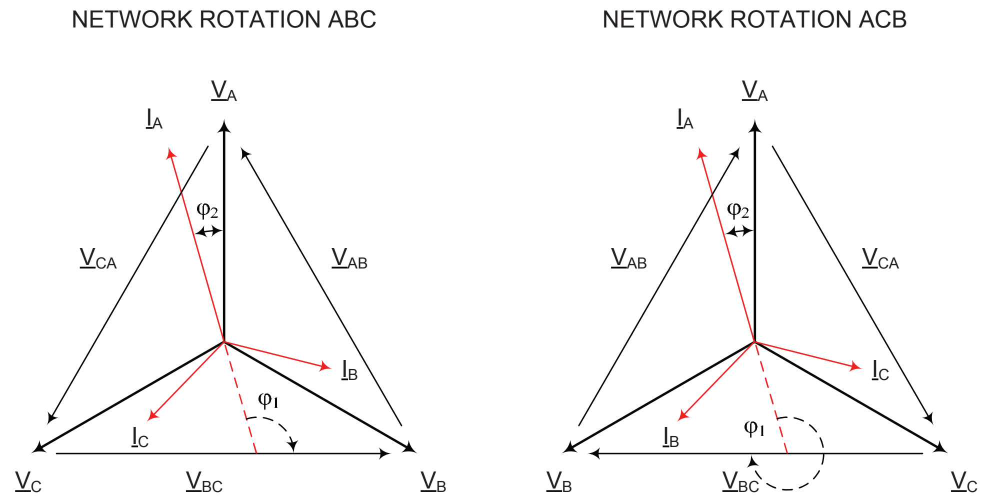


Figure 74: Examples of network rotating direction

4.1.3.7 Application

67/51P and 67/50P is used as short-circuit protection in three-phase distribution or sub transmission networks operating at 50 or 60 Hz.

In radial networks, phase overcurrent protection relays are often sufficient for the short circuit protection of lines, transformers and other equipment. The current-time characteristic should be chosen according to the common practice in the network. It is recommended to use the same current-time characteristic for all overcurrent protection relays in the network. This includes the overcurrent protection of transformers and other equipment.

The phase overcurrent protection can also be used in closed ring systems as short circuit protection. Because the setting of a phase overcurrent protection system in closed ring networks can be complicated, a large number of fault current calculations are needed. There are situations with no possibility to have the selectivity with a protection system based on overcurrent protection relays in a closed ring system.

In some applications, the possibility of obtaining the selectivity can be improved significantly if 67/51P and 67/50P is used. This can also be done in the closed ring networks and radial networks with the generation connected to the remote in the system thus giving fault current infeed in reverse direction. Directional overcurrent protection relays are also used to have a selective protection scheme, for example in case of parallel distribution lines or power transformers fed by the same single source.In ring connected supply feeders between substations or feeders with two feeding sources, 67/51P and 67/50P is also used.

Parallel lines or transformers

When the lines are connected in parallel and if a fault occurs in one of the lines, it is practical to have 67/51P and 67/50P to detect the direction of the fault. Otherwise, there is a risk that the fault situation in one part of the feeding system can de-energize the whole system connected to the LV side.

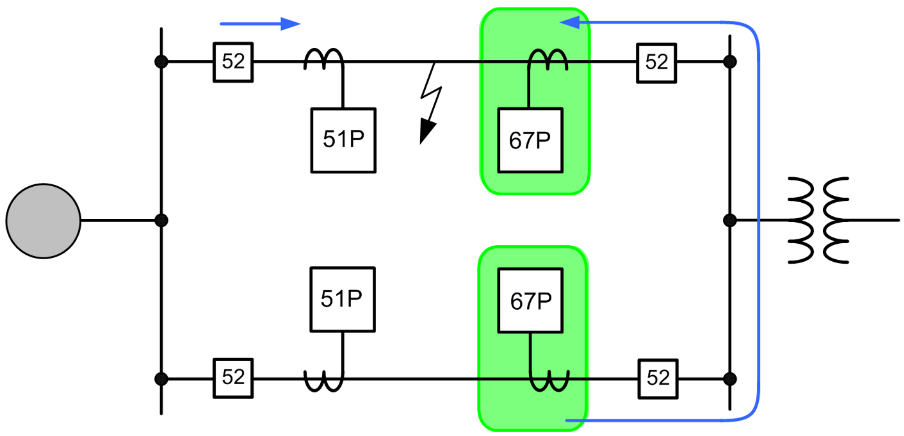


Figure 75: Overcurrent protection of parallel lines using directional protection relays

67/51P and 67/50P can be used for parallel operating transformer applications. In these applications, there is a possibility that the fault current can also be fed from the LV-side up to the HV-side. Therefore, the transformer is also equipped with directional overcurrent protection.

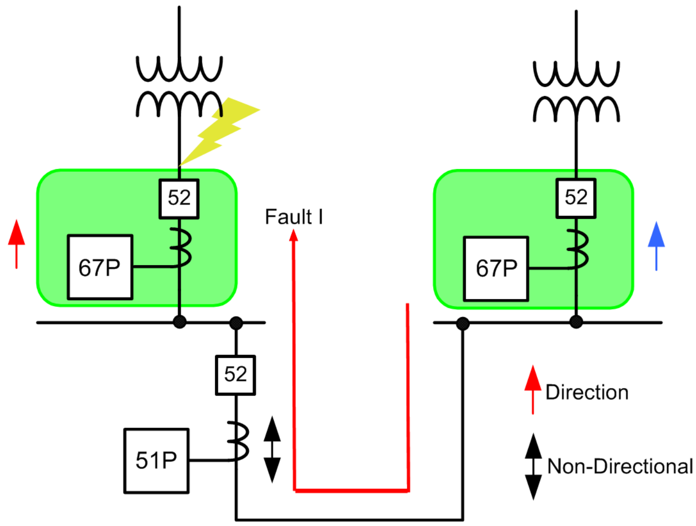


Figure 76: Overcurrent protection of parallel operating transformers

Closed ring network topology

The closed ring network topology is used in applications where electricity distribution for the consumers is secured during network fault situations. The power is fed at least from two directions which means that the current direction can be varied. The time grading between the network level stages is challenging without unnecessary delays in the time settings. In this case, it is practical to use the directional overcurrent protection relays to achieve a selective protection scheme. Directional overcurrent functions can be used in closed ring applications. The arrows define the operating direction of the directional functionality. The double arrows define the non-directional functionality where faults can be detected in both directions.

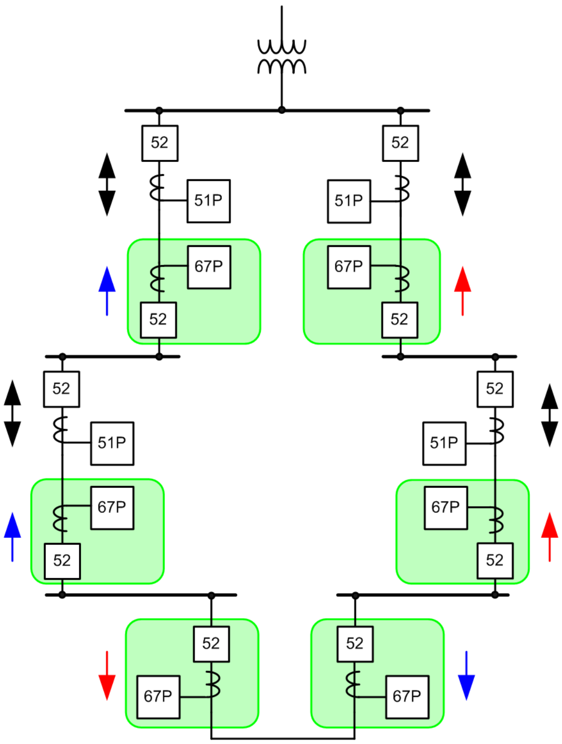


Figure 77: Closed ring network topology where feeding lines are protected with directional overcurrent protection relays

4.1.3.8 Signals

Table 102: 67/51P 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 phase sequence current
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
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 103: 67/50P 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 phase sequence current
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
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 104: 67/51P Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 105: 67/50P Output signals

Name	Type	Description
PICKUP	BOOLEAN	Pickup
TRIP	BOOLEAN	Trip

4.1.3.9 Settings

Table 106: 67/51P Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...5.00	xIn	0.01	0.05	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 107: 67/51P Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Min trip current	0.01...1.00	xIn	0.01	0.01	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.01	Minimum trip voltage

Table 108: 67/50P Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	40...200000	ms	10	40	Trip delay time
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 109: 67/50P Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min trip current	0.01...1.00	xIn	0.01	0.01	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.01	Minimum trip voltage
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
Num of pickup 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 for trip activation

4.1.3.10 Monitored data

Table 110: 67/51P Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
67/51P	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 111: 67/50P Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information

Table continues on next page

Name	Type	Values (Range)	Unit	Description
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
67/50P	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.1.3.11 Technical data

Table 112: 67/51P and 67/50P Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current/voltage measured: f_n ±2 Hz		
	67/51P	Current: ±1.5% of the set value or ±0.002 × I_n Voltage: ±1.5% of the set value or ±0.002 × V_n Phase angle: ±2°		
	67/50P-1 and 67/50P-2	Current: ±1.5% of the set value or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n) Voltage: ±1.5% of the set value or ±0.002 × V_n Phase angle: ±2°		
Pickup time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Pickup value*	38 ms	43 ms	46 ms
Reset time		<40 ms		
Table continues on next page				

Characteristic	Value
Reset ratio	Typically 0.96
Retardation time	<35 ms
Trip time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Trip time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms[3)]
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

1) *Measurement mode* and *Pol quantity* = default, current before fault = 0.0 × I_n, voltage before fault = 1.0 × V_n, f_n = 60 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 2.5 × I_n, *Pickup value* multiples in range of 1.5...20

4.1.4 Non-directional neutral overcurrent protection 51N/50N and Non-directional ground fault protection 51G/50G

4.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional ground-fault protection, low stage	EFLPTOC	Io>	51N/G
Non-directional ground-fault protection, high stage	EFHPTOC	Io>>	50N/G-1/2
Non-directional ground-fault protection, instantaneous stage	EFIPTOC	Io>>>	50N/G-3

4.1.4.2 Function block

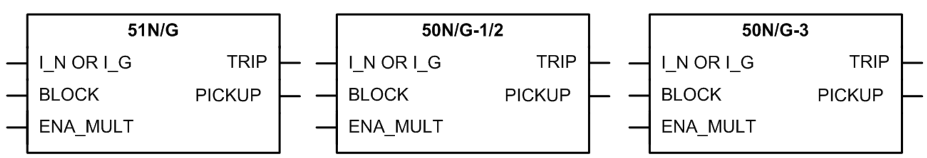


Figure 78: Function block

4.1.4.3 Functionality

The ground-fault function 51N/50N or 51G/50G is used as non-directional ground-fault protection.

The function picks up and trips when the measured (IG) or calculated (IN) ground current exceeds the set limit. The trip time characteristic for low stage 51N/G and high stage 50N/G-1/2 can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage 50N/G-3 always trips with the DT characteristic.

In the DT mode, the function trips after a predefined trip time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

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

4.1.4.4 Operation principle

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

The operation of 51N/50N and 51G/50G can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

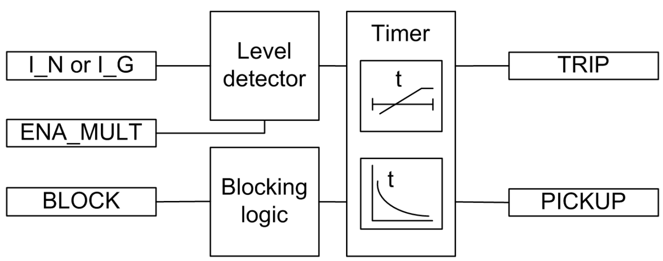


Figure 79: Functional module diagram

Level detector

The measured ground current is compared to the set *Pickup value*. If the measured value exceeds the set *Pickup value*, the level detector sends an enable-signal to the timer module. If the ENA_MULT input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

Do not set the multiplier setting *Pickup value Mult* higher than necessary. If the value is too high, the function may not trip at all during an inrush followed by a fault, no matter how severe the fault is.

The pickup value multiplication is normally done when the inrush detection function (INR) is connected to the ENA_MULT input.

Timer

Once activated, the timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the `TRIP` output is activated.

When the user-programmable IDMT curve is selected, the operation time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the `PICKUP` output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT trip and reset times.

The setting parameter *Minimum trip time* defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.1.4.5 Measurement modes

The function operates on three alternative measurement modes: "RMS", "DFT" and "Peak-to-Peak". The measurement mode is selected with the *Measurement mode* setting.

Table 113: Measurement modes supported by 51N/50N or 51G/50G stages

Measurement mode	51N/G	50N/G-1/2	50N/G-3
RMS	x	x	
DFT	x	x	
Peak-to-Peak	x	x	x

For a detailed description of the measurement modes, see the Measurement modes section in this manual.

4.1.4.6 Timer characteristics

51N/50N or 51G/50G supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* and *Type of reset curve* settings. When the DT characteristic is selected, it is only affected by the *Trip delay time* and *Reset delay time* settings.

The protection relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The following characteristics, which comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages:

Table 114: Timer characteristics supported by different stages

Operating curve type	51N/G	50N/G-1/2
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	x
(10) IEC Very Inverse	x	x
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	x
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable curve	x	x
(18) RI type	x	
(19) RD type	x	

50N/G-3 supports only definite time characteristics.

For a detailed description of timers, see the General function block features section in this manual.

Table 115: Reset time characteristics supported by different stages

Reset curve type	51N/G	50N/G-1/2	Note
(1) Immediate	x	x	Available for all reset time curves
(2) Def time reset	x	x	Available for all reset time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

The *Type of reset curve* setting does not apply to 50N/G-3 or when the DT operation is selected. The reset is purely defined by the *Reset delay time* setting.

4.1.4.7 Application

51N/50N or 51G/50G is designed for protection and clearance of ground faults in distribution and sub-transmission networks where the neutral point is isolated or grounded via a resonance coil or through low resistance. It also applies to solidly grounded networks and ground-fault protection of different equipment connected to the power systems, such as shunt capacitor bank or shunt reactors and for backup ground-fault protection of power transformers.

Many applications require several steps using different current pickup levels and time delays. 51N/50N or 51G/50G consists of three different protection stages:

- Low 51N/G
- High 50N/G-1/2
- Instantaneous 50N/G-3

51N/G contains several types of time-delay characteristics. 50N/G-1/2 and 50N/G-3 are used for fast clearance of serious ground faults.

4.1.4.8 Signals

Table 116: 51N/G Input signals

Name	Type	Default	Description
IN or IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 117: 50N/G-1/2 Input signals

Name	Type	Default	Description
IN or IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 118: 50N/G-3 Input signals

Name	Type	Default	Description
IN or IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 119: 51N/G Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 120: 50N/G-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 121: 50N/G-3 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.4.9 Settings

Table 122: 51N/G Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...5.000	xIn	0.005	0.010	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 123: 51N/G Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
IG/I0 signal Sel	1=Measured IG 2=Calculated I0			1=Measured IG	Measured IG or calculated I0

Table 124: 50N/G-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 125: 50N/G-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
IG/I0 signal Sel	1=Measured IG 2=Calculated I0			1=Measured IG	Measured IG or calculated I0

Table 126: 50N/G-3 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	1.00...40.00	xIn	0.01	1.00	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Trip delay time	20...200000	ms	10	20	Trip delay time

Table 127: 50N/G-3 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
IG/I0 signal Sel	1=Measured IG 2=Calculated I0			1=Measured IG	Measured IG or calculated I0

4.1.4.10 Monitored data

Table 128: 51N/G Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
51N/G	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 129: 50N/G-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
50N/G-1/2	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 130: 50N/G-3 Monitored data

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

4.1.4.11 Technical data

Table 131: 51N/G, 50N/G-1/2 & 50N/G-3 Technical data

Characteristic		Value		
Operation accuracy	51N/G	±1.5% of the set value or ±0.002 × I_n		
	50N-1/2 & 50G-1/2 and 50N/G-3	±1.5% of set value or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n)		
Pickup time 1)2)		Minimum	Typical	Maximum
	50N/G-3: I_{Fault} = 2 × set Pickup value I_{Fault} = 10 × set Pickup value	15 ms 12 ms	16 ms 13 ms	17 ms 14 ms
	50N-1/2 & 50G-1/2 and 51N/G: I_{Fault} = 2 × set Pickup value	23 ms	25 ms	28 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<30 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms 3)		
Suppression of harmonics		RMS: No suppression DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression		

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 × I_n, f_n = 60 Hz, ground-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 2.5 × I_n, *Pickup value* multiples in range of 1.5...20

4.1.5 Directional earth-fault protection 67/51N and 67/50N

4.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional earth-fault protection, low stage	DEFLPDEF1	I0> ->(1)	67/51N
Directional earth-fault protection, high stage	DEFHPDEF1 DEFHPDEF2	I0>> ->(1) I0>> ->(2)	67/50N-1 67/50N-2

4.1.5.2 Function block

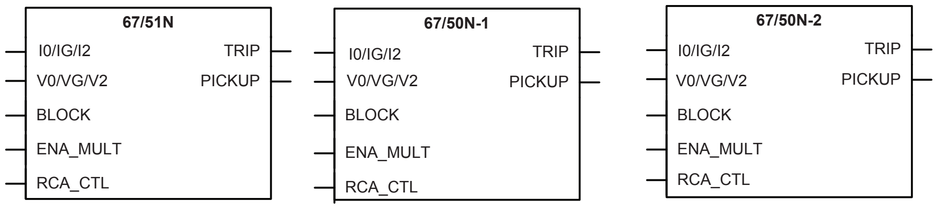


Figure 80: Function block

4.1.5.3 Functionality

The earth-fault function 67/51N and 67/50N is used as directional earth-fault protection.

There are three different polarization signals - measured zero sequence voltage, calculated zero sequence voltage and negative sequence voltage. The function picks up and trips when the zero sequence current (I_0) and zero sequence voltage ($-V_0$) exceed the set limits and the angle between them is inside the set operating sector. The function also picks up and trips when the negative sequence current (I_2) and negative sequence voltage ($-V_2$) exceed the set limits and the angle between them is inside the set operating sector. The trip time characteristic for low stage (67/51N) and high stage (67/50N-1 and 67/50N-2) can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

In the DT mode, the function trips after a predefined trip time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

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

4.1.5.4 Operation principle

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

The operation of 67/51N and 67/50N can be described using a module diagram. All the modules in the diagram are explained in the next sections.

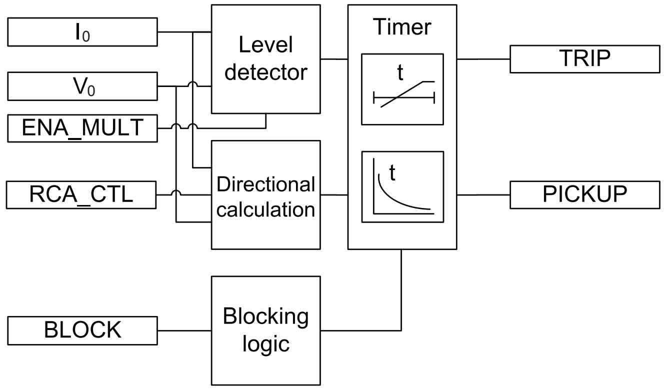


Figure 81: Functional module diagram

Level detector

The measured ground current is compared to the set *Pickup value*. The zero sequence voltage (-Vo) also needs to be compared to the set *Voltage pickup value*. If both limits are exceeded, the level detector sends an enable-signal to the timer module. When the *Enable voltage limit* setting is set to "False", the *Voltage pickup* value has no effect and the level detection is purely based on the ground current. If the ENA_MULT input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

If the *Enable voltage limit* setting is set to "True", the magnitude of the polarizing quantity is checked even if the *Directional mode* was set to "Non-directional" or *Allow Non Dir* to "True". The protection relay does not accept the *Pickup value* or *Pickup value Mult* setting if the product of these settings exceeds the *Pickup value* setting range.

Do not set the multiplier setting *Pickup value Mult* higher than necessary. If the value is too high, the function may not trip at all during an inrush followed by a fault, no matter how severe the fault is.

The pickup value multiplication is normally done when the inrush detection function (INR) is connected to the ENA_MULT input.

Directional calculation

The directional calculation module monitors the angle between the operating current and polarizing voltage. When the angle is in the operation sector, the module sends the enable signal to the timer module. When the angle is in the operation sector, the module sends the enabling signal to the timer module.

For defining the operation sector, there are five modes available through the *Operation mode* setting.

Table 132: Operation modes

Operation mode	Description
Phase angle	The operating sectors for forward and reverse are defined with the settings *Min forward angle*, *Max forward angle*, *Min reverse angle* and *Max reverse angle*.
IoSin	The operating sectors are defined as "forward" when the mathematical expression has a positive value and "reverse" when the value is negative
IoCos	As "IoSin" mode. Only cosine is used for calculating the operation current.
Phase angle 80	The sector maximum values are frozen to 80 degrees respectively. Only *Min forward angle* and *Min reverse angle* are settable.
Phase angle 88	The sector maximum values are frozen to 88 degrees. Otherwise as "Phase angle 80" mode.

The directional operation can be selected with the *Directional mode* setting. The alternatives are "Non-directional", "Forward" and "Reverse" operation. The operation criterion is selected with the *Operation mode* setting. By setting *Allow Non Dir* to "True", non-directional operation is allowed when the directional information is invalid.

Typically, the network rotating direction is counter-clockwise and defined as "ABC". If the network rotating direction is reversed, meaning clockwise, that is, "ACB", the equation for calculating the negative sequence voltage component need to be changed. The network rotating direction is defined with a system parameter *Phase rotation*. The calculation of the component is affected but the angle difference calculation remains the same. When the residual voltage is used as the polarizing method, the network rotating direction change has no effect on the direction calculation.

The network rotating direction is set in the protection relay using the parameter in the HMI menu: **Configuration/System/Phase rotation**. The default parameter value is "ABC".

The *Characteristic angle* setting is used in the "Phase angle" mode to adjust the operation according to the method of neutral point grounding so that in an isolated network the *Characteristic angle* (φ_{RCA}) = -90° and in a compensated network φ_{RCA} = 0°. In addition, the characteristic angle can be changed via the control signal `RCA_CTL`, in which case the alternatives are -90° and 0°. The operation of `RCA_CTL` depends on the *Characteristic angle* setting.

The *Correction angle* setting can be used to improve selectivity due the inaccuracies in the measurement transformers. The setting decreases the operation sector. The correction can only be used with the "IoCos" or "IoSin" modes.

When polarizing quantity (zero sequence voltage (-U_0)) is inverted because of switched voltage measurement cables, the correction can be done by setting the *Pol reversal* to "True" which turns polarizing quantity by 180 degrees.

For definitions of different directional ground-fault characteristics, see the Directional ground-fault characteristics section in this manual.

The directional calculation module calculates several values which are presented in the monitored data.

Table 133: Monitored data values

Monitored data values	Description
FAULT_DIR	The detected direction of fault during fault situations, that is, when PICKUP output is active.
DIRECTION	The momentary operating direction indication output.
ANGLE	Also called operating angle, shows the angle difference between the VG (polarizing quantity) and Io (operating quantity).
ANGLE_RCA	The angle difference between the operating angle and *Characteristic angle*, that is, ANGLE_RCA = ANGLE – *Characteristic angle*.
I_OPER	The current that is used for fault detection. If the *Operation mode* setting is "Phase angle", "Phase angle 80" or "Phase angle 88", I_OPER is the measured or calculated residual current. If the *Operation mode* setting is "IoSin", I_OPER is calculated as follows I_OPER = IG x sin(ANGLE). If the *Operation mode* setting is "IoCos", I_OPER is calculated as follows I_OPER = IG x cos(ANGLE).

Monitored data values are accessible on the LHMI or through tools via communications.

Timer

Once activated, the timer activates the PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the TRIP output is activated.

When the user-programmable IDMT curve is selected, the operation time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT trip and reset times.

The setting parameter *Minimum trip time* defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.1.5.5 Directional ground-fault principles

In many cases it is difficult to achieve selective ground-fault protection based on the magnitude of zero-sequence current only. To obtain a selective ground-fault protection scheme, it is necessary to take the phase angle of I_0 into account. This is done by comparing the phase angle of I_0 to that of the zero-sequence voltage ($-V_0$).

Relay characteristic angle

The *Characteristic angle* setting, also known as Relay Characteristic Angle (RCA), Relay Base Angle or Maximum Torque Angle (MTA), is used in the "Phase angle" mode to turn the directional characteristic if the expected fault current angle does not coincide with the polarizing quantity to produce the maximum torque. That is, RCA is the angle between the maximum torque line and polarizing quantity. If the polarizing quantity is in phase with the maximum torque line, RCA is 0 degrees. The angle is positive if the operating current lags the polarizing quantity and negative if it leads the polarizing quantity.

Example 1

The "Phase angle" mode is selected, compensated network (φRCA = 0 deg)

=> *Characteristic angle* = 0 deg

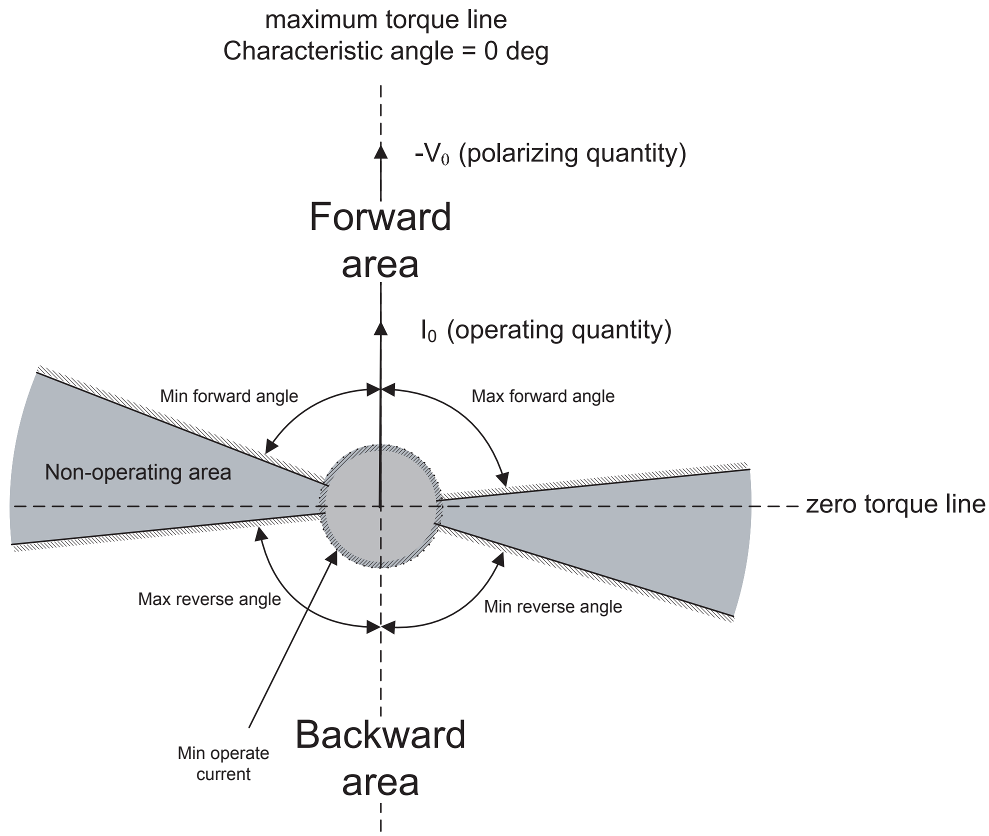


Figure 82: Definition of the relay characteristic angle, RCA=0 degrees in a compensated network

Example 2

The "Phase angle" mode is selected, solidly grounded network (φRCA = +60 deg)

=> *Characteristic angle* = +60 deg

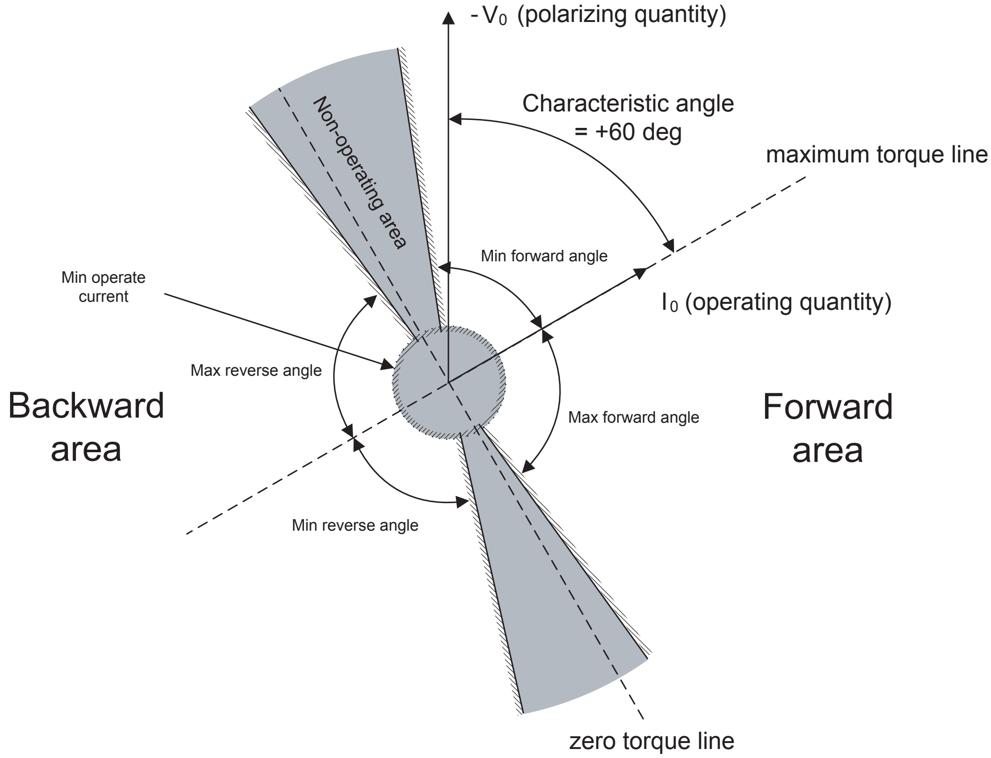


Figure 83: Definition of the relay characteristic angle, RCA=+60 degrees in a solidly grounded network

Example 3

The "Phase angle" mode is selected, isolated network (φRCA = -90 deg)

=> *Characteristic angle* = -90 deg

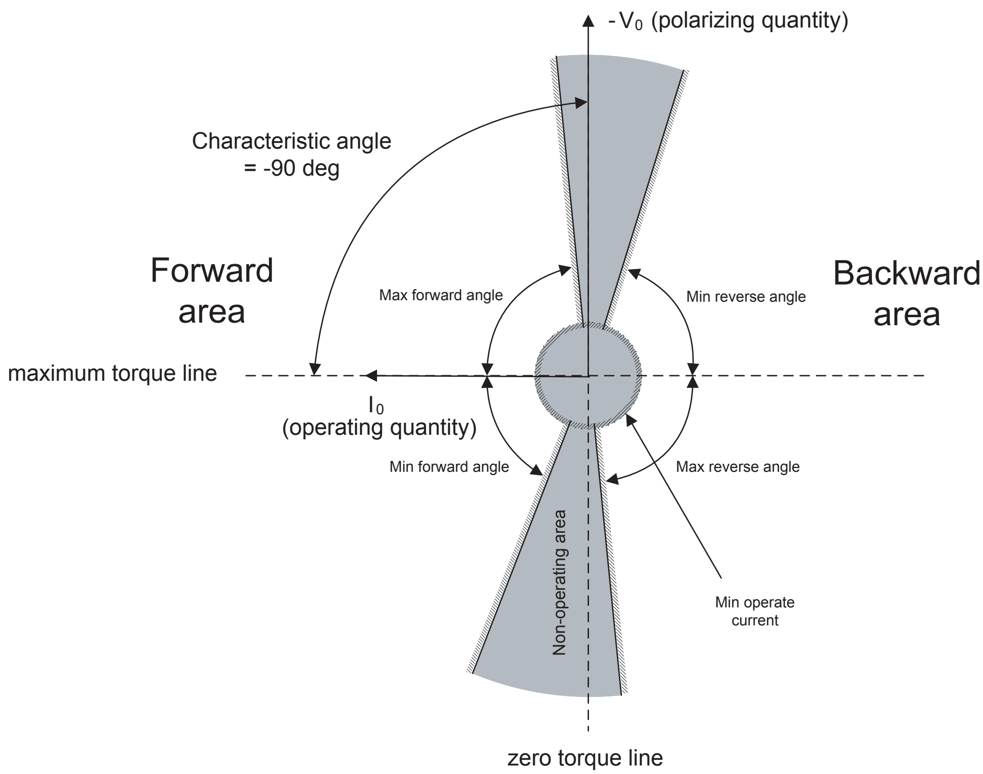


Figure 84: Definition of the relay characteristic angle, RCA=–90 degrees in an isolated network

Directional ground-fault protection in an isolated neutral network

In isolated networks, there is no intentional connection between the system neutral point and ground. The only connection is through the line-to-ground capacitances (C_0) of phases and leakage resistances (R_0). This means that the zero-sequence current is mainly capacitive and has a phase shift of -90 degrees compared to the residual voltage ($-V_0$). Consequently, the relay characteristic angle (RCA) should be set to -90 degrees and the operation criteria to "IoSin" or "Phase angle". The width of the operating sector in the phase angle criteria can be selected with the settings *Min forward angle*, *Max forward angle*, *Min reverse angle* or *Max reverse angle*. Figure 85 describes how the ground-fault current is defined in isolated neutral networks.

For definitions of different directional ground-fault characteristics, see Directional ground-fault principles.

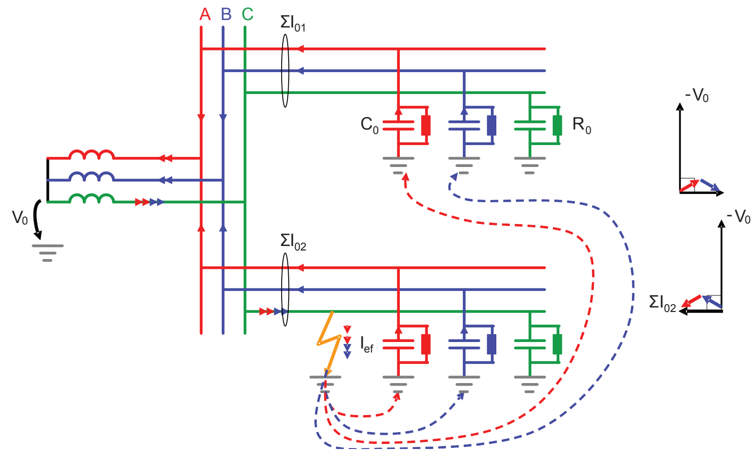


Figure 85: Ground-fault situation in an isolated network

Directional ground-fault protection in a compensated network

In compensated networks, the capacitive fault current and the inductive resonance coil current compensate each other. The protection cannot be based on the reactive current measurement, since the current of the compensation coil would disturb the operation of the protection relays. In this case, the selectivity is based on the measurement of the active current component. The magnitude of this component is often small and must be increased by means of a parallel resistor in the compensation equipment. When measuring the resistive part of the zero-sequence current, the relay characteristic angle (RCA) should be set to 0 degrees and the operation criteria to $I_0\cos(\varphi)$ or phase angle.

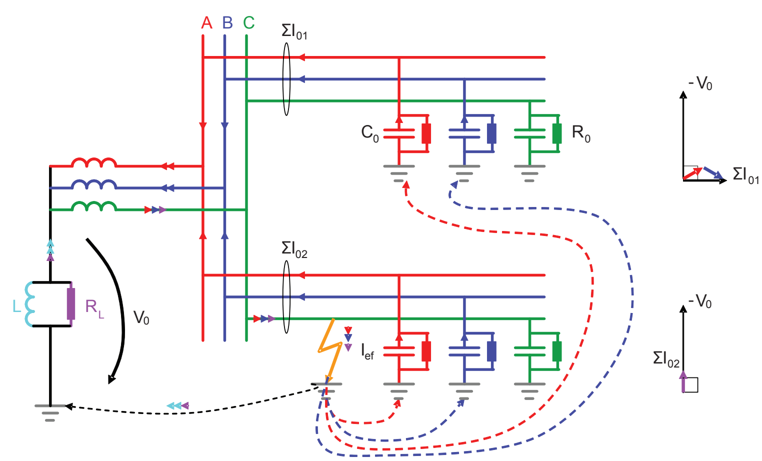


Figure 86: Ground-fault situation in a compensated network

The Petersen coil or the grounding resistor may be temporarily out of operation. To keep the protection scheme selective, it is necessary to update the *Characteristic angle* setting accordingly. This is done with an auxiliary input in the protection relay which receives a signal from an auxiliary switch of the disconnector of the Petersen coil in compensated networks or of the grounding resistor in grounded networks. As a result, the characteristic angle is set automatically to suit the grounding method used. The RCA_CTL input can be used to change the Io characteristic:

Table 134: Relay characteristic angle control in Iosin(φ) and Iocos(φ) operation criteria

Operation mode setting:	RCA_CTL = FALSE	RCA_CTL = TRUE
Iosin	Actual operation mode: Iosin	Actual operation mode: Iocos
Iocos	Actual operation mode: Iocos	Actual operation mode: Iosin

Table 135: Characteristic angle control in phase angle operation mode

Characteristic angle setting	RCA_CTL = FALSE	RCA_CTL = TRUE
-90°	φ_{RCA} = -90°	φ_{RCA} = 0°
0°	φ_{RCA} = 0°	φ_{RCA} = -90°

Use of the extended phase angle characteristic

In addition to the RCA_CTL input, the extended phase angle characteristic can be used when the compensation coil is temporarily disconnected in compensated networks. When the extended operation area is used, the operation area is wide enough to detect ground faults selectively in compensated networks regardless of whether the compensation coil is connected or not. Therefore, the RCA_CTL input is not required if the extended operation area is used.

Sometimes the distance between the start point and the protection relay is long, which makes it impractical to apply the scheme based on signal wiring between the protection relay and the Petersen coil or the grounding resistor. This is the case when, for example, a directional ground-fault protection relay is used in an MV-switching substation some kilometers from the HV/MV-substation where the grounding facilities are located. Another example is when HV/MV-substations are connected in parallel but located far from each other.

It is easy to give the tripping sector such a width that all possible directions of the I_0-phasors of a faulty line are covered by one and the same sector. Thus, the problem of setting the characteristic angle according to the grounding status of the network is easily solved. There is no need to change any settings when a Petersen coil or a grounding resistor is switched on or off. Auxiliary switches and other pieces of extra hardware are no longer required for ensuring the selectivity of the directional ground-fault protection.

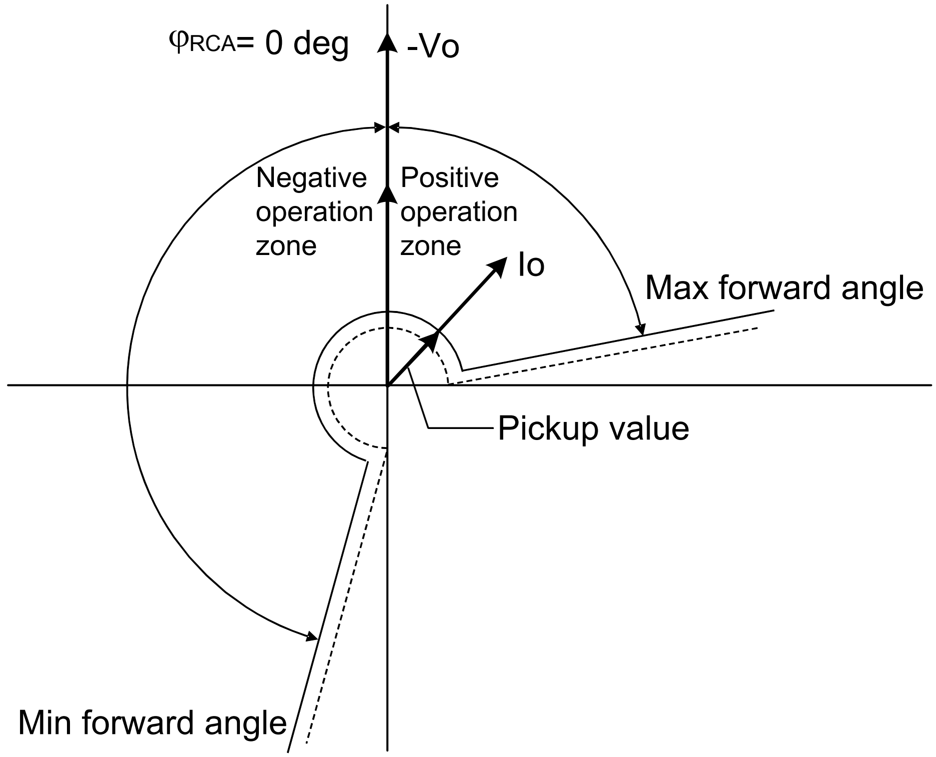


Figure 87: Extended operation area in directional ground-fault protection

4.1.5.6 Measurement modes

The function operates on three alternative measurement modes: "RMS", "DFT" and "Peak-to-Peak". The measurement mode is selected with the *Measurement mode* setting.

Table 136: Measurement modes supported by 67/51N and 67/50N stages

Measurement mode	67/51N	67/50N-1 and 67/50N-2
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

For a detailed description of the measurement modes, see the Measurement modes section in this manual.

4.1.5.7 Timer characteristics

67/51N and 67/50N supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* setting.

The protection relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The following characteristics, which comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages.

Table 137: Timer characteristics supported by different stages

Operating curve type	67/51N	67/50N-1 and 67/50N-2
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	
(10) IEC Very Inverse	x	
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable curve	x	x
(18) RI type	x	
(19) RD type	x	

For a detailed description of the timers, see the General function block features section in this manual.

Table 138: Reset time characteristics supported by different stages

Reset curve type	67/51N	67/50N-1 and 67/50N-2	Note
(1) Immediate	x	x	Available for all operate time curves
(2) Def time reset	x	x	Available for all operate time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

4.1.5.8 Directional ground-fault characteristics

Phase angle characteristic

The operation criterion phase angle is selected with the *Operation mode* setting using the value "Phase angle".

When the phase angle criterion is used, the function indicates with the `DIRECTION` output whether the operating quantity is within the forward or reverse operation sector or within the non-directional sector.

The forward and reverse sectors are defined separately. The forward operation area is limited with the *Min forward angle* and *Max forward angle* settings. The reverse operation area is limited with the *Min reverse angle* and *Max reverse angle* settings.

The sector limits are always given as positive degree values.

In the forward operation area, the *Max forward angle* setting gives the clockwise sector and the *Min forward angle* setting correspondingly the counterclockwise sector, measured from the *Characteristic angle* setting.

In the reverse operation area, the *Max reverse angle* setting gives the clockwise sector and the *Min reverse angle* setting correspondingly the counterclockwise sector, measured from the complement of the *Characteristic angle* setting (180 degrees phase shift) .

The relay characteristic angle (RCA) is set to positive if the operating current lags the polarizing quantity. It is set to negative if it leads the polarizing quantity.

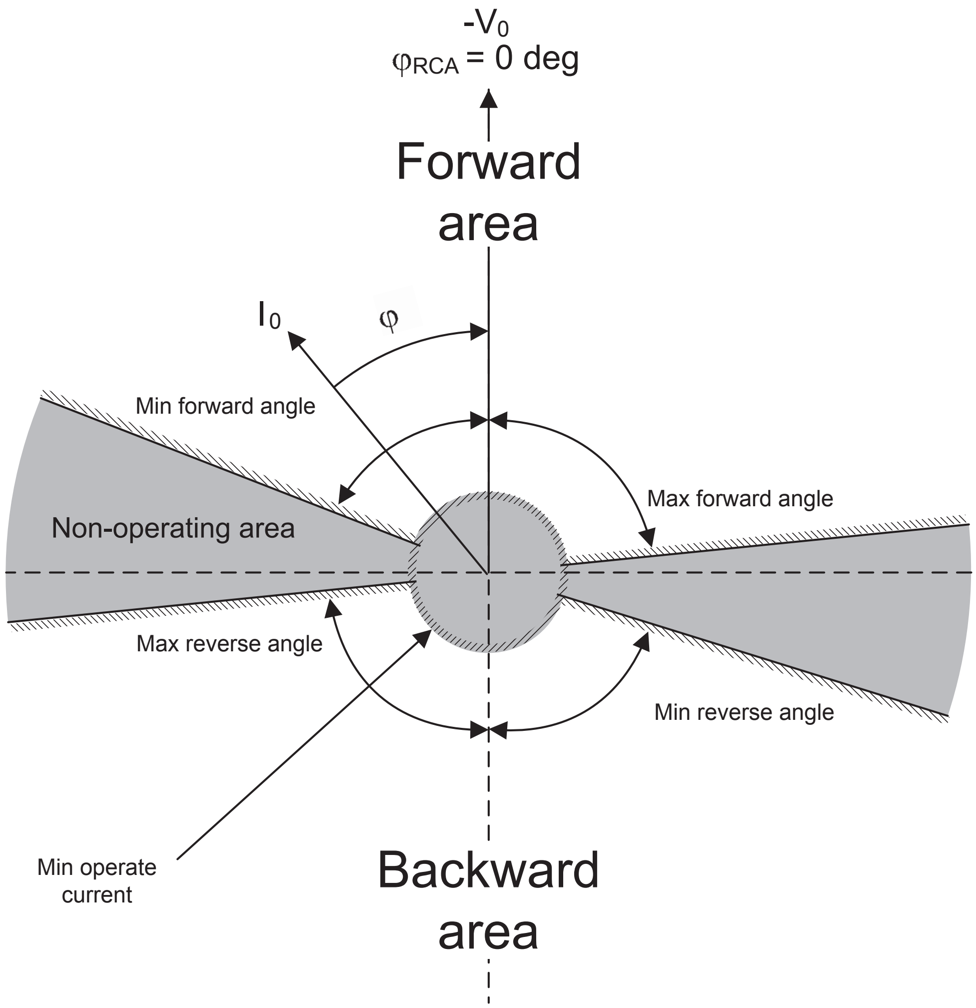


Figure 88: Configurable operating sectors in phase angle characteristic

Table 139: Momentary operating direction

Fault direction	The value for DIRECTION
Angle between the polarizing and operating quantity is not in any of the defined sectors.	0 = unknown
Angle between the polarizing and operating quantity is in the forward sector.	1= forward
Angle between the polarizing and operating quantity is in the reverse sector.	2 = backward
Angle between the polarizing and operating quantity is in both the forward and the reverse sectors, that is, the sectors are overlapping.	3 = both

Directional operation is not allowed (the setting *Allow Non Dir* is "False") when the measured polarizing or operating quantities are not valid, that is, their magnitude is below the set minimum values. The minimum values can be defined with the settings *Min trip current* and *Min trip voltage*. In case of low magnitudes, the FAULT_DIR and DIRECTION outputs are set to 0 = unknown, except when the *Allow non dir* setting is "True". In that case, the function is allowed to operate in the directional mode as non-directional, since the directional information is invalid.

The RCA_CTL input is used in compensated networks where the compensation coil sometimes can be disconnected. When the coil is disconnected, the compensated network becomes isolated and the *Characteristic angle* setting (φRCA) must be changed. This can be done automatically with the RCA_CTL input. Note that the RCA_CTL input only works when the *Characteristic angle* setting is set to exactly -90 degrees or 0 degrees. The value of the input affects the *Characteristic angle* setting in the following way:

Table 140: Characteristic angle control in phase angle operation mode

Characteristic angle setting	**RCA_CTL** = "False"	**RCA_CTL** = "True"
-90°	φRCA = -90°	φRCA = 0°
0°	φRCA = 0°	φRCA = -90°

Iosin(φ) and Iocos(φ) criteria

A more modern approach to directional protection is the active or reactive current measurement. The operating characteristic of the directional operation depends on the grounding principle of the network. The I_0sin(φ) characteristics is used in an isolated network, measuring the reactive component of the fault current caused by the ground capacitance. The I_0cos(φ) characteristics is used in a compensated network, measuring the active component of the fault current.

The operation criteria Iosin(φ) and Iocos(φ) are selected with the *Operation mode* setting using the values "IoSin" or "IoCos" respectively.

In isolated networks, I_0sin(φ) does not differ from the phase angle criterion, since the phase angle of the operating quantity is fairly close to -90 degrees. Furthermore, in completely compensated networks the fault current is usually mostly resistive. Therefore, the phase angle and I_0cos(φ) criteria are equally sensitive. However, if the fault is in the background network, the fault current of a sound and healthy line is almost fully capacitive and its phase angle is close to the operation area of the component. Therefore, the I_0cos(φ) characteristic is recommended, since the risk of faulty operation is smaller than with the phase angle criterion.

The angle correction setting can be used to improve selectivity. The setting decreases the operation sector. The correction can only be used with the Iosin(φ) or Iocos(φ) criterion. The RCA_CTL input is used to change the IG characteristic:

Table 141: *Relay characteristic angle control in the IoSin and IoCos operation criteria*

Operation mode:	RCA_CTL = "False"	RCA_CTL = "True"
IoSin	Actual operation criterion: Iosin(φ)	Actual operation criterion: Iocos(φ)
IoCos	Actual operation criterion: Iocos(φ)	Actual operation criterion: Iosin(φ)

When the Iosin(φ) or Iocos(φ) criterion is used, the component indicates a forward- or reverse-type fault through the FAULT_DIR and DIRECTION outputs, in which 1 equals a forward fault and 2 equals a reverse fault. Directional operation is not allowed (the *Allow non dir* setting is "False") when the measured polarizing or operating quantities are not valid, that is, when their magnitude is below the set minimum values. The minimum values can be defined with the *Min trip current* and *Min trip voltage* settings. In case of low magnitude, the FAULT_DIR and DIRECTION outputs are set to 0 = unknown, except when the *Allow non dir* setting is "True". In that case, the function is allowed to operate in the directional mode as non-directional, since the directional information is invalid.

The calculated Iosin(φ) or Iocos(φ) current used in direction determination can be read through the I_OPER monitored data. The value can be passed directly to a decisive element, which provides the final pickup and trip signals.

The I_OPER monitored data gives an absolute value of the calculated current.

The following examples show the characteristics of the different operation criteria:

Example 1.

Iosin(φ) criterion selected, forward-type fault

=> FAULT_DIR = 1

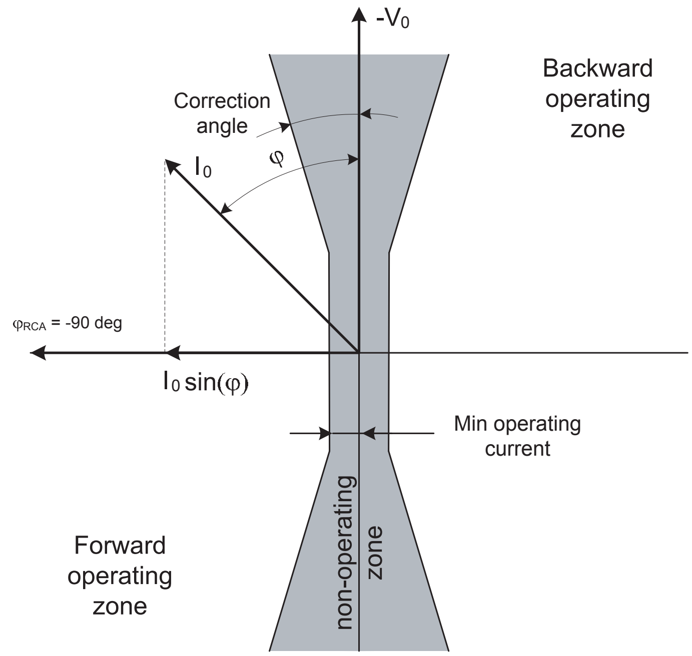


Figure 89: Operating characteristic I_0sin(φ) in forward fault

The operating sector is limited by angle correction, that is, the operating sector is 180 degrees - 2*(angle correction).

Example 2.

Iosin(φ) criterion selected, reverse-type fault

```
=> FAULT_DIR = 2
```

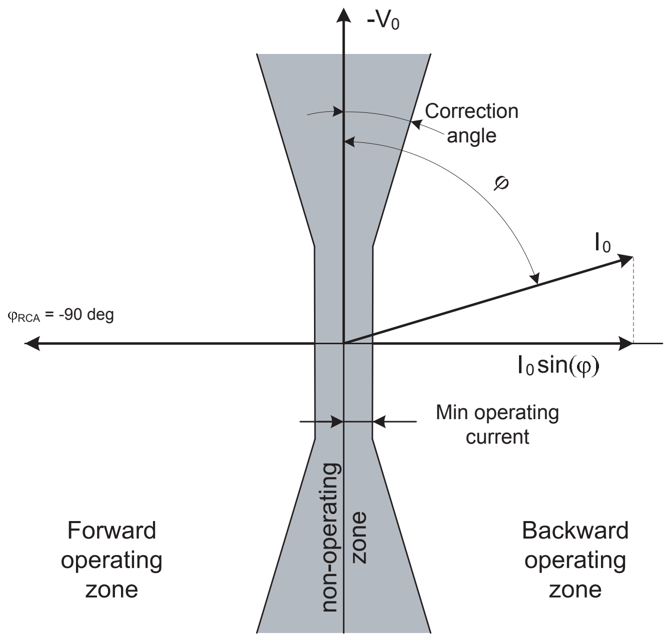


Figure 90: Operating characteristic $I_0 sin(\varphi)$ in reverse fault

Example 3.

Iocos(φ) criterion selected, forward-type fault

```
=> FAULT_DIR = 1
```

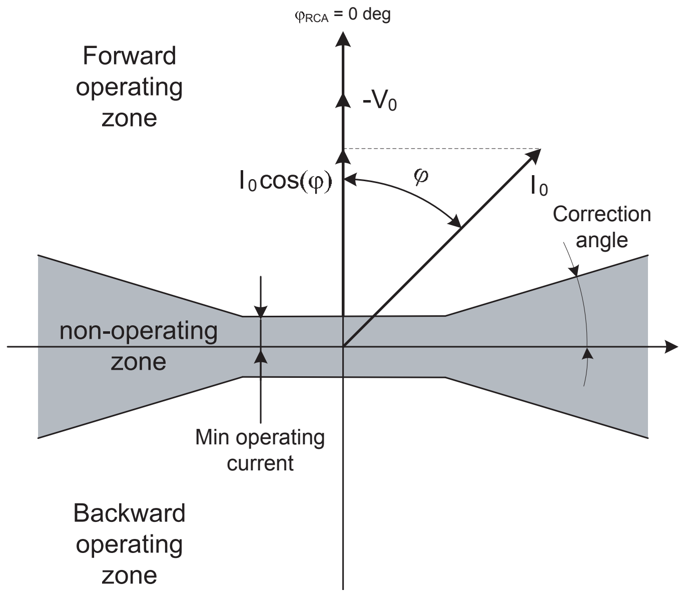


Figure 91: Operating characteristic I_0cos(φ) in forward fault

Example 4.

Iocos(φ) criterion selected, reverse-type fault

`=> FAULT_DIR = 2`

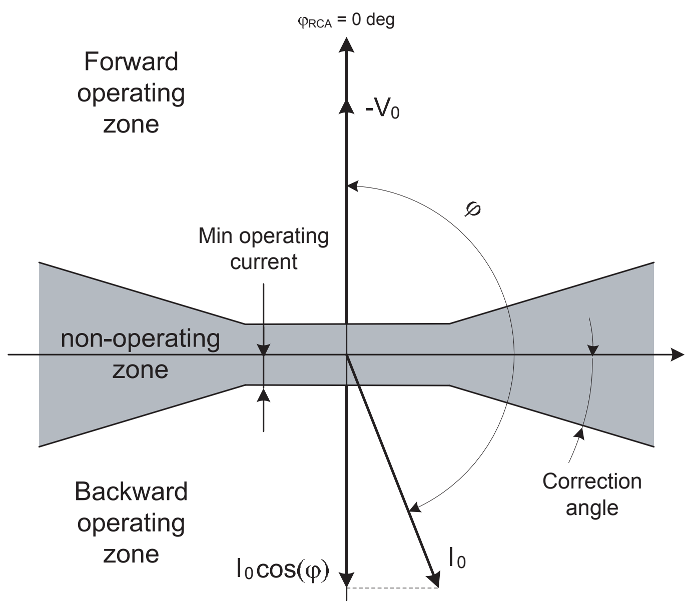


Figure 92: Operating characteristic I_0cos(φ) in reverse fault

Phase angle 80

The operation criterion phase angle 80 is selected with the *Operation mode* setting by using the value "Phase angle 80".

Phase angle 80 implements the same functionality as the phase angle but with the following differences:

- The *Max forward angle* and *Max reverse angle* settings cannot be set but they have a fixed value of 80 degrees
- The sector limits of the fixed sectors are rounded.

The sector rounding is used for cancelling the CT measurement errors at low current amplitudes. When the current amplitude falls below three percent of the nominal current, the sector is reduced to 70 degrees at the fixed sector side. This makes the protection more selective, which means that the phase angle measurement errors do not cause faulty operation.

There is no sector rounding on the other side of the sector.

If the current amplitude falls below one percent of the nominal current, the direction enters the non-directional area.

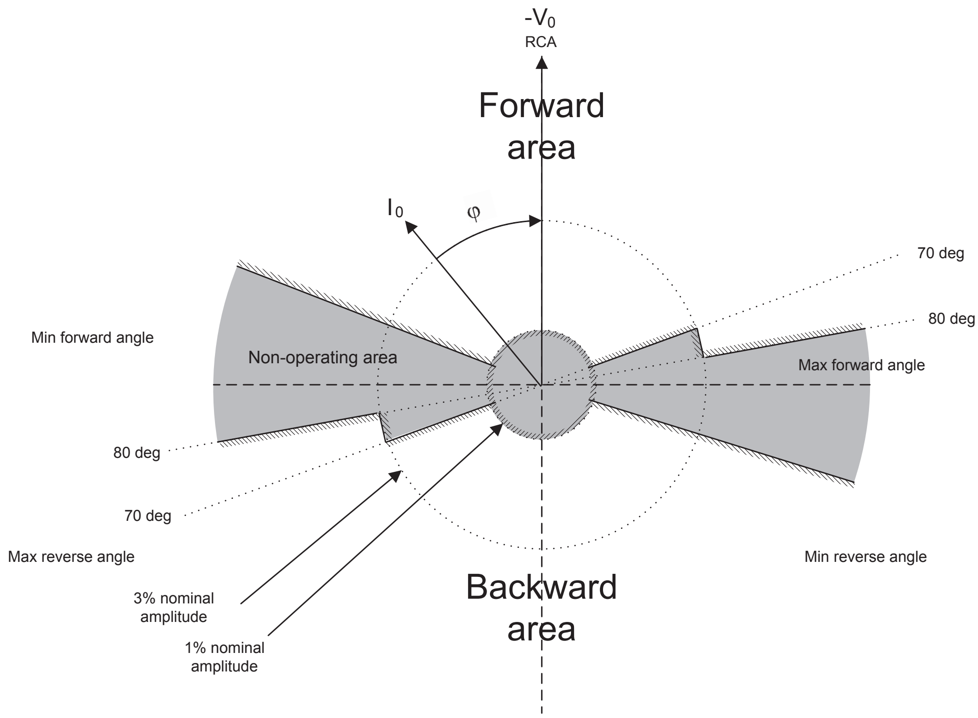


Figure 93: Operating characteristic for phase angle classic 80

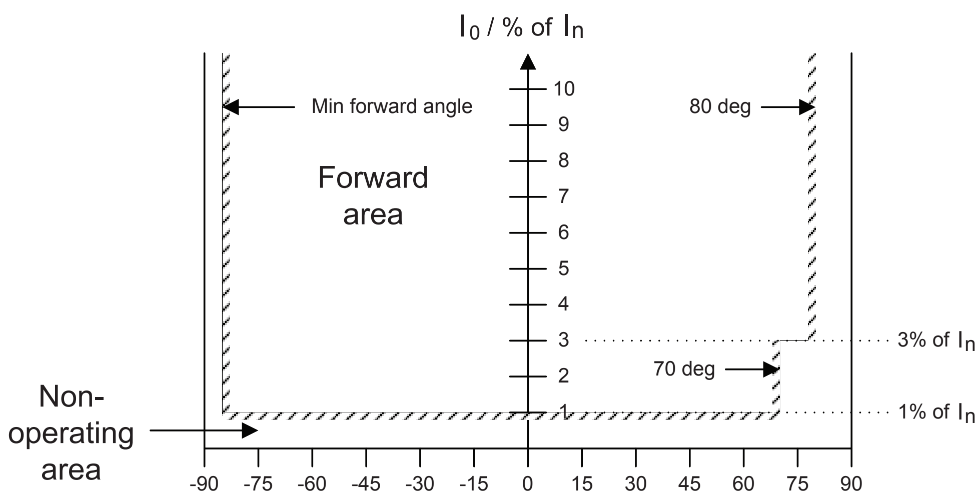


Figure 94: Phase angle classic 80 amplitude

Phase angle 88

The operation criterion phase angle 88 is selected with the *Operation mode* setting using the value "Phase angle 88".

Phase angle 88 implements the same functionality as the phase angle but with the following differences:

- The *Max forward angle* and *Max reverse angle* settings cannot be set but they have a fixed value of 88 degrees
- The sector limits of the fixed sectors are rounded.

Sector rounding in the phase angle 88 consists of three parts:

- If the current amplitude is between 1...20 percent of the nominal current, the sector limit increases linearly from 73 degrees to 85 degrees
- If the current amplitude is between 20...100 percent of the nominal current, the sector limit increases linearly from 85 degrees to 88 degrees
- If the current amplitude is more than 100 percent of the nominal current, the sector limit is 88 degrees.

There is no sector rounding on the other side of the sector.

If the current amplitude falls below one percent of the nominal current, the direction enters the non-directional area.

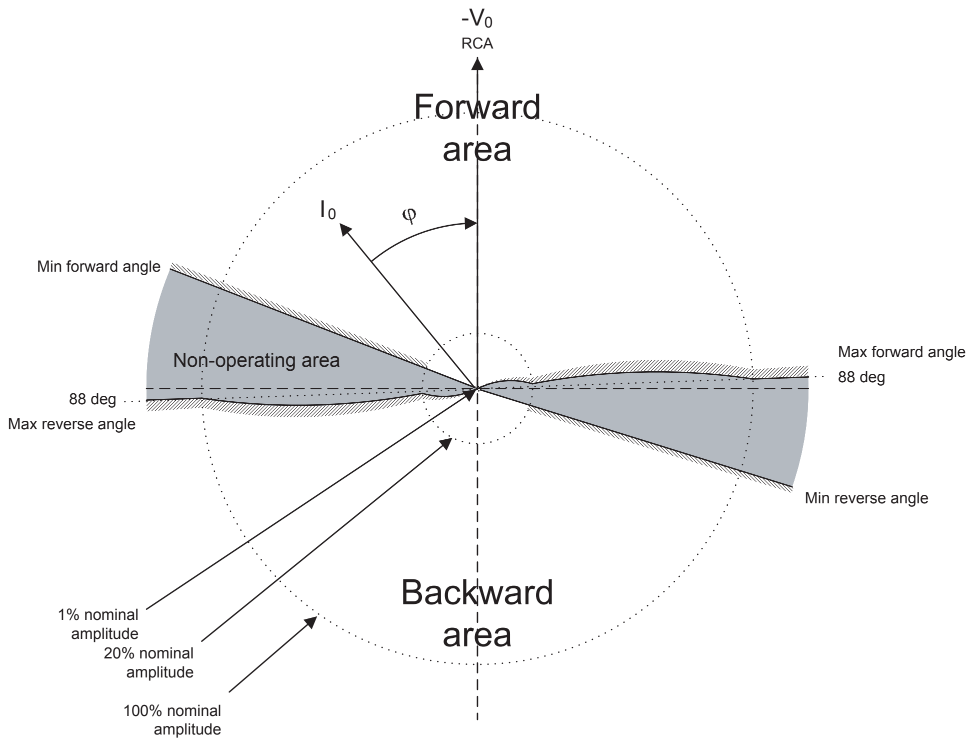


Figure 95: Operating characteristic for phase angle classic 88

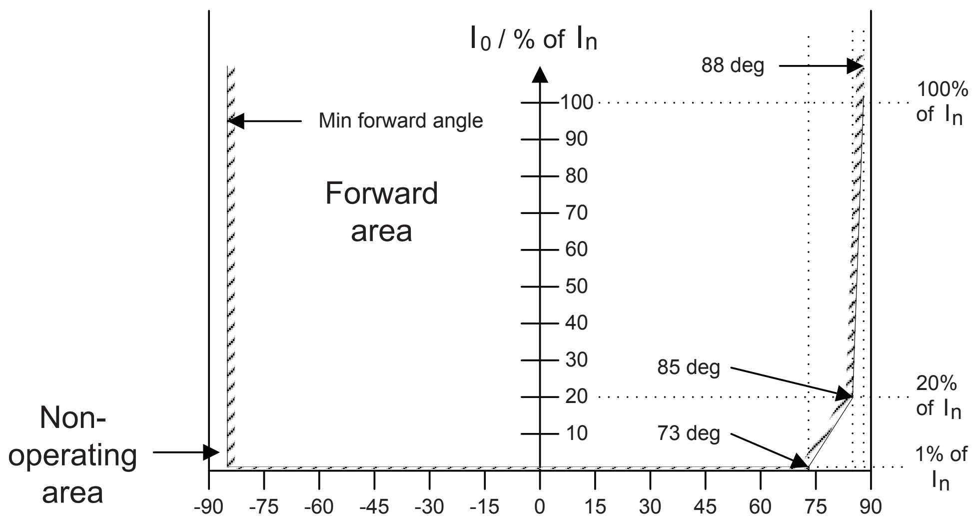


Figure 96: Phase angle classic 88 amplitude

4.1.5.9 Application

The directional earth-fault protection 67/51N and 67/50N is designed for protection and clearance of ground faults and for ground-fault protection of different equipment connected to the power systems, such as shunt capacitor banks or shunt reactors, and for backup ground-fault protection of power transformers.

Many applications require several steps using different current pickup levels and time delays. 67/51N and 67/50N consist of two different stages.

- Low 67/51N
- High 67/50N-1 and 67/50N-2

67/51N contains several types of time delay characteristics. 67/50N-1 and 67/50N-2 is used for fast clearance of serious ground faults.

The protection can be based on the phase angle criterion with extended operating sector. It can also be based on measuring either the reactive part $I_0\sin(\varphi)$ or the active part $I_0\cos(\varphi)$ of the zero sequence current. In isolated networks or in networks with high impedance grounding, the phase-to-ground fault current is significantly smaller than the short-circuit currents. In addition, the magnitude of the fault current is almost independent of the fault location in the network.

The function uses the zero sequence current components $I_0\cos(\varphi)$ or $I_0\sin(\varphi)$ according to the grounding method, where φ is the angle between the zero sequence current and the reference zero sequence voltage ($-V_0$). In compensated networks, the phase angle criterion with extended operating sector can also be used. When the relay characteristic angle RCA is 0 degrees, the negative quadrant of the operation sector can be extended with the *Min forward angle* setting. The operation sector can be set between 0 and -180 degrees, so that the total operation sector is from +90 to -180 degrees. In other words, the sector can be up to 270 degrees wide. This allows the protection settings to stay the same when the resonance coil is disconnected from between the neutral point and ground.

System neutral grounding is meant to protect personnel and equipment and to reduce interference for example in telecommunication systems. The neutral grounding sets challenges for protection systems, especially for ground-fault protection.

In isolated networks, there is no intentional connection between the system neutral point and ground. The only connection is through the line-to-ground capacitances (C_0) of phases and leakage resistances (R_0). This means that the zero sequence current is mainly capacitive and has -90 degrees phase shift compared to the zero sequence voltage ($-V_0$). The characteristic angle is -90 degrees.

In resonance-grounded networks, the capacitive fault current and the inductive resonance coil current compensate each other. The protection cannot be based on the reactive current measurement, since the current of the compensation coil would disturb the operation of the relays. In this case, the selectivity is based on the measurement of the active current component. This means that the zero sequence current is mainly resistive and has zero phase shift compared to the zero sequence voltage ($-V_0$) and the characteristic angle is 0 degrees. Often the magnitude of this component is small, and must be increased by means of a parallel resistor in the compensation equipment.

In networks where the neutral point is grounded through low resistance, the characteristic angle is also 0 degrees (for phase angle). Alternatively, Iocos(φ) operation can be used.

In solidly grounded networks, the *Characteristic angle* is typically set to +60 degrees for the phase angle. Alternatively, Iosin(φ) operation can be used with a reversal polarizing quantity. The polarizing quantity can be rotated 180 degrees by setting the *Pol reversal* parameter to "True" or by switching the polarity of the zero sequence voltage measurement wires. Although the I_0sin(φ) operation can be used in solidly grounded networks, the phase angle is recommended. In some applications, negative sequence polarization is preferred over zero sequence polarization. The protection relay also offers negative sequence polarization option where users can set the angle between V_2 and I_2 based on their application and practice.

Connection of measuring transformers in directional ground fault applications

The zero sequence current I_0 can be measured with a core balance current transformer or the residual connection of the phase current signals. If the neutral of the network is either isolated or grounded with high impedance, a core balance current transformer is recommended to be used in ground-fault protection. To ensure sufficient accuracy of zero sequence current measurements and consequently the selectivity of the scheme, the core balance current transformers should have a transformation ratio of at least 70:1. Lower transformation ratios such as 50:1 or 50:5 are not recommended.

Attention should be paid to make sure the measuring transformers are connected correctly so that 67/51N and 67/50N is able to detect the fault current direction without failure. As directional ground fault uses zero sequence current and zero sequence voltage ($-V_0$), the polarities of the measuring transformers must match each other and also the fault current direction. Also the grounding of the cable sheath must be taken into consideration when using core balance current transformers. The following figure describes how measuring transformers can be connected to the protection relay.

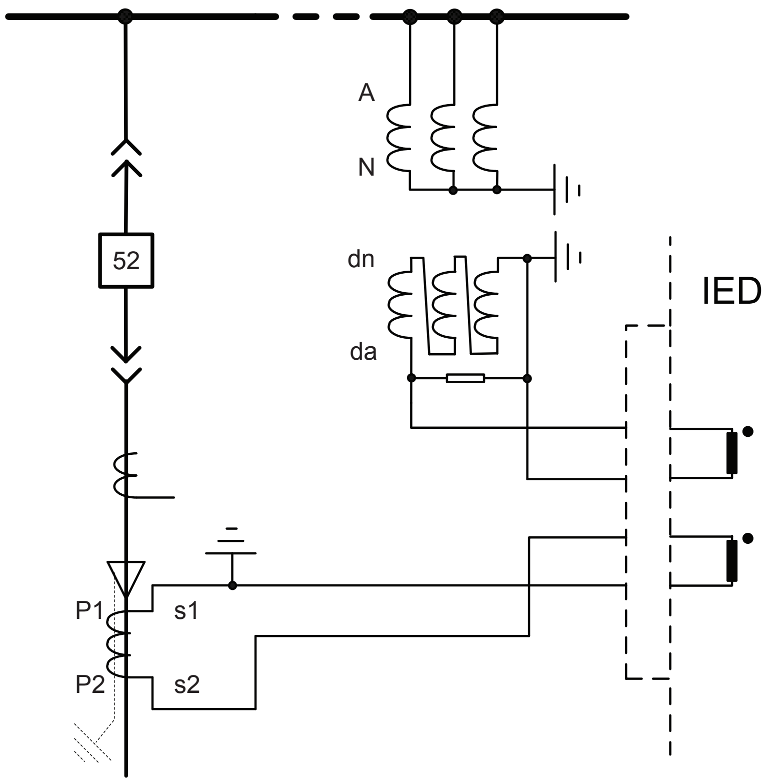


Figure 97: Connection of measuring transformers

4.1.5.10 Signals

Table 142: 67/51N Input signals

Name	Type	Default	Description
I0 or IG or I2	SIGNAL	0	Zero Sequence current / Negative sequence current
V0 or VG or V2	SIGNAL	0	Zero Sequence voltage / Negative sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
RCA_CTL	BOOLEAN	0=False	Relay characteristic angle control

Table 143: 67/50N Input signals

Name	Type	Default	Description
I0 or IG or I2	SIGNAL	0	Zero Sequence current / Negative sequence current
V0 or VG or V2	SIGNAL	0	Zero Sequence voltage / Negative sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
RCA_CTL	BOOLEAN	0=False	Relay characteristic angle control

Table 144: 67/51N Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 145: 67/50N Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.5.11 Settings

Table 146: 67/51N Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...5.000	xIn	0.005	0.010	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	60...200000	ms	10	60	Trip delay time
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	80	Minimum phase angle in reverse direction
Voltage pickup value	0.010...1.000	xUn	0.001	0.010	Voltage pickup value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 147: 67/51N Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum trip time	60...60000	ms	1	60	Minimum trip time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Min trip current	0.005...1.000	xIn	0.001	0.005	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.01	Minimum trip voltage
Correction angle	0.0...10.0	deg	0.1	0.0	Angle correction
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
IG/I0 signal Sel	1=Measured IG 2=Calculated I0			1=Measured IG	Measured IG or calculated I0
Pol signal Sel	1=Measured VG 2=Calculated V0 3=Neg. seq. volt.			1=Measured VG	Selection for used polarization signal

Table 148: 67/50N Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 15=IEC DT 17=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	40...200000	ms	10	40	Trip delay time
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Max forward angle	0...180	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	80	Minimum phase angle in reverse direction
Voltage pickup value	0.010...1.000	xUn	0.001	0.010	Voltage pickup value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 149: 67/50N Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum trip time	40...60000	ms	1	40	Minimum trip time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min trip current	0.005...1.000	xIn	0.001	0.005	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.01	Minimum trip voltage
Correction angle	0.0...10.0	deg	0.1	0.0	Angle correction
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
IG/I0 signal Sel	1=Measured IG 2=Calculated I0			1=Measured IG	Measured IG or calculated I0
Pol signal Sel	1=Measured VG 2=Calculated V0 3=Neg. seq. volt.			1=Measured VG	Selection for used polarization signal

4.1.5.12 Monitored data

Table 150: 67/51N Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
I_OPER	FLOAT32	0.00...40.00		Calculated operating current
67/51N	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Table 151: 67/50N Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
I_OPER	FLOAT32	0.00...40.00		Calculated operating current
67/50N	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.1.5.13 Technical data

Table 152: 67/51N and 67/50N Technical data

<table>
<tr><th colspan="2">Characteristic</th><th colspan="3">Value</th></tr>
<tr><td rowspan="3">Operation accuracy</td><td rowspan="2">67/51N</td><td colspan="3">Depending on the frequency of the measured current: f_n ±2 Hz</td></tr>
<tr><td colspan="3">Current:
±1.5% of the set value or ±0.002 × I_n
Voltage
±1.5% of the set value or ±0.002 × V_n
Phase angle:
±2°</td></tr>
<tr><td>67/50N-1 and 67/50N-2</td><td colspan="3">Current:
±1.5% of the set value or ±0.002 × I_n
(at currents in the range of 0.1…10 × I_n)
±5.0% of the set value
(at currents in the range of 10…40 × I_n)
Voltage:
±1.5% of the set value or ±0.002 × V_n
Phase angle:
±2°</td></tr>
<tr><td rowspan="2">Pickup time 1)2)</td><td rowspan="2">67/50N-2 and 67/51N and 67/50N-1:
I_{Fault} = 2 × set Pickup value</td><td>Minimum</td><td>Typical</td><td>Maximum</td></tr>
<tr><td>62 ms</td><td>65 ms</td><td>69 ms</td></tr>
<tr><td colspan="2">Reset time</td><td colspan="3"><40 ms</td></tr>
<tr><td colspan="2">Reset ratio</td><td colspan="3">Typically 0.96</td></tr>
<tr><td colspan="2">Retardation time</td><td colspan="3"><30 ms</td></tr>
<tr><td colspan="2">Trip time accuracy in definite time mode</td><td colspan="3">±1.0% of the set value or ±20 ms</td></tr>
<tr><td colspan="2">Trip time accuracy in inverse time mode</td><td colspan="3">±5.0% of the theoretical value or ±20 ms 3)</td></tr>
<tr><td colspan="2">Suppression of harmonics</td><td colspan="3">RMS: No suppression
DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…
Peak-to-Peak: No suppression</td></tr>
</table>

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 × I_n, f_n = 60 Hz, ground-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 2.5 × I_n, *Pickup value* multiples in range of 1.5...20

4.1.6 Sensitive earth-fault protection 50SEF

4.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional sensitive earth-fault protection	EFLPTOC	Io>	50SEF

4.1.6.2 Function block

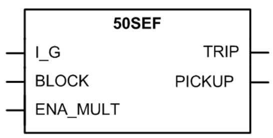


Figure 98: Function block

4.1.6.3 Functionality

A small percentage of the ground faults have very large impedance. It is possible to detect these faults by using a very sensitive earth-fault protection. It is applicable for networks where normal unbalance current level is low enough to allow for sensitive setting of 50SEF.

The function also contains a blocking functionality. It is possible to block function outputs.

4.1.6.4 Operation principle

See function 51N.

4.1.6.5 Measurement modes

See function 51N.

4.1.6.6 Timer characteristics

See function 51N.

4.1.6.7 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. 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. If the natural unbalance in the system is low, the sensitive earth-fault protection can be used to detect the ground fault.

4.1.6.8 Signals

See function 51N.

4.1.6.9 Settings

See function 51N.

4.1.6.10 Monitored data

See function 51N.

4.1.6.11 Technical data

See function 50N.

4.1.7 Negative-sequence overcurrent protection 46

4.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative-sequence overcurrent protection	NSPTOC	I2>	46

4.1.7.2 Function block

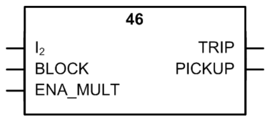


Figure 99: Function block

4.1.7.3 Functionality

The negative-sequence overcurrent protection function 46 is used for increasing sensitivity to detect single-phase and phase-to-phase faults or unbalanced loads due to, for example, broken conductors or unsymmetrical feeder voltages.

46 can also be used for detecting broken conductors.

The function is based on the measurement of the negative sequence current. In a fault situation, the function picks up when the negative sequence current exceeds the set limit. The trip time characteristics can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). In the DT mode, the function trips after a predefined trip time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

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

4.1.7.4 Operation principle

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

The operation of 46 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

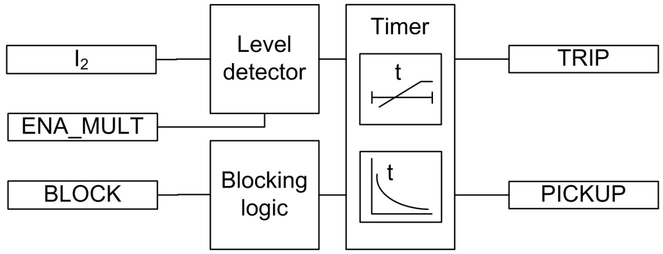


Figure 100: Functional module diagram

Level detector

The measured negative sequence current is compared to the set *Pickup value*. If the measured value exceeds the set *Pickup value*, the level detector activates the timer module. If the ENA_MULT input is active, the set *Pickup value* is multiplied by the set *Pickup value Mult*.

Do not set the multiplier setting *Pickup value Mult* higher than necessary. If the value is too high, the function may not trip at all during an inrush followed by a fault, no matter how severe the fault is.

Timer

Once activated, the timer activates the PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve, the TRIP output is activated.

When the user-programmable IDMT curve is selected, the operation time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT trip and reset times.

The setting parameter *Minimum trip time* defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.1.7.5 Application

Since the negative sequence current quantities are not present during normal, balanced load conditions, the negative sequence overcurrent protection elements can be set for faster and more sensitive operation than the normal phase-overcurrent protection for fault conditions occurring between two phases. The negative sequence overcurrent protection also provides a back-up protection functionality for the feeder ground-fault protection in solid and low resistance grounded networks.

The negative sequence overcurrent protection provides the back-up ground-fault protection on the high voltage side of a delta-wye connected power transformer for ground faults taking place on the wye-connected low voltage side. If a ground fault occurs on the wye-connected side of the power transformer, negative sequence current quantities appear on the delta-connected side of the power transformer.

Probably the most common application for the negative sequence overcurrent protection is rotating machines, where negative sequence current quantities indicate unbalanced loading conditions (unsymmetrical voltages). Unbalanced loading normally causes extensive heating of the machine and can result in severe damage even over a relatively short time period.

Multiple time curves and time multiplier settings are also available for coordinating with other devices in the system.

4.1.7.6 Signals

Table 153: 46 Input signals

Name	Type	Default	Description
I_2	SIGNAL	0	Negative phase sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 154: 46 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.7.7 Settings

Table 155: 46 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.01...5.00	xIn	0.01	0.30	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 156: 46 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Minimum trip time	20...60000	ms	1	20	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

4.1.7.8 Monitored data

Table 157: 46 Monitored data

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

4.1.7.9 Technical data

Table 158: 46 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × I_n		
Pickup time 1)2)		Minimum	Typical	Maximum
	I_{Fault} = 2 × set *Pickup value* I_{Fault} = 10 × set *Pickup value*	22 ms 14 ms	25 ms 17 ms	27 ms 19 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms 3)		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) Negative sequence current before fault = 0.0, f_n = 60 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 2.5 × I_n, *Pickup value* multiples in range of 1.5...20

4.1.8 Phase discontinuity protection 46PD

4.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase discontinuity protection	PDNSPTOC	I2/I1>	46PD

4.1.8.2 Function block

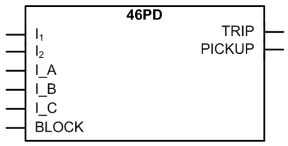


Figure 101: Function block

4.1.8.3 Functionality

The phase discontinuity protection function 46PD is used for detecting unbalance situations caused by broken conductors.

The function picks up and trips when the unbalance current I_2/I_1 exceeds the set limit. To prevent faulty operation at least one phase current needs to be above the minimum level. 46PD trips with DT characteristic.

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

4.1.8.4 Operation principle

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

The operation of 46PD can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

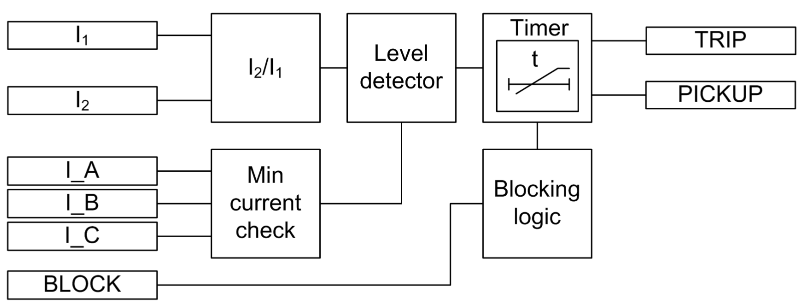


Figure 102: Functional module diagram

I_2/I_1

The I_2/I_1 module calculates the ratio of the negative and positive sequence current. It reports the calculated value to the level detector.

Level detector

The level detector compares the calculated ratio of the negative and positive-sequence currents to the set *Pickup value*. If the calculated value exceeds the set *Pickup value* and the min current check module has exceeded the value of *Min phase current*, the level detector reports the exceeding of the value to the timer.

Min current check

The min current check module checks whether the measured phase currents are above the set *Min phase current*. At least one of the phase currents needs to be above the set limit to enable the level detector module.

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 fault 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.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the `TRIP` output is not deactivated when blocking is activated. 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.

4.1.8.5 Application

In three-phase distribution and subtransmission network applications the phase discontinuity in one phase can cause an increase of zero-sequence voltage and short overvoltage peaks and also oscillation in the corresponding phase.

46PD is a three-phase protection with DT characteristic, designed for detecting broken conductors in distribution and subtransmission networks. The function is applicable for both overhead lines and underground cables.

The operation of 46PD is based on the ratio of positive-sequence and negative-sequence currents. This gives better sensitivity and stability compared to plain negative-sequence current protection since the calculated ratio of positive-sequence and negative-sequence currents is relatively constant during load variations.

The unbalance of the network is detected by monitoring the negative-sequence and positive-sequence current ratio, where the negative-sequence current value is I_2 and I_1 is the positive-sequence current value. The unbalance is calculated with the equation.

$$Iratio = \frac{I_2}{I_1}$$

(Equation 2)

Broken conductor fault situation can occur in phase A in a feeder.

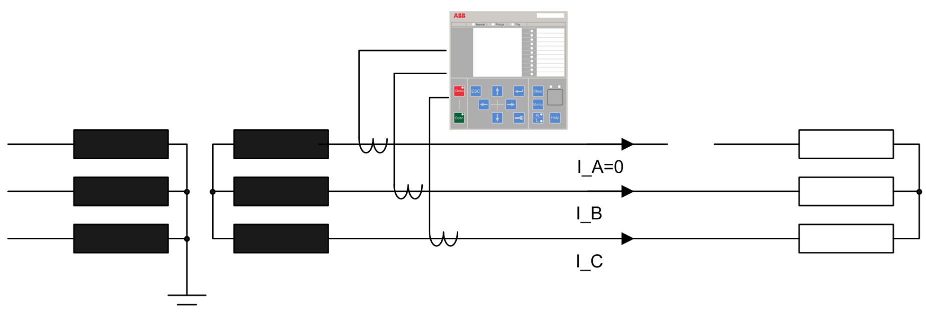


Figure 103: Broken conductor fault in phase A in a distribution or subtransmission feeder

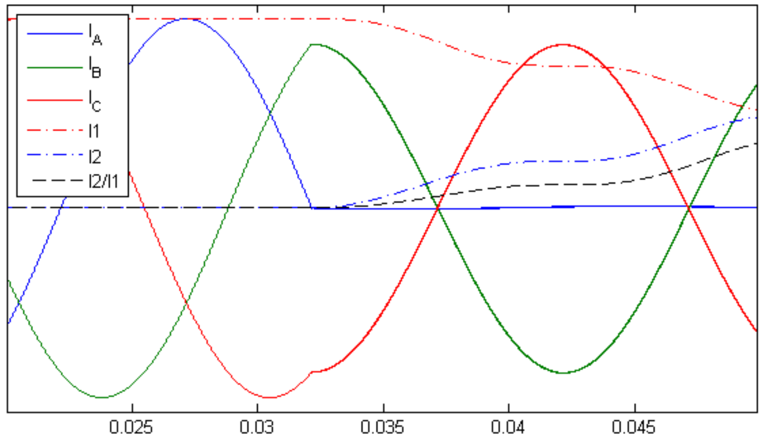


Figure 104: Three-phase current quantities during the broken conductor fault in phase A with the ratio of negative-sequence and positive-sequence currents

4.1.8.6 Signals

Table 159: 46PD Input signals

Name	Type	Default	Description
I_1	SIGNAL	0	Positive sequence current
I_2	SIGNAL	0	Negative sequence current
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

Table 160: 46PD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.8.7 Settings

Table 161: 46PD Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	10...100	%	1	10	Pickup value
Trip delay time	100...30000	ms	1	100	Trip delay time

Table 162: 46PD Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Min phase current	0.05...0.30	xIn	0.01	0.10	Minimum phase current

4.1.8.8 Monitored data

Table 163: 46PD Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
RATIO_I2_I1	FLOAT32	0.00...999.99	%	Measured current ratio I2 / I1
46PD	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.1.8.9 Technical data

Table 164: 46PD Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±2% of the set value
Pickup time	<70 ms
Reset time	<40 ms
Reset ratio	Typically 0.96
Retardation time	<35 ms
Trip time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…

4.1.9 Loss of phase 37

4.1.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loss of phase	PHPTUC	3I<	37

4.1.9.2 Function block

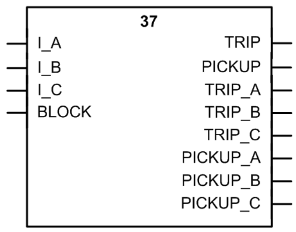


Figure 105: Function block

4.1.9.3 Functionality

The loss of phase function 37 is used to detect an undercurrent that is considered as a fault condition.

37 picks up when the current is less than the set limit. Operation time characteristics are according to definite time (DT).

The function contains a blocking functionality. It is possible to block function outputs and reset the definite timer if desired.

4.1.9.4 Operation principle

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

The operation of 37 can be described with a module diagram. All the modules in the diagram are explained in the next sections.

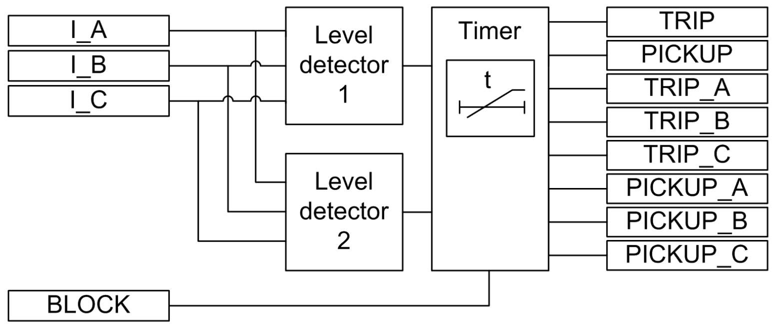


Figure 106: Functional module diagram

Level detector 1

This module compares the phase currents (RMS value) to the *Pickup value* setting. The *Operation mode* setting can be used to select the "Three Phase" or "Single Phase" mode.

If in the "Three Phase" mode all the phase current values are less than the value of the *Pickup value* setting, the condition is detected and an enabling signal is sent to the timer. This signal is disabled after one or several phase currents have exceeded the set *Pickup value* value of the element.

If in the "Single Phase" mode any of the phase current values are less than the value of the *Pickup value* setting, the condition is detected and an enabling signal is sent to the timer. This signal is disabled after all the phase currents have exceeded the set *Pickup value* value of the element.

The protection relay does not accept the *Pickup value* to be smaller than *Current block value*.

Level detector 2

This is a low-current detection module that monitors the de-energized condition of the protected object. The module compares the phase currents (RMS value) to the *Current block value* setting. If all the phase current values are less than the *Current block value* setting, a signal is sent to block the operation of the timer.

Timer

Once activated, the timer activates the `PICKUP` output and the phase-specific `PICKUP_X` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Trip delay time*, the `TRIP` output and the phase-specific `TRIP_X` output are activated. If the fault 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 percentage ratio of the pickup situation and the set trip time. The value is available through the monitored data view.

The BLOCK signal blocks the operation of the function and resets the timer.

4.1.9.5 Application

In some cases, smaller distribution power transformers are used where the high-side protection involves only power fuses. When one of the high-side fuses blows in a single-phase condition, knowledge of it on the secondary side is lacking. The resulting negative-sequence current leads to a premature failure due to excessive heating and breakdown of the transformer insulation. Knowledge of this condition when it occurs allows for a quick fuse replacement and saves the asset.

The *Current block value* setting can be set to zero to not block 37 with a low three-phase current. However, this results in an unnecessary event sending when the transformer or protected object is disconnected.

Phase-specific pickup and trip can give a better picture about the evolving faults when one phase has picked up first and another follows.

37 is meant to be a general protection function, so that it could be used in other cases too.

In case of undercurrent-based motor protection, see the Loss of load protection.

4.1.9.6 Signals

Table 165: 37 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase Bcurrent
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block all binary outputs by resetting timers

Table 166: 37 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
TRIP_A	BOOLEAN	Trip phase A
TRIP_B	BOOLEAN	Trip phase B
TRIP_C	BOOLEAN	Trip phase C
PICKUP	BOOLEAN	Pickup
PICKUP_A	BOOLEAN	Pickup phase A
PICKUP_B	BOOLEAN	Pickup phase B
PICKUP_C	BOOLEAN	Pickup phase C

4.1.9.7 Settings

Table 167: 37 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Current block value	0.00...0.50	xIn	0.01	0.10	Low current setting to block internally
Pickup value	0.01...1.00	xIn	0.01	0.50	Current setting to pickup
Trip delay time	50...200000	ms	10	2000	Trip delay time

Table 168: 37 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Operation mode	1=Three Phase 2=Single Phase			1=Three Phase	Number of phases needed to pickup
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.9.8 Monitored data

Table 169: 37 Monitored data

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

4.1.9.9 Technical data

Table 170: 37 Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × I_n
Pickup time	Typically <55 ms
Reset time	<40 ms
Reset ratio	Typically 1.04
Retardation time	<35 ms
Trip time accuracy in definite time mode	mode ±1.0% of the set value or ±20 ms

4.2 Voltage protection

4.2.1 Three-phase overvoltage protection 59

4.2.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase overvoltage protection	PHPTOV	3U>	59

4.2.1.2 Function block

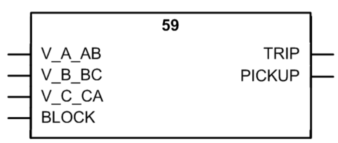


Figure 107: Function block

4.2.1.3 Functionality

The three-phase overvoltage protection function 59 is applied on power system elements, such as generators, transformers, motors and power lines, to protect the system from excessive voltages that could damage the insulation and cause insulation breakdown. The three-phase overvoltage function includes a settable value for the detection of overvoltage either in a single phase, two phases or three phases.

59 includes both definite time (DT) and inverse definite minimum time (IDMT) characteristics for the delay of the trip.

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

4.2.1.4 Operation principle

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

The operation of 59 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

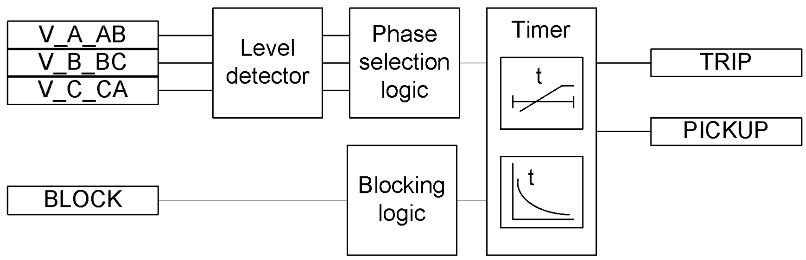


Figure 108: Functional module diagram

Level detector

The fundamental frequency component of the measured three-phase voltages are compared phase-wise to the set value of the *Pickup value* setting. If the measured value is higher than the set value of the *Pickup value* setting, the level detector enables the phase selection logic module. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly differs from the *Pickup value* setting. After leaving the hysteresis area, the pickup condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

The *Voltage selection* setting is used for selecting phase-to-ground or phase-to-phase voltages for protection.

For the voltage IDMT operation mode, the used IDMT curve equations contain discontinuity characteristics. The *Curve Sat relative* setting is used for preventing undesired operation.

For a more detailed description of the IDMT curves and the use of the *Curve Sat Relative* setting, see the IDMT curve saturation of the over voltage protection section in this manual.

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases match with the set *Num of pickup phases*, the phase selection logic activates the Timer.

Timer

Once activated, the Timer activates the `PICKUP` output. Depending on the value of the set *Operating curve type*, the time characteristics are selected according to DT or IDMT.

For a detailed description of the voltage IDMT curves, see the IDMT curves for overvoltage protection section in this manual.

When the operation timer has reached the value set by *Trip delay time* in the DT mode or the maximum value defined by the IDMT, the `TRIP` output is activated.

When the user-programmable IDMT curve is selected, the trip time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation occurs, that is, a fault suddenly disappears before the trip delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected trip time characteristics. If the DT characteristics are selected, the reset timer runs until the set *Reset delay time* value is exceeded. If the drop-off situation exceeds the set *Reset delay time*, the Timer is reset and the `PICKUP` output is deactivated.

When the IDMT operate time curve is selected, the functionality of the Timer in the drop-off state depends on the combination of the *Type of reset curve* and *Reset delay time* settings.

Table 171: The reset time functionality when the IDMT trip time curve is selected

Type of reset curve	Description of operation
“Immediate”	The trip timer is reset instantaneously when drop-off occurs.
“Def time reset”	The trip timer is frozen during drop-off. The trip timer is reset after the set *Reset delay time* is exceeded.
“DT Lin decr rst”	The trip timer value linearly decreases during the drop-off situation. The trip timer is reset after the set *Reset delay time* is exceeded.

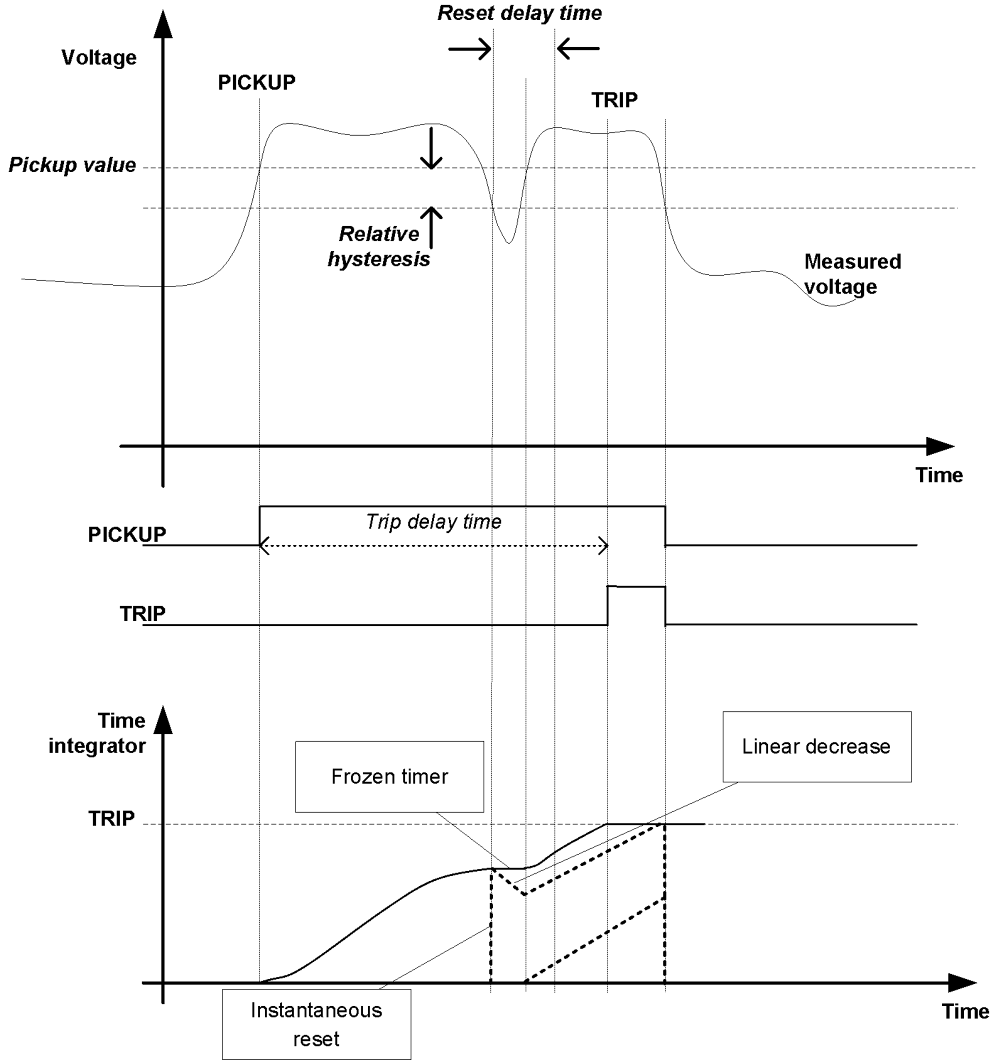


Figure 109: Behavior of different IDMT reset modes. The value for Type of reset curve is "Def time reset". Also other reset modes are presented for the time integrator.

The *Time multiplier* setting is used for scaling the IDMT trip times.

The *Minimum trip time* setting parameter defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overvoltage protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's program. The influence of the BLOCK input signal activation is preselected with the global *Blocking mode* setting.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operation timer is frozen to the prevailing value, but the TRIP is blocked and the Timers are reset. 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.

The “Freeze timers” mode of blocking has no effect during the inverse reset mode.

4.2.1.5 Timer characteristics

The operating curve types supported by 59 are:

Table 172: Timer characteristics supported by IDMT operate curve types

Operating curve type
(5) ANSI Def. Time
(15) IEC Def. Time
(17) Inv. Curve A
(18) Inv. Curve B
(19) Inv. Curve C
(20) Programmable

4.2.1.6 Application

Overvoltage in a network occurs either due to the transient surges on the network or due to prolonged power frequency overvoltages. Surge arresters are used to protect the network against the transient overvoltages, but the relay's protection function is used to protect against power frequency overvoltages.

The power frequency overvoltage may occur in the network due to contingencies such as:

- The defective operation of the automatic voltage regulator when the generator is in isolated operation.
- Operation under manual control with the voltage regulator out of service. A sudden variation of load, in particular the reactive power component, gives rise to a substantial change in voltage because of the inherent large voltage regulation of a typical alternator.
- Sudden loss of load due to the tripping of outgoing feeders, leaving the generator isolated or feeding a very small load. This causes a sudden rise in the terminal voltage due to the trapped field flux and overspeed.

If a load sensitive to overvoltage remains connected, it leads to equipment damage.

It is essential to provide power frequency overvoltage protection, in the form of time delayed element, either IDMT or DT to prevent equipment damage.

4.2.1.7 Signals

Table 173: 59-1/2 Input signals

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 activating the blocking mode

Table 174: 59-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.2.1.8 Settings

Table 175: 59-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...1.60	xUn	0.01	1.10	Pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...300000	ms	10	40	Trip delay time
Operating curve type	5=ANSI DT 15=IEC DT 17=Inv. Curve A 18=Inv. Curve B 19=Inv. Curve C 20=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 176: 59-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	40...60000	ms	1	40	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.2.1.9 Monitored data

Table 177: 59-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
59-1/2	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.2.1.10 Technical data

Table 178: 59 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × V_n		
Pickup time[1)2)]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 × set *Pickup value*	23 ms	27 ms	30 ms
Reset time		<40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Pickup value* = 1.0 × V_n, Voltage before fault = 0.9 × V_n, f_n = 60 Hz, overvoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Pickup value* = 1.20 × V_n, *Pickup value* multiples in range of 1.10...2.00

4.2.2 Three-phase undervoltage protection 27

4.2.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase undervoltage protection	PHPTUV	3U<	27

4.2.2.2 Function block

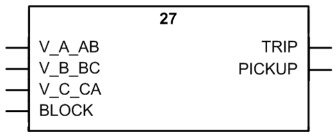


Figure 110: Function block

4.2.2.3 Functionality

The three-phase undervoltage protection function 27 is used to disconnect from the network devices, for example electric motors, which are damaged when subjected to service under low voltage conditions. 27 includes a settable value for the detection of undervoltage either in a single phase, two phases or three phases.

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

4.2.2.4 Operation principle

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

The operation of 27 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

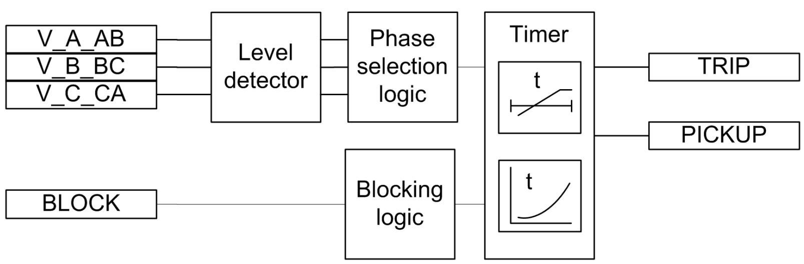


Figure 111: Functional module diagram

Level detector

The fundamental frequency component of the measured three phase voltages are compared phase-wise to the set *Pickup value*. If the measured value is lower than the set value of the *Pickup value* setting, the level detector enables the phase selection logic module. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly varies above or below the *Pickup value* setting.

After leaving the hysteresis area, the pickup condition has to be fulfilled again and it is not sufficient for the signal to only return back to the hysteresis area.

The *Voltage selection* setting is used for selecting the phase-to-ground or phase-to-phase voltages for protection.

For the voltage IDMT mode of operation, the used IDMT curve equations contain discontinuity characteristics. The *Curve Sat relative* setting is used for preventing unwanted operation.

For more detailed description on IDMT curves and usage of *Curve Sat Relative* setting, see the IDMT curves for under voltage protection section in this manual.

The level detector contains a low-level blocking functionality for cases where one of the measured voltages is below the desired level. This feature is useful when unnecessary pickups and trips are wanted to avoid during, for example, an autoreclose sequence. The low-level blocking is activated by default (*Enable block value* is set to "True") and the blocking level can be set with the *Voltage block value* setting.

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases match with the set *Num of pickup phases*, the phase selection logic activates the Timer.

Timer

Once activated, the Timer activates the `PICKUP` output. Depending on the value of the set *Operating curve type*, the time characteristics are selected according to DT or IDMT.

For a detailed description of the voltage IDMT curves, see the IDMT curves for under voltage protection section in this manual.

When the operation timer has reached the value set by *Trip delay time* in the DT mode or the maximum value defined by the IDMT, the `TRIP` output is activated.

When the user-programmable IDMT curve is selected, the trip time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation occurs, that is, a fault suddenly disappears before the trip delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected trip time characteristics. If the DT characteristics are selected, the reset timer runs until the set *Reset delay time* value is exceeded. If the drop-off situation exceeds the set *Reset delay time*, the Timer is reset and the `PICKUP` output is deactivated.

When the IDMT trip time curve is selected, the functionality of the Timer in the drop-off state depends on the combination of the *Type of reset curve* and *Reset delay time* settings.

Table 179: The reset time functionality when the IDMT trip time curve is selected

Type of reset curve	Description of operation
"Immediate"	The trip timer is reset instantaneously when drop-off occurs
"Def time reset"	The trip timer is frozen during drop-off. The trip timer is reset after the set *Reset delay time* is exceeded
"DT Lin decr rst"	The trip timer value linearly decreases during the drop-off situation. The trip timer is reset after the set *Reset delay time* is exceeded

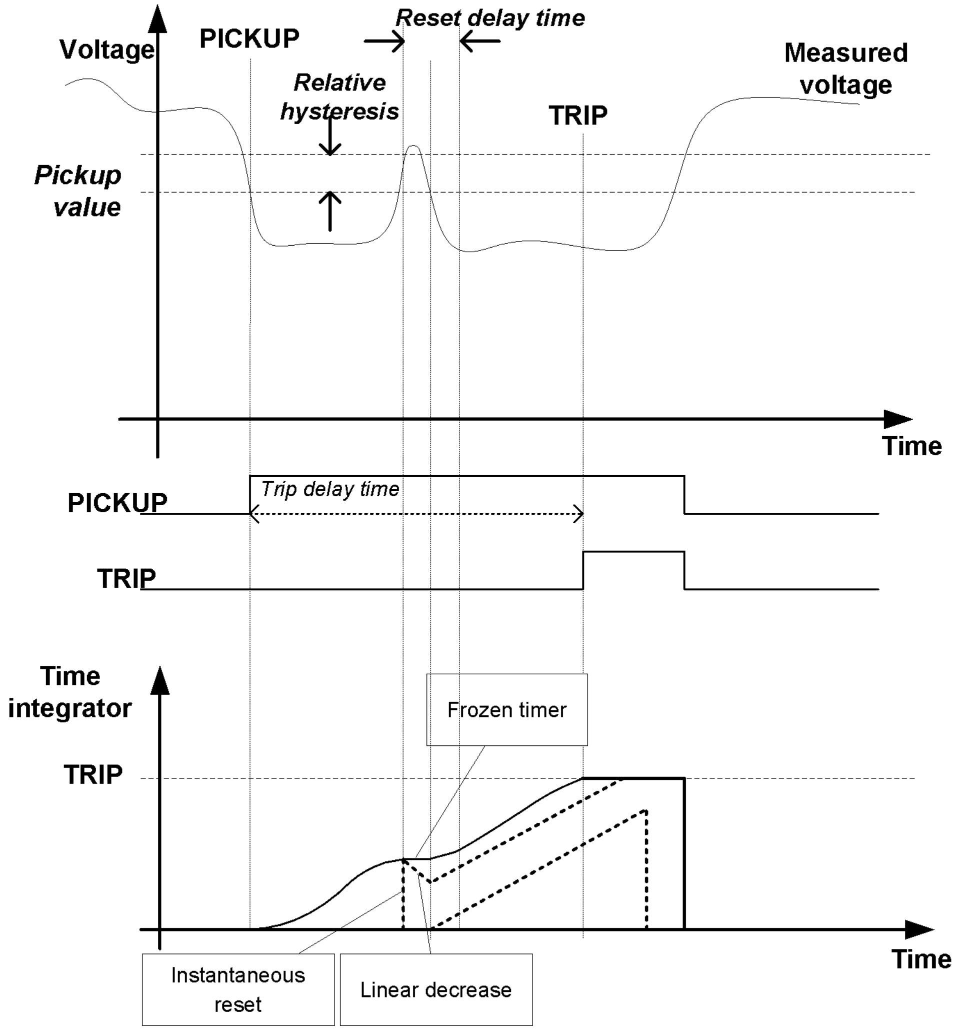


Figure 112: Behavior of different IDMT reset modes. The value for Type of reset curve is "Def time reset". Also other reset modes are presented for the time integrator.

The *Time multiplier* setting is used for scaling the IDMT trip times.

The *Minimum trip time* setting parameter defines the minimum desired trip time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum trip time* setting should be used with care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum trip time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

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

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's program. The influence of the `BLOCK` input signal activation is preselected with the global *Blocking mode* setting.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operation timer is frozen to the prevailing value, but the `TRIP` output is not deactivated when blocking is activated. 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.

The “Freeze timers” mode of blocking has no effect during the “Inverse reset” mode.

4.2.2.5 Timer characteristics

The operating curve types supported by 27 are:

Table 180: Supported IDMT operate curve types

Operating curve type
(5) ANSI Def. Time
(15) IEC Def. Time
(21) Inv. Curve A
(22) Inv. Curve B
(23) Programmable

4.2.2.6 Application

27 is applied to power system elements, such as generators, transformers, motors and power lines, to detect low voltage conditions. Low voltage conditions are caused by abnormal operation or a fault in the power system. 27 can be used in combination with overcurrent protections. Other applications are the detection of a no-voltage condition, for example before the energization of a high voltage line, or an automatic breaker trip in case

of a blackout. 27 is also used to initiate voltage correction measures, such as insertion of shunt capacitor banks, to compensate for a reactive load and thereby to increase the voltage.

27 can be used to disconnect from the network devices, such as electric motors, which are damaged when subjected to service under low voltage conditions. 27 deals with low voltage conditions at power system frequency. Low voltage conditions can be caused by:

- Malfunctioning of a voltage regulator or incorrect settings under manual control (symmetrical voltage decrease)
- Overload (symmetrical voltage decrease)
- Short circuits, often as phase-to-ground faults (unsymmetrical voltage increase).

27 prevents sensitive equipment from running under conditions that could cause overheating and thus shorten their life time expectancy. In many cases, 27 is a useful function in circuits for local or remote automation processes in the power system.

4.2.2.7 Signals

Table 181: 27-1/2 Input signals

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 activating the blocking mode

Table 182: 27-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.2.2.8 Settings

Table 183: 27-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...1.20	xUn	0.01	0.90	Pickup value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	60...300000	ms	10	60	Trip delay time
Operating curve type	5=ANSI DT 15=IEC DT 21=Inv. Curve A 22=Inv. Curve B 23=Programmable			15=IEC DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 184: 27-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Num of pickup 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 for trip activation
Minimum trip time	60...60000	ms	1	60	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage block value	0.05...1.00	xUn	0.01	0.20	Low level blocking for undervoltage mode
Enable block value	0=False 1=True			1=True	Enable internal blocking
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.2.2.9 Monitored data

Table 185: 27-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
27-1/2	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.2.2.10 Technical data

Table 186: 27 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × V_n		
Pickup time[1)2)]		Minimum	Typical	Maximum
	V_{Fault} = 0.9 × set *Pickup value*	62 ms	66 ms	69 ms
Reset time		<40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Pickup value* = 1.0 × V_n, Voltage before fault = 1.1 × V_n, f_n = 60 Hz, undervoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Minimum *Pickup value* = 0.50, *Pickup value* multiples in range of 0.90...0.20

4.2.3 Residual overvoltage protection 59G/N

4.2.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual overvoltage protection	ROVPTOV	Uo>	59G/N

4.2.3.2 Function block

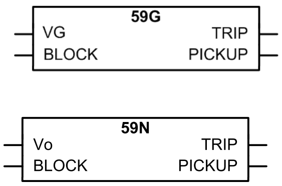


Figure 113: Function block

4.2.3.3 Functionality

The residual overvoltage protection function 59G/N is used in distribution networks where the ground overvoltage can reach non-acceptable levels in, for example, high impedance grounding.

The function picks up when the ground voltage exceeds the set limit. 59G/N operates with the definite time (DT) characteristic.

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

4.2.3.4 Operation principle

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

The operation of 59G/N can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

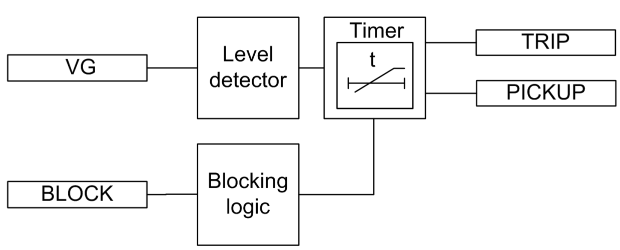


Figure 114: Functional module diagram

Level detector

The measured ground voltage is compared to the set *Pickup value*. If the value exceeds the set *Pickup value*, the level detector sends an enable signal to the timer.

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 fault 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.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.2.3.5 Application

59G is designed to be used for ground-fault protection in isolated neutral, resistance grounded or reactance grounded systems. In compensated networks, the pickup of the function can be used to control the switching device of the neutral resistor. The function can also be used for the back-up protection of feeders for busbar protection when a more dedicated busbar protection would not be justified.

In compensated and isolated neutral systems, the system neutral voltage, that is, the ground voltage, increases in case of any fault connected to ground. Depending on the type of the fault and the fault resistance, the ground voltage reaches different values. The highest ground voltage, equal to the phase-to-ground voltage, is achieved for a single-phase ground fault. The ground voltage increases approximately the same amount in the whole system and does not provide any guidance in finding the faulty component.

Therefore, this function is often used as a back-up protection or as a release signal for the feeder ground-fault protection.

The protection can also be used for the ground-fault protection of generators and motors and for the unbalance protection of capacitor banks.

The ground voltage can be calculated internally based on the measurement of the three-phase voltage. This voltage can also be measured by a single-phase voltage transformer, located between a transformer star point and ground, or by using an open-delta connection of three single-phase voltage transformers.

The function is typically designated as 59G when broken delta voltage from the VT is measured as 3V0 value on Sensor 9 or 10 input. Alternatively, it is designated as 59N when a calculated 3V0 value is used as input to the function based on calculated 3V0 from the three phase-ground voltage inputs.

When the input VT is V (open delta) connected, zero sequence voltage cannot be calculated and hence 59N function cannot be employed.

4.2.3.6 Signals

Table 187: 59G/N Input signals

Name	Type	Default	Description
VG	SIGNAL	0	Ground voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 188: 59G/N Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.2.3.7 Settings

Table 189: 59G/N Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...1.000	xUn	0.001	0.030	Pickup value
Trip delay time	40...300000	ms	1	40	Trip delay time

Table 190: 59G/N Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
VG/V0 Select	1=Measured VG 2=Calculated V0			1=Measured VG	Selection for used VG/V0 signal

4.2.3.8 Monitored data

Table 191: 59G/N Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
59G/N	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.2.3.9 Technical data

Table 192: 59G/N Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × V_n		
Pickup time1)2)		Minimum	Typical	Maximum
	V_{Fault} = 1.1 × set *Pickup value*	55 ms	57 ms	60 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) Ground voltage before fault = 0.0 × V_n, f_n = 60 Hz, ground voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.2.4 Negative-sequence overvoltage protection 47

4.2.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative-sequence overvoltage protection	NSPTOV	U2>	47

4.2.4.2 Function block

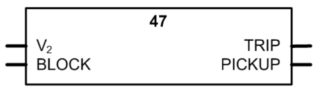


Figure 115: Function block

4.2.4.3 Functionality

The negative-sequence overvoltage protection function 47 is used to detect negative-sequence overvoltage conditions. 47 is used for the protection of machines.

he function picks up when the negative-sequence voltage exceeds the set limit. 47 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.

4.2.4.4 Operation principle

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

The operation of 47 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

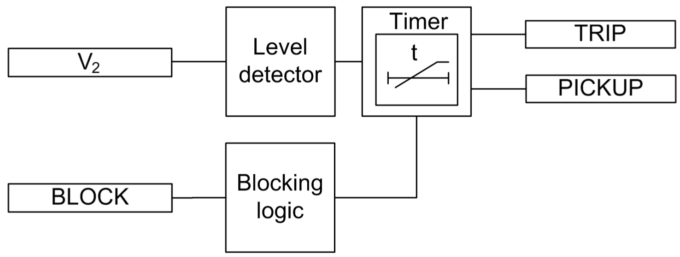


Figure 116: Functional module diagram

Level detector

The calculated negative-sequence voltage is compared to the set *Pickup value* setting. If the value exceeds the set *Pickup value*, the level detector enables the timer.

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 overvoltage condition persists. If the negative-sequence voltage normalizes 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.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the `TRIP` output is not deactivated when blocking is activated. 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.

4.2.4.5 Application

A continuous or temporary voltage unbalance can appear in the network for various reasons. The voltage unbalance mainly occurs due to broken conductors or asymmetrical loads and is characterized by the appearance of a negative-sequence component of the voltage. In rotating machines, the voltage unbalance results in a current unbalance, which heats the rotors of the machines. The rotating machines, therefore, do not tolerate a continuous negative-sequence voltage higher than typically 1-2 percent x V_n.

The negative-sequence component current I_2, drawn by an asynchronous or a synchronous machine, is linearly proportional to the negative-sequence component voltage V_2. When V_2 is P% of V_n, I_2 is typically about 5 x P% x I_n.

The negative-sequence overcurrent 46 blocks are used to accomplish a selective protection against the voltage and current unbalance for each machine separately. Alternatively, the protection can be implemented with the 47 function, monitoring the voltage unbalance of the busbar.

If the machines have an unbalance protection of their own, the 47 operation can be applied as a backup protection or it can be used as an alarm. The latter can be applied when it is not required to trip loads tolerating voltage unbalance better than the rotating machines.

If there is a considerable degree of voltage unbalance in the network, the rotating machines should not be connected to the network at all. This logic can be implemented by inhibiting the closure of the circuit breaker if the 47 operation has picked up. This scheme also prevents connecting the machine to the network if the phase sequence of the network is not correct.

An appropriate value for the setting parameter *Voltage pickup value* is approximately 3 percent of V_n. A suitable value for the setting parameter *Trip delay time* depends on the application. If the 47 operation is used as a backup protection, the trip time should be set in accordance with the trip time of 46 used as the main protection. If the 47 operation is used as the main protection, the trip time should be approximately one second.

4.2.4.6 Signals

Table 193: 47 Input signals

Name	Type	Default	Description
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 194: 47 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.2.4.7 Settings

Table 195: 47 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...1.000	xUn	0.001	0.030	Pickup value
Trip delay time	40...120000	ms	1	40	Trip delay time

Table 196: 47 Non group settings

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

4.2.4.8 Monitored data

Table 197: 47 Monitored data

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

4.2.4.9 Technical data

Table 198: 47 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × V_n		
Pickup time[1)2)]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 × set *Pickup value* V_{Fault} = 2.0 × set *Pickup value*	33 ms 25 ms	35 ms 27 ms	38 ms 30 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) Negative-sequence voltage before fault = 0.0 × V_n, f_n = 60 Hz, negative-sequence overvoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.2.5 Voltage per hertz protection 24

4.2.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage per hertz protection	OEPVPH	U/f>	24

4.2.5.2 Function block

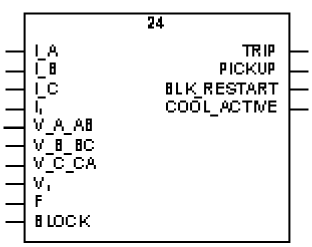


Figure 117: Function block

4.2.5.3 Functionality

The overexcitation protection function 24 is used to protect generators and power transformers against an excessive flux density and saturation of the magnetic core.

The function calculates the V/f ratio (volts/hertz) proportional to the excitation level of the generator or transformer and compares this value to the setting limit. The function picks up when the excitation level exceeds the set limit and trips when the set tripping time has elapsed. The tripping time characteristic can be selected to be either definite time (DT) or overexcitation inverse definite minimum time (overexcitation type IDMT).

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

4.2.5.4 Operation principle

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

The operation of 24 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

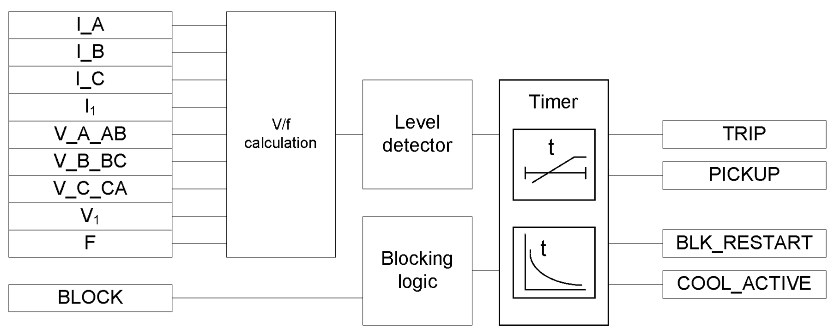


Figure 118: Functional module diagram

V/f calculation

This module calculates the V/f ratio, that is, the excitation level from the internal induced voltage (E) and frequency. The actual measured voltage (V_m) deviates from the internal induced voltage (emf) E, a value the equipment has to withstand. This voltage compensation is based on the load current (I_L) and the leakage reactance (X_{leak}) of the equipment. The leakage reactance of the transformer or generator is set through the *Leakage React* setting in percentage of the Z base.

The internal induced voltage (E) is calculated from the measured voltage. The settings *Voltage selection* and *Phase supervision* determine which voltages and currents are to be used. If the *Voltage selection* setting is set to "phase-to-ground" or "phase-to-phase", the *Phase supervision* setting is used for determining which phases or phase-to-phase voltages ("A or AB", "B or BC" and "C or CA") and currents are to be used for the calculation of the induced voltage.

Table 199: Voltages and currents used for induced voltage (emf) E calculation

Voltage selection setting	Phase supervision setting	Calculation of internal induced voltage (emf) E[1)]
phase-to-ground	A or AB	$\overline{E} = \sqrt{3} \times \left(\overline{V_A} + \overline{I_A} \times (j \times X_{leak}) \right)$
phase-to-ground	B or BC	$\overline{E} = \sqrt{3} \times \left(\overline{V_B} + \overline{I_B} \times (j \times X_{leak}) \right)$
phase-to-ground	C or CA	$\overline{E} = \sqrt{3} \times \left(\overline{V_C} + \overline{I_C} \times (j \times X_{leak}) \right)$
phase-to-phase	A or AB	$\overline{E} = \overline{V_{AB}} + \left((\overline{I_A} - \overline{I_B}) \times (j \times X_{leak}) \right)$
phase-to-phase	B or BC	$\overline{E} = \overline{V_{BC}} + \left((\overline{I_B} - \overline{I_C}) \times (j \times X_{leak}) \right)$
phase-to-phase	C or CA	$\overline{E} = \overline{V_{CA}} + \left((\overline{I_C} - \overline{I_A}) \times (j \times X_{leak}) \right)$
Pos sequence	N/A	$\overline{E} = \sqrt{3} \times \left(\overline{V_1} + \overline{I_1} \times (j \times X_{leak}) \right)$

1) Voltages, currents and the leakage reactance X_{leak} in the calculations are given in volts, amps and ohms.

If all three phase or phase-to-phase voltages and phase currents are fed to the protection relay, the positive-sequence alternative is recommended.

If the leakage reactance of the protected equipment is unknown or if the measured voltage (V_m) is to be used in the excitation level calculation, then by setting the leakage reactance value to zero the calculated induced voltage (E) is equal to the measured voltage.

The calculated V/f ratio is scaled to a value based on the nominal V_n/f_n ratio. However, the highest allowed continuous voltage (in % V_n) can be defined by setting the parameter *Voltage Max Cont* to change the basis of the voltage. The measured voltage is compared to the new base value to obtain the excitation level.

The excitation level (M) can be calculated:

$$M = \frac{\frac{E}{f_m}}{\frac{V_n}{f_n} \cdot \frac{Volt\ Max\ continuous}{100}}$$

(Equation 3)

M excitation level (V/f ratio or volts/hertz) in pu

E internal induced voltage (emf)

f_m measured frequency

V_n nominal phase-to-phase voltage

f_n nominal frequency

If the input frequency (f_m) is less than 20 percent of the nominal frequency (f_n), the calculation of the excitation level is disabled and forced to zero value. This means that the function is blocked from picking up and tripping during a low-frequency condition.

The calculated excitation level (V/f ratio or volts/hertz) VOLTPERHZ is available in the Monitored data view.

Level detector

Level detector compares the calculated excitation level to the *Pickup value* setting. If the excitation level exceeds the set limit, the module sends an enabling signal to start Timer.

Timer

Once activated, Timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value set by *Trip delay time* in the DT mode or the value defined by the inverse time curve, the `TRIP` output is activated.

In a drop-off situation, that is, when the excitation level drops below *Pickup value* before the function trips, the reset timer is activated and the `PICKUP` output resets after the time delay of *Reset delay time* for the DT characteristics. For the IDMT curves, the reset operation is as described in the Timer characteristics chapter.

For the IDMT curves, it is possible to define the maximum and minimum trip times via the *Minimum trip time* and *Maximum trip time* settings. The *Maximum trip time* setting is used to prevent infinite pickup situations at low degrees of overexcitation. The *Time multiplier* setting is used for scaling the IDMT trip times.

The activation of the `TRIP` output activates the `BLK_RESTART` output.

The beginning of the cooling process deactivates the TRIP output and activates the COOL_ACTIVE output. COOL_ACTIVE is kept active during the cooling process. If a new overexcitation start ceases cooling, COOL_ACTIVE is deactivated during that start time. BLK_RESTART is kept active until the set total cooling time has elapsed. It means that even during the new overexcitation start ceases cooling, BLK_RESTART is kept active. Due to the updated cooling time, the BLK_RESTART activation time is prolonged with these new starts during cooling. A new overexcitation start during cooling does not immediately reactivate TRIP, but PICKUP is first activated and a new TRIP activation depends on the already run cooling time. If, for example, 60 percent of the set cooling time has run before a new start, 40 percent of the operating time is needed to reactivate TRIP.

The T_ENARESTART output indicates in seconds the duration for which the BLK_RESTART output still remains active. The value is available in the Monitored data view.

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

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 protection relay's 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 operation 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.

4.2.5.5 Timer characteristics

24 supports both DT and IDMT characteristics. The DT timer characteristics can be selected as "ANSI Def. Time" or "IEC Def. Time" in the *Operating curve type* setting. The functionality is identical in both cases. When the DT characteristics are selected, the functionality is only affected by the *Trip delay time* and *Reset delay time* settings.

24 also supports four overexcitation IDMT characteristic curves: "OvExt IDMT Crv1", "OvExt IDMT Crv2", "OvExt IDMT Crv3" and "OvExt IDMT Crv4".

Overexcitation inverse definite minimum time curve (IDMT)

In the inverse time modes, the trip time depends on the momentary value of the excitation: the higher the excitation level, the shorter the trip time. The trip time calculation or integration starts immediately when the excitation level exceeds the set *Pickup value* and the PICKUP output is activated.

The TRIP output is activated when the cumulative sum of the integrator calculating the overexcitation 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 *Minimum trip time* and *Maximum trip time* settings define the minimum trip time and maximum trip time possible for the IDMT mode. For setting these parameters, a careful study of the particular IDMT curves is recommended.

The tripping time of the function block can vary much between different operating curve types even if other setting parameters for the curves were not changed.

Once activated, the timer activates the PICKUP output for the IDMT curves. If the excitation level drops below the *Pickup value* setting before the function trips, the reset timer is activated. If the fault reoccurs during the reset time, the tripping calculation is made based on the effects of the period when PICKUP was previously active. This is intended to allow a tripping condition to occur in less time to account for the heating effects from the previous active pickup period.

When the fault disappears, the reset time can be calculated:

$$reset\ time = \left(\frac{PICKUP\_DUR}{100}\right) \cdot Cooling\ time$$

(Equation 4)

For the IDMT curves, when the fault disappears, the integral value calculated during PICKUP is continuously decremented by a constant that causes its value to become zero when the reset time elapses during the reset period. If a fault reoccurs, the integration continues from the current integral value and the pickup time is adjusted, as shown in Figure 119. The pickup time becomes the value at the time when the fault dropped off minus the amount of reset time that occurred. If the reset period elapses without a fault being detected, the saved values of the pickup time and integration are cleared.

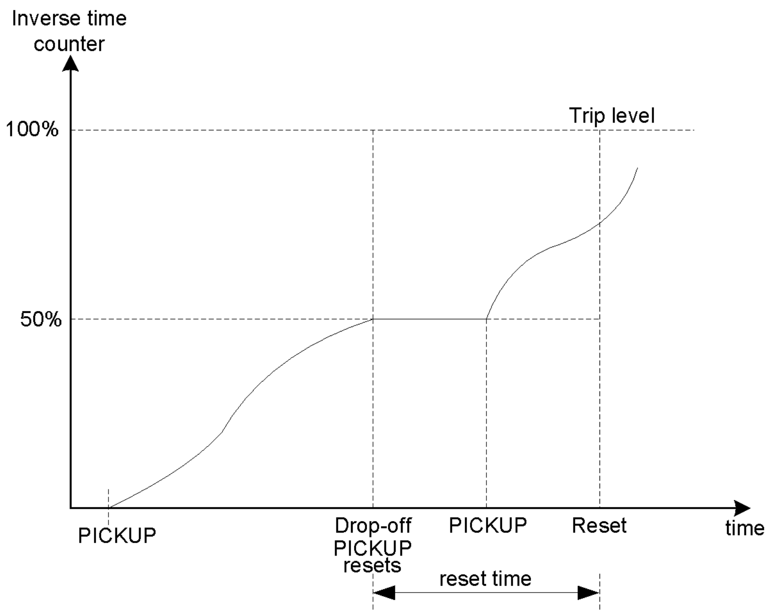


Figure 119: An example of a delayed reset in the inverse time characteristics. When the pickup becomes active during the reset period, the trip time counter continues from the level corresponding to the drop-off (reset time = 0.50 · Cooling time)

Overexcitation IDMT curves 1, 2 and 3

The base equation for the IDMT curves "OvExt IDMT Crv1", "OvExt IDMT Crv2" and "OvExt IDMT Crv3" is:

$$t(s) = 60 \cdot e^{\left(\frac{ak+b-100M}{c}\right)}$$

(Equation 5)

t(s)	Trip time in seconds
M	Excitation level (V/f ratio or volts/hertz) in pu
k	*Time multiplier* setting

The constant "60" in Equation 5 converts time from minutes to seconds.

Table 200: Parameters a, b and c for different IDMT curves

Operating curve type setting	a	b	c
OvExt IDMT Crv1	2.5	115.00	4.886
OvExt IDMT Crv2	2.5	113.50	3.040
OvExt IDMT Crv3	2.5	108.75	2.443

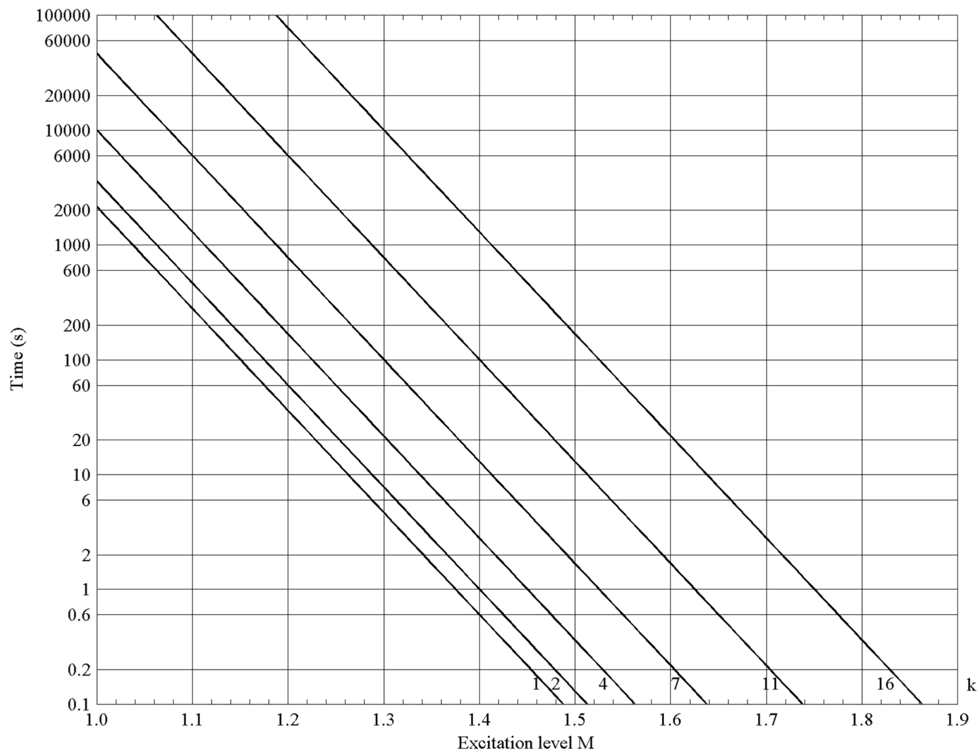


Figure 120: Trip time curves for the overexcitation IDMT curve ("OvExt IDMT Crv1") for parameters a = 2.5, b = 115.0 and c = 4.886

Overexcitation IDMT curve 4

The base equation for the IDMT curve “OvExt IDMT Crv4” is:

t(s) Trip time in seconds

d

M Excitation value (V/f ratio or volts/hertz) in pu

k *Time multiplier* setting

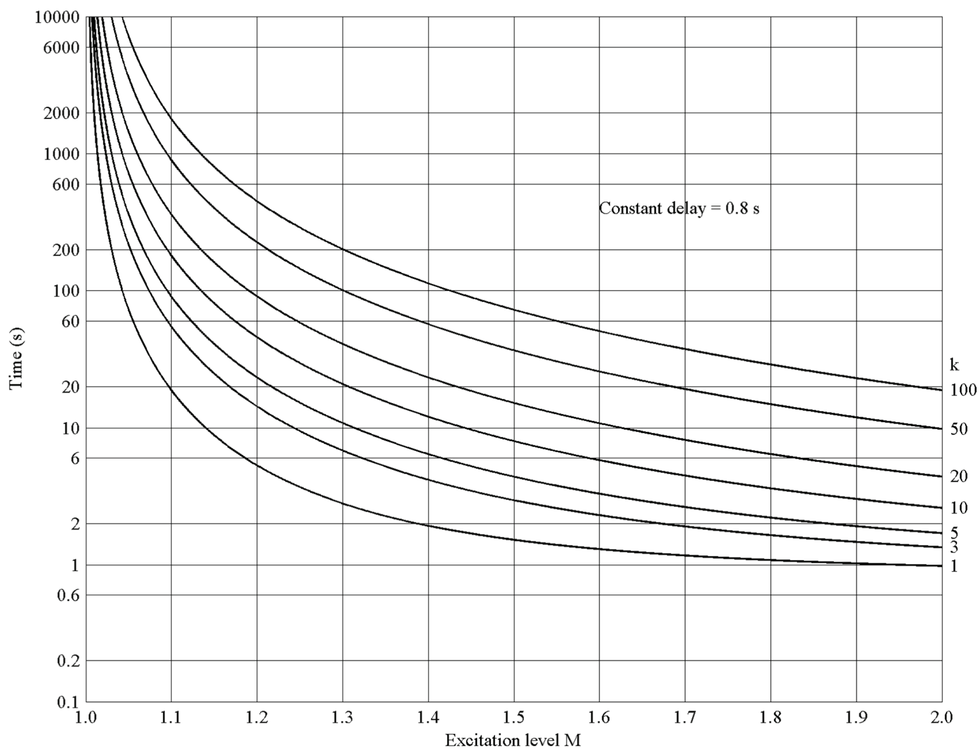


Figure 121: Trip time curves for the overexcitation IDMT curve 4 ("OvExt IDMT Crv4") for different values of the Time multiplier setting when the Constant delay is 800 milliseconds

The activation of the TRIP output activates the BLK_RESTART output.

For the IDMT characteristic "OvExt IDMT Crv4", the deactivation of the TRIP output activates the cooling timer. The timer is set to the value entered in the *Cooling time* setting. The COOL_ACTIVE output is kept active until the cooling timer is reset, whereas the BLK_RESTART output remains active until the timer exceeds the value to enable the restart time, given in Equation 7. The *Restart Ena level* setting determines the level when BLK_RESTART should be released.

$$enable\ restart\ time = \left(\frac{100 - Ena\ restart\ level}{100}\right) \cdot Cooling\ time$$

(Equation 7)

If the excitation level increases above the set value when BLK_RESTART is active, the TRIP output is activated immediately.

If the excitation level increases above the set value when BLK_RESTART is not active but COOL_ACTIVE is active, the TRIP output is not activated instantly. In this case, the remaining part of the cooling timer affects the calculation of the operation timer as shown in Figure 122. This compensates for the heating effect and makes the overall trip time shorter.

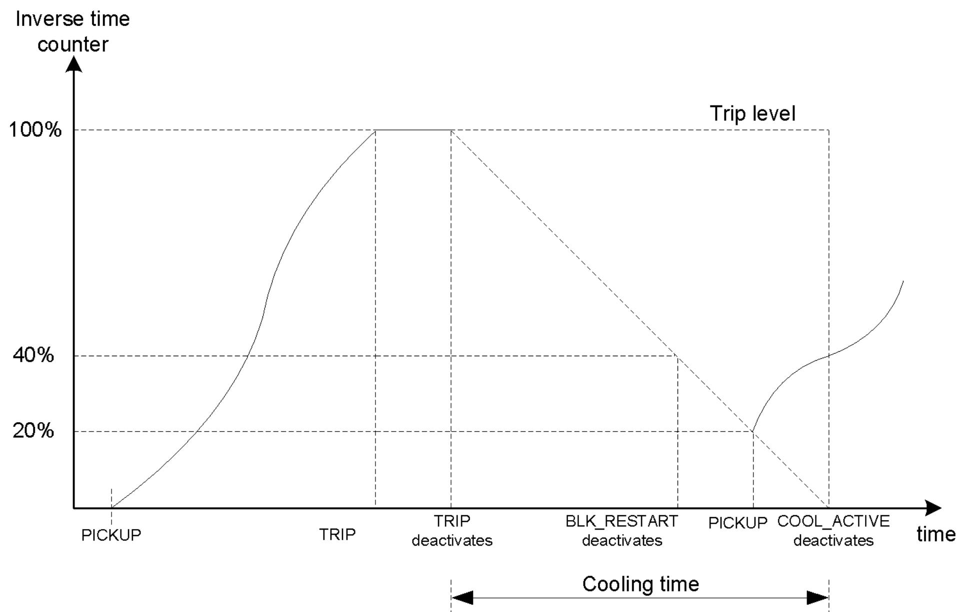


Figure 122: Example of an inverse time counter operation if TRIP occurs when BLK_RESTART is inactive while COOL_ACTIVE is active. The Restart Ena level setting is considered to be 40 percent.

4.2.5.6 Application

If the laminated core of a power transformer or generator is subjected to a magnetic flux density beyond its designed limits, the leakage flux increases. This results in a heavy hysteresis and eddy current losses in the non-laminated parts. These losses can cause excessive heating and severe damage to the insulation and adjacent parts in a relatively short time.

Overvoltage, underfrequency or a combination of the two, results in an excessive flux density level. Since the flux density is directly proportional to the voltage and inversely proportional to the frequency, the overexcitation protection calculates the relative V/Hz ratio instead of measuring the flux density directly. The nominal level (nominal voltage at nominal frequency) is usually considered as the 100 percent level, which can be exceeded slightly based on the design.

The greatest risk for overexcitation exists in a thermal power station when the generator-transformer unit is disconnected from the rest of the network or in the network islands where high voltages or low frequencies can occur.

Overexcitation can occur during the start-up and shutdown of the generator if the field current is not properly adjusted. The loss-of-load or load shedding can also result in overexcitation if the voltage control and frequency governor do not function properly. The low frequency in a system isolated from the main network can result in overexcitation if the voltage-regulating system maintains a normal voltage.

Overexcitation protection for the transformer is generally provided by the generator overexcitation protection, which uses the VTs connected to the generator terminals. The curves that define the generator and transformer V/Hz limits must be coordinated properly to protect both equipment.

If the generator can be operated with a leading power factor, the high-side voltage of the transformer can have a higher pu V/Hz than the generator V/Hz. This needs to be considered in a proper overexcitation protection of the transformer. Also, measurement for the voltage must not be taken from any winding where OLTC is located.

It is assumed that overexcitation is a symmetrical phenomenon caused by events such as loss-of-load. A high phase-to-ground voltage does not mean overexcitation. For example, in an ungrounded power system, a single-phase-to-ground fault means high voltages of the healthy two phases to ground but no overexcitation on any winding. The phase-to-phase voltages remain essentially unchanged. An important voltage to be considered for the overexcitation is the voltage between the two ends of each winding.

Example calculations for overexcitation protection

Example 1

Nominal values of the machine

Nominal phase-to-phase voltage (V_n)	11000 V
Nominal phase current (I_n)	7455 A
Nominal frequency (f_n)	50 Hz

Leakage reactance (X_{leak})	20% or 0.2 pu

Measured voltage and load currents of the machine

Phase A-to-phase B voltage (V_{AB})	11500∠0° V
Phase A current (I_A)	5600∠-63.57° A
Phase B current (I_B)	5600∠176.42° A
Measured frequency (f_m)	49.98 Hz
The setting *Voltage Max Cont*	100%
The setting *Voltage selection*	phase-to-phase
The setting *Phase supervision*	A or AB

The pu leakage reactance X_{leakPU} is converted to ohms.

$$X_{leak\Omega} = X_{leakPU} \cdot \left(V_n \big/ \left(I_n \cdot \sqrt{3} \right) \right) = 0.2 \cdot \left(11000 \big/ \left(7455 \cdot \sqrt{3} \right) \right) = 0.170378\ ohms$$

(Equation 8)

The internal induced voltage E of the machine is calculated.

$$\overline{E} = \overline{V_{AB}} + (\overline{I_A} - \overline{I_B}) \cdot (jX_{leak})$$

(Equation 9)

E = 11500∠0°+ (5600∠-63.57°- 5600∠176.42°) · (0.170378∠90°) = 12490 V

The excitation level M of the machine is calculated.

$$Excitation\,level\ M = \frac{12490 \big/ 49.98}{11000 \big/ 50 \cdot 1.00} = 1.1359$$

(Equation 10)

Example 2

The situation and the data are according to Example 1. In this case, the manufacturer of the machine allows the continuous operation at 105 percent of the nominal voltage at the rated load and this value to be used as the base for overexcitation.

Usually, the V/f characteristics are specified so that the ratio is 1.00 at the nominal voltage and nominal frequency. Therefore, the value 100 percent for the setting *Voltage Max Cont* is recommended.

If the *Voltage Max Cont* setting is 105 percent, the excitation level M of the machine is calculated with the equation.

$$Excitation\,level\;M = \frac{12490/49.98}{11000/50 \cdot 1.05} = 1.0818$$

(Equation 11)

Example 3

In this case, the function operation is according to IDMT. The *Operating curve type* setting is selected as "OvExt IDMT Crv2". The corresponding example settings for the IDMT curve operation are given as: *Pickup value* = 110%, *Voltage Max Cont* = 100%, *Time multiplier* = 4, *Maximum trip time* = 1000000 milliseconds and *Minimum trip time* = 1000 milliseconds.

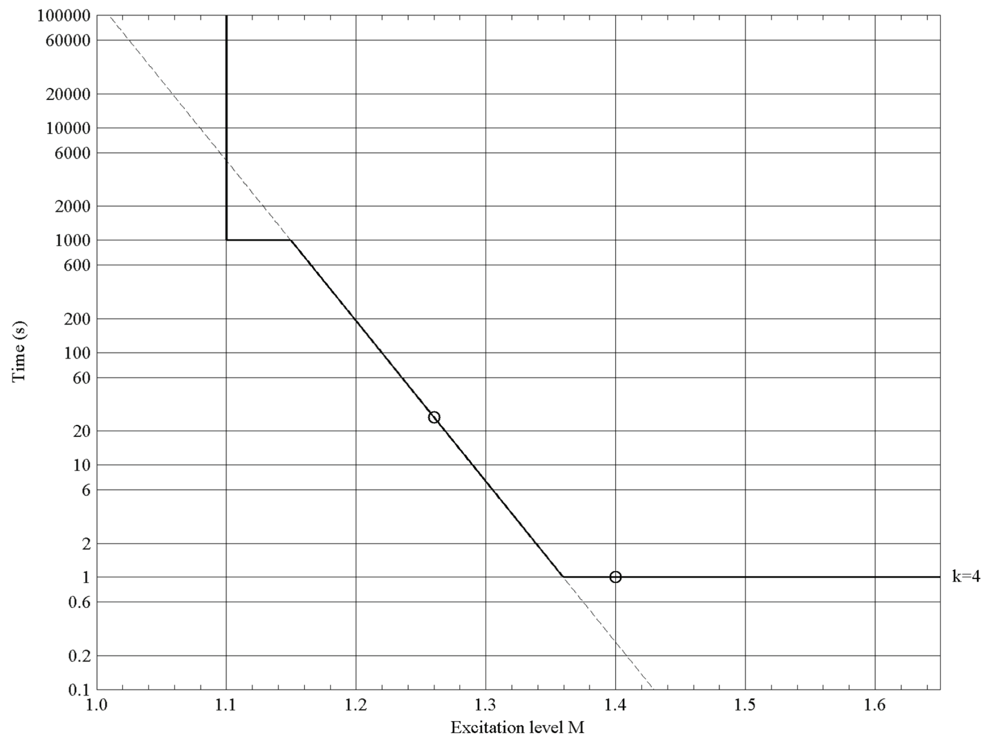


Figure 123: Tripping curve of "OvExt IDMT Crv2" based on the settings specified in example 3. The two dots marked on the curve are referred to in the text.

If the excitation level stays at 1.26, the tripping occurs after 26360 milliseconds as per the marked dot in Figure 123. For the excitation level of 1.4, the second dot in Figure 123, the curve "OvExt IDMT Crv2" gives 260 milliseconds as per Equation 5, but the *Minimum trip time* setting limits the trip time to 1000 milliseconds. The *Maximum trip time* setting limits the trip time to 1000000 milliseconds if the excitation level stays between 1.1 and 1.16.

In general, however, the excitation level seldom remains constant. Therefore, the exact trip times in any inverse time mode are difficult to predict.

Example 4

In this case, the function operation is according to IDMT. The *Operating curve type* setting is selected as "OvExt IDMT Crv4". The corresponding example settings for the IDMT curve operation are given as: *Pickup value* = 110%, *Voltage Max Cont* = 100%, *Time multiplier* = 5, *Maximum trip time* = 3600000 milliseconds and *Constant delay* = 800 milliseconds.

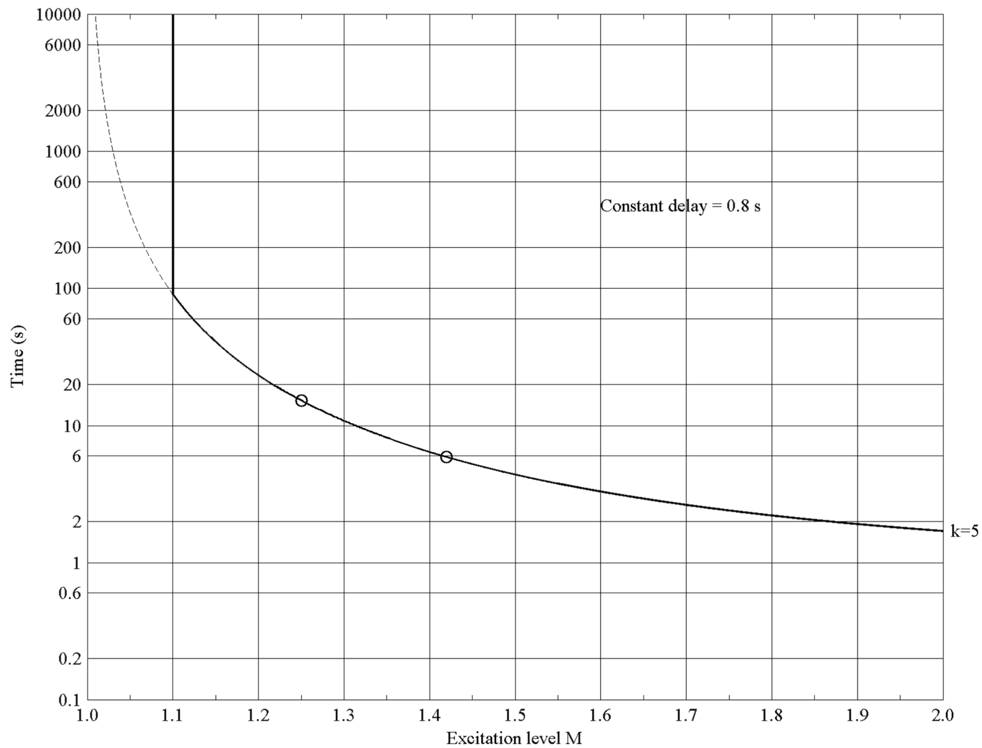


Figure 124: Tripping curve of "OvExt IDMT Crv4" based on the specified settings. The two dots marked on the curve are referred to in the text.

If the excitation level stays at 1.25, the tripping occurs after 15200 milliseconds. At the excitation level of 1.42, the time to tripping would be 5900 milliseconds as per the two dots in Figure 124. In this case, the setting *Maximum trip time* = 3600000 milliseconds does not limit the maximum trip time because the trip time at *Pickup value* = 110% (1.1 pu) is approximately 75000 milliseconds.

4.2.5.7 Signals

Table 201: 24 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_1	SIGNAL	0	Positive-phase sequence current
Table continues on next page			

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
V_1	SIGNAL	0	Positive-phase sequence voltage
F	SIGNAL	0	Measured frequency
BLOCK	BOOLEAN	0=False	Block signal

Table 202: 24 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup
BLK_RESTART	BOOLEAN	Signal for blocking reconnection of an overheated machine
COOL_ACTIVE	BOOLEAN	Signal to indicate machine is in cooling process

4.2.5.8 Settings

Table 203: 24 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	100...200	%	1	100	Over excitation pickup value
Operating curve type	5=ANSI DT 15=IEC DT 17=OvExt IDMT Crv1 18=OvExt IDMT Crv2 19=OvExt IDMT Crv3 20=OvExt IDMT Crv4			15=IEC DT	Selection of time delay curve type
Time multiplier	0.1...100.0		0.1	3.0	Time multiplier for Overexcitation IDMT curves
Trip delay time	200...200000	ms	10	500	Trip delay time in definite- time mode

Table 204: 24 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Mode Disable/Enable
Cooling time	5...10000	s	1	600	Time required to cool the machine
Constant delay	100...120000	ms	10	800	Parameter constant delay
Reset delay time	0...60000	ms	10	100	Resetting time of the trip time counter in DT mode
Maximum trip time	500000...10000000	ms	10	1000000	Maximum trip time for IDMT curves
Minimum trip time	200...60000	ms	10	200	Minimum trip time for IDMT curves
Restart Ena level	0...100	%	1	0	Determines the level in % when block restart is released
Voltage selection	1=phase-to-earth 2=phase-to-phase 3=pos sequence			3=pos sequence	Selection of phase / phase-to-phase / pos sequence voltages
Phase selection	1=A or AB 2=B or BC 3=C or CA			1=A or AB	Parameter for phase selection
Leakage React	0.0...50.0	%	0.1	0.0	Leakage reactance of the machine
Voltage Max Cont	80...160	%	1	110	Maximum allowed continuous operating voltage ratio

4.2.5.9 Monitored data

Table 205: 24 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time (in %)
T_ENARESTART	INT32	0...10000	s	Estimated time to reset of block restart
VOLTPERHZ	FLOAT32	0.00...10.00	pu	Excitation level, i.e U/f ratio or Volts/Hertz
24	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.2.5.10 Technical data

Table 206: 24 Technical data

Characteristic	Value	
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2 Hz	
	±2.5% of the set value or 0.01 × Ub/f	
Pickup time[1)2)]	Frequency change	Typically 200 ms (±20 ms)
	Voltage change	Typically 100 ms (±20 ms)
Reset time	<60 ms	
Reset ratio	Typically 0.96	
Retardation time	<45 ms	
Operate time accuracy in definite-time mode	±1.0% of the set value or ±20 ms	
Operate time accuracy in inverse-time mode	±5.0% of the theoretical value or ±50 ms	

1) Results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.3 Frequency protection

4.3.1 Frequency protection 81

4.3.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency protection	FRPFRQ	f>/f<,df/dt	81

4.3.1.2 Function block

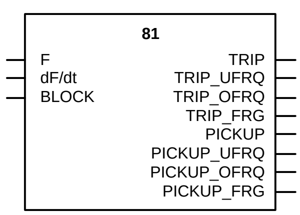


Figure 125: Function block

4.3.1.3 Functionality

The frequency protection function 81 is used to protect network components against abnormal frequency conditions.

The function provides basic overfrequency, underfrequency and frequency rate-of-change protection. Additionally, it is possible to use combined criteria to achieve even more sophisticated protection schemes for the system.

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

4.3.1.4 Operation principle

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

The operation of 81 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

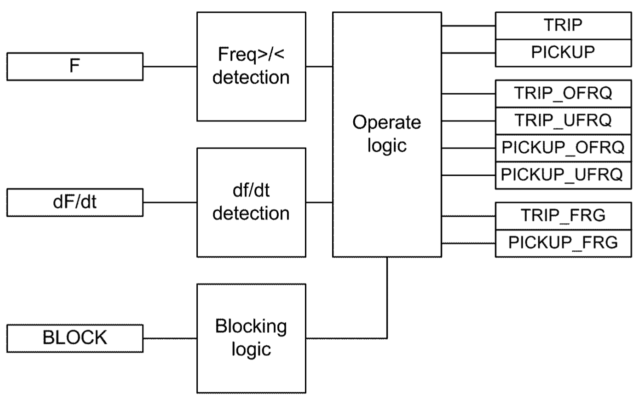


Figure 126: Functional module diagram

Over/under frequency detection

The frequency detection module includes an overfrequency or underfrequency detection based on the *Operation mode* setting.

In the “Freq>” mode, the measured frequency is compared to the set *Pickup value Freq>*. If the measured value exceeds the set value of the *Pickup value Freq>* setting, the module reports the exceeding of the value to the trip logic module.

In the “Freq<” mode, the measured frequency is compared to the set *Pickup value Freq<*. If the measured value is lower than the set value of the *Pickup value Freq<* setting, the module reports the value to the trip logic module.

df/dt detection

The frequency gradient detection module includes a detection for a positive or negative rate-of-change (gradient) of frequency based on the set *Pickup value df/dt* value. The negative rate-of-change protection is selected when the set value is negative. The positive rate-of-change protection is selected when the set value is positive. When the frequency gradient protection is selected and the gradient exceeds the set *Pickup value df/dt* value, the module reports the exceeding of the value to the trip logic module.

The protection relay does not accept the set value "0.00" for the *Pickup value df/dt* setting.

Operate logic

This module is used for combining different protection criteria based on the frequency and the frequency gradient measurement to achieve a more sophisticated behavior of the function. The criteria are selected with the *Operation mode* setting.

Table 207: Operation modes for operation logic

Operation mode	Description
Freq<	The function trips independently as the underfrequency ("Freq<") protection function. When the measured frequency is below the set value of the *Pickup value Freq<* setting, the module activates the PICKUP and PICKUP_UFRQ outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Trip Tm Freq* setting, the TRIP and TRIP_UFRQ outputs are activated. If the frequency restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operation timer resets and the PICKUP and PICKUP_UFRQ outputs are deactivated.
Freq>	The function trips independently as the overfrequency ("Freq>") protection function. When the measured frequency exceeds the set value of the *Pickup value Freq>* setting, the module activates the PICKUP and PICKUP_OFRQ outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Trip Tm Freq* setting, the TRIP and TRIP_OFRQ outputs are activated. If the frequency restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operation timer resets and the PICKUP and PICKUP_OFRQ outputs are deactivated.
df/dt	The function trips independently as the frequency gradient ("df/dt"), rate-of-change, protection function. When the frequency gradient exceeds the set value of the *Pickup value df/dt* setting, the module activates the PICKUP and PICKUP_FRG outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Trip Tm df/dt* setting, the TRIP and TRIP_FRG outputs are activated. If the frequency gradient restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operation timer resets and the PICKUP and PICKUP_FRG outputs are deactivated.
Freq< + df/dt	A consecutive operation is enabled between the protection methods. When the measured frequency is below the set value of the *Pickup value Freq<* setting, the frequency gradient protection is enabled. After the frequency has dropped below the set value, the frequency gradient is compared to the set value of the *Pickup value df/dt* setting. When the frequency gradient exceeds the set value, the module activates the PICKUP and PICKUP_FRG outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Trip Tm df/dt* setting, the TRIP and TRIP_FRG outputs are activated. If the frequency gradient restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operation timer resets and the PICKUP and PICKUP_FRG outputs are deactivated. The TRIP_UFRQ output is not active when this operation mode is used.

Table continues on next page

Operation mode	Description
Freq> + df/dt	A consecutive operation is enabled between the protection methods. When the measured frequency exceeds the set value of the *Pickup value Freq>* setting, the frequency gradient protection is enabled. After the frequency exceeds the set value, the frequency gradient is compared to the set value of the *Pickup value df/dt* setting. When the frequency gradient exceeds the set value, the module activates the PICKUP and PICKUP_FRG outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Trip Tm df/dt* setting, the TRIP and TRIP_FRG outputs are activated. If the frequency gradient restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operation timer resets and the PICKUP and PICKUP_FRG outputs are deactivated. The TRIP_OFRQ output is not active when this operation mode is used.
Freq< OR df/dt	A parallel operation between the protection methods is enabled. The PICKUP output is activated when either of the measured values of the protection module exceeds its set value. Detailed information about the active module is available at the PICKUP_UFRQ and PICKUP_FRG outputs. The shortest trip delay time from the set *Trip Tm Freq* or *Trip Tm df/dt* is dominant regarding the TRIP output. The time characteristic is according to DT. The characteristic that activates the TRIP output can be seen from the TRIP_UFRQ or TRIP_FRG output. If the frequency gradient restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operation timer resets and the PICKUP_FRG output is deactivated. If the frequency restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operation timer resets and the PICKUP_UFRQ output is deactivated.
Freq> OR df/dt	A parallel operation between the protection methods is enabled. The PICKUP output is activated when either of the measured values of the protection module exceeds its set value. Detailed information about the active module is available at the PICKUP_OFRQ and PICKUP_FRG outputs. The shortest trip delay time from the set *Trip Tm Freq* or *Trip Tm df/dt* is dominant regarding the TRIP output. The time characteristic is according to DT. The characteristic that activates the TRIP output can be seen from the TRIP_OFRQ or TRIP_FRG output. If the frequency gradient restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operation timer resets and the PICKUP_FRG output is deactivated. If the frequency restores before the module trips, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operation timer resets and the PICKUP_UFRQ output is deactivated.

The module calculates the pickup duration value PICKUP_DUR which indicates the percentage ratio of the pickup situation and set trip time DT. The pickup duration is available according to the selected value of the *Operation mode* setting.

Table 208: Pickup duration value

Operation mode in use	Available pickup duration value
Freq<	ST_DUR_UFRQ
Freq>	ST_DUR_OFRQ
df/dt	ST_DUR_FRG

The combined pickup duration PICKUP_DUR indicates the maximum percentage ratio of the active protection modes. The values are available via the Monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 operation timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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.

4.3.1.5 Application

The frequency protection function uses the positive phase-sequence voltage to measure the frequency reliably and accurately.

The system frequency stability is one of the main principles in the distribution and transmission network maintenance. To protect all frequency-sensitive electrical apparatus in the network, the departure from the allowed band for a safe operation should be inhibited.

The overfrequency protection is applicable in all situations where high levels of the fundamental frequency of a power system voltage must be reliably detected. The high fundamental frequency in a power system indicates an unbalance between production and consumption. In this case, the available generation is too large compared to the power demanded by the load connected to the power grid. This can occur due to a sudden loss of a significant amount of load or due to failures in the turbine governor system. If the situation continues and escalates, the power system loses its stability.

The underfrequency is applicable in all situations where a reliable detection of a low fundamental power system voltage frequency is needed. The low fundamental frequency in a power system indicates that the generated power is too low to meet the demands of the load connected to the power grid.

The underfrequency can occur as a result of the overload of generators operating in an isolated system. It can also occur as a result of a serious fault in the power system due to the deficit of generation when compared to the load. This can happen due to a fault in the grid system on the transmission lines that link two parts of the system. As a result, the system splits into two with one part having the excess load and the other part the corresponding deficit.

The frequency gradient is applicable in all the situations where the change of the fundamental power system voltage frequency should be detected reliably. The frequency gradient can be used for both increasing and decreasing the frequencies. This function provides an output signal suitable for load shedding, generator shedding, generator boosting, set point change in sub-transmission DC systems and gas turbine startup. The frequency gradient is often used in combination with a low frequency signal, especially in smaller power systems where the loss of a large generator requires quick remedial actions to secure the power system integrity. In such situations, the load shedding actions are required at a rather high frequency level. However, in combination with a large negative frequency gradient, the underfrequency protection can be used at a high setting.

4.3.1.6 Signals

Table 209: 81 Input signals

Name	Type	Default	Description
F	SIGNAL	0	Measured frequency
dF/dt	SIGNAL	0	Rate of change of frequency
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 210: 81 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
OPR_OFRQ	BOOLEAN	Trip signal for overfrequency
OPR_UFRQ	BOOLEAN	Trip signal for underfrequency
OPR_FRG	BOOLEAN	Trip signal for frequency gradient
PICKUP	BOOLEAN	Pickup
ST_OFRQ	BOOLEAN	Pickup signal for overfrequency
ST_UFRQ	BOOLEAN	Pickup signal for underfrequency
ST_FRG	BOOLEAN	Pickup signal for frequency gradient

4.3.1.7 Settings

Table 211: 81 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Trip mode	1=Freq< 2=Freq> 3=df/dt 4=Freq< + df/dt 5=Freq> + df/dt 6=Freq< OR df/dt 7=Freq> OR df/dt			1=Freq<	Frequency protection trip mode selection
Pickup value Freq>	0.900...1.200	xFn	0.001	1.050	Frequency pickup value overfrequency
Pickup value Freq<	0.800...1.100	xFn	0.001	0.950	Frequency pickup value underfrequency
Pickup value df/dt	-0.200...0.200	xFn /s	0.005	0.010	Frequency pickup value rate of change
Trip Tm Freq	80...200000	ms	10	200	Trip delay time for frequency
Trip Tm df/dt	120...200000	ms	10	400	Trip delay time for frequency rate of change

Table 212: 81 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay Tm Freq	0...60000	ms	1	0	Reset delay time for frequency
Reset delay Tm df/dt	0...60000	ms	1	0	Reset delay time for rate of change

4.3.1.8 Monitored data

Table 213: 81 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Pickup duration
ST_DUR_OFRQ	FLOAT32	0.00...100.00	%	Pickup duration
ST_DUR_UFRQ	FLOAT32	0.00...100.00	%	Pickup duration
ST_DUR_FRG	FLOAT32	0.00...100.00	%	Pickup duration
81	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.3.1.9 Technical data

Table 214: 81 Technical data

Characteristic		Value
Operation accuracy	f>/f<	±10 mHz
	df/dt	±100 mHz/s (in range |df/dt| <5 Hz/s) ±2.0% of the set value (in range 5 Hz/s < |df/dt| < 15 Hz/s)
Pickup time	f>/f<	<80 ms
	df/dt	<120 ms
Reset time		<150 ms
Trip time accuracy		±1.0% of the set value or ±30 ms

4.3.2 Load shedding and restoration 81LSH

4.3.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Load shedding and restoration	LSHDPFRQ	UFLS/R	81LSH

4.3.2.2 Function block

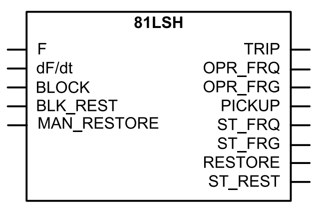


Figure 127: Function block

4.3.2.3 Functionality

The load-shedding and restoration function 81LSH is capable of performing load-shedding based on underfrequency and the rate of change of the frequency. The load that is shed during the frequency disturbance can be restored once the frequency has stabilized to the normal level.

The measured system frequency is compared to the set value to detect the underfrequency condition. The measured rate of change of frequency (df/dt) is compared to the set value to detect a high frequency reduction rate. The combination of the detected underfrequency and the high df/dt is used for the activation of the load-shedding. There is a definite time delay between the detection of the underfrequency and high df/dt and the activation of 81LSH. This time delay can be set and it is used to prevent unwanted load-shedding actions when the system frequency recovers to the normal level.

Throughout this document, “high df/dt” is used to mean “a high rate of change of the frequency in negative direction.”

Once the frequency has stabilized, 81LSH can restore the load that is shed during the frequency disturbance. The restoration is possible manually or automatically.

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

4.3.2.4 Operation principle

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

The operation of 81LSH can be described using a module diagram. All the modules are explained in the next sections.

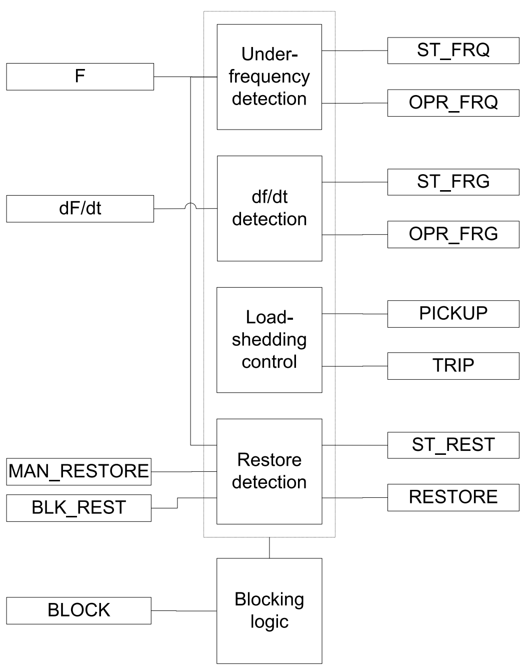


Figure 128: Functional module diagram

Underfrequency detection

The underfrequency detection measures the input frequency calculated from the voltage signal. An underfrequency is detected when the measured frequency drops below the set value of the *Pickup value Freq* setting.

The underfrequency detection module includes a timer with the definite time (DT) characteristics. Upon detection of underfrequency, operation timer activates the `ST_FRQ` output. When the underfrequency timer has reached the value set by *Trip Tm Freq*, the `OPR_FRQ` output is activated if the underfrequency condition still persists. If the frequency becomes normal before the module trips, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the timer resets and the `ST_FRQ` output is deactivated.

df/dt detection

The df/dt detection measures the input frequency calculated from the voltage signal and calculates its gradient. A high df/dt condition is detected by comparing the gradient to the *Pickup value df/dt* setting.The df/dt detection is activated when the frequency gradient decreases at a faster rate than the set value of *Pickup value df/dt*.

The df/dt detection module includes a timer with the DT characteristics. Upon detection of df/dt, operation timer activates the `ST_FRG` output. When the timer has reached the value set by *Trip Tm df/dt*, the `OPR_FRG` output is activated if the df/dt condition still persists. If df/dt becomes normal before the module trips, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the `ST_FRG` output is deactivated.

Load-shedding control

The way of load-shedding, that is, whether to operate based on underfrequency or high df/dt or both, is defined with the *Load shed mode* user setting. The valid operation modes for the *Load shed mode* settings are "Freq<", "Freq< AND df/dt" and "Freq< OR df/dt".

Once the selected operation mode conditions are satisfied, the `PICKUP` and `TRIP` output signals are activated.

When the `PICKUP` output is active, the percentage of the elapsed delay time can be monitored through `PICKUP_DUR` which is available as monitored data.

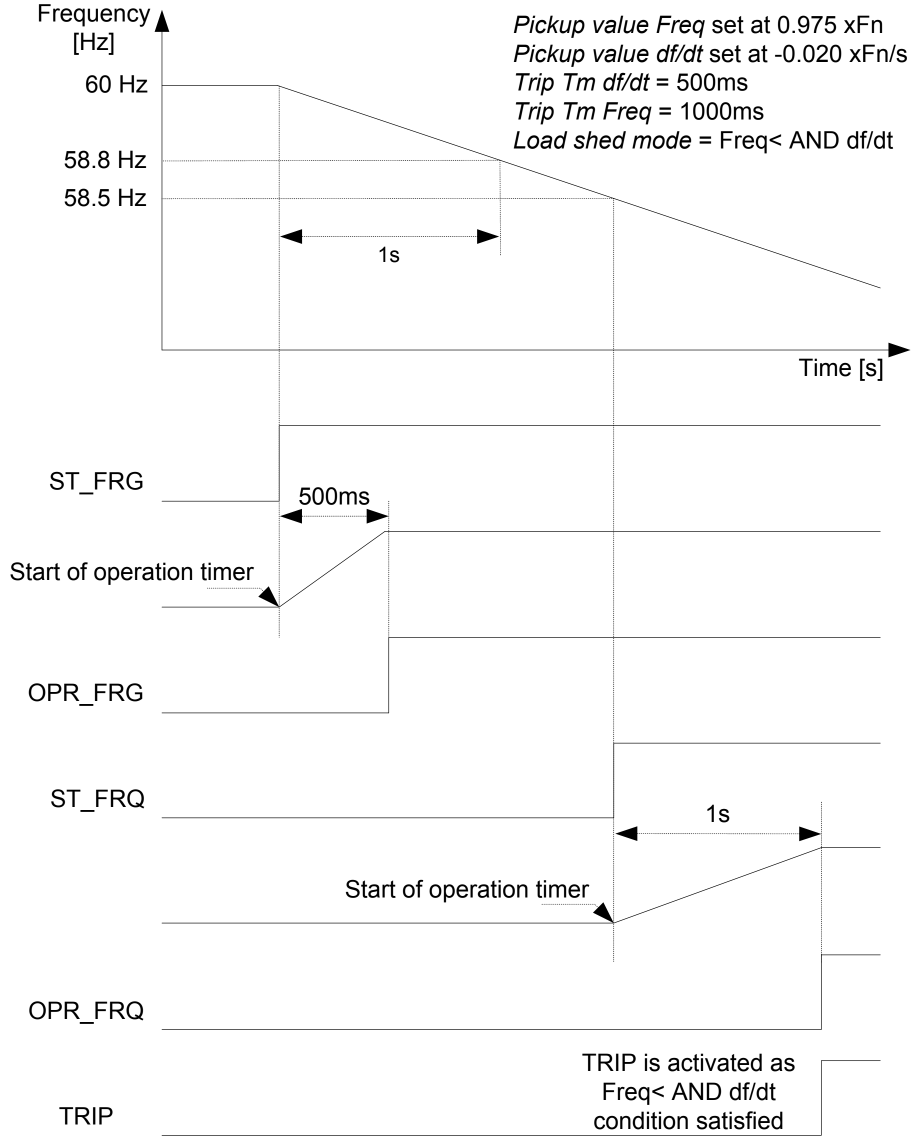


Figure 129: Load-shedding operation in the "Freq< AND df/dt>" mode when both Freq< and df/dt conditions are satisfied (Rated frequency=60 Hz)

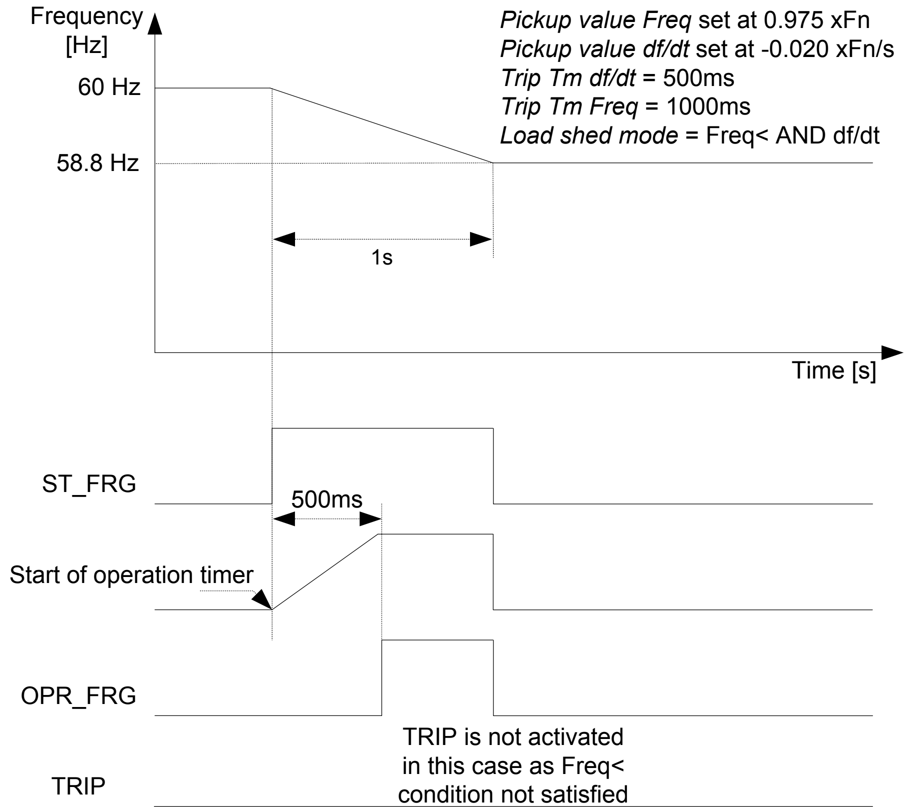


Figure 130: Load-shedding operation in the “Freq< AND df/dt>” mode when only the df/dt condition is satisfied (Rated frequency=60 Hz)

Restore detection

If after the activation of the `TRIP` input the frequency recovers to a level above the *Restore pickup Val* setting, the `RESTORE` signal output is activated. The `RESTORE` output remains active for a 100 ms. The *Restore mode* setting is used to select the restoring mode to be "Disabled", "Auto" or "Manual".

Restoring mode	Description
Disabled	Load restoration is disabled.
Auto	In the “Auto” mode, input frequency is continuously compared to the *Restore pickup Val* setting. The restore detection module includes a timer with the DT characteristics. Upon detection of restoring, the operation timer activates the ST_REST output. When the timer has reached the value of the *Restore delay time* setting, the RESTORE output is activated if the restoring condition still persists. If the frequency drops below the *Restore pickup Val* before the RESTORE output is activated, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the ST_REST start output is deactivated.
Manual	In the “Manual” mode, a manual restoration is possible through the MAN_RESTORE input or via communication. The ST_REST output is activated if the MAN_RESTORE command is available and the frequency has exceeded the *Restore pickup Val* setting. The manual restoration includes a timer with the DT characteristics. When the timer has reached the set value of the *Restore delay time* setting, the RESTORE output is activated if the restoring condition still persists. If the frequency drops below the *Restore pickup Val* setting before the RESTORE output is activated, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the ST_REST start output is deactivated.

A condition can arise where the restoring operation needs to be canceled. Activating the BLK_REST input for the "Auto" or "Manual" modes cancels the restoring operation. In the "Manual" restoring mode, the cancellation happens even if MAN_RESTORE is present.

Once the RESTORE output command is cancelled, the reactivation of RESTORE is possible only after the reactivation of the TRIP output, that is, when the next load-shedding operation is detected.

If there is a sharp frequency change in the waveform it can result in a prolonged operate time. The reason is that the frequency algorithm does not see it as a change in frequency, but as a loss of mains situation. In this case frequency protection is delayed with 160 ms to give room for vector shift protection to operate.

Blocking logic

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

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the trip timer is frozen to the prevailing value, but the TRIP output is not deactivated when blocking is activated. 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`, `OPR_FRQ` and `OPR_FRG` outputs are not activated.

4.3.2.5 Application

An AC power system operates at a defined rated frequency. The nominal frequency in most systems in the world is 50 Hz or 60 Hz. The system operation is such that the operating frequency remains approximately at the nominal frequency value by a small margin. The safe margin of operation is usually less than ±0.5 Hz. The system frequency stability is one of the main concerns in the transmission and distribution network operation and control. To protect the frequency-sensitive electrical equipment in the network, departure from the allowed band for safe operation should be inhibited.

Any increase in the connected load requires an increase in the real power generation to maintain the system frequency. Frequency variations form whenever there are system conditions that result in an unbalance between the generation and load. The rate of change of the frequency represents the magnitude of the difference between the load and generation. A reduction in frequency and a negative rate of change of the frequency are observed when the load is greater than the generation, and an increase in the frequency along with a positive rate of change of the frequency are observed if the generation is greater than the load. The rate of change of the frequency is used for a faster decision of load-shedding. In an underfrequency situation, the load-shedding trips out the unimportant loads to stabilize the network. Thus, loads are normally prioritized so that the less important loads are shed before the important loads.

During the operation of some of the protective schemes or other system emergencies, the power system is divided into small islands. There is always a load - generation imbalance in such islands that leads to a deviation in the operating frequency from the nominal frequency. This off-nominal frequency operation is harmful to power system components like turbines and motors. Therefore, such situation must be prevented from continuing. The frequency-based load-shedding scheme should be applied to restore the operation of the system to normal frequency. This is achieved by quickly creating the load - generation balance by disconnecting the load.

As the formation of the system islands is not always predefined, several load-shedding relays are required to be deployed at various places near the load centers. A quick shedding of a large amount of load from one place can cause a significant disturbance in the system. The load-shedding scheme can be made most effective if the shedding of load feeders is distributed and discrete, that is, the loads are shed at various locations and in distinct steps until the system frequency reaches the acceptable limits.

Due to the action of load-shedding schemes, the system recovers from the disturbance and the operating frequency value recovers towards the nominal frequency. The load that was shed during the disturbance can be restored. The load-restoring operation should be done stepwise in such a way that it does not lead the system back to the emergency condition. This is done through an operator intervention or in case of remote location through an automatic load restoration function. The load restoration function also detects the system frequency and restores the load if the system frequency remains above the value of the set restoration frequency for a predefined duration.

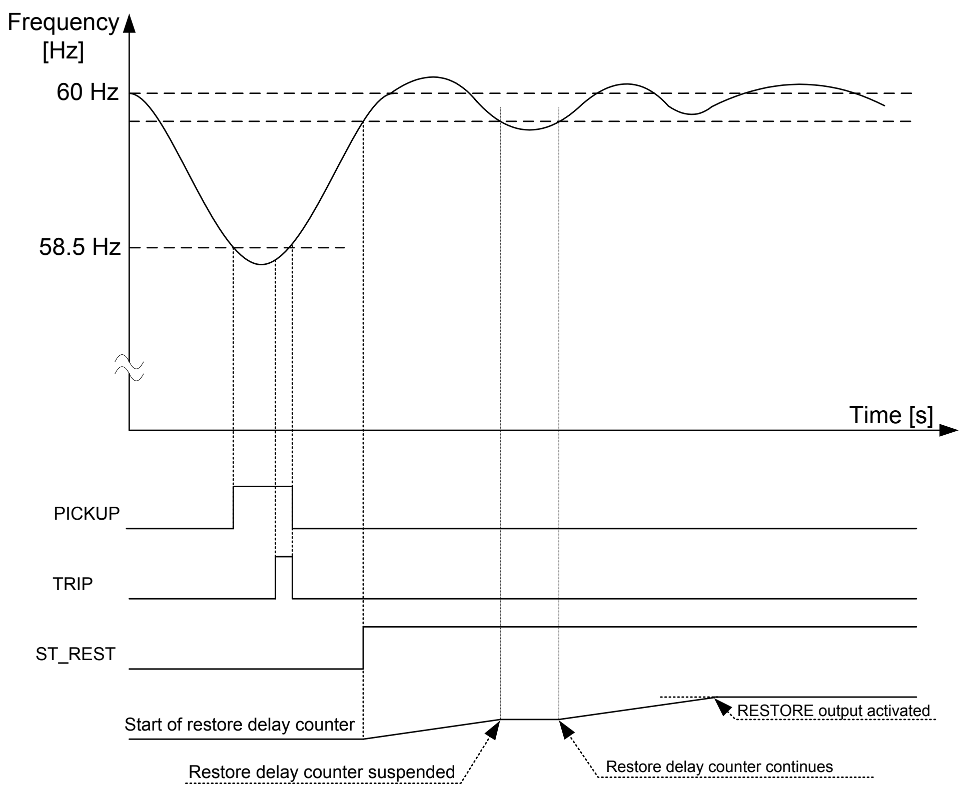


Figure 131: Operation of the load-shedding function

Power system protection by load-shedding

The decision on the amount of load that is required to be shed is taken through the measurement of frequency and the rate of change of frequency (df/dt). At a single location, many steps of load-shedding can be defined based on different criteria of the frequency and df/dt. Typically, the load-shedding is performed in six or four steps with each shedding increasing the portion of load from five to twenty-five percent of full load within a few seconds. After every shedding, the system frequency is read back and further shedding actions are taken only if necessary. In order to take the effect of any transient, a sufficient time delay should be set.

The value of the setting has to be well below the lowest occurring normal frequency and well above the lowest acceptable frequency of the system. The setting level, the number of steps and the distance between two steps (in time or in frequency) depend on the characteristics of the power system under consideration. The size of the largest loss of generation compared to the size of the power system is a critical parameter. In large systems, the load-shedding can be set at a high frequency level and the time delay is normally not critical. In small systems, the frequency pickup level has to be set at a low value and the time delay must be short.

If a moderate system operates at 50 Hz, an underfrequency should be set for different steps from 49.2 Hz to 47.5 Hz in steps of 0.3 – 0.4 Hz. The operating time for the underfrequency can be set from a few seconds to a few fractions of a second stepwise from a higher frequency value to a lower frequency value.

Table 215: Setting for a five-step underfrequency operation

Load-shedding steps	Pickup value Freq setting	Trip Tm Freq setting
1	0.984 · Fn (59 Hz)	45000 ms
2	0.978 · Fn (58.7 Hz)	30000 ms
3	0.968 · Fn (58.1 Hz)	15000 ms
4	0.958 · Fn (57.5 Hz)	5000ms
5	0.950 · Fn (57 Hz)	500 ms

The rate of change of frequency function is not instantaneous since the function needs time to supply a stable value. It is recommended to have a time delay long enough to take care of the signal noise.

Small industrial systems can experience the rate of change of frequency as large as 5 Hz/s due to a single event. Even large power systems can form small islands with a large imbalance between the load and generation when severe faults or combinations of faults are cleared. Up to 3 Hz/s has been experienced when a small island becomes isolated from a large system. For normal severe disturbances in large power systems, the rate of change of the frequency is much less, often just a fraction of 1.0 Hz/s.

Similarly, the setting for df/dt can be from 0.1 Hz/s to 1.2 Hz/s in steps of 0.1 Hz/s to 0.3 Hz/s for large distributed power networks, with the operating time varying from a few seconds to a few fractions of a second. Here, the operating time should be kept in minimum for the higher df/dt setting.

Table 216: Setting for a five-step df/dt< operation

Load-shedding steps	Pickup value df/dt setting	Trip Tm df/dt setting
1	-0.005 · Fn /s (-0.25 Hz/s)	8000 ms
2	-0.010 · Fn /s (-0.25 Hz/s)	2000 ms
3	-0.015 · Fn /s (-0.25 Hz/s)	1000 ms
4	-0.020 · Fn /s (-0.25 Hz/s)	500 ms
5	-0.025 · Fn /s (-0.25 Hz/s)	250 ms

Once the frequency has stabilized, the shed load can be restored. The restoring operation should be done stepwise, taking care that it does not lead the system back to the emergency condition.

Table 217: Setting for a five-step restoring operation

Load-shedding steps	Restoring pickup Val setting	Restore delay time setting
1	0.990 · Fn (59.4 Hz)	200000 ms
2	0.990 · Fn (59.4 Hz)	160000 ms
3	0.990 · Fn (59.4 Hz)	100000 ms
4	0.990 · Fn (59.4 Hz)	50000 ms
5	0.990 · Fn (59.4 Hz)	10000 ms

4.3.2.6 Signals

Table 218: 81LSH Input signals

Name	Type	Default	Description
F	SIGNAL	0	Measured frequency
dF/dt	SIGNAL	0	Rate of change of frequency
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
BLK_REST	BOOLEAN	0=False	Block restore
MAN_RESTORE	BOOLEAN	0=False	Manual restore signal

Table 219: 81LSH Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip of load shedding
OPR_FRQ	BOOLEAN	Trip signal for under frequency
OPR_FRG	BOOLEAN	Trip signal for high df/dt
PICKUP	BOOLEAN	Pickup
ST_FRQ	BOOLEAN	Pick-Up signal for under frequency detection
Table continues on next page		

Name	Type	Description
ST_FRG	BOOLEAN	Pick-Up signal for high df/dt detection
RESTORE	BOOLEAN	Restore signal for load restoring purposes
ST_REST	BOOLEAN	Restore frequency attained and restore timer started

4.3.2.7 Settings

Table 220: 81LSH Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Load shed mode	1=Freq< 6=Freq< OR df/dt 8=Freq< AND df/dt			1=Freq<	Set the operation mode for load shedding function
Restore mode	1=Disabled 2=Auto 3=Manual			1=Disabled	Mode of operation of restore functionality
Pickup value Freq	0.800...1.200	xFn	0.001	0.975	Frequency setting/pickup value
Pickup value df/dt	-0.200...-0.005	xFn /s	0.005	-0.010	Setting of frequency gradient for df/dt detection
Trip Tm Freq	80...200000	ms	10	200	Time delay to trip for under frequency stage
Trip Tm df/dt	120...200000	ms	10	200	Time delay to trip for df/dt stage
Restore pickup Val	0.800...1.200	xFn	0.001	0.998	Restore frequency setting value
Restore delay time	80...200000	ms	10	300	Time delay to restore

Table 221: 81LSH Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	50	Time delay after which the definite timers will reset

4.3.2.8 Monitored data

Table 222: 81LSH Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Pickup duration
81LSH	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.3.2.9 Technical data

Table 223: 81LSH Technical data

Characteristic		Value
Operation accuracy	f<	±10 mHz
	df/dt	±100 mHz/s (in range |df/dt| < 5 Hz/s) ± 2.0% of the set value (in range 5 Hz/s < |df/dt| < 15 Hz/s)
Pickup time	f<	<80 ms
	df/dt	<120 ms
Reset time		<150 ms
Trip time accuracy		±1.0% of the set value or ±30 ms

4.4 Power protection

4.4.1 Three phase directional power protection 32P

4.4.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase directional power protection	DPSRDIR	I1->	32P

4.4.1.2 Function block

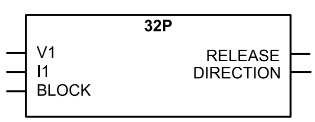


Figure 132: Function block

4.4.1.3 Functionality

The three-phase directional power protection 32P is used to detect positive-sequence power direction. The output of the function is used for blocking or releasing other functions in protection scheme.

The directional positive-sequence power protection contains a blocking functionality which blocks function output and resets Timer.

32P executes on the direction of positive-sequence power and not the value. If overpower or underpower is needed, refer to 32O and 32U. 32P is generally used for directional controls.

4.4.1.4 Operation principle

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

The operation of 32P can be described with a module diagram. All the modules in the diagram are explained in the next sections.

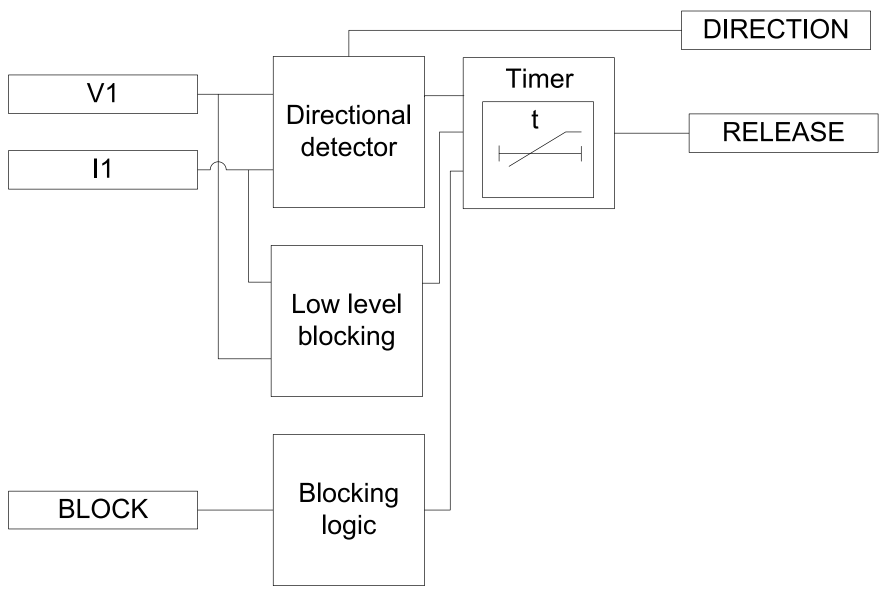


Figure 133: Functional module diagram

Directional detector

The Directional detector module compares the angle of the positive-sequence current I1 to the angle of the positive-sequence voltage V1. Using the positive-sequence voltage angle as reference, the positive-sequence current angle is compared to the *Characteristic angle* setting. If the angular difference is within the operating sector selected with the *Directional mode* setting, the Enable signal is sent to Timer.

The operating sector is defined by the setting *Min forward angle*, *Max forward angle*, *Min reverse angle* and *Max reverse angle*. The options that can be selected for the *Directional mode* setting are “Forward” and “Reverse”.

The sector limits are always given as positive degree values.

The *Characteristic angle* setting is also known as Relay Characteristic Angle (RCA), Relay Base Angle or Maximum Torque Line.

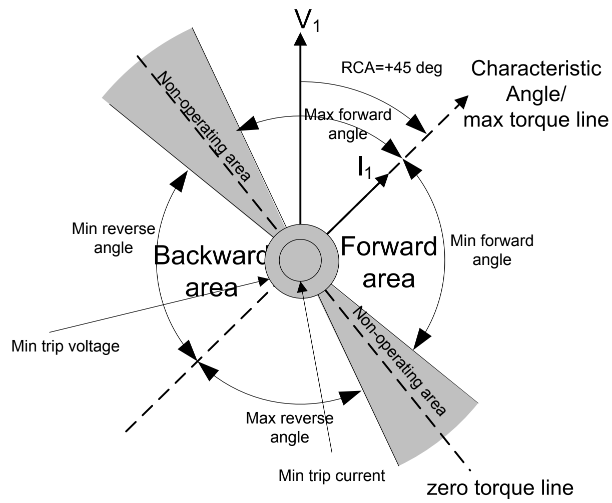


Figure 134: Configurable directional settings

Low-level blocking

For a reliable operation, signal levels should be greater than the minimum level. If they are not greater than the minimum level, Timer is blocked. If the amplitude of the positive-sequence current is greater than the *Min trip current* value and the positive-sequence voltage amplitude is greater than the *Min trip voltage* value, the Enable signal is sent to Timer.

Timer

Once activated, the internal operating timer is started. The Timer characteristic is according to definite time DT. When Timer has reached the value of *Release delay time*, the RELEASE output is activated. If a drop-off situation happens, that is, if the operating current moves outside the operating sector or signal amplitudes drop below the minimum level before *Release delay time* is exceeded, the Timer reset state is activated. If the drop-off continues for more than *Reset delay time*, Timer is deactivated.

Blocking logic

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates the RELEASE output and resets Timer.

4.4.1.5 Application

The three-phase directional power protection 32P improves the possibility to obtain a selective function of the overcurrent protection in meshed networks. The function is used to block or release other overcurrent protection functions.

4.4.1.6 Signals

Table 224: 32P Input signals

Name	Type	Default	Description
V1	REAL	0.0	Positive sequence voltage
I1	REAL	0.0	Positive sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 225: 32P Output signals

Name	Type	Description
RELEASE	BOOLEAN	direction signal
DIRECTION	Enum	Direction information

4.4.1.7 Settings

Table 226: 32P Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Release delay time	0...1000	ms	1	10	Release delay time
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	88	Minimum phase angle in reverse direction
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode

Table 227: 32P Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Min trip current	0.01...1.00	xIn	0.01	0.10	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.30	Minimum trip voltage

4.4.1.8 Monitored data

Table 228: 32P Monitored data

Name	Type	Values (Range)	Unit	Description
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
32P	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.4.2 Ground directional power protection 32N

4.4.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Ground directional power protection	DNZSRDIR	I2->, Io->	32N

4.4.2.2 Function block

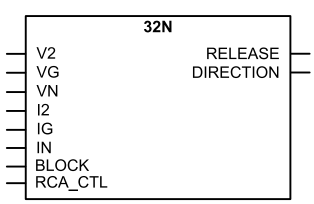


Figure 135: Function block

4.4.2.3 Functionality

Ground directional power protection 32N is used to detect negative or residual power direction. The output of the function is used for blocking or releasing other functions in protection scheme.

In negative-sequence voltage selection, if the angle difference between negative-sequence voltage and negative-sequence current is in a predefined direction (either in forward or reverse direction), 32N gives a release signal after a definite time delay.

In residual voltage selection, if the angle difference between residual voltage and residual current is in a predefined direction (either in forward or reverse direction), 32N gives release signal after a definite time delay.

This function contains a blocking functionality which blocks the function output and resets Timer.

32N executes on the direction of either negative-sequence or zero-sequence power and not the value. 32N is generally used for directional controls.

4.4.2.4 Operation principle

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

The operation of 32N can be described with a module diagram. All the modules in the diagram are explained in the next sections.

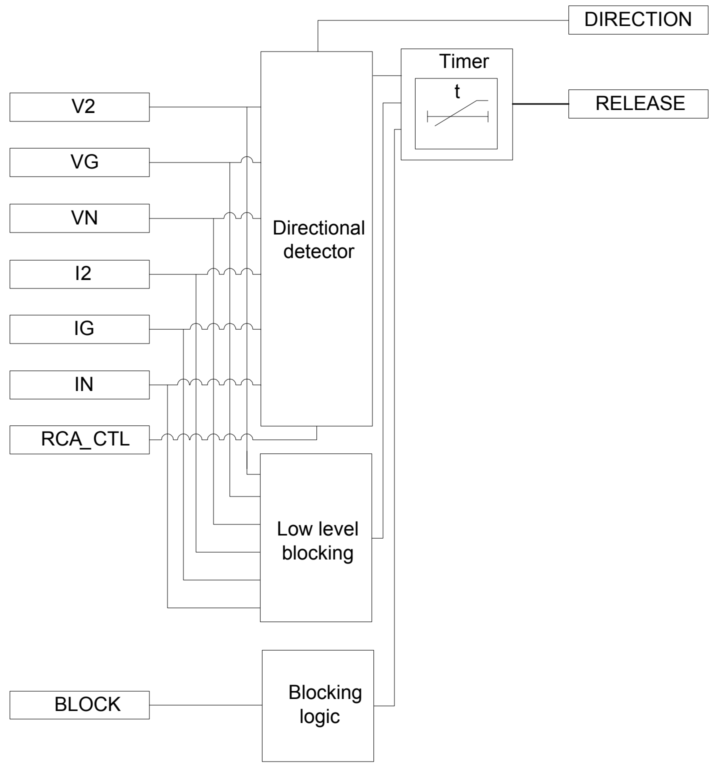


Figure 136: Functional module diagram

Directional detector

When "Neg. seq. volt." selection is made using *Pol signal Sel*, the Directional detector module compares the angle of the negative-sequence current (I2) to the negative-sequence voltage (-V2). Using the negative-sequence voltage angle as the reference, the negative-sequence current angle is compared to the *Characteristic angle* setting. If the angle difference is within the operating sector selected by *Direction mode* setting, the Enable signal is sent to Timer.

The value of *Characteristic angle* should be chosen in such way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the backward zone.

The operating sector is defined by the settings *Max forward angle*, *Max reverse angle*, *Min forward angle* and *Min reverse angle*. The options that can be selected for *Directional mode* settings are “Forward” and “Reverse”.

Characteristic angle is also known as Relay Characteristic Angle RCA, Relay Base Angle or Maximum Torque Line.

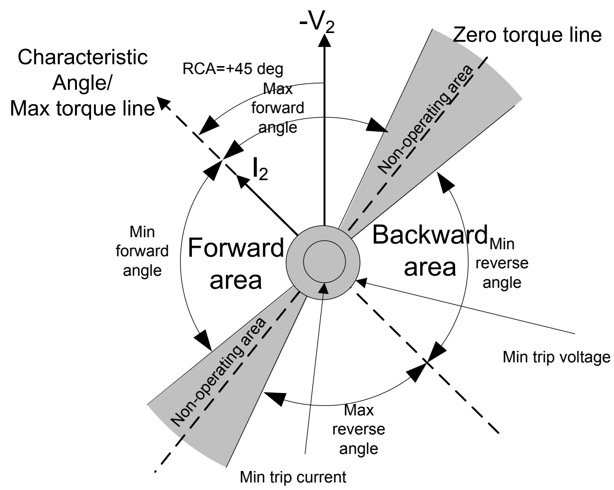


Figure 137: Configurable directional setting when "Neg. seq. volt." selection is made using Pol signal Sel.

When "Measured VG" or "Calculated VN" voltage selection is made using *Pol signal Sel* setting, the directional detector module compares the angle of the residual current to the residual voltage. Using the residual voltage as reference, the residual current angle is compared to the *Characteristic angle* setting. If the angle difference is within the operating sector selected by the *Directional mode* setting, the Enable signal is sent to Timer.

"Measured IG" or "Calculated IN" (residual current) can be selected with the *Io signal Sel* setting.
The "Measured VG", "Calculated VN" (residual voltage) can be selected with the *Pol signal Sel* setting.

The polarizing quantity (residual voltage) is inverted because of switched voltage measurement cables, the correction can be done by setting the *Pol reversal* setting to "True", which rotates the polarizing quantity by 180 degrees.

The operating sector is defined by the settings *Max forward angle*, *Max reverse angle*, *Min forward angle* and *Min reverse angle*. The options that can be selected for the *Directional mode* settings are "Forward" and "Reverse".

The directional characteristic for the measured or calculated residual power is same.

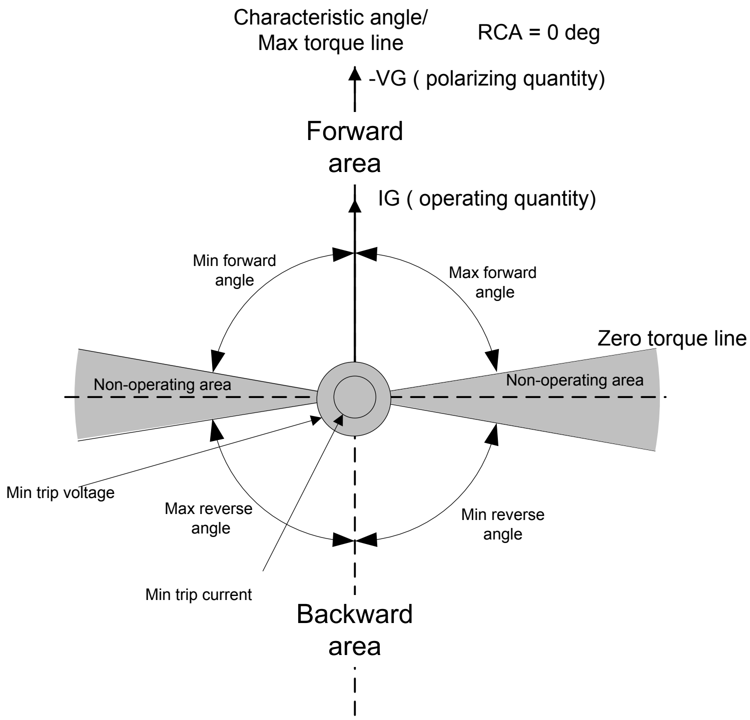


Figure 138: Configurable directional setting for "Measured VG" or "Calculated VN" (residual voltage) using Pol signal Sel setting

The *Characteristic angle* setting is done based on method of grounding employed in the network. For example, in case of an isolated network, *Characteristic angle* is set to -90°, and in case of a compensated network, *Characteristic angle* is set to 0° and 60° for solidly grounded systems. In general *Characteristic angle* is selected so that it matches close to the expected fault angle value, which results in maximum sensitivity. *Characteristic angle* can be set anywhere between -179° to +180°. The figures show examples of the operating area with RCA set to +60° and -90°, respectively.

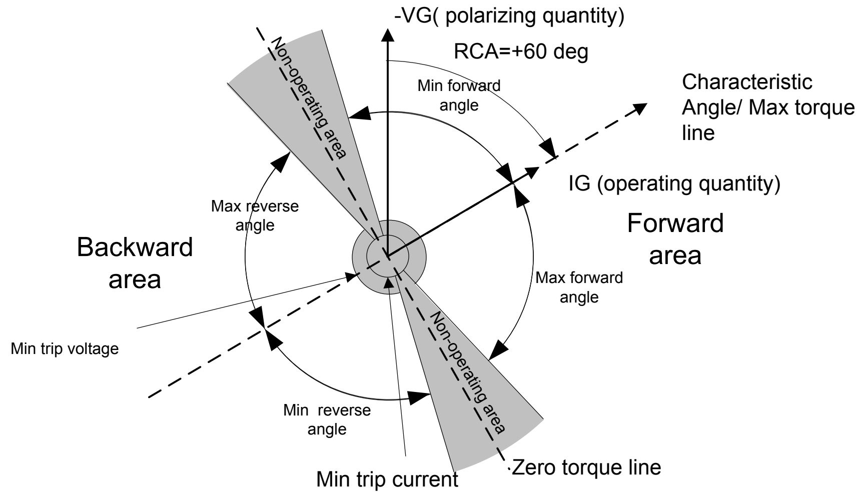


Figure 139: Configurable directional characteristics (RCA =+60˚) for a solidly grounded network

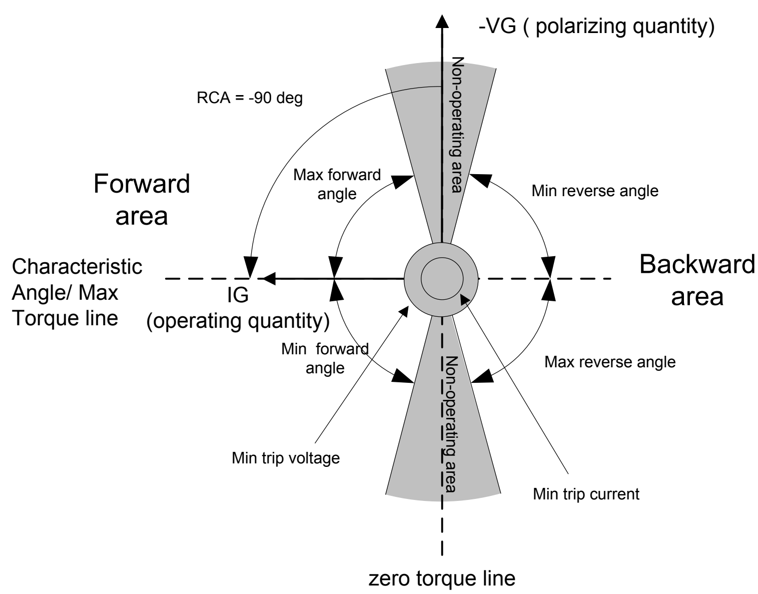


Figure 140: Configurable directional characteristics (RCA = -90˚) for an isolated network

Characteristic angle should be set to a positive value if the operating signal IG or IN lags the polarizing quantity –VG or –VN, respectively, and a negative value if operating signal IG or IN leads the polarizing quantity –VG or –VN, respectively.

Table 229: Recommended Characteristic angle setting for different network

Type of network	Characteristic angle recommended
Compensated network	0°
Solidly grounded network	+60°
Isolated network	-90°

The *Characteristic angle* setting is adjusted to the operation according to the method of neutral-point grounding, so that in an isolated network *Characteristic angle* is -90° and in a compensated network 0°. In addition, *Characteristic angle* can be changed via the control signal RCA_CTL, in which case the alternatives are -90° and 0°. The operation of the RCA_CTL input depends on the *Characteristic angle* setting.

The Peterson coil or the grounding resistor may be temporarily out of operation. To keep the protection scheme selective, it is necessary to update the *Characteristic angle* settings accordingly. This is done with an auxiliary input in the relay which receives a signal from an auxiliary switch of the disconnector of the Peterson coil in compensated networks or of the grounding resistor in grounded network as a result the *Characteristic angle* is set automatically to suit the grounding method.

Table 230: Characteristic angle control for the RCA_CTL condition

Characteristic angle Setting	RCA_CTL=FALSE	RCA_CTL=TRUE
-90°	*Characteristic angle* =-90°	*Characteristic angle* = 0°
0°	*Characteristic angle* = 0°	*Characteristic angle* =-90°

Low-level blocking

For a reliable operation, signal levels should be greater than the minimum level. If they are not greater than the minimum level, Timer is blocked.

In the "Neg. seq. volt." polarization selection using *Pol signal Sel*, if the amplitude of the negative-sequence current is greater than the *Min trip current* value and the negative-sequence voltage amplitude is greater than the *Min trip voltage* value, the enabling signal is sent to Timer.

In the "Measured VG" or "Calculated VN" polarization selection using *Pol signal Sel*, if the amplitude of the residual current is greater than the *Min trip current* value and residual voltage amplitude is greater than the *Min trip voltage* value, the enabling signal is sent to Timer.

Timer

Once activated, the internal operating timer is started. The Timer characteristic is according to DT. When Timer has reached the value of *Release delay time*, the RELEASE output is activated. If a drop-off situation happens, that is, if the operating current moves out of the operating sector or signal amplitudes drop below the minimum levels, before *Release delay time* is exceeded, the Timer reset state is activated. If the drop-off continues for more than *Reset delay time*, Timer is deactivated.

Blocking logic

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates RELEASE output and resets Timer.

4.4.2.5 Application

The ground directional power protection 32N improves the possibility to obtain selective function of the overcurrent protection in meshed networks. 32N is used to block or release other overcurrent protection functions.

4.4.2.6 Signals

Table 231: 32N Input signals

Name	Type	Default	Description
V2	REAL	0	Negative sequence voltage
VG	REAL	0	Measured residual voltage or Ground voltage
VN	REAL	0	Calculated residual voltage or Neutral voltage
I2	REAL0	0	Negative sequence current
IG	REAL	0	Measured residual current or Ground current
IN	REAL	0	Calculated residual current or Neutral current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
RCA_CTL	BOOLEAN	0=False	Relay characteristic angle control

Table 232: 32N Output signals

Name	Type	Description
RELEASE	BOOLEAN	direction signal
DIRECTION	Enum	Direction information

4.4.2.7 Settings

Table 233: 32N Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Release delay time	0...1000	ms	10	10	Release delay time
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...180	deg	1	88	Maximum phase angle in forward direction
Min forward angle	0...180	deg	1	88	Minimum phase angle in forward direction
Max reverse angle	0...180	deg	1	88	Maximum phase angle in reverse direction
Min reverse angle	0...180	deg	1	88	Minimum phase angle in reverse direction

Table 234: 32N Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Min trip current	0.01...1.00	xIn	0.01	0.10	Minimum trip current
Min trip voltage	0.01...1.00	xUn	0.01	0.30	Minimum trip voltage
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
IG/I0 Sel	1=Measured IG 2=Calculated I0			1=Measured IG	IG/I0 selection
Pol signal Sel	1=Measured VG 2=Calculated V0 3=Neg. seq. volt.			1=Measured VG	Selection for used polarization signal

4.4.2.8 Monitored data

Table 235: 32N Monitored data

Name	Type	Values (Range)	Unit	Description
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
32N	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.5 Thermal protection

4.5.1 Three-phase thermal protection for feeders, cables and distribution transformers 49F

4.5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	3Ith>F	49F

4.5.1.2 Function block

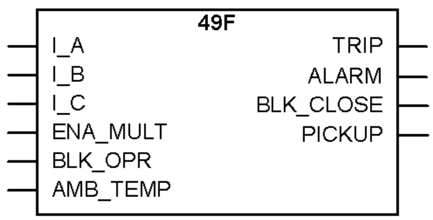


Figure 141: Function block

4.5.1.3 Functionality

The increased utilization of power systems closer to the thermal limits has generated a need for a thermal overload function for power lines as well.

A thermal overload is in some cases not detected by other protection functions, and the introduction of the thermal overload function 49F allows the protected circuit to operate closer to the thermal limits.

An alarm level gives an early warning to allow operators to take action before the line trips. The early warning is based on the three-phase current measuring function using a thermal model with first order thermal loss with the settable time constant. If the temperature rise continues the function operates based on the thermal model of the line.

Re-energizing of the line after a thermal overload operation can be inhibited for a time to allow the line to cool. The time for the line to cool is estimated by the thermal model.

4.5.1.4 Operation principle

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

The operation of 49F can be described using a module diagram. All the modules in the diagram are explained in the next sections.

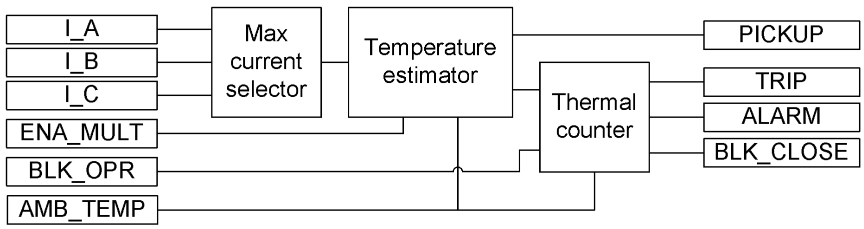


Figure 142: Functional module diagram

Max current selector

The max current selector of the function continuously checks the highest measured TRMS phase current value. The selector reports the highest value to the temperature estimator.

Temperature estimator

The final temperature rise is calculated from the highest of the three-phase currents according to the expression:

$$\Theta_{final} = \left(\frac{I}{I_{ref}}\right)^2 \cdot T_{ref}$$

(Equation 12)

I	the largest phase current
I_{ref}	set *Current reference*
T_{ref}	set *Temperature rise*

The ambient temperature is added to the calculated final temperature rise estimation, and the ambient temperature value used in the calculation is also available in the monitored data as TEMP_AMB in degrees. If the final temperature estimation is larger than the set *Maximum temperature*, the PICKUP output is activated.

Current reference and *Temperature raise* setting values are used in the final temperature estimation together with the ambient temperature. It is suggested to set these values to the maximum steady state current allowed for the line or cable under emergency operation for a few hours per years. Current values with the corresponding conductor temperatures are given in cable manuals. These values are given for conditions such as ground temperatures, ambient air temperature, the way of cable laying and ground thermal resistivity.

Thermal counter

The actual temperature at the actual execution cycle is calculated as:

$$\Theta_n = \Theta_{n-1} + \left(\Theta_{final} - \Theta_{n-1}\right) \cdot \left(1 - e^{-\frac{\Delta t}{\tau}}\right)$$

(Equation 13)

Θ_n	calculated present temperature
Θ_{n-1}	calculated temperature at previous time step
Θ_{final}	calculated final temperature with actual current
Δt	time step between calculation of actual temperature
τ	thermal time constant for the protected device (line or cable), set *Time constant*

The actual temperature of the protected component (line or cable) is calculated by adding the ambient temperature to the calculated temperature, as shown above. The ambient temperature can be given a constant value or it can be measured. The calculated component temperature can be monitored as it is exported from the function as a real figure.

When the component temperature reaches the set alarm level *Alarm value*, the output signal `ALARM` is set. When the component temperature reaches the set trip level *Maximum temperature*, the `TRIP` output is activated. The `TRIP` signal pulse length is fixed to 100 ms.

There is also a calculation of the present time to operation with the present current. This calculation is only monitored if the final temperature is calculated to be above the operation temperature. If the final temperature is below the operation temperature, maximum estimated time to trip is monitored. The value is available in the monitored data view as `T_TRIP` in seconds:

$$t_{trip} = -\tau \cdot \ln\left(\frac{\Theta_{final} - \Theta_{trip}}{\Theta_{final} - \Theta_n}\right)$$

(Equation 14)

Caused by the thermal overload protection function, there can be a lockout to reconnect the tripped circuit after operating. The lockout output BLK_CLOSE is activated at the same time when the TRIP output is activated and is not reset until the device temperature has cooled down below the set value of the *Reclose temperature* setting. BLK_CLOSE works also as hysteresis for the TRIP signal preventing a new TRIP signal activation until BLK_CLOSE has reset. The *Maximum temperature* value must be set at least two degrees above the set value of *Reclose temperature*.

The time to lockout release is calculated, that is, the calculation of the cooling time to a set value. The calculated temperature can be reset to its initial value (the *Initial temperature* setting) via a control parameter that is located under the clear menu. This is useful during testing when secondary injected current has given a calculated false temperature level.

$$t_{lockout\_release} = -\tau \cdot \ln\left(\frac{\Theta_{final} - \Theta_{lockout\_release}}{\Theta_{final} - \Theta_n}\right)$$

(Equation 15)

Here the final temperature is equal to the set or measured ambient temperature.

In some applications, the measured current can involve a number of parallel lines. This is often used for cable lines where one bay connects several parallel cables. By setting the *Current multiplier* parameter to the number of parallel lines (cables), the actual current on one line is used in the protection algorithm. To activate this option, the ENA_MULT input must be activated.

The *Env temperature set* setting is used to define the ambient temperature.

The temperature calculation is initiated from the value defined with the *Initial temperature* setting parameter. This is done in case the protection relay is powered up, the function is disabled and enabled back or reset through the Clear menu. The temperature is also stored in the nonvolatile memory and restored in case the protection relay is restarted.

The thermal time constant of the protected circuit is given in seconds with the *Time constant* setting. Please see cable manufacturers manuals for further details.

4.5.1.5 Application

The lines and cables in the power system are constructed for a certain maximum load current level. If the current exceeds this level, the losses will be higher than expected. As a consequence, the temperature of the conductors will increase. If the temperature of the lines and cables reaches too high values, it can cause a risk of damages by, for example, the following ways:

- The sag of overhead lines can reach an unacceptable value.
- If the temperature of conductors, for example aluminium conductors, becomes too high, the material will be destroyed.
- Overheating can damage the insulation on cables which in turn increases the risk of phase-to-phase or phase-to-ground faults.

In stressed situations in the power system, the lines and cables may be required to be overloaded for a limited time. This should be done without any risk for the above-mentioned risks.

The thermal overload protection provides information that makes temporary overloading of cables and lines possible. The thermal overload protection estimates the conductor temperature continuously. This estimation is made by using a thermal model of the line/cable that is based on the current measurement.

If the temperature of the protected object reaches a set warning level, a signal is given to the operator. This enables actions in the power system to be done before dangerous temperatures are reached. If the temperature continues to increase to the maximum allowed temperature value, the protection initiates a trip of the protected line.

4.5.1.6 Signals

Table 236: 49F 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 trip outputs
ENA_MULT	BOOLEAN	0=False	Enable Current multiplier
TEMP_AMB	FLOAT32	0	The ambient temperature used in the calculation

Table 237: 49F Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup
ALARM	BOOLEAN	Thermal Alarm
BLK_CLOSE	BOOLEAN	Thermal overload indicator. To inhibite reclose.

4.5.1.7 Settings

Table 238: 49F Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Env temperature set	-50...100	°C	1	40	Ambient temperature used when AmbiSens is set to Off
Current multiplier	1...5		1	1	Current multiplier when function is used for parallel lines
Current reference	0.05...4.00	xIn	0.01	1.00	The load current leading to Temperature raise temperature
Temperature raise	0.0...200.0	°C	0.1	75.0	End temperature rise above ambient
Time constant	60...60000	s	1	2700	Time constant of the line in seconds.
Maximum temperature	20.0...200.0	°C	0.1	90.0	Temperature level for trip
Alarm value	20.0...150.0	°C	0.1	80.0	Temperature level for pickup (alarm)
Reclose temperature	20.0...150.0	°C	0.1	70.0	Temperature for reset of block reclose after trip

Table 239: 49F Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Initial temperature	-50.0...100.0	°C	0.1	0.0	Temperature raise above ambient temperature at startup

4.5.1.8 Monitored data

Table 240: 49F Monitored data

Name	Type	Values (Range)	Unit	Description
TEMP	FLOAT32	-100.0...9999.9	°C	The calculated temperature of the protected object
TEMP_RL	FLOAT32	0.00...99.99		The calculated temperature of the protected object relative to the trip level
T_TRIP	INT32	0...60000	s	Estimated time to trip
T_ENA_CLOSE	INT32	0...60000	s	Estimated time to deactivate BLK_CLOSE
49F	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.5.1.9 Technical data

Table 241: 49F Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	Current measurement: ±1.5% of the set value or ±0.002 × I_n (at currents in the range of 0.01...4.00 × I_n)
Trip time accuracy1)	±2.0% of the theoretical value or ±0.50 s

1) Overload current > 1.2 × Trip level temperature

4.6 Differential protection

4.6.1 Numerical stabilized low impedance restricted earth-fault protection 87LOZREF

4.6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Numerical stabilized low impedance restricted earth-fault protection	LREFPNDF	dIoLo>	87LOZREF

4.6.1.2 Function block

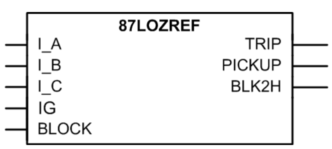


Figure 143: Function block

4.6.1.3 Functionality

Numerical stabilized low impedance restricted earth-fault protection function 87LOZREF for a two winding transformer is based on the numerically stabilized differential current principle. No external stabilizing resistor or non-linear resistor are required.

The fundamental components of the currents are used for calculating the residual current of the phase currents, the neutral current, differential currents and stabilizing currents. The operating characteristics are according to the definite time.

The function contains a blocking functionality. The neutral current second harmonic is used for blocking during the transformer inrush situation. It is also possible to block function outputs, timers or the function itself, if desired.

4.6.1.4 Operation principle

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

The operation of 87LOZREF can be described using a module diagram. All the modules in the diagram are explained in the next sections.

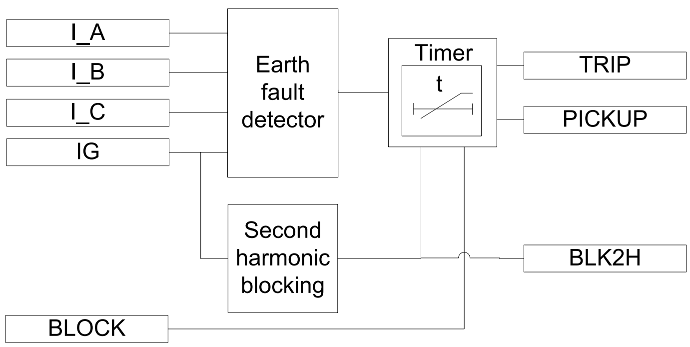


Figure 144: Functional module diagram

Earth fault detector

The operation is based on comparing the amplitude and the phase difference between the sum of the fundamental frequency component of the phase currents (ΣI, residual current) and the fundamental frequency component of the neutral current (IG) flowing in the conductor between the transformer or generator's neutral point and ground. The differential current is calculated as the absolute value of the difference between the residual current (the sum of the fundamental frequency components of the phase currents I_A, I_B and I_C) and the neutral current. The directional differential current ID_COSPHI is the product of the differential current and cosφ. The value is available in the monitored data view.

$$ID\_COSPHI = \left(\left|\overline{\Sigma I} - \overline{IG}\right|\right) \times \cos\varphi$$

(Equation 16)

$\overline{\Sigma I}$	Residual current
φ	Phase difference between the residual and neutral currents
$\overline{IG}$	Neutral current

A ground fault occurring in the protected area, that is, between the phase CTs and the neutral connection CT, causes a differential current. The directions, that is, the phase difference of the residual current and the neutral current, are considered in the operation criteria to maintain selectivity. A correct value for *CT connection type* is determined by the connection polarities of the current transformer.

The current transformer ratio mismatch between the phase current transformer and neutral current transformer (residual current in the analog input settings) is taken into account by the function with the properly set analog input setting values.

During a ground fault in the protected area, the currents ΣI and IG are directed towards the protected area. The factor cosφ is 1 when the phase difference of the residual current and the neutral current is 180 degrees, that is, when the currents are in opposite direction at the ground faults within the protected area. Similarly, ID_COSPHI is specified to be 0 when the phase difference between the residual current and the neutral current is less than 90 degrees in situations where there is no ground fault in the protected area. Thus tripping is possible only when the phase difference between the residual current and the neutral current is above 90 degrees.

The stabilizing current IB used by the stabilizing current principle is calculated as an average of the phase currents in the windings to be protected. The value is available in the monitored data view.

$$IB = \frac{\left|\overline{I\_A}\right| + \left|\overline{I\_B}\right| + \left|\overline{I\_C}\right|}{3}$$

(Equation 17)

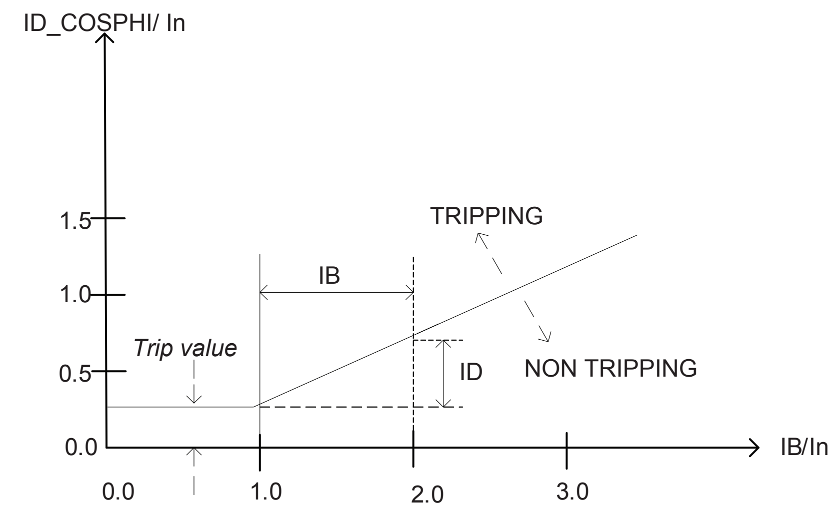


Figure 145: Operating characteristics of the stabilized ground-fault protection function

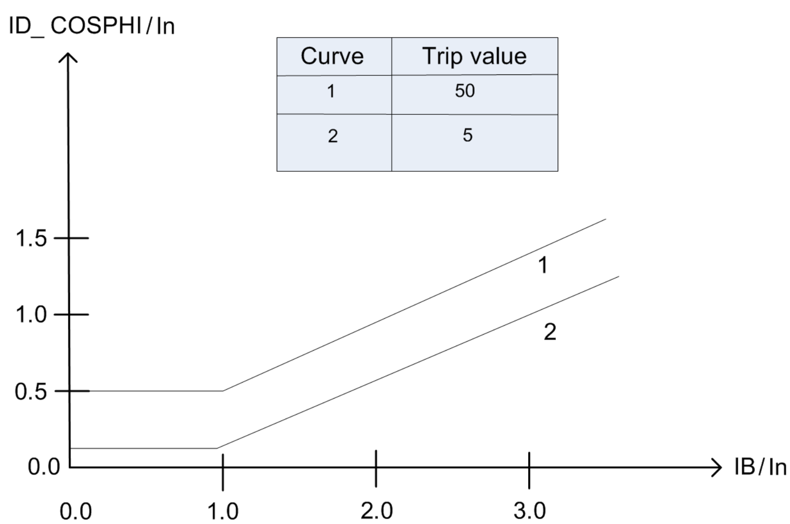


Figure 146: Setting range of the operating characteristics for the stabilized differential current principle of the ground-fault protection function

The *Trip value* setting is used for defining the characteristics of the function. The differential current value required for tripping is constant at the stabilizing current values 0.0 < IB/In < 1.0, where In is the nominal current, and the In in this context refers to the nominal of the phase current inputs. When the stabilizing current is higher than 1.0, the slope of the operation characteristic (ID/IB) is constant at 50 percent. Different operating characteristics are possible based on the *Trip value* setting.

To calculate the directional differential current ID_COSPHI, the fundamental frequency amplitude of both the residual and neutral currents has to be above 4 percent of In. If neither or only one condition is fulfilled at a time, the cosφ term is forced to 1. After the conditions are fulfilled, both currents must stay above 2 percent of In to allow the continuous calculation of the cosφ term.

Second harmonic blocking

This module compares the ratio of the current second harmonic (IG_2H) and IG to the set value *Pickup value 2.H*. If the ratio (IG_2H / IG) value exceeds the set value, the `BLK2H` output is activated.

The blocking also prevents unwanted operation at the recovery and sympathetic magnetizing inrushes. At the recovery inrush, the magnetizing current of the transformer to be protected increases momentarily when the voltage returns to normal after the clearance of a fault outside the protected area. The sympathetic inrush is caused by the energization of a transformer running in parallel with the protected transformer connected to the network.

The second harmonic blocking is disabled when *Restraint mode* is set to "None" and enabled when set to "Harmonic2".

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 *Minimum trip time*, the `TRIP` output is activated. If the fault disappears before the module trips, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the reset timer resets and the `PICKUP` output is deactivated.

The Timer calculates the pickup duration value PICKUP_DUR which indicates the percentage ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 operate timer is frozen to the prevailing value, but the `TRIP` output is not deactivated when blocking is activated. 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. The activation of the output of the second harmonic blocking signal BLK2H deactivates the TRIP output.

4.6.1.5 Application

A ground-fault protection using an overcurrent element does not adequately protect the transformer winding in general and the 87LOZREF winding in particular.

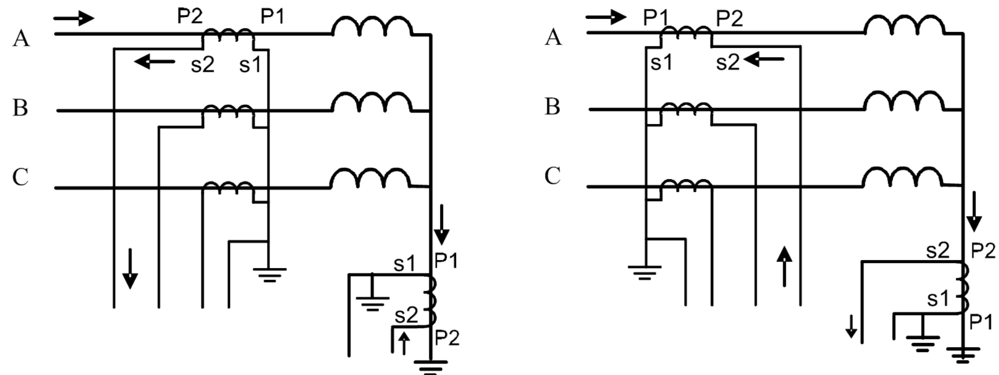
The restricted ground-fault protection is mainly used as a unit protection for the transformer windings. 80LOZREF is a sensitive protection applied to protect the 87LOZREF winding of a transformer. This protection system remains stable for all the faults outside the protected zone.

87LOZREF provides a higher sensitivity for the detection of ground faults than the overall transformer differential protection. This is a high-speed unit protection scheme applied to the 87LOZREF winding of the transformer. In 87LOZREF, the difference of the fundamental component of all three phase currents and the neutral current is provided to the differential element to detect the ground fault in the transformer winding based on the numerical stabilized differential current principle.

Connection of current transformers

The connections of the main CTs are designated as "Type 1" and "Type 2". In case the groundings of the current transformers on the phase side and the neutral side are both either inside or outside the area to be protected, the setting parameter *CT connection type* is "Type 1".

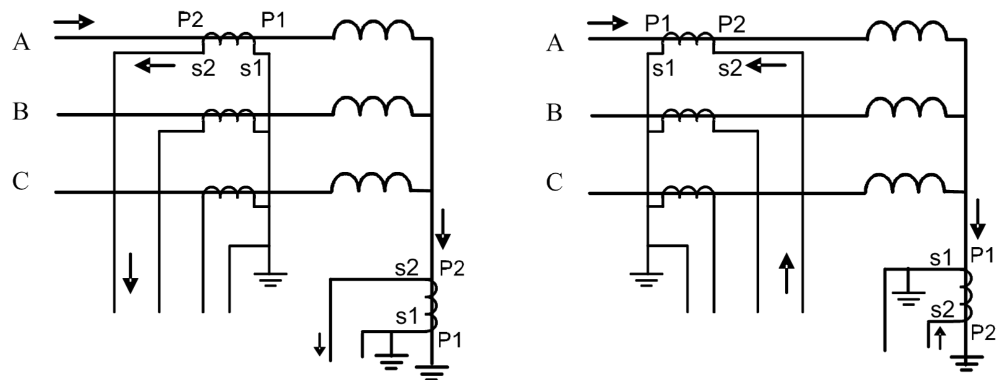
If the grounding of the current transformers on the phase side is inside the area to be protected and the neutral side is outside the area to be protected or vice versa, the setting parameter *CT connection type* is "Type 2".



a. Both groundings are inside area to be protected

b. Both groundings are outside area to be protected

Figure 147: Connection of the current transformers of Type 1. The connected phase currents and the neutral current have opposite directions at an external ground-fault situation.



a. Phase grounding is inside and neutral grounding is outside area to be protected

b. Phase grounding is outside and neutral grounding is inside area to be protected

Figure 148: Connection of the current transformers of Type 2. The phase currents and the neutral current have equal directions at an external ground-fault situation.

Internal and external faults

87LOZREF does not respond to any faults outside the protected zone. An external fault is detected by checking the phase angle difference of the neutral current and the sum of the phase currents. When the difference is less than 90 degrees, the operation is internally restrained or blocked. Hence the protection is not sensitive to an external fault.

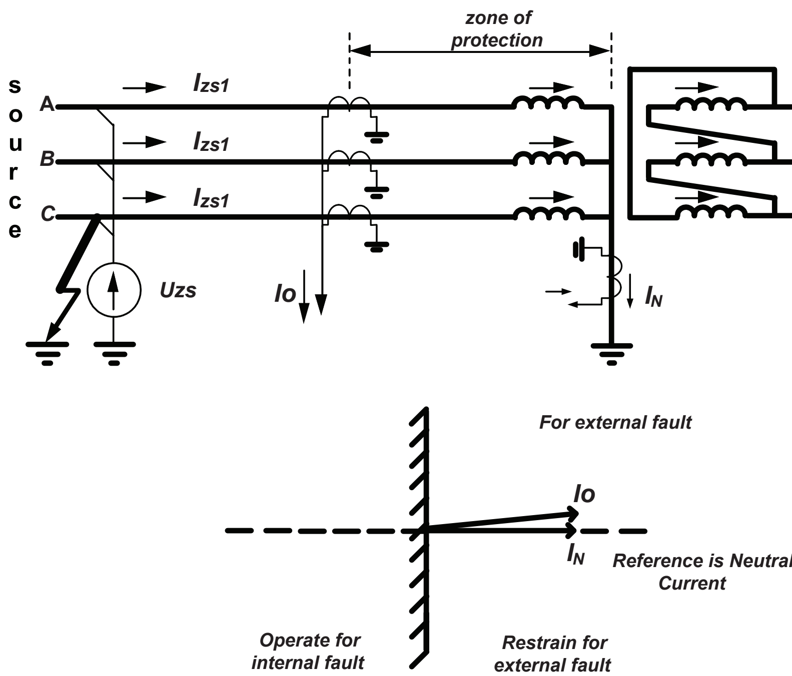


Figure 149: Current flow in all the CTs for an external fault

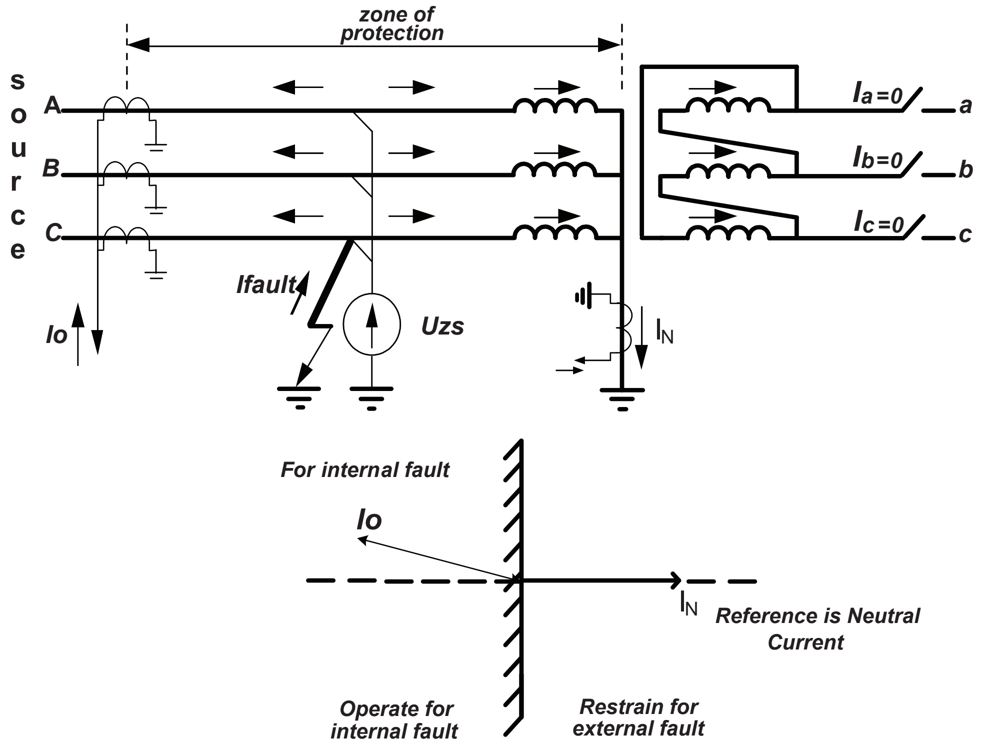


Figure 150: Current flow in all the CTs for an internal fault

87LOZREF does not respond to phase-to-phase faults either, as in this case the fault current flows between the two line CTs and so the neutral CT does not experience this fault current.

87LOZREF is normally applied when the transformer is solidly grounded because in this case the fault current is high enough and the ground fault can be detected easily.

Blocking based on the second harmonic of the neutral current

The transformer magnetizing inrush currents occur when the transformer is energized after a period of de-energization. The inrush current can be many times the rated current, and the halving time can be up to several seconds. For the differential protection relay, the inrush current represents the differential current, which causes the protection relay to trip almost always when the transformer is connected to the network. Typically, the inrush current contains a large amount of second harmonics.

The blocking also prevents unwanted operation at the recovery and sympathetic magnetizing inrushes. At the recovery inrush, the magnetizing current of the transformer to be protected increases momentarily when the voltage returns to normal after the clearance of a fault outside the protected area. The sympathetic inrush is caused by the energization of a transformer running in parallel with the protected transformer already connected to the network.

Blocking the pickup of the restricted ground-fault protection at the magnetizing inrush is based on the ratio of the second harmonic and the fundamental frequency amplitudes of the neutral current IG_2H / IG. Typically, the second harmonic content of the neutral current at the magnetizing inrush is higher than that of the phase currents.

4.6.1.6 Signals

Table 242: 87LOZREF 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_0	SIGNAL	0	Zero-sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 243: 87LOZREF Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup
BLK2H	BOOLEAN	2nd harmonic block

4.6.1.7 Settings

Table 244: 87LOZREF Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Trip value	5...50	%In	1	5	Trip value
Minimum trip time	40...300000	ms	1	40	Minimum trip time
Restraint mode	1=None 2=Harmonic2			1=None	Restraint mode
Pickup value 2.H	10...50	%In	1	50	The ratio of the 2. harmonic to fundamental component required for blocking

Table 245: 87LOZREF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
CT connection type	1=Type 1 2=Type 2			2=Type 2	CT connection type

4.6.1.8 Monitored data

Table 246: 87LOZREF Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
RES2H	BOOLEAN	0=False 1=True		2nd harmonic restraint
IDIFF	FLOAT32	0.00...80.00	xIn	Differential current
IBIAS	FLOAT32	0.00...80.00	xIn	Stabilization current
87LOZREF	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

4.6.1.9 Technical data

Table 247: 87LOZREF Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
		±2.5% of the set value or ±0.002 x I_n		
Pickup time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Trip value*	37 ms	40 ms	45 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5, …		

1) Current before fault = 0.0, f_n = 60 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

Section 5 Protection-related functions

5.1 Three-phase 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

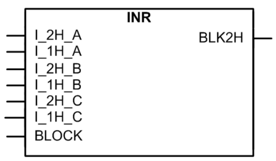


Figure 151: Function block

5.1.3 Functionality

The three-phase inrush detector function 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 INR can be described using a module diagram. All the modules in the diagram are explained in the next sections.

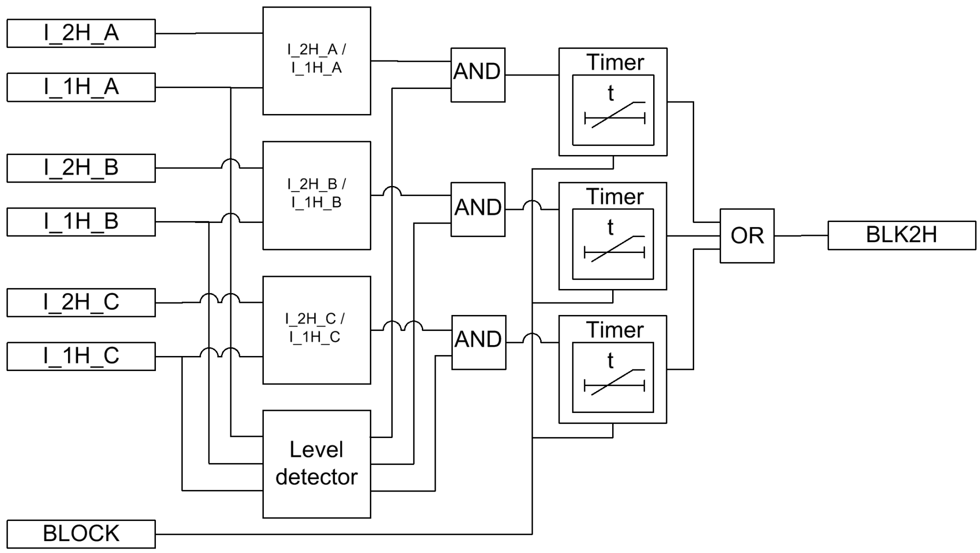


Figure 152: Functional module diagram

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 to 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 operation 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 operation 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.

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

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.

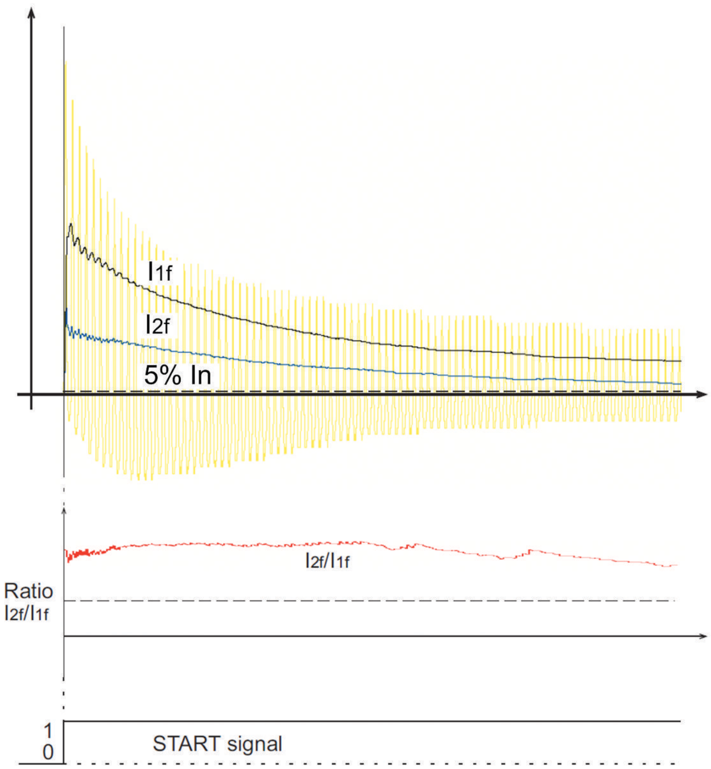


Figure 153: Inrush current in transformer

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

5.1.6 Signals

Table 248: 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 249: INR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

5.1.7 Settings

Table 250: 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
Trip delay time	20...60000	ms	1	20	Trip delay time

Table 251: INR Non group settings

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

5.1.8 Monitored data

Table 252: 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 253: INR Technical data

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$
	Current measurement: ±1.5% of the set value or ±0.002 × I_n Ratio I2f/I1f measurement: ±5.0% of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typically 0.96
Trip time accuracy	20 ms / -10 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

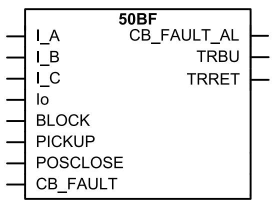


Figure 154: Function block

5.2.3 Functionality

The circuit breaker failure protection 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 retrip function, and also a three-phase conditional back-up trip function.

50BF uses the same levels of current detection for both retrip 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 retrip 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 50BF can be described using a module diagram. All the modules in the diagram are explained in the next sections. Also further information on the retrip and backup trip logics is given in sub-module diagrams.

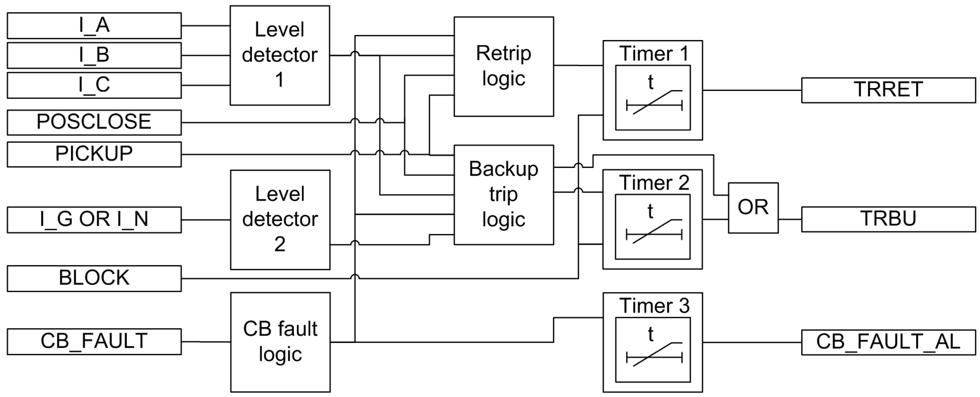


Figure 155: Functional module diagram

Level detector 1

The measured phase currents are compared phasewise to the set *Current value*. If the measured value exceeds the set *Current value*, the level detector reports the exceeding of the value to the start, retrip and backup trip logics. The parameter should be set low enough so that breaker failure 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 residual current is compared to 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 pickup and backup trip logics. In high-impedance grounded systems, the residual current at phase-to-ground faults is 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 residual 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 current setting should be chosen in accordance with the setting of the sensitive ground-fault protection.

Start logic

The start logic is used to manage the starting of the timer 1 and timer 2. It also resets the function after the circuit breaker failure is handled. On the rising edge of the `PICKUP` input, the enabling signal is send to the timer 1 and timer 2.

Function resetting is prohibited in 150 ms after TRRET or TRBU is set. The 150 ms time elapse is provided to prevent malfunctioning due to oscillation in the starting signal.

In case the setting *Pickup latching mode* is set to "Level sensitive", the 50BF is reset immediately after the `PICKUP` signal is deactivated. The recommended setting value is "Rising edge".

The resetting of the function depends on the *CB failure mode* setting.

- If *CB failure mode* is set to "Current", the resetting logic further depends on the *CB failure trip mode* setting.
    - If *CB failure trip mode* is set to "1 out of 3", the resetting logic requires that the values of all the phase currents drop below the *Current value* setting.
    - If *CB failure trip mode* is set to "1 out of 4", the resetting logic requires that the values of the phase currents and the residual current drops below the *Current value* and *Current value Res* setting respectively.
    - If *CB failure trip mode* is set to "2 out of 4", the resetting logic requires that the values of all the phase currents and the residual current drop below the *Current value* and *Current value Res* setting.
- If *CB failure mode* is set to the "Breaker status" mode, the resetting logic requires that the circuit breaker is in the open condition.
- If the *CB failure mode* setting is set to "Both", the resetting logic requires that the circuit breaker is in the open condition and the values of the phase currents and the residual current drops below the *Current value* and *Current value Res* setting respectively.

The activation of the `BLOCK` input resets the function.

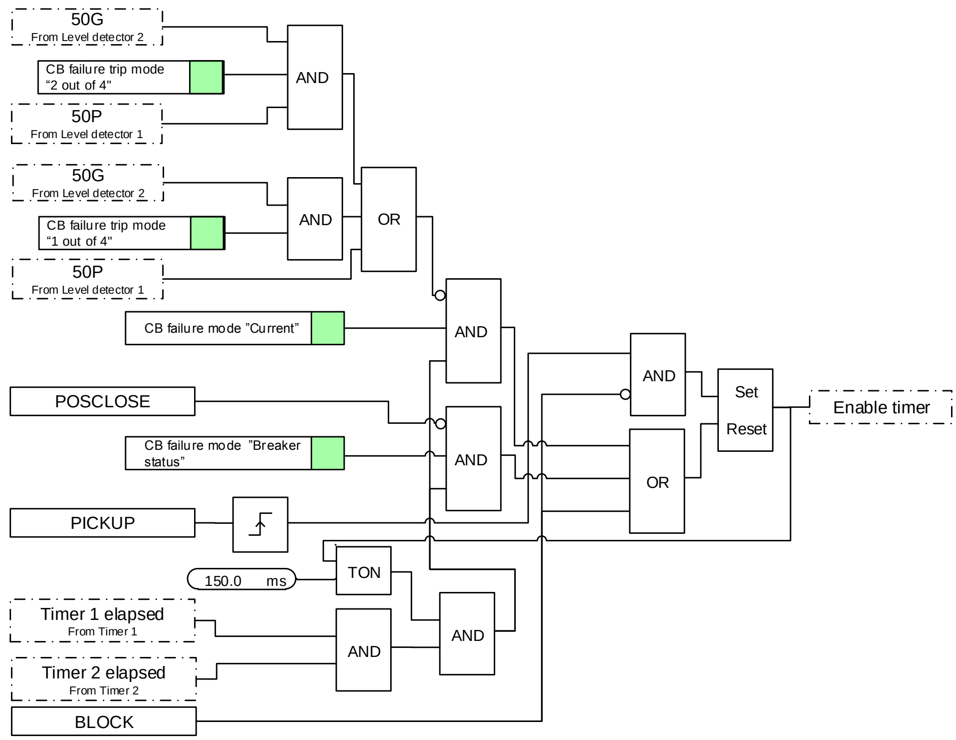


Figure 156: Start logic

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 value set with *Retrip time*, the retrip logic is activated. A typical setting is 0...50 ms.

Timer 2

Once activated, the timer runs until the set *CB failure delay* value has elapsed. The time characteristic is according to DT. When the operation timer has reached the set maximum time value *CB failure delay*, the backup trip logic 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 CB failure delay can be estimated as:

$$CBfailuredelay \geq Retriptime + t_{cbopen} + t_{BFP\_reset} + t_{margin}$$

(Equation 18)

t_{cbopen}	maximum opening time for the circuit breaker
t_{BFP_reset}	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 often depends on the ability to maintain transient stability in case of a fault close to a power plant.

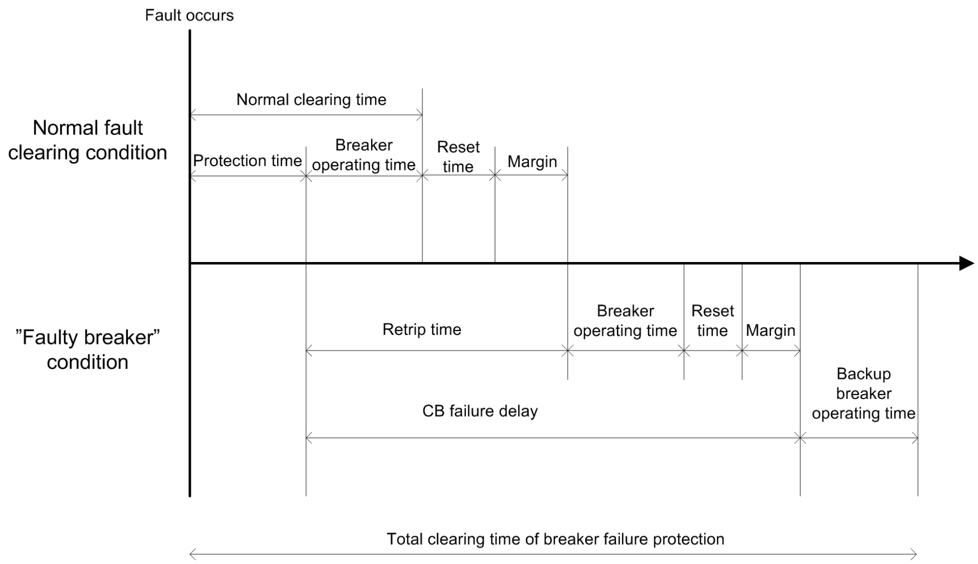


Figure 157: Timeline of the breaker failure protection

Timer 3

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

Retrip logic

The retrip logic provides the `TRRET` output, which can be used to give a retrip signal for the main circuit breaker. Timer 1 activates the retrip logic. The operation of the retrip logic depends on the *CB fail retrip mode* setting.

- The retrip logic is inactive if the *CB fail retrip mode* setting is set to "Disabled".
- If *CB fail retrip mode* is set to the "Current check" mode, the activation of the retrip output TRRET depends on the *CB failure mode* setting.
  - If *CB failure mode* is set to the "Current" mode, TRRET is activated when the value of any phase current exceeds the *Current value* setting. The TRRET output remains active for the time set with the *Trip pulse time* setting or until all phase current values drop below the *Current value* setting, whichever is longer.
  - If *CB failure mode* is set to the "Breaker status" mode, TRRET is activated if the circuit breaker is in the closed position. The TRRET output remains active for the time set with the *Trip pulse time* setting or the time the circuit breaker is in the closed position, whichever is longer.
  - If *CB failure mode* is set to "Both", TRRET is activated when either of the "Breaker status" or "Current" mode condition is satisfied.
- If *CB fail retrip mode* is set to the "Without check" mode, TRRET is activated once the timer 1 is activated without checking the current level. The TRRET output remains active for a fixed time set with the *Trip pulse time* setting.

The activation of the BLOCK input or the CB_FAULT_AL output deactivates the TRRET output.

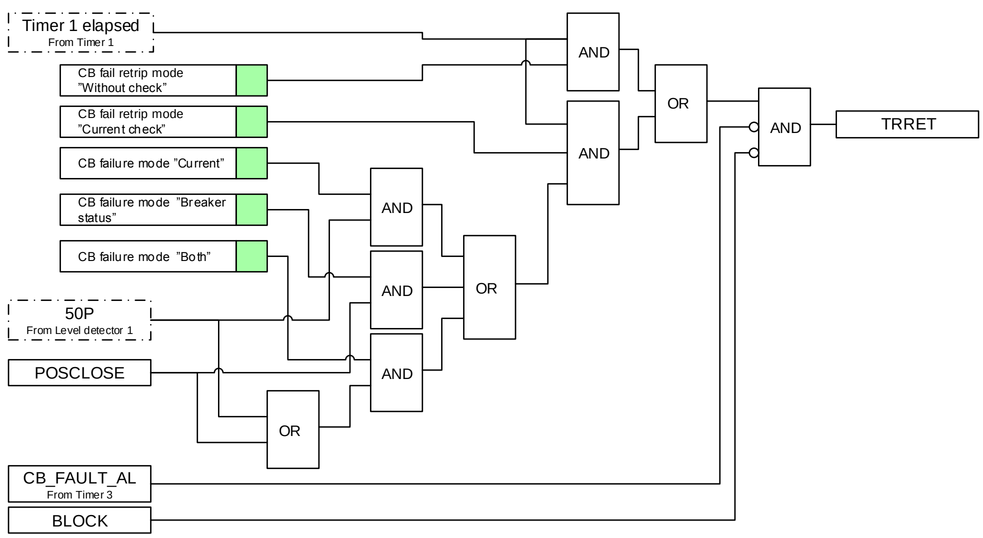


Figure 158: Retrip logic

Backup trip logic

The backup trip logic provides the TRBU output which can be used to trip the upstream backup circuit breaker when the main circuit breaker fails to clear the fault. The backup trip logic is activated by the timer 2 module or timer-enabling signal from the start logic module (rising edge of the PICKUP input detected), and simultaneously CB_FAULT_AL is active. The operation of the backup logic depends on the *CB failure mode* setting.

- If the *CB failure mode* is set to "Current", the activation of TRBU depends on the *CB failure trip mode* setting.
  - If *CB failure trip mode* is set to "1 out of 3", the failure detection is based on any of the phase currents exceeding the *Current value* setting. Once TRBU is activated, it remains active for the time set with the *Trip pulse time* setting or until the values of all the phase currents drop below the *Current value* setting, whichever takes longer.
  - If *CB failure trip mode* is set to "1 out of 4", the failure detection is based on either a phase current or a residual current exceeding the *Current value* or *Current value Res* setting respectively. Once TRBU is activated, it remains active for the time set with the *Trip pulse time* setting or until the values of all the phase currents or residual currents drop below the *Current value* and *Current value Res* setting respectively, whichever takes longer.
  - If *CB failure trip mode* is set to "2 out of 4", the failure detection requires that a phase current and a residual current both exceed the *Current value* and *Current value Res* setting respectively or two phase currents exceeding the *Current value*. Once TRBU is activated, it remains active for the time set with the *Trip pulse time* setting or until the values of all the phase currents drop below the *Current value*, whichever takes longer.

In most applications, "1 out of 3" is sufficient.

- If the *CB failure mode* is set to "Breaker status", the TRBU output is activated if the circuit breaker is in the closed position. Once activated, the TRBU output remains active for the time set with the *Trip pulse time* setting or the time the circuit breaker is in the closed position, whichever is longer.
- If the *CB failure mode* setting is set to "Both", TRBU is activated when the "Breaker status" or "Current" mode conditions are satisfied.

The activation of the BLOCK input deactivates the TRBU output.

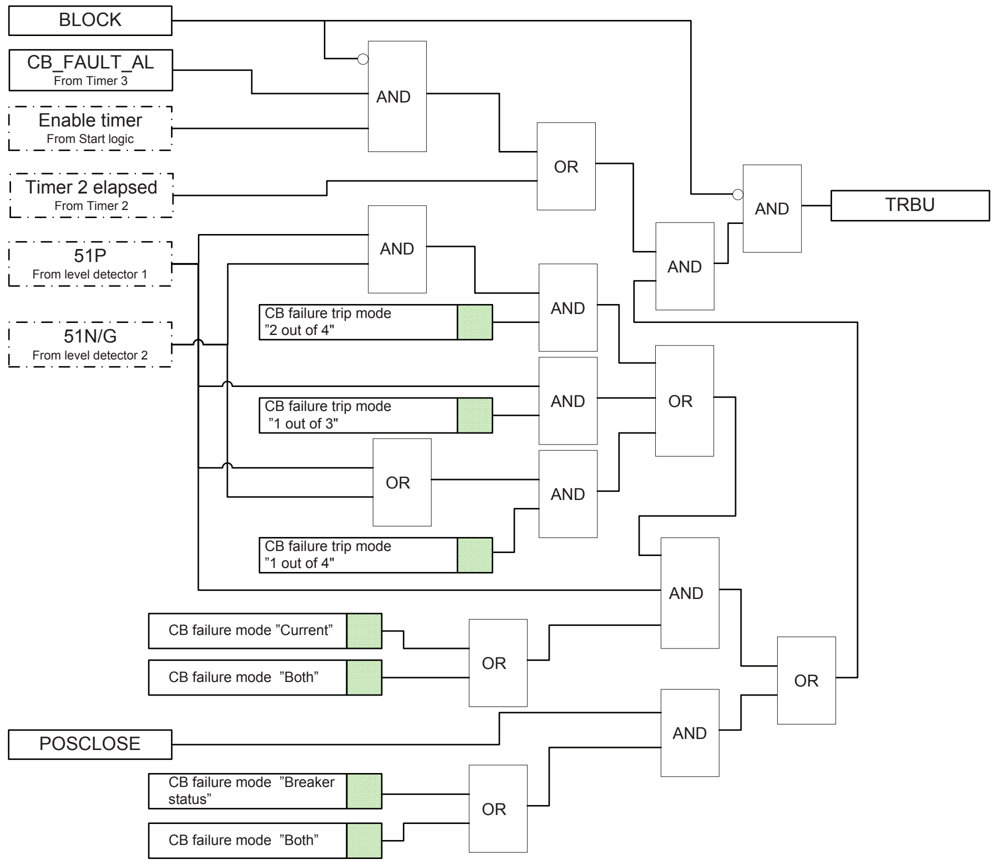


Figure 159: Backup trip logic

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 backup trip command to up-stream 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 backup tripping of several breakers in case mistakes occur during protection relay maintenance and tests.

50BF is initiated by operating different protection functions or digital logics inside the protection relay. 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.

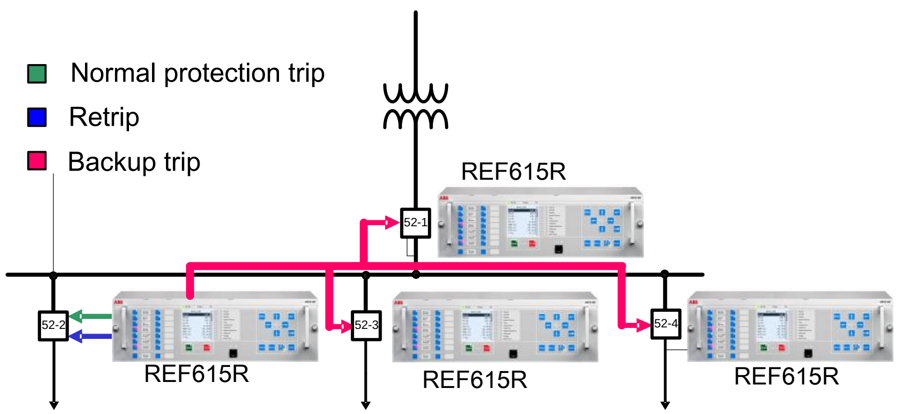


Figure 160: Typical breaker failure protection scheme in distribution substations

5.2.6 Signals

Table 254: 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 255: 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 256: 50BF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Current value	0.05...1.00	xIn	0.05	0.30	Operating phase current
Current value Res	0.05...1.00	xIn	0.05	0.30	Operating residual 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
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
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	150	Pulse length of retrip and backup trip outputs

5.2.8 Monitored data

Table 257: 50BF Monitored data

Name	Type	Values (Range)	Unit	Description
CCBRBRF	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

5.2.9 Technical data

Table 258: 50BF Technical data

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

5.3 Master trip 86/94

5.3.1 Identification

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

5.3.2 Function block

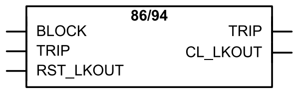


Figure 161: Function block

5.3.3 Functionality

The master trip 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 minimum trip pulse length can be set 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 86/94 can be described with a module diagram. All the modules in the diagram are explained in the next sections.

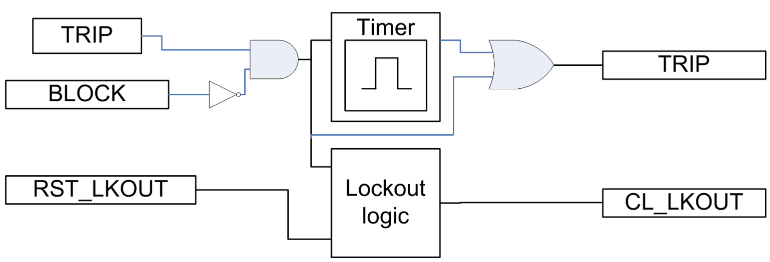


Figure 162: Functional module diagram

Timer

The duration of a trip output signal from 86/94 can be adjusted with the *Trip pulse time* setting when the "Non-latched" operation mode is used. 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 protection relay, or from external protection functions via one or more of the protection relay's binary inputs. The function has a single trip output TRIP for connecting the function to one or more of the protection relay's binary outputs, and also to other functions within the protection relay requiring this signal.

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

Lockout logic

The CL_LKOUT and TRIP outputs can be blocked with the BLOCK input.

Table 259: Operation modes for the 86/94 trip output

Mode	Operation
Non-latched	The *Trip pulse length* parameter gives the minimum pulse length for TRIP
Latched	TRIP is latched ; both local and remote clearing is possible.
Lockout	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, 86/94 can block the 52 closing.

86/94 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 TRIP output is connected to the binary outputs on the IO board. This signal can also be used for other purposes within the protection relay, for example when starting the breaker failure protection.

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

When applied to replace DPU2000R, the two instances of 86/94 can be applied to mimic the DPU2000R master trip feature. The programmability using graphic interfaces in the protection relay allows programming of more functions than allowed in DPU2000R.

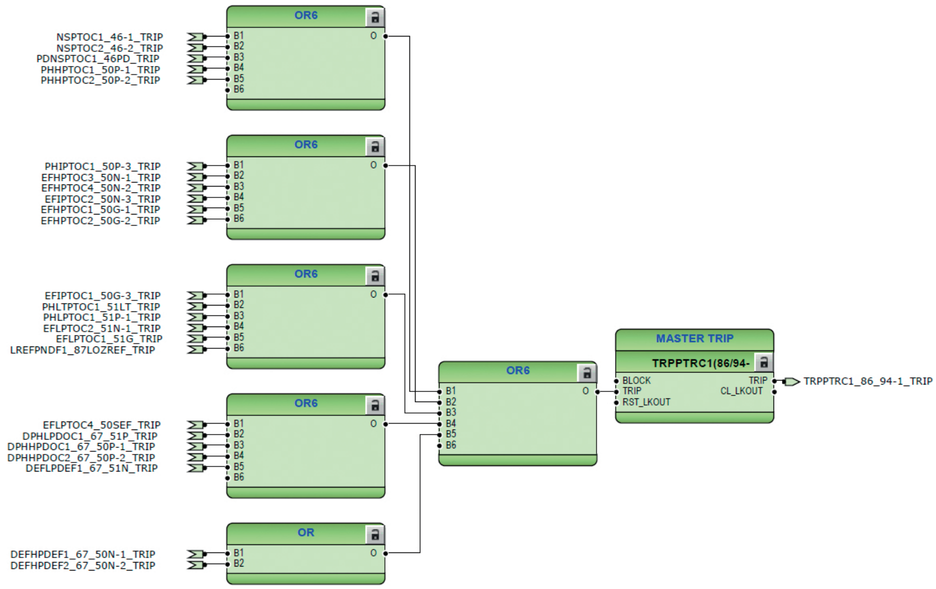


Figure 163: Typical 86/94 connection

5.3.6 Signals

Table 260: 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 261: 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 262: 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			2=Latched	Select the operation mode for trip output

5.3.8 Monitored data

Table 263: 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 detection HIZ

5.4.1 Identification

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

5.4.2 Function block

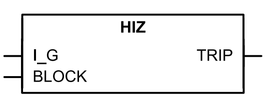


Figure 164: Function block

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 a high-impedance fault.

The high-impedance fault detection 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.

Although the HIZ algorithm is very sophisticated, the setting required to operate the function is simple. The *Security Level* setting, with the setting range of 1 to 10, is set to strike a balance between the extremes of security and dependability which together constitute the reliability of any system. The setting value “10” is more secure than “1”.

The higher the *Security Level* setting, the lower the probability of false detection, but the system might miss out some genuine fault. On the other hand, a lower setting would make the system operate more dependably for high-impedance faults in the line, but the operation is more likely for other transients in the system.

It is hence recommended to set the value midway to “5” initially. Based on experience and confidence gained in a particular application, the setting can be moved either side.

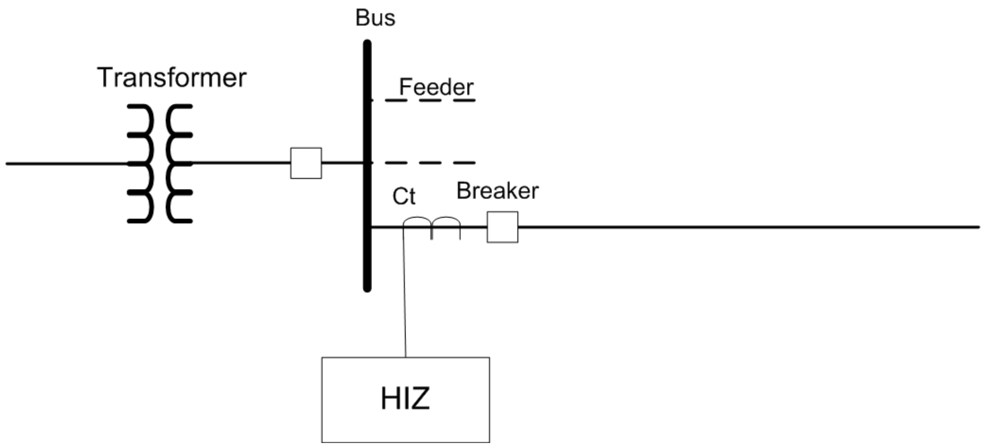


Figure 165: Electrical power system equipped with HIZ

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 a decision logic to provide the detection decision. The decision logic can be modified depending on the application requirement.

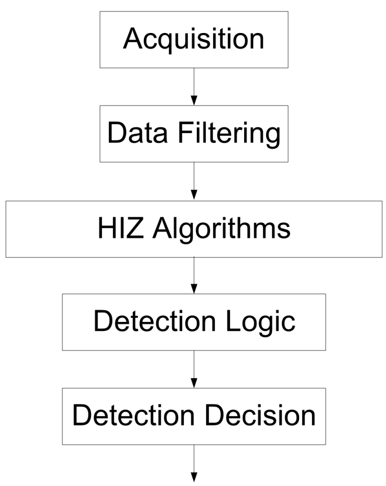


Figure 166: Block diagram of HIZ

HIZ is based on algorithms that use line residual 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 167: Validation of HIZ on gravel

Figure 168: Validation of HIZ on concrete

Figure 169: Validation of HIZ on sand

Figure 170: 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 the electrical network 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 ten years of research resulting in many successful field tests.

5.4.6 Signals

Table 264: HIZ Input signals

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

Table 265: HIZ Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip

5.4.7 Settings

Table 266: HIZ Group settings

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

Table 267: HIZ Non group settings

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

5.4.8 Monitored data

Table 268: 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

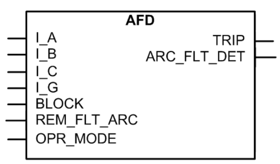


Figure 171: Function block

5.5.3 Functionality

The arc protection function 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 AFD can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

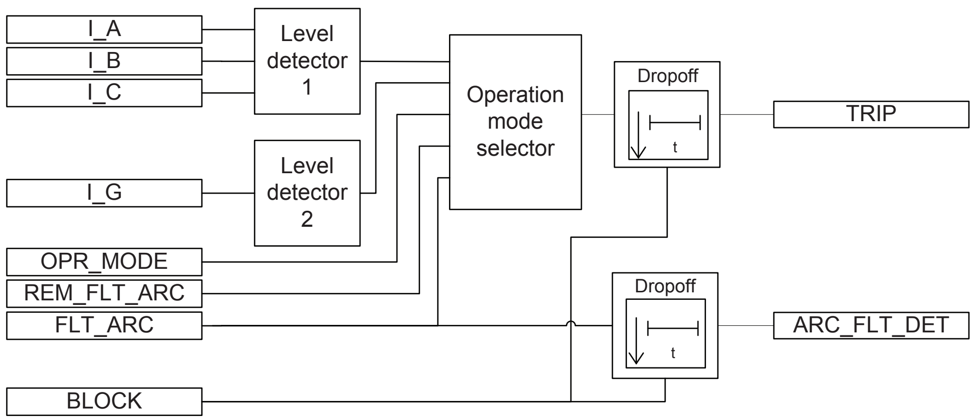


Figure 172: Functional module diagram

Level detector 1

The measured phase currents are compared phasewise to 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 to 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 ARC_FLT_DET.

5.5.5 Application

The arc protection can be realized as a stand-alone function in a single relay or as a station-wide arc protection, including several protection relays. If realized as a station-wide arc protection, 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.

When the arc flash detector is used directly to initiate trip, it is recommended to select REF615R with the High Speed Trip Output option. See the product guide for ordering details

The arc protection consists of:

- Optional arc light detection hardware with automatic backlight compensation for lens type sensors
- Light signal output ARC_FLT_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 protection 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 protection stage ARC_FLT_DET is activated immediately in the detection of light in all situations. A station-wide arc protection 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 protection stage with a binary input or a signal from another function block.

Cover unused inputs with dust caps.

Arc protection with one protection relay

In installations, with limited possibilities to realize signalling between protection relays protecting incoming and outgoing feeders, or if only the protection relay for the incoming feeder is to be exchanged, an arc protection with a lower protective level can be achieved with one protection relay. An arc protection with one protection relay only is realized by installing two arc lens sensors connected to the protection relay protecting the incoming feeder to detect an arc on the busbar. In arc detection, the arc protection 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.

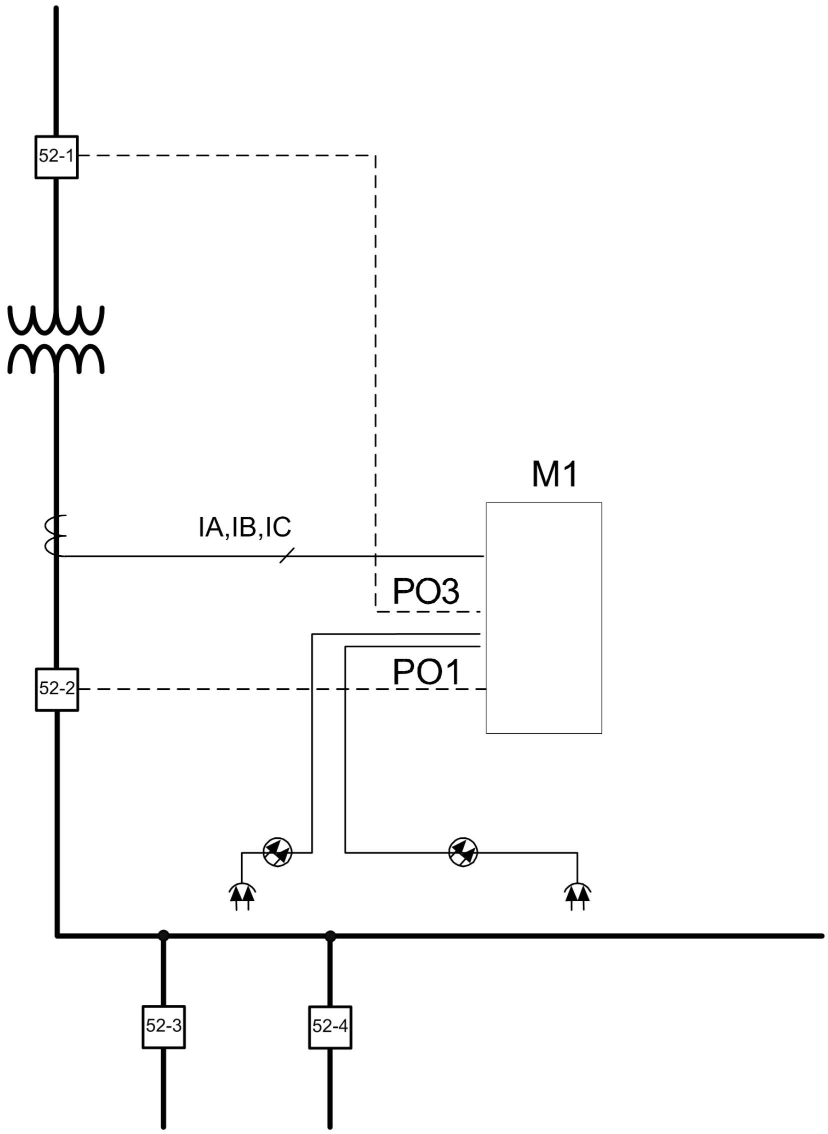


Figure 173: Arc protection with one protection relay

Arc protection with several protection relays

When using several protection relays, the protection relay protecting the outgoing feeder trips the circuit breaker of the outgoing feeder when detecting an arc at the cable terminations. If the protection relay 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 protection relay protecting the incoming feeder. When detecting the signal, the protection relay protecting the incoming feeder trips the circuit breaker of the incoming feeder and generates an external trip signal to all protection relays protecting the outgoing feeders, which in turn results in tripping of all circuit breakers of the outgoing feeders. For maximum safety, the protection relays can be configured to trip all the circuit breakers regardless of where the arc is detected.

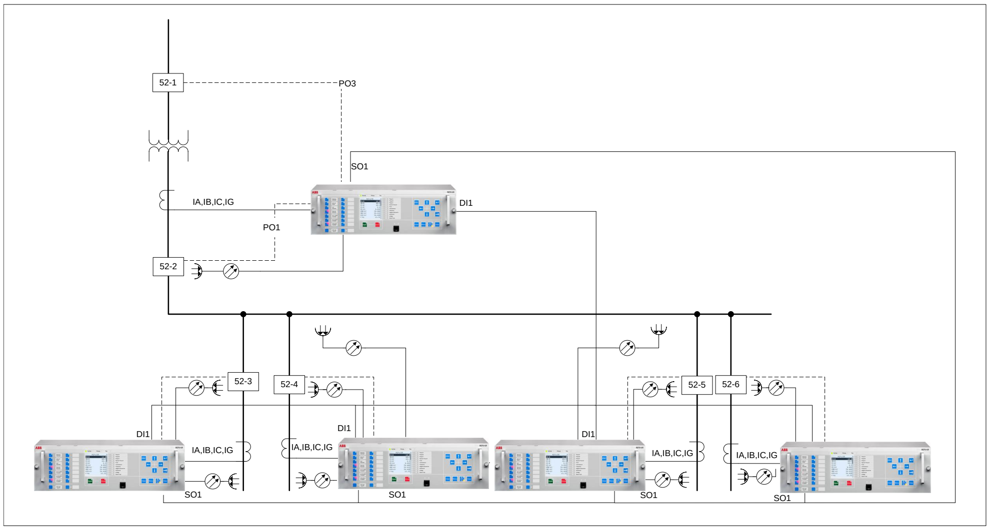


*Figure 174:	Arc flash detector with several protection relays*

Arc protection with several protection relays and a separate arc protection system

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

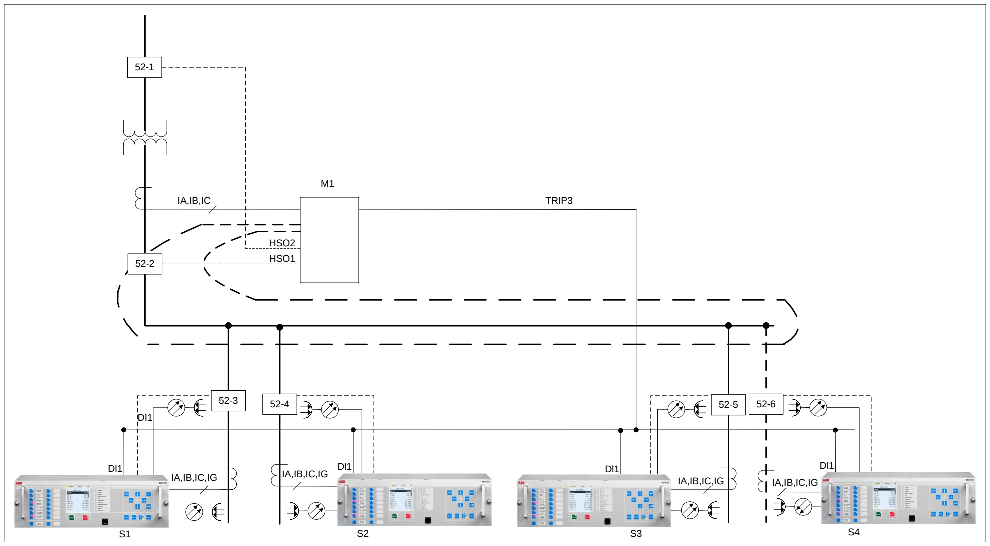


Figure 175: Arc flash detector with several protection relays and a separate arc flash detector system

5.5.6 Signals

Table 269: 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 270: AFD Output signals

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

5.5.7 Settings

Table 271: 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 residual current
Operation mode	1=Light+current 2=Light only 3=BI controlled			1=Light+current	Operation mode

Table 272: AFD Non group settings

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

5.5.8 Monitored data

Table 273: 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 274: AFD Technical data

Characteristic		Value		
Operation accuracy		±3% of the set value or ±0.01 × I_n		
Trip time		Minimum	Typical	Maximum
	Operation mode = "Light only"	9 ms	10 ms	12 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		

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

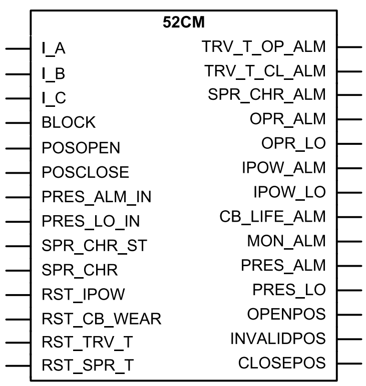


Figure 176: Function block

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 sub-functions. 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 52CM can be described with a module diagram. All the modules in the diagram are explained in the next sections.

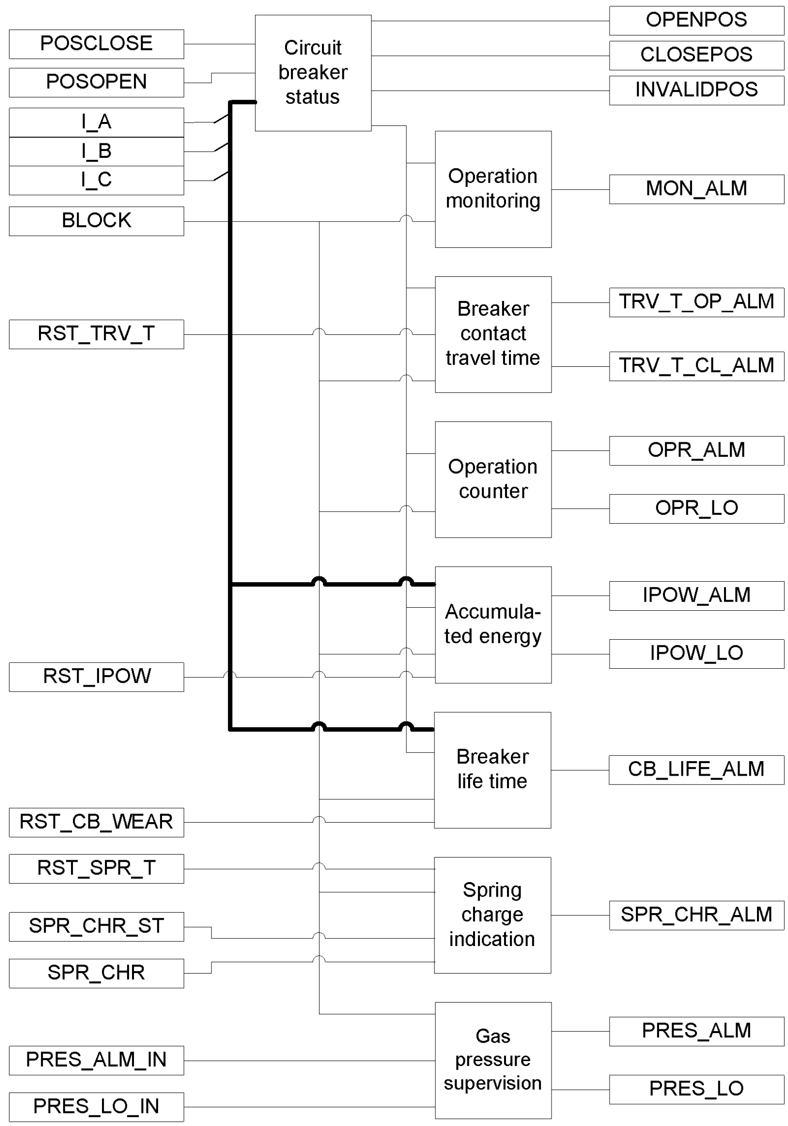


Figure 177: Functional module diagram

6.1.4.1 Circuit breaker status

The Circuit breaker status sub-function monitors the position of the circuit breaker, that is, whether the breaker is in open, closed or invalid 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.

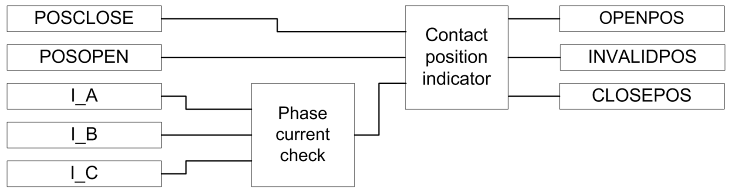


Figure 178: Functional module diagram for monitoring circuit breaker status

Phase current check

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

Contact position indicator

The `OPENPOS` output is activated when the auxiliary input contact `POSCLOSE` is FALSE, the `POSOPEN` input is TRUE and all the phase currents are below the setting *Acc stop current*.

The `CLOSEPOS` output is activated when the auxiliary `POSOPEN` input is FALSE and the `POSCLOSE` input is TRUE.

The `INVALIDPOS` output is activated when both the auxiliary contacts have the same value, that is, both are in the same logical level, or if the auxiliary input contact `POSCLOSE` is FALSE and the `POSOPEN` input is TRUE and any of the phase currents exceed the setting `Acc stop current`.

The status of the breaker is indicated by the binary outputs `OPENPOS`, `INVALIDPOS` and `CLOSEPOS` for open, invalid 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 with a module diagram. All the modules in the diagram are explained in the next sections.

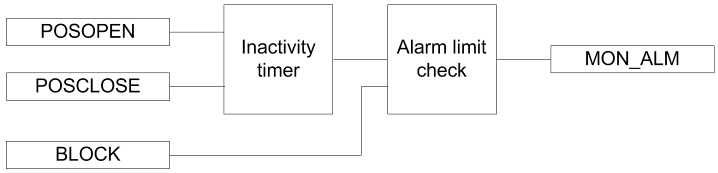


Figure 179: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

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 INA_DAYS is available in the monitored data view. It is also possible to set the initial inactive days with the *Ini inactive days* parameter.

Alarm limit check

When the inactive days exceed the limit value defined with the *Inactive Alm days* setting, the MON_ALM alarm is initiated. The time in hours at which this alarm is activated can be set with the *Inactive Alm hours* parameter as coordinates of UTC. The alarm signal MON_ALM 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 with a module diagram. All the modules in the diagram are explained in the next sections.

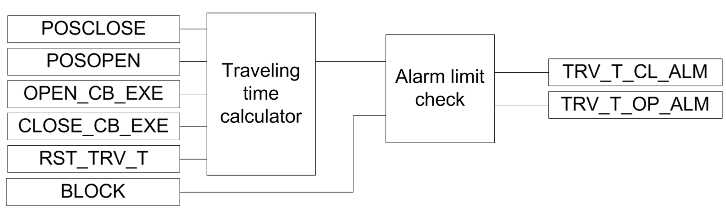


Figure 180: Functional module diagram for breaker contact travel time

Traveling time calculator

The opening travel time is measured between the opening of the POSCLOSE auxiliary contact and the closing of the POSOPEN auxiliary contact. The travel time is also measured between the opening of the POSOPEN auxiliary contact and the closing of the POSCLOSE auxiliary contact.

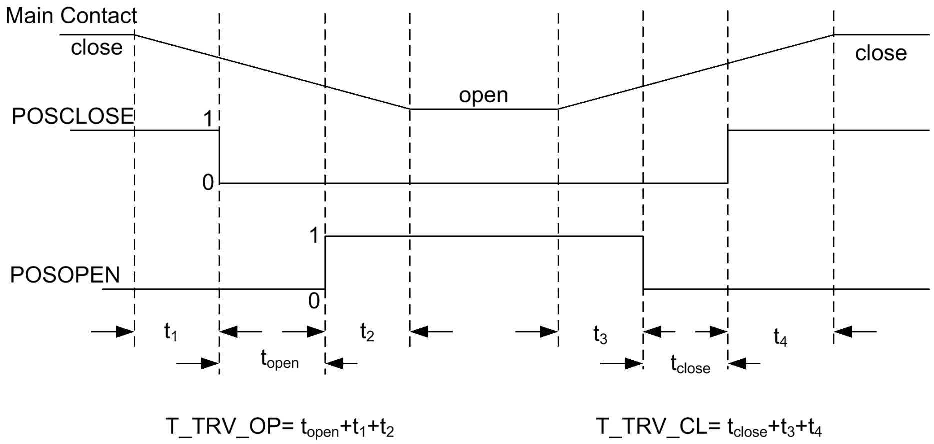


Figure 181: Travel time calculation

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. 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* (= $t_1 + t_2$) setting. 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 in the monitored data view on the LHMI or through tools via communications.

Alarm limit check

When the measured opening 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 closing travel time is longer than the value set with the *Close alarm time* setting, 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. The opening and closing operations are both included in one operation cycle. The operation counter value is updated after each opening operation.

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

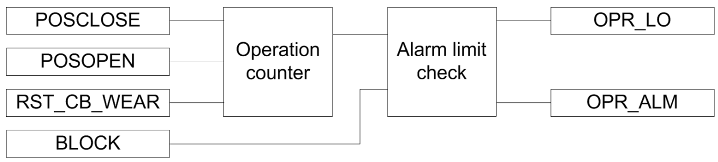


Figure 182: Functional module diagram for counting circuit breaker operations

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 in 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 *Counter initial Val* parameter and by setting the parameter *Initial CB Rmn life* in the clear menu from WHMI or LHMI.

Alarm limit check

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

The binary outputs OPR_LO and OPR_ALM 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 with a module diagram. All the modules in the diagram are explained in the next sections.

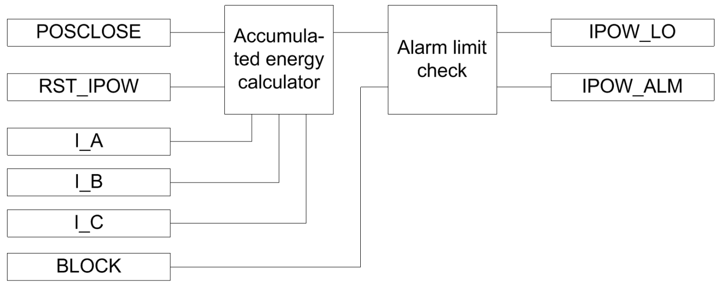


Figure 183: Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

This module calculates the accumulated energy $I^y t$ [$(kA)^y s$]. The factor y is set with the *Current exponent* setting.

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

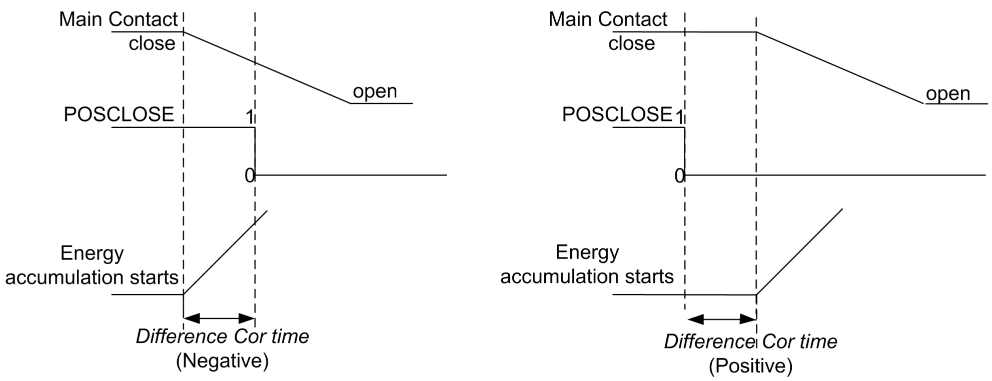


Figure 184: Significance of the Difference Cor time setting

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 in the monitored data view on the LHMI or through tools via communications. The values can be reset by setting the parameter *Initial CB Rmn life* 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 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 with a module diagram. All the modules in the diagram are explained in the next sections.

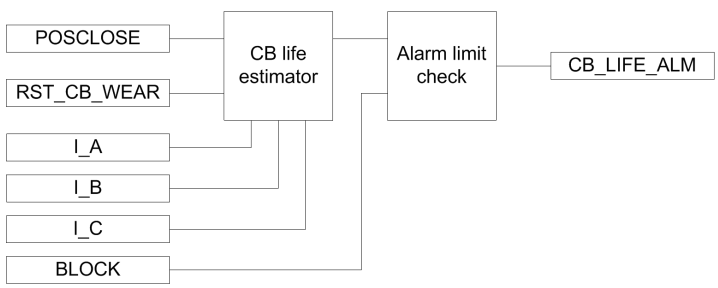


Figure 185: Functional module diagram for estimating the life of the circuit breaker

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 from WHMI or LHMI.

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 with a module diagram. All the modules in the diagram are explained in the next sections.

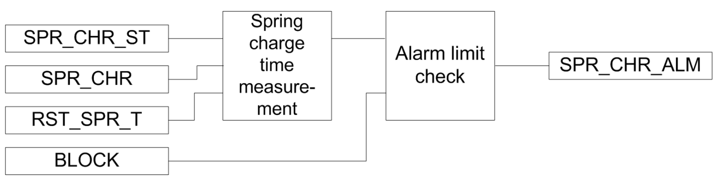


Figure 186: Functional module diagram for circuit breaker spring-charged indication and alarm

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 in 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 with a module diagram. All the modules in the diagram are explained in the next sections.

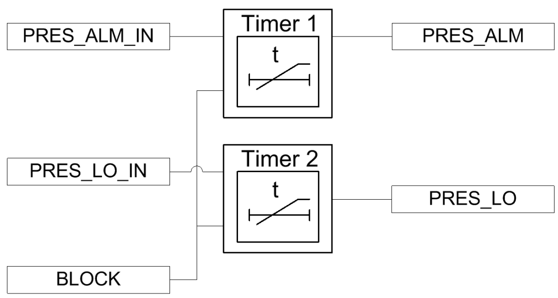


Figure 187: Functional module diagram for circuit breaker gas pressure alarm

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 traveling times indicate the need for the maintenance of the circuit breaker mechanism. Therefore, detecting excessive traveling 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 closed 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 $I^y t$

Accumulation of $I^y t$ calculates the accumulated energy $\Sigma I^y t$, 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

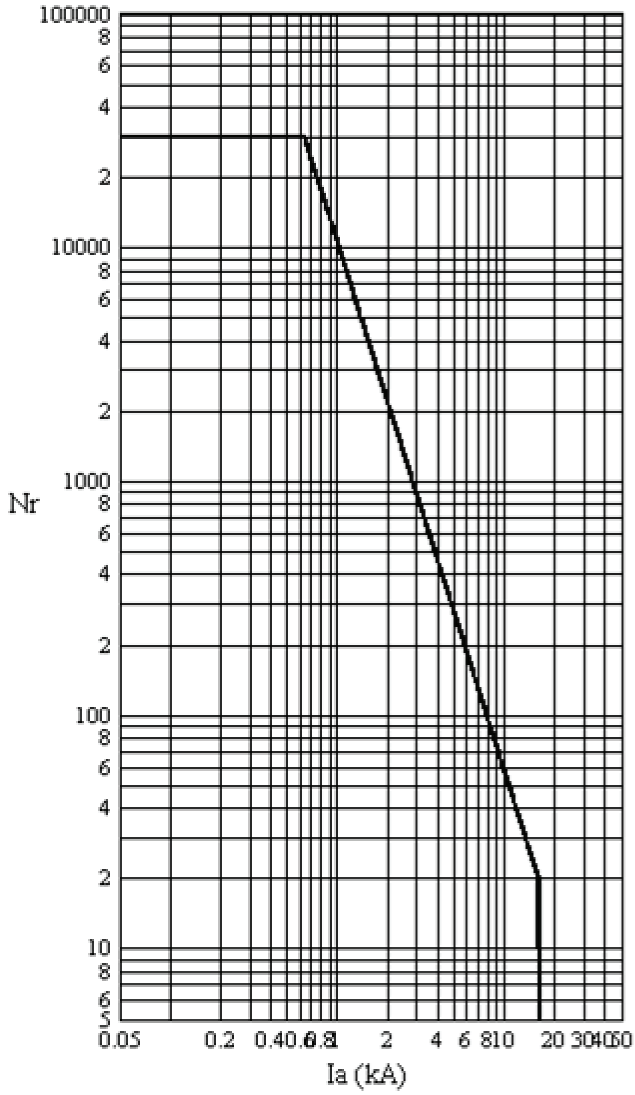


Figure 188: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

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 19)

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

Figure 188 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 30,000/60=500 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 15,000-500=14,500 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 275: 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
Table continues on next page			

Name	Type	Default	Description
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 276: 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 tripped 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 277: 52CM Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	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
Initial CB Rmn life	0...9999		1	5000	Initial value for the CB remaining life
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 278: 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	0.000...30000.000		Accumulated currents power (Iyt), phase A
IPOW_B	FLOAT32	0.000...30000.000		Accumulated currents power (Iyt), phase B
IPOW_C	FLOAT32	0.000...30000.000		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 279: 52CM Technical data

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

6.2 Current circuit supervision CCM

6.2.1 Identification

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

6.2.2 Function block

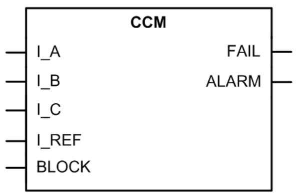


Figure 189: Function block

6.2.3 Functionality

The current circuit supervision function CCM is used for monitoring current transformer secondary circuits.

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 protection relay.

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.

6.2.4 Operation principle

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

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

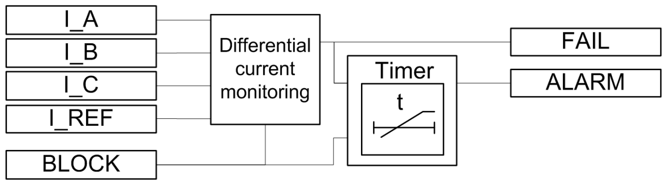


Figure 190: Functional module diagram

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 × In, the differential current limit is defined with *Pickup value*. When the highest phase current is more than 1.0 × In, the differential current limit is calculated with the equation.

$$MAX(I\_A, I\_B, I\_C) \times Pickup\ value$$

(Equation 20)

The differential current is limited to 1.0 × In.

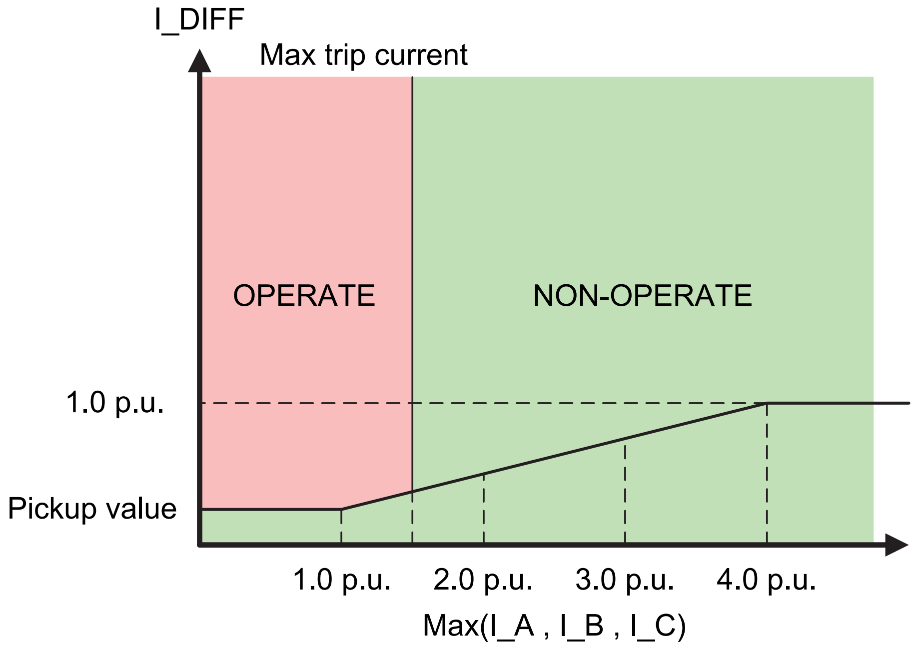


Figure 191: CCM operating characteristics

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 in the monitored data view on the LHMI or through other communication tools. The value is calculated with the equation.

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

(Equation 21)

The *Pickup value* setting is given in units of ×In 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 deactivates 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.

6.2.5 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 can result in differences in the secondary currents from the two CT cores. An 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 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 protection relay, 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

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

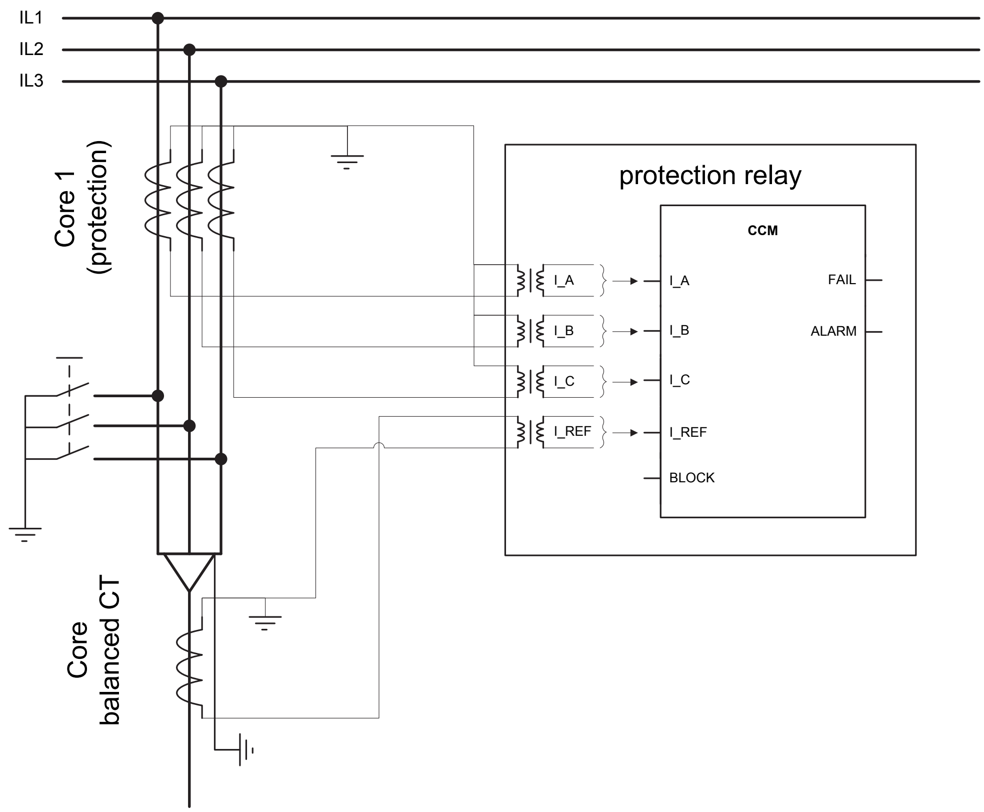


Figure 192: Connection diagram for reference current measurement with core-balanced current transformer

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

Figure 193 and Figure 194 show diagrams of connections where the reference current is measured with two independent three-phase sets of CT cores.

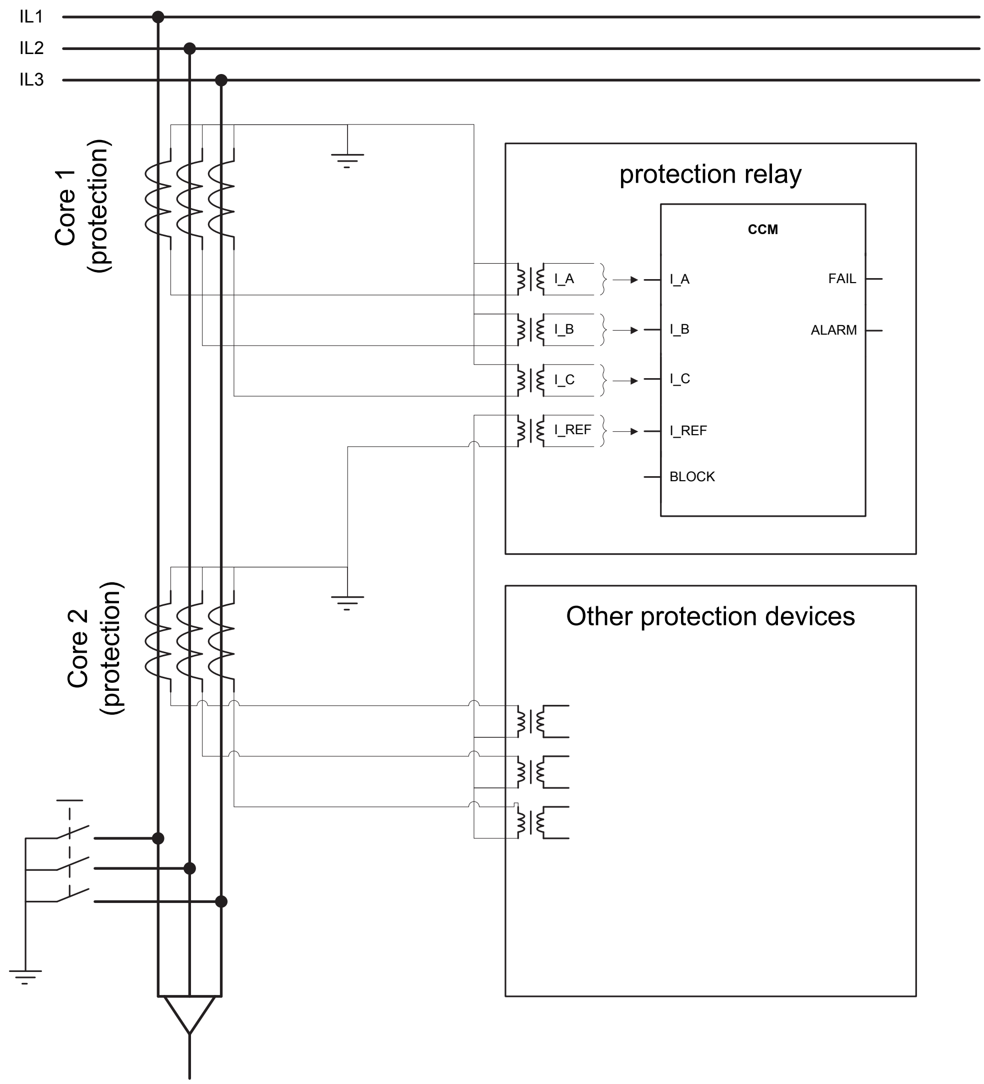


Figure 193: Connection diagram for current circuit supervision with two sets of three-phase current transformer protection cores

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.

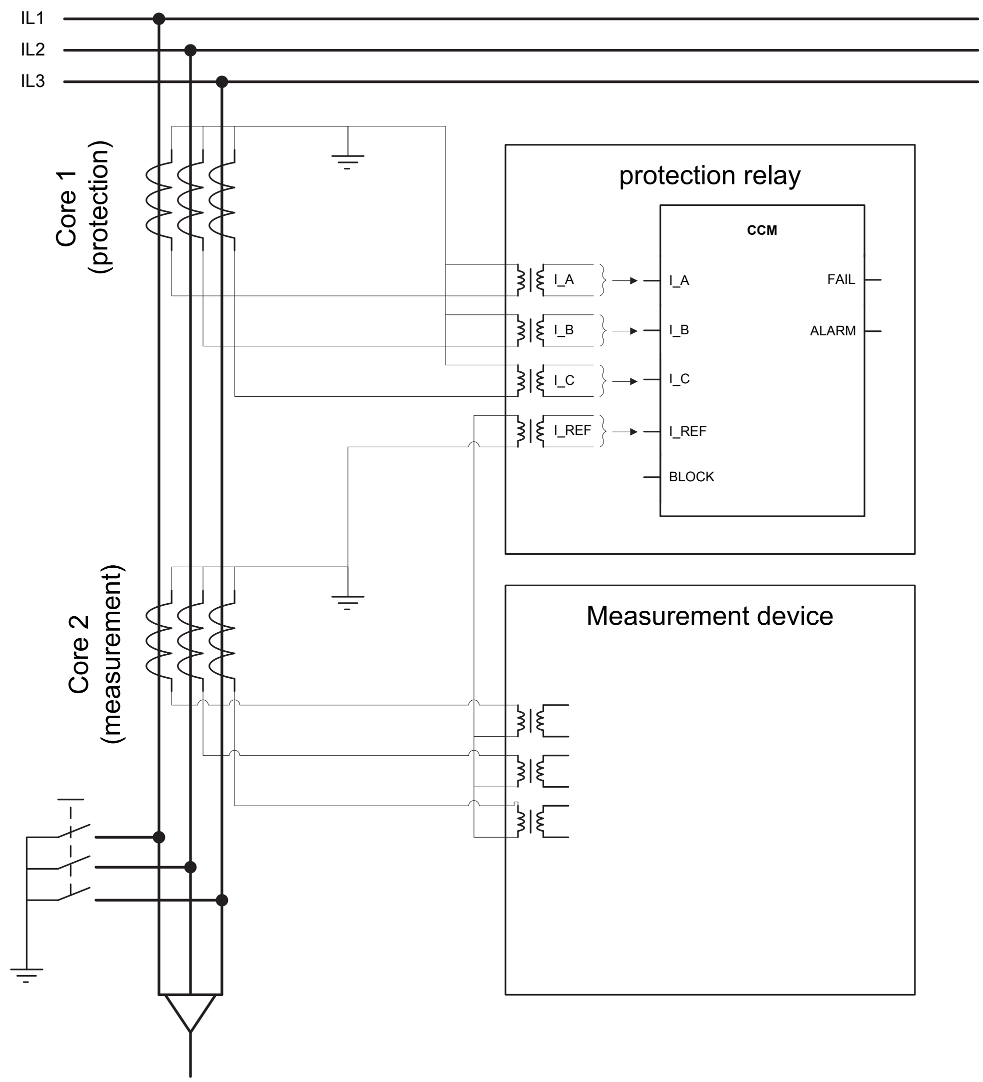


Figure 194: Connection diagram for current circuit supervision with two sets of three-phase current transformer cores (protection and measurement)

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.

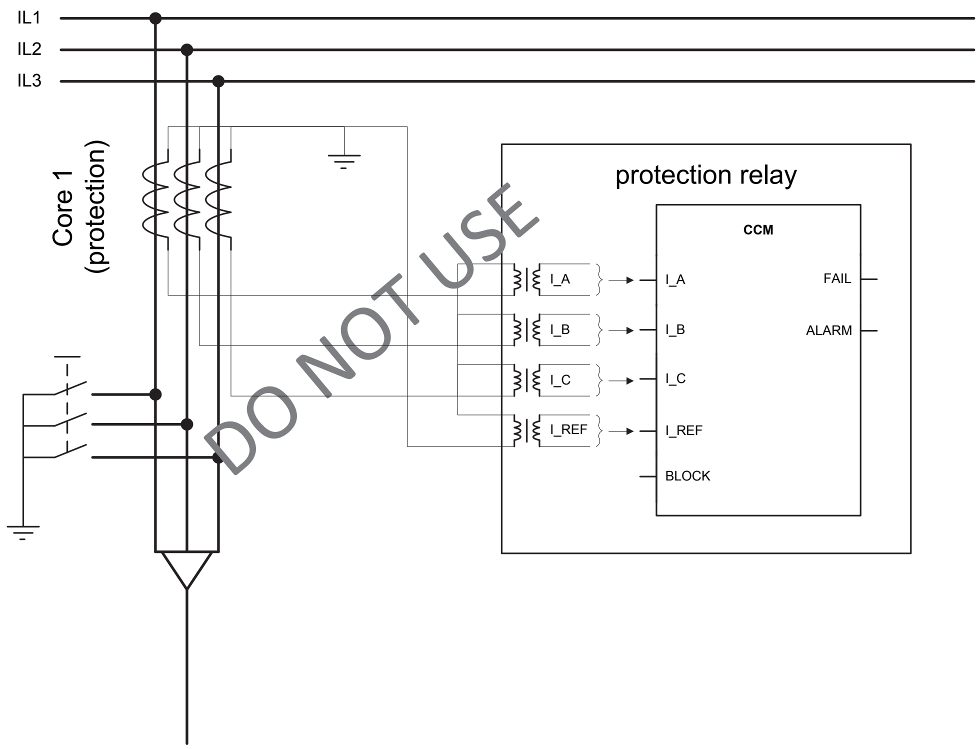


Figure 195: Example of incorrect reference current connection

6.2.6 Signals

Table 280: 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 281: CCM Output signals

Name	Type	Description
FAIL	BOOLEAN	Fail output
ALARM	BOOLEAN	Alarm output

6.2.7 Settings

Table 282: 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 alarm current	1.00...5.00	xIn	0.01	1.50	Block of the function at high phase current

6.2.8 Monitored data

Table 283: 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

6.2.9 Technical data

Table 284: CCM Technical data

Characteristic	Value
Trip time [1)]	<30 ms

1) Including the delay of the output contact

6.3 Fuse failure supervision 60

6.3.1 Identification

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

6.3.2 Function block

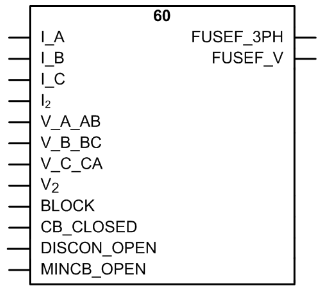


Figure 196: Function block

6.3.3 Functionality

The fuse failure supervision function 60 is used to block the voltage-measuring functions when failure occurs in the secondary circuits between the voltage transformer (or combi sensor or voltage sensor) and protection relay to avoid faulty operation of the voltage protection functions.

60 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.

6.3.4 Operation principle

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

The operation of 60 can be described with a module diagram. All the modules in the diagram are explained in the next sections.

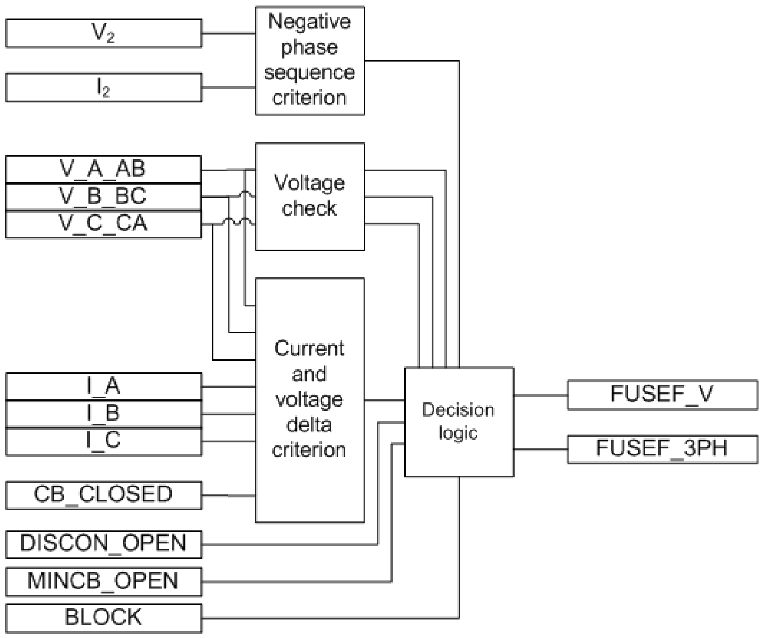


Figure 197: Functional module diagram

Negative phase-sequence criterion

A fuse failure based on the negative-sequence criterion is detected if the measured negative-sequence voltage exceeds the set *Neg Seq voltage Lev* value and the measured negative-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. If 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 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 dV/dt exceeds the corresponding value of the *Voltage change rate* setting and magnitude of dI/dt is below the value of the *Current change rate* setting in any phase at the same time due to the closure of the circuit breaker (CB_CLOSED = TRUE).
- The magnitude of dV/dt exceeds the value of the *Voltage change rate* setting and the magnitude of dI/dt is below the Current change rate setting in any phase at the same time and the magnitude of the phase current in the same phase exceeds the *Min Op current delta* 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. In this way only the second criterion can activate the delta function.

The second condition requires the delta criterion to be fulfilled in one phase together with a 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 285: Fuse failure output control

Fuse failure detection criterion	Conditions and function response
Negative-sequence criterion	If a fuse failure is detected based on the negative sequence criterion, the FUSEF_V 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 "True", the function activates the FUSE_3PH output signal.
	The FUSEF_V 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_V 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 "True", the function activates the FUSE_3PH output signal.
External fuse failure detection	The MINCB_OPEN input signal is supposed to be connected through a protection relay 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_V 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 a protection relay binary input to the N.C. auxiliary contact of the line disconnector.The DISCON_OPEN signal sets the FUSEF_V 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 "True". 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_V and FUSEF_3PH outputs.

6.3.5 Application

Some protection functions operate on the basis of the measured voltage value in the protection relay point. These functions can fail if there is a fault in the measuring circuits between the voltage transformer (or combi sensor or voltage sensor) and protection relay.

A fault in the voltage-measuring circuit is called 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 faulty operation of some of the protection functions, it is important to detect the fuse failures. A fast fuse failure detection is one of the means to block voltage-based functions before they trip.

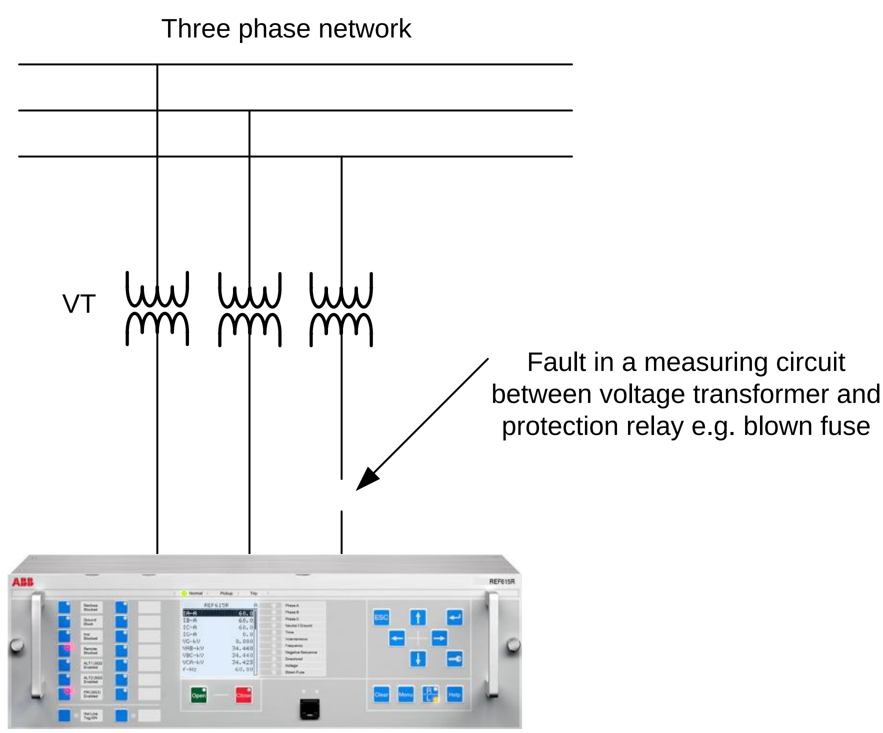


Figure 198: Fault in a circuit from the voltage transformer to the protection relay

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 be intact. 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.

6.3.6 Signals

Table 286: 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 287: 60 Output signals

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

6.3.7 Settings

Table 288: 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	Trip level of neg seq undercurrent element
Neg Seq voltage Lev	0.03...0.20	xUn	0.01	0.10	Trip level of neg seq overvoltage element
Current change rate	0.01...0.50	xIn	0.01	0.15	Trip level of change in phase current
Voltage change rate	0.50...0.90	xUn	0.01	0.60	Trip level of change in phase voltage
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Change rate enable	0=False 1=True			0=False	Enabling operation of change based function
Min Op voltage delta	0.01...1.00	xUn	0.01	0.70	Minimum trip level of phase voltage for delta calculation
Min Op current delta	0.01...1.00	xIn	0.01	0.10	Minimum trip level of phase current for delta calculation
Seal in voltage	0.01...1.00	xUn	0.01	0.70	Trip 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	Trip level for open phase current detection

6.3.8 Monitored data

Table 289: 60 Monitored data

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

6.3.9 Technical data

Table 290: 60 Technical data

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

6.4 Cable fault detection CFD

6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Cable fault detection	RCFD	RCFD	CFD

6.4.2 Function block

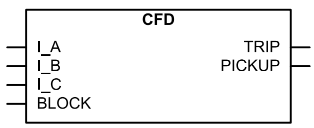


Figure 199: Function block

6.4.3 Functionality

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

The CFD function is reset 500 ms after detecting a cable fault to get ready for the next fault. Fault counters are stored and can be cleared only manually.

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

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

6.4.4 Operation principle

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

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

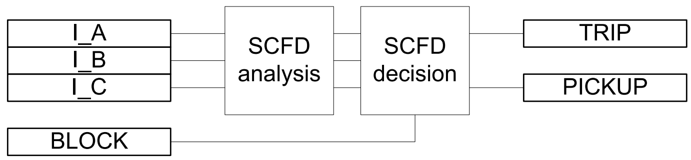


Figure 200: Functional module diagram.

SCFD analysis

The self-clearing fault detection SCFD analysis module detects the self-clearing fault in each phase by comparing the corresponding phase current magnitude to the set value *PhPu*.

If the phase current I_A magnitude goes above double the set value *PhPu*, the module calculates the time duration for which the current I_A continuously stays above double the set value *PhPu*. If the calculated time duration is greater than 1/4 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 the monitored data is set to "True". If the time duration criterion fails, `PickUpNoTripA` in the monitored data is set to "True". Once the self-clearing fault is detected in phase A, function increments the count `SCA` in the 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, that is, by comparing I_B and I_C magnitudes to the set value *PhPu* and by checking the time duration. If the fault is detected in phase B or phase C, `DetectfaultPhB` or respectively `DetectfaultPhC` in the monitored data is set to "True". If the time duration criterion fails for phase B or phase C, the corresponding `PickUpNoTripB` or `PickUpNoTripC` in the monitored data is set to "True". Once the fault is detected in phase B or phase C, the corresponding fault count `SCB` or `SCC` is incremented.

If the *AdapPhPu* setting 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 *AdapPhPu* setting 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, the 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 the 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 the monitored data is set to "True".

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

Activation of the BLOCK input deactivates all the binary outputs.

6.4.5 Signals

Table 291: 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	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 292: CFD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

6.4.6 Settings

Table 293: CFD Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
PhPu	0...100000		10	500	Fault Pickup parameter Threshold
CyMulit	1...20		1	5	Fault detect threshold parameter
AbsMinLoad	0...300		10	100	Absolute min loading on the feeder
AdapPhPu	0=False 1=True			0=False	Adaptive phase pickup

Table 294: CFD Non group settings

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

6.4.7 Monitored data

Table 295: CFD Monitored data

Name	Type	Values (Range)	Unit	Description
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	INT32	0...10000		Number of faults in Phase A
SCB	INT32	0...10000		Number of faults in Phase B
SCC	INT32	0...10000		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
CFD	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Section 7 Measurement functions

7.1 Basic measurements

7.1.1 Functions

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 F is used for monitoring and metering the power system frequency.

The single-phase power and energy measurement SP, SE and 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.

If the measured data is within parentheses, there are some problems to express the data.

7.1.2 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".

Demand value calculation

The demand values are calculated separately for each measurement function and per phase when applicable. The available measurement modes are "Linear" and "Logarithmic". The "Logarithmic" measurement mode is only effective for phase current and residual current demand value calculations. The demand value calculation mode is selected with the setting parameter **Configuration/Measurements/A demand Av mode**. The time interval for all demand value calculations is selected with the setting parameter **Configuration/Measurements/Demand interval**.

If the *Demand interval* setting is set to "15 minutes", for example, the demand values are updated every quarter of an hour. The demand time interval is synchronized to the real-time clock of the protection relay. When the demand time interval or calculation mode is changed, it initializes the demand value calculation. For the very first demand value calculation interval, the values are stated as invalid until the first refresh is available.

The "Linear" calculation mode uses the periodic sliding average calculation of the measured signal over the demand time interval. A new demand value is obtained once in a minute, indicating the analog signal demand over the demand time interval proceeding 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 "Logarithmic" calculation mode uses the periodic calculation using a log10 function over the demand time interval to replicate thermal demand ammeters. The logarithmic demand calculates a snapshot of the analog signal every 1/15 x demand time interval.

Each measurement function has its own recorded data values. In protection relay, these are found in **Monitoring/Recorded data/Measurements**. In the technical manual these are listed in the monitored data section of each measurement function. These values are periodically updated with the maximum and minimum demand values. The time stamps are provided for both values.

Value reporting

The measurement functions are capable of reporting 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 the 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 the zero-clamping limit, new values are reported.

Table 296: 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)
Single-phase power and energy measurement (SP, SE)	1.5% of the nominal (Sn)
Three-phase power and energy measurement (P, E)	1.5% of the nominal (Sn)

When the frequency measurement function F is unable to measure the network frequency in the undervoltage situation, the measured values are set to the nominal and also the quality information of the data set accordingly. The undervoltage limit is fixed to 10 percent of the nominal for the frequency measurement.

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.

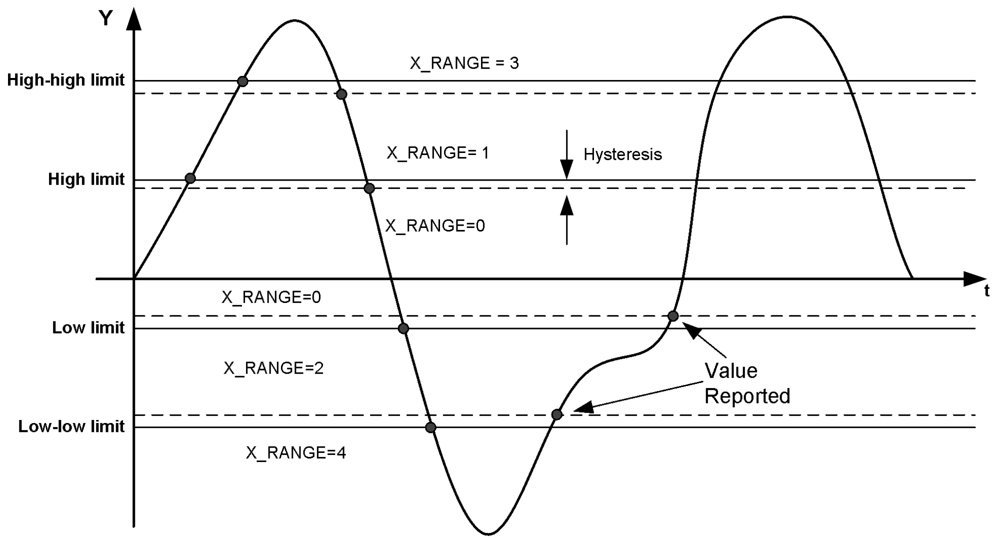


Figure 201: Presentation of operating limits

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.

Table 297: 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	-
Frequency measurement (F)	High limit	*F high limit*
	Low limit	*F low limit*
	High-high limit	*F high high limit*
	Low-low limit	*F 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,*

Table continues on next page

Function	Settings for limit value supervision	
Three-phase power and energy measurement (SP, SE)	High limit	-
	Low limit	-
	High-high limit	-
	Low-low limit	-
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.

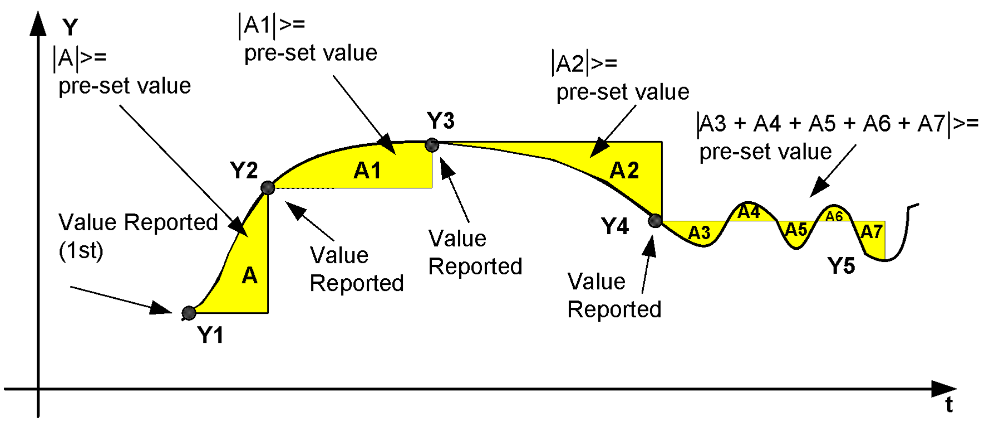


Figure 202: Integral deadband supervision

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 x 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 22)

Example for IA, IB, IC:

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

$\texttt{I\_INST\_A} = \texttt{I\_DB\_A} = 0.30$

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

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

Table 298: 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)*
Frequency measurement (F)	*F deadband*	*75 / 35 (=40Hz)*
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)*
Single-phase power and energy measurement (SP, SE)	-	
Three-phase power and energy measurement (P, E)	-	

In the power and energy measurement functions P, E and SP, SE, the deadband supervision is done separately for apparent power S, with the preset value of fixed 10 percent of the Sn and the power factor PF, with the preset 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 preset limit.

Power and energy calculation

The single-phase and three-phase power is calculated from the phase-to-ground voltages and phase-to-ground currents. The power measurement function is capable of calculating a 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 23)

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

$$P = \mathrm{Re}(\overline{S})$$

(Equation 24)

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

(Equation 25)

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

(Equation 26)

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

(Equation 27)

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.

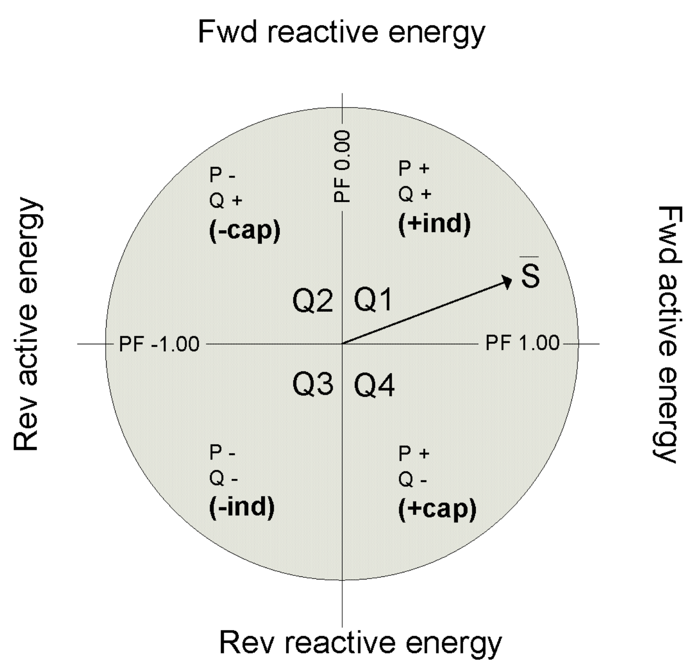


Figure 203: Complex power and power quadrants

Table 299: 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 reactive (`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 defined maximum value, the counter value is reset and restarted from 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 components are calculated using the phase currents and phase voltages. More information on calculating the phase-sequence components can be found in Calculated measurements in this manual.

7.1.3 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 relays 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 protection relay analog measurement chain can be verified during normal service by a periodic comparison of the measured value from the protection relay 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.

7.1.4 Three-phase current IA, IB, IC

7.1.4.1 Identification

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

7.1.4.2 Function block

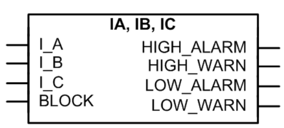


Figure 204: Function block

7.1.4.3 Signals

Table 300: 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 301: 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

7.1.4.4 Settings

Table 302: IA-IB-IC Non group settings

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

7.1.4.5 Monitored data

Table 303: 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 IA	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase A
Max demand IB	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase B
Max demand IC	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase C
Min demand IA	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase A
Min demand IB	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase B
Min demand IC	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase C
Time max demand IA	Timestamp			Time of maximum demand phase A
Time max demand IB	Timestamp			Time of maximum demand phase B
Time max demand IC	Timestamp			Time of maximum demand phase C
Time min demand IA	Timestamp			Time of minimum demand phase A
Time min demand IB	Timestamp			Time of minimum demand phase B
Time min demand IC	Timestamp			Time of minimum demand phase C

7.1.4.6 Technical data

Table 304: IA, IB, IC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz at currents in the range of 0.01...4.00 × I_n
	Current: ±0.5% or ±0.002 × I_n (at currents in the range of 0.01...4.00 × I_n) Phase angle: ±2.5°
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.5 Three-phase voltage VA, VB, VC

7.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase voltage measurement	VMMXU	3U	VA, VB, VC

7.1.5.2 Function block

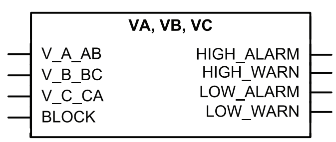


Figure 205: Function block

When using open delta and delta VT connection types in the system, ignore line-to-neutral voltage values.

7.1.5.3 Signals

Table 305: 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 306: 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

7.1.5.4 Settings

Table 307: VA, VB, VC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
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	xUn		1.40	High alarm voltage limit
V high limit	0.00...4.00	xUn		1.20	High warning voltage limit
V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit
V low low limit	0.00...4.00	xUn		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)

7.1.5.5 Monitored data

Table 308: VA, VB, VC Monitored data

Name	Type	Values (Range)	Unit	Description
VAB-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase AB
VBC-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase BC
VCA-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase CA

7.1.5.6 Technical data

Table 309: VA, VB, VC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2 Hz At voltages in range 0.01…1.15 × V_n
	Voltage:±0.5% or ±0.002 × V_n Phase angle: ±2.5°
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.6 Ground current IG

7.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual current measurement	RESCMMXU	Io	IG

7.1.6.2 Function block

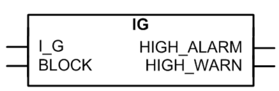


Figure 206: Function block

7.1.6.3 Signals

Table 310: IG Input signals

Name	Type	Default	Description
IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 311: IG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.6.4 Settings

Table 312: IG Non group settings

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

7.1.6.5 Monitored data

Table 313: IG Monitored data

Name	Type	Values (Range)	Unit	Description
IG-A	FLOAT32	0.00...40.00	xIn	Measured residual current
Max demand IG	FLOAT32	0.00...40.00	xIn	Maximum demand for residual current
Min demand IG	FLOAT32	0.00...40.00	xIn	Minimum demand for residual current
Time max demand IG	Timestamp			Time of maximum demand residual current
Time min demand IG	Timestamp			Time of minimum demand residual current

7.1.6.6 Technical data

Table 314: IG Technical data

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$
	±0.5% or ±0.002 × I_n (at currents in the range of 0.01...4.00 × I_n)
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.7 Ground voltage VG

7.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual voltage measurement	RESVMMXU	Uo	VG

7.1.7.2 Function block

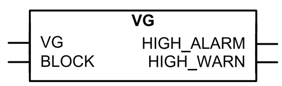


Figure 207: Function block

7.1.7.3 Signals

Table 315: VG Input signals

Name	Type	Default	Description
VG	SIGNAL	0	Ground voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 316: VG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.7.4 Settings

Table 317: VG Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
V Hi high limit res	0.00...4.00	xUn		0.20	High alarm voltage limit
V high limit res	0.00...4.00	xUn		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)

7.1.7.5 Monitored data

Table 318: VG Monitored data

Name	Type	Values (Range)	Unit	Description
VG-kV	FLOAT32	0.00...4.00	xUn	Measured residual voltage

7.1.7.6 Technical data

Table 319: VG Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: f/f_n = ±2 Hz
	±0.5% or ±0.002 × V_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.8 Sequence current I1, I2, I0

7.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sequence current measurement	CSMSQI	I1, I2, I0	I1, I2, I0

7.1.8.2 Function block

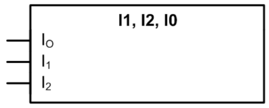


Figure 208: Function block

7.1.8.3 Signals

Table 320: 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

7.1.8.4 Settings

Table 321: I1-I2-I0 Non group settings

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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
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)

7.1.8.5 Monitored data

Table 322: 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

7.1.8.6 Technical data

Table 323: I1, I2, I0 Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f/f_n = ±2 Hz
	±1.0% or ±0.002 × I_n at currents in the range of 0.01...4.00 × I_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

7.1.9 Sequence voltage V1, V2, V0

7.1.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sequence voltage measurement	VSMSQI	U1, U2, U0	V1, V2, V0

7.1.9.2 Function block

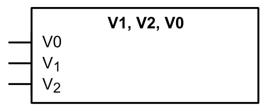


Figure 209: Function block

7.1.9.3 Signals

Table 324: 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

7.1.9.4 Settings

Table 325: V1, V2, V0 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Ps Seq V Hi high Lim	0.00...4.00	xUn		1.40	High alarm voltage limit for positive sequence voltage
Ps Seq V high limit	0.00...4.00	xUn		1.20	High warning voltage limit for positive sequence voltage
Ps Seq V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for positive sequence voltage
Ps Seq V low low Lim	0.00...4.00	xUn		0.00	Low alarm voltage limit for positive sequence voltage
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
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	xUn		0.20	High alarm voltage limit for negative sequence voltage
Ng Seq V High limit	0.00...4.00	xUn		0.05	High warning voltage limit for negative sequence voltage
Ng Seq V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for negative sequence voltage
Ng Seq V low low Lim	0.00...4.00	xUn		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	xUn		0.20	High alarm voltage limit for zero sequence voltage
Zro V High limit	0.00...4.00	xUn		0.05	High warning voltage limit for zero sequence voltage
Zro V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for zero sequence voltage
Zro V low low Lim	0.00...4.00	xUn		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)

7.1.9.5 Monitored data

Table 326: V1, V2, V0 Monitored data

Name	Type	Values (Range)	Unit	Description
V2-kV	FLOAT32	0.00...4.00	xUn	Measured negative sequence voltage
V1-kV	FLOAT32	0.00...4.00	xUn	Measured positive sequence voltage
V0-kV	FLOAT32	0.00...4.00	xUn	Measured zero sequence voltage

7.1.9.6 Technical data

Table 327: V1, V2, V0 Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2 Hz At voltages in range 0.01…1.15 × V_n
	±1.0% or ±0.002 × V_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

7.1.10 Three-phase power and energy P, E

7.1.10.1 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

7.1.10.2 Function block

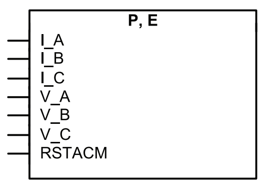


Figure 210: Function block

7.1.10.3 Signals

Table 328: 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

7.1.10.4 Settings

Table 329: P,E 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

7.1.10.5 Monitored data

Table 330: 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
Max demand S	FLOAT32	-999999.9...999999.9	kVA	Maximum demand value of apparent power
Min demand S	FLOAT32	-999999.9...999999.9	kVA	Minimum demand value of apparent power
Max demand P	FLOAT32	-999999.9...999999.9	kW	Maximum demand value of active power
Min demand P	FLOAT32	-999999.9...999999.9	kW	Minimum demand value of active power
Max demand Q	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand value of reactive power
Min demand Q	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand value of reactive power
Time max dmd S	Timestamp			Time of maximum demand

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Time min dmd S	Timestamp			Time of minimum demand
Time max dmd P	Timestamp			Time of maximum demand
Time min dmd P	Timestamp			Time of minimum demand
Time max dmd Q	Timestamp			Time of maximum demand
Time min dmd Q	Timestamp			Time of minimum demand

7.1.10.6 Technical data

Table 331: P, E Technical data

Characteristic	Value
Operation accuracy	At all three currents in range 0.10…1.20 × I_n At all three voltages in range 0.50…1.15 × V_n At the frequency f_n ±1 Hz 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 × f_n, where n = 2, 3, 4, 5,…

7.1.11 Single-phase power and energy measurement SP, SE

7.1.11.1 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

7.1.11.2 Function block

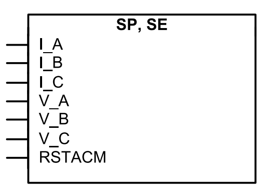


Figure 211: Function block

7.1.11.3 Signals

Table 332: 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

7.1.11.4 Settings

Table 333: 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

7.1.11.5 Monitored data

Table 334: SP,SE Monitored data

Name	Type	Values (Range)	Unit	Description
SA-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent Power, Phase A
SB-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent Power, Phase B
SC-kVA	FLOAT32	-999999.9...999999.9	kVA	Apparent Power, Phase C
PA-kW	FLOAT32	-999999.9...999999.9	kW	Active Power, Phase A
PB-kW	FLOAT32	-999999.9...999999.9	kW	Active Power, Phase B
PC-kW	FLOAT32	-999999.9...999999.9	kW	Active Power, Phase C
QA-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive Power, Phase A
QB-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive Power, Phase B
QC-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Reactive Power, Phase C
PFA	FLOAT32	-1.00...1.00		Average Power factor, Phase A
PFB	FLOAT32	-1.00...1.00		Average Power factor, Phase B
PFC	FLOAT32	-1.00...1.00		Average Power factor, Phase C
Max demand SA	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase A
Max demand SB	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase B
Max demand SC	FLOAT32	-999999.9...999999.9	kVA	Maximum demand for Phase C
Min demand SA	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase A
Min demand SB	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase B
Min demand SC	FLOAT32	-999999.9...999999.9	kVA	Minimum demand for Phase C
Max demand PA	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase A
Max demand PB	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase B
Max demand PC	FLOAT32	-999999.9...999999.9	kW	Maximum demand for Phase C

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Min demand PA	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase A
Min demand PB	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase B
Min demand PC	FLOAT32	-999999.9...999999.9	kW	Minimum demand for Phase C
Max demand QA	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase A
Max demand QB	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase B
Max demand QC	FLOAT32	-999999.9...999999.9	kVAr	Maximum demand for Phase C
Min demand QA	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase A
Min demand QB	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase B
Min demand QC	FLOAT32	-999999.9...999999.9	kVAr	Minimum demand for Phase B
Time max dmd SA	Timestamp			Time of maximum demand phase A
Time max dmd SB	Timestamp			Time of maximum demand phase B
Time max dmd SC	Timestamp			Time of maximum demand phase C
Time max dmd PA	Timestamp			Time of maximum demand phase A
Time max dmd PB	Timestamp			Time of maximum demand phase B
Time max dmd PC	Timestamp			Time of maximum demand phase C
Time max dmd QA	Timestamp			Time of maximum demand phase A
Time max dmd QB	Timestamp			Time of maximum demand phase B
Time max dmd QC	Timestamp			Time of maximum demand phase C
Time min dmd SA	Timestamp			Time of minimum demand phase A
Time min dmd SB	Timestamp			Time of minimum demand phase B
Time min dmd SC	Timestamp			Time of minimum demand phase C
Time min dmd PA	Timestamp			Time of minimum demand phase A

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Time min dmd PB	Timestamp			Time of minimum demand phase B
Time min dmd PC	Timestamp			Time of minimum demand phase C
Time min dmd QA	Timestamp			Time of minimum demand phase A
Time min dmd QB	Timestamp			Time of minimum demand phase B
Time min dmd QC	Timestamp			Time of minimum demand phase C

7.1.11.6 Technical data

Table 335: SP, SE Technical data

Characteristic	Value
Operation 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 ±1 Hz 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,…

7.1.12 Frequency f

7.1.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency measurement	FMMXU	f	f

7.1.12.2 Function block

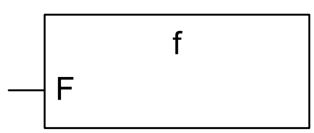


Figure 212: Function block

7.1.12.3 Signals

Table 336: f Input signals

Name	Type	Default	Description
F	SIGNAL	-	Measured system frequency

7.1.12.4 Settings

Table 337: f Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
F Hi 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 Lo 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)

7.1.12.5 Monitored data

Table 338: f Monitored data

Name	Type	Values (Range)	Unit	Description
f-Hz	FLOAT32	35.00...75.00	Hz	Measured frequency

7.1.12.6 Technical data

Table 339: f Technical data

Characteristic	Value
Operation accuracy	±10 mHz (in measurement range 35...75 Hz)

Section 8 Power quality measurement functions

8.1 Current total demand distortion PQI

8.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current total demand distortion	CMHAI	PQM3I	PQI

8.1.2 Function block

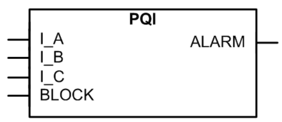


Figure 213: Function block

8.1.3 Functionality

The current total demand distortion function PQI is used for monitoring the current total demand distortion TDD.

8.1.4 Operation principle

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

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

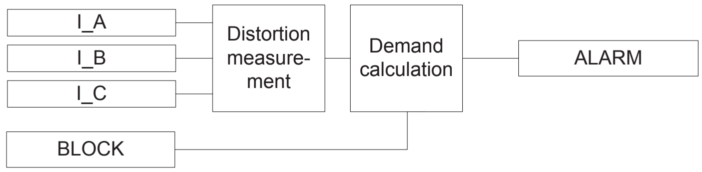


Figure 214: Functional module diagram

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 28)

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}.

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 "Non-sliding".

The activation of the BLOCK input blocks the ALARM output.

8.1.5 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.

8.1.6 Signals

Table 340: PQI 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 341: PQI Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm signal for TDD

8.1.7 Settings

Table 342: PQI Non group settings

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

8.1.8 Monitored data

Table 343: PQI 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

8.2 Voltage total harmonic distortion PQVPH

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage total harmonic distortion	VMHAI	PQM3U	PQVPH

8.2.2 Function block

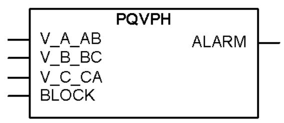


Figure 215: Function block

8.2.3 Functionality

The voltage total harmonic distortion function PQVPH is used for monitoring the voltage total harmonic distortion THD.

8.2.4 Operation principle

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

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

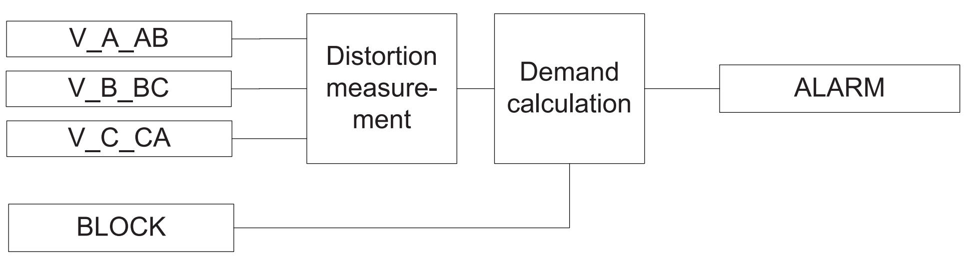


Figure 216: Functional module diagram

Distortion measurement

The distortion measurement module measures harmonics up to the 11th 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 29)

V_k k^{th} harmonic component

V_1 the voltage fundamental component amplitude

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 "Non-sliding".

The activation of the BLOCK input blocks the ALARM output.

8.2.5 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.

8.2.6 Signals

Table 344: PQVPH 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 345: PQVPH Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm signal for THD

8.2.7 Settings

Table 346: PQVPH Non group settings

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

8.2.8 Monitored data

Table 347: PQVPH Monitored data

Name	Type	Values (Range)	Unit	Description
Max demand THD VA	FLOAT32	0.00...500.00	%	Maximum demand THD for phase A
Max demand THD VB	FLOAT32	0.00...500.00	%	Maximum demand THD for phase B
Max demand THD VC	FLOAT32	0.00...500.00	%	Maximum demand THD for phase C
Time max dmd THD VA	Timestamp			Time of maximum demand THD phase A
Time max dmd THD VB	Timestamp			Time of maximum demand THD phase B
Time max dmd THD VC	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
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
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

8.3 Voltage variation PQSS

8.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage variation	PHQVVR	PQ 3U<>	PQSS

8.3.2 Function block

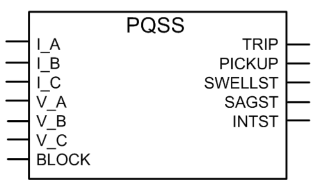


Figure 217: Function block

8.3.3 Functionality

The voltage variation function PQSS is used for measuring the short-duration 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.

8.3.4 Operation principle

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

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

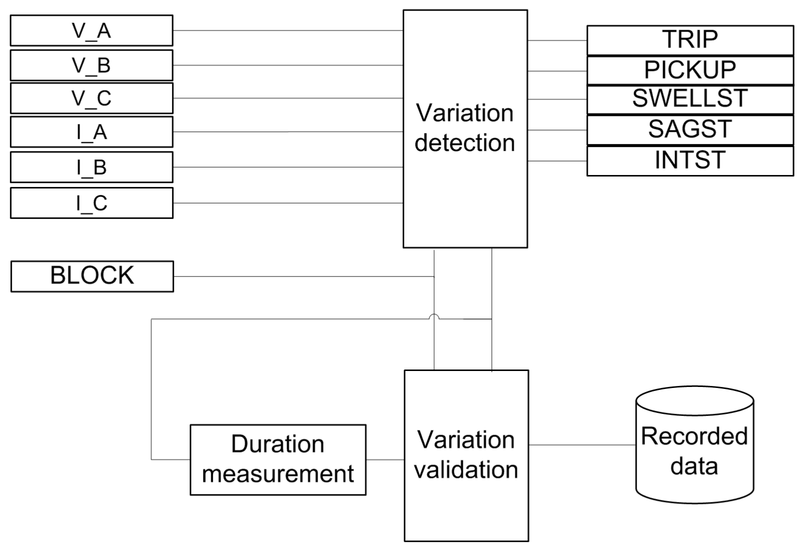


Figure 218: Functional module diagram

8.3.4.1 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.

8.3.4.2 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.

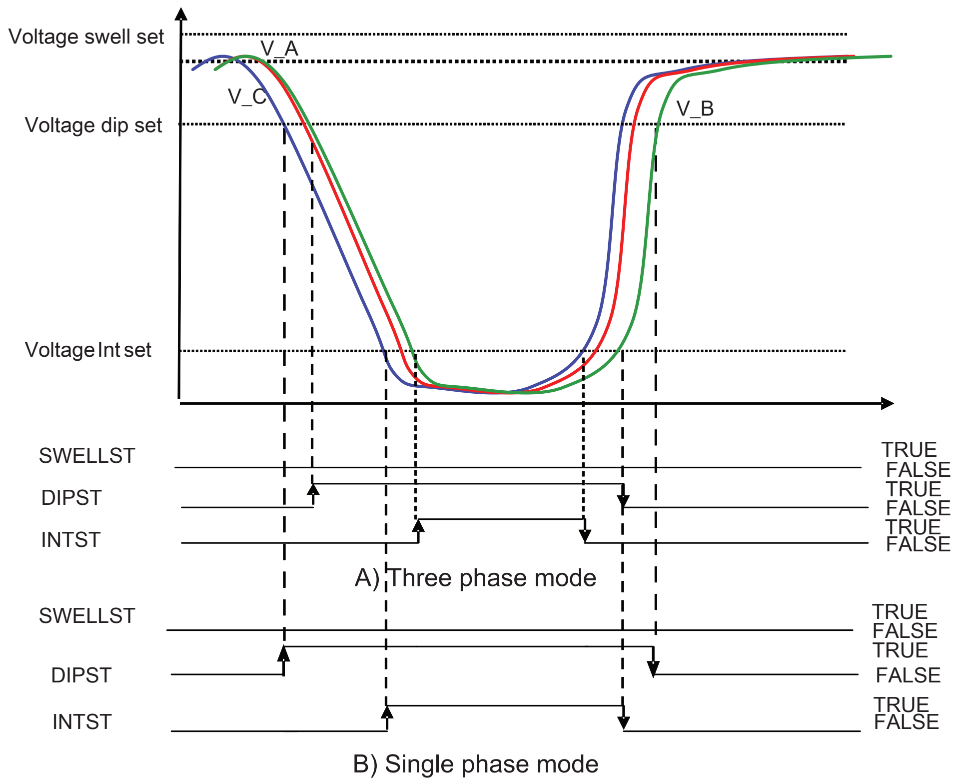


Figure 219: Detection of three-phase voltage interruption

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.

8.3.4.3 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 220 shows voltage dip operational regions. In Figure 219, 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.

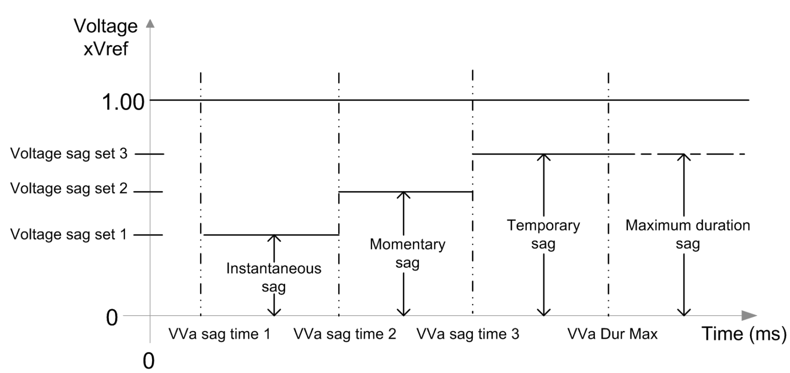


Figure 220: Voltage dip operational regions

In Figure 221, 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.

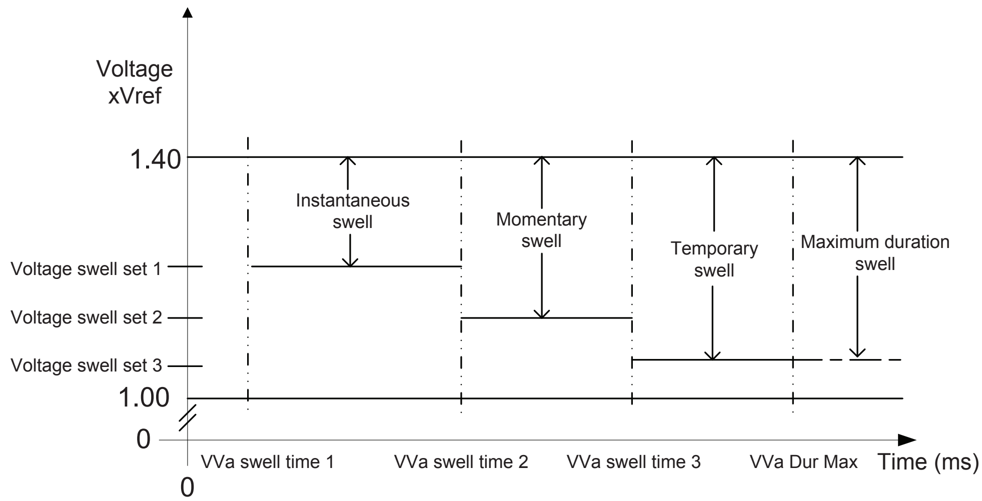


Figure 221: Voltage swell operational regions

For interruption, as shown in Figure 222, 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.

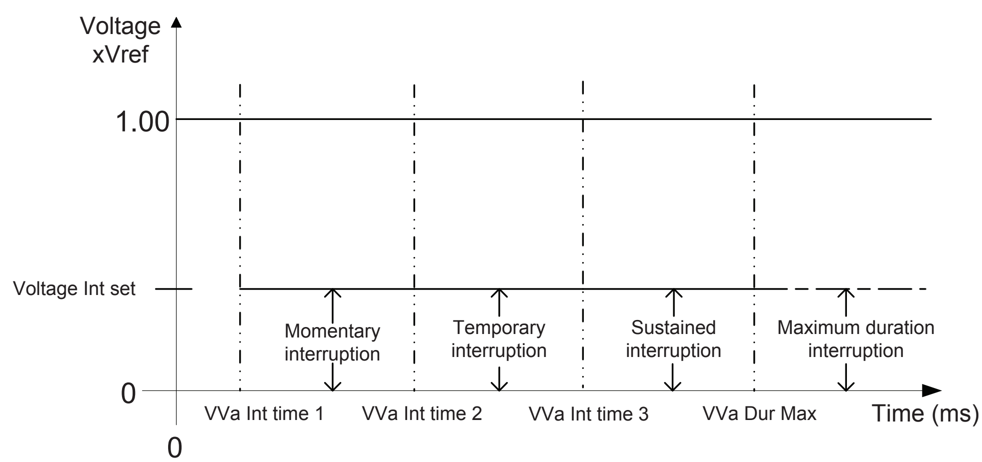


Figure 222: Interruption operating regions

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 the 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*.

There is a validation functionality built-in function that checks the relationship adherence so that if *VVa x time 1* is set higher than *VVa x time 2* or *VVa x time 3*, *VVa x time 2* and *VVa x time 3* are set equal to the new *VVa x time 1*. If *VVa x time 2* is set higher than *VVa x time 3*, *VVa x time 3* is set to the new *VVa x time 2*. If *VVa x time 2* is set lower than *VVa x time 1*, the entered *VVa x time 2* is rejected. If *VVa x time 3* is set lower than *VVa x time 2*, the entered *VVa x time 3* is rejected.

8.3.4.4 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 223. 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 single-phase 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.

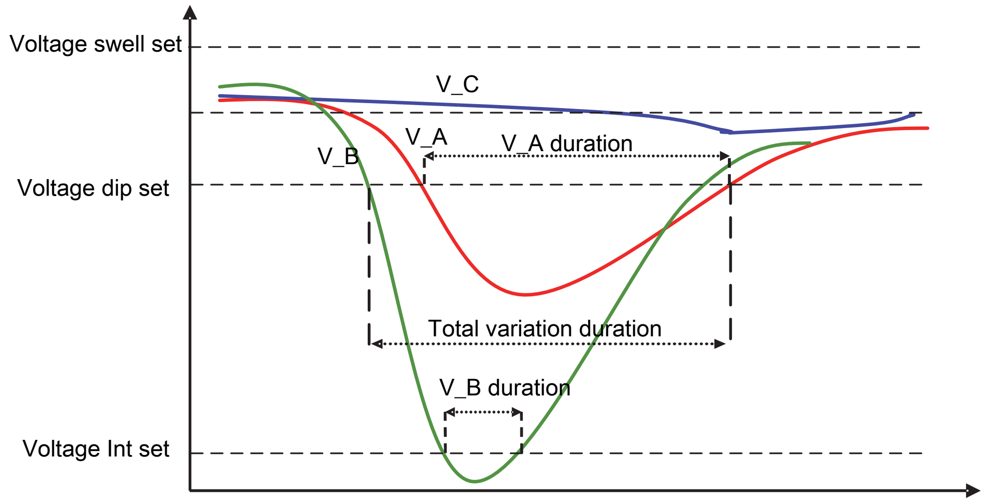


Figure 223: Single-phase interruption for the Phase mode value "Single Phase"

8.3.4.5 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 219. 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 223, 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 224. 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.

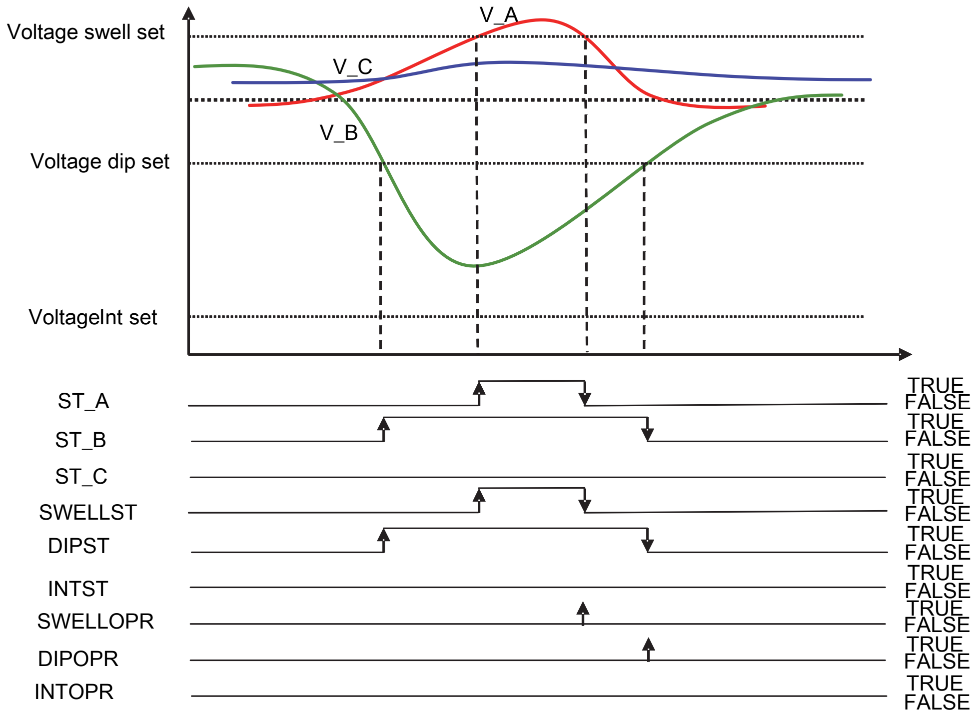


Figure 224: Concurrent dip and swell when Phase mode is "Single Phase"

In Figure 225, 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 225 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 224 and Figure 225 it is assumed that variation durations are sufficient for detections to take place.

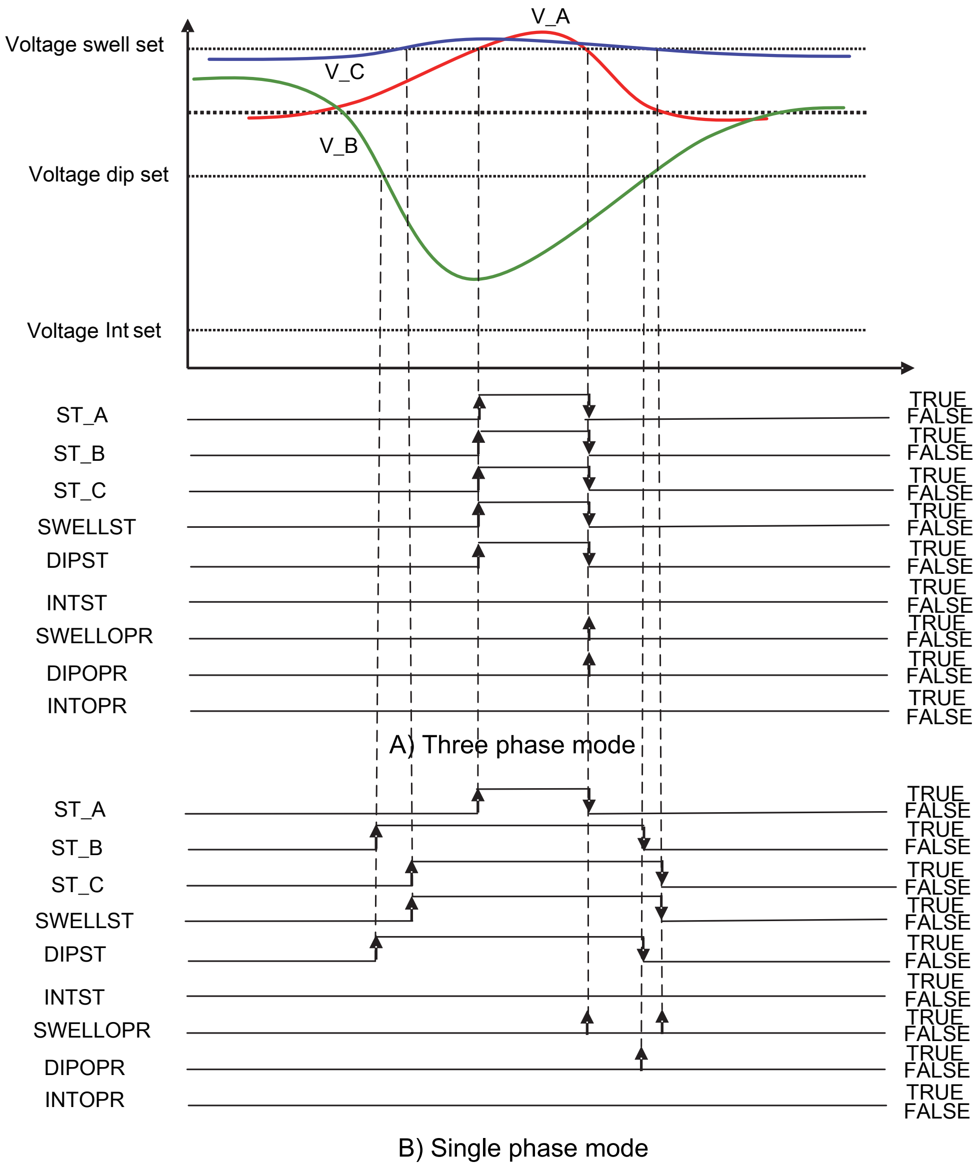


Figure 225: Concurrent dip and two-phase swell

8.3.5 Recorded data

Besides counter increments, the information required for a later fault analysis is stored after a valid voltage variation is detected.

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 226. 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 348. 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 226 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 226. 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.

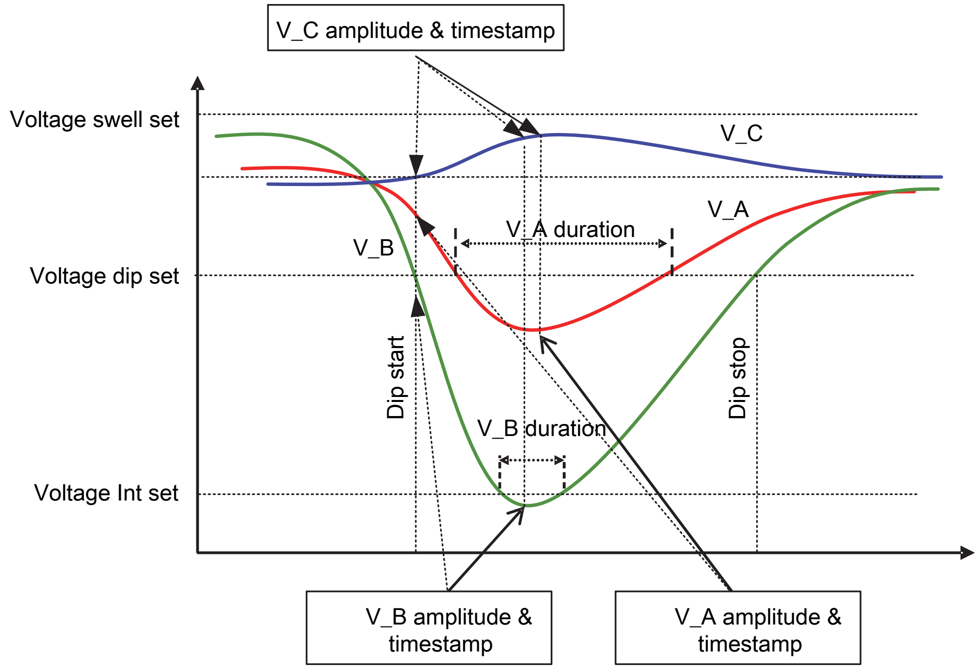


Figure 226: Valid recorded voltage interruption and two dips

Table 348: PQSS recording data bank parameters

Parameter description	Parameter name
Event detection triggering time stamp	Time
Variation type	Variation type
Variation magnitude Ph A	Variation Ph A
Variation magnitude Ph A time stamp (maximum/ minimum magnitude measuring time moment during variation)	Var Ph A rec time
Variation magnitude Ph B	Variation Ph B
Variation magnitude Ph B time stamp (maximum/ minimum magnitude measuring time moment during variation)	Var Ph B rec time
Variation magnitude Ph C	Variation Ph C
Variation magnitude Ph C time stamp (maximum/ minimum magnitude measuring time moment during variation)	Var Ph C rec time
Variation duration Ph A	Variation Dur Ph A
Variation Ph A start time stamp (phase A variation start time moment)	Var Dur Ph A time
Variation duration Ph B	Variation Dur Ph B

Table continues on next page

Parameter description	Parameter name
Variation Ph B start time stamp (phase B variation start time moment)	Var Dur Ph B time
Variation duration Ph C	Variation Dur Ph C
Variation Ph C start time stamp (phase C variation start time moment)	Var Dur Ph C time
Current magnitude Ph A preceding variation	Var current Ph A
Current magnitude Ph B preceding variation	Var current Ph B
Current magnitude Ph C preceding variation	Var current Ph C

Table 349: 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

8.3.6 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.

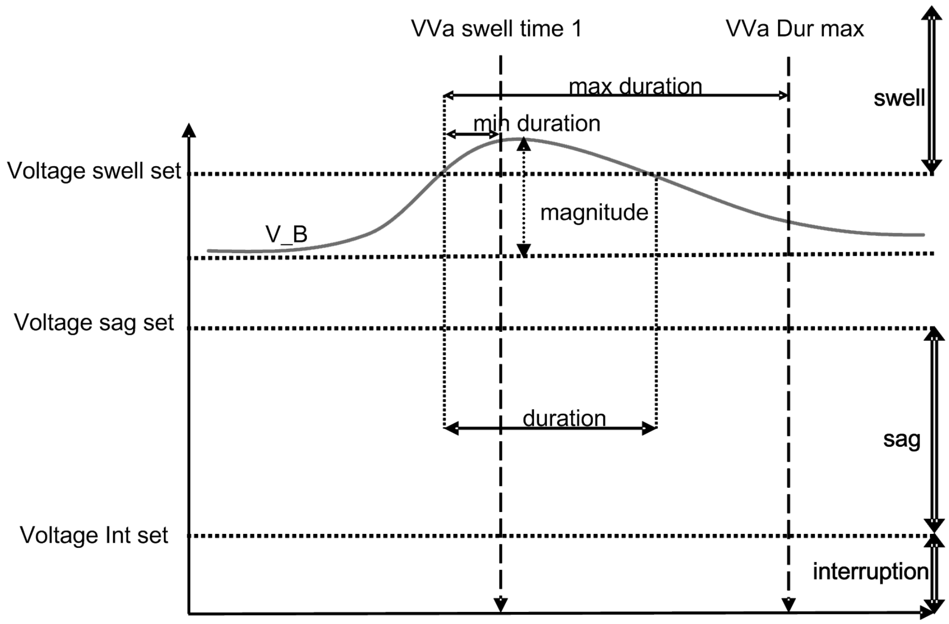


Figure 227: Duration and voltage magnitude limits for swell, dip and interruption measurement

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.

8.3.7 Signals

Table 350: PQSS 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
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 351: 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

8.3.8 Settings

Table 352: PQSS Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Reference voltage	10.0...200.0	%Un	0.1	57.7	Reference supply voltage in %
Voltage dip set 1	10.0...100.0	%	0.1	80.0	Dip limit 1 in % of reference voltage
VVa dip time 1	0.5...54.0	cycles	0.1	3.0	Voltage variation dip duration 1
Voltage dip set 2	10.0...100.0	%	0.1	80.0	Dip limit 2 in % of reference voltage
VVa dip time 2	10.0...180.0	cycles	0.1	30.0	Voltage variation dip duration 2
Voltage dip set 3	10.0...100.0	%	0.1	80.0	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	120.0	Swell limit 1 in % of reference voltage
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
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	120.0	Swell limit 2 in % of reference voltage
VVa swell time 2	10.0...80.0	cycles	0.1	10.0	Voltage variation swell duration 2
Voltage swell set 3	100.0...140.0	%	0.1	120.0	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	10.0	Interruption limit in % of reference voltage
VVa Int time 1	0.5...30.0	cycles	0.1	3.0	Voltage variation Int duration 1
VVa Int time 2	10.0...180.0	cycles	0.1	30.0	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 353: PQSS Non group settings

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

8.3.9 Monitored data

Table 354: PQSS Monitored data

Name	Type	Values (Range)	Unit	Description
ST_A	BOOLEAN	0=False 1=True		Pickup Phase A (Voltage Variation Event in progress)
ST_B	BOOLEAN	0=False 1=True		Pickup Phase B (Voltage Variation Event in progress)
ST_C	BOOLEAN	0=False 1=True		Pickup Phase C (Voltage Variation Event in progress)

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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
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=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		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	xUn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xUn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xUn	Variation magnitude Phase C

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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 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	xUn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xUn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xUn	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

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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 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	xUn	Variation magnitude Phase A
Var Ph A rec time	Timestamp			Variation magnitude Phase A time stamp
Variation Ph B	FLOAT32	0.00...5.00	xUn	Variation magnitude Phase B
Var Ph B rec time	Timestamp			Variation magnitude Phase B time stamp
Variation Ph C	FLOAT32	0.00...5.00	xUn	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

8.4 Voltage unbalance PQVUB

8.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage unbalance	VSQVUB	PQMUBU	PQVUB

8.4.2 Function block

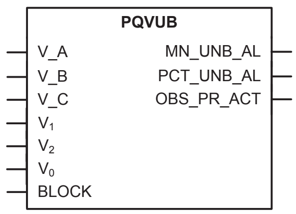


Figure 228: Function block

8.4.3 Functionality

The voltage unbalance function PQVUB monitors voltage unbalance conditions in power transmission and distribution networks. It can be applied to identify a network and load unbalance that can cause sustained voltage unbalance. PQVUB is also used to monitor the commitment of the power supply utility of providing a high-quality, that is, a balanced voltage supply on a continuous basis.

PQVUB uses five different methods for calculating voltage unbalance. The methods are the negative-sequence voltage magnitude, zero-sequence voltage magnitude, ratio of the negative-sequence voltage magnitude to the positive-sequence voltage magnitude, ratio of the zero-sequence voltage magnitude to the positive-sequence voltage magnitude and ratio of maximum phase voltage magnitude deviation from the mean voltage magnitude to the mean of the phase voltage magnitude.

PQVUB provides statistics which can be used to verify the compliance of the power quality with the European standard EN 50160 (2000). The statistics over selected period include a freely selectable percentile for unbalance. PQVUB also includes an alarm functionality providing a maximum unbalance value and the date and time of occurrence.

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

8.4.4 Operation principle

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

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

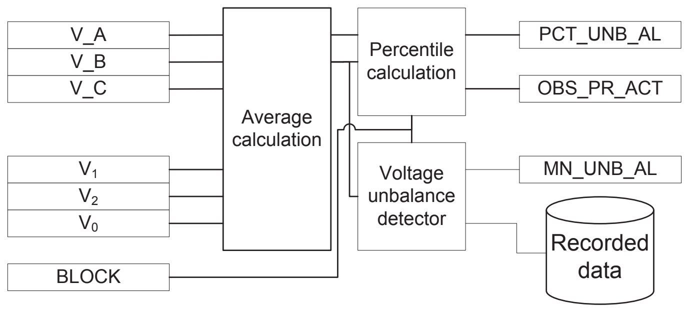


Figure 229: Functional module diagram

Average calculation

PQVUB calculates two sets of measured voltage unbalance values, a three-second and a ten-minute non-sliding average value. The three-second average value is used for continuous monitoring. The ten-minute average is used for percentile calculation for a longer period.

The Average calculation module uses five different methods for the average calculation. The required method can be selected with the *Unb detection method* parameter.

When the "Neg Seq" mode is selected with *Unb detection method*, the voltage unbalance is calculated based on the negative-sequence voltage magnitude. Similarly, when the "Zero Seq" mode is selected, the voltage unbalance is calculated based on the zero-sequence voltage magnitude. When the "Neg to Pos Seq" mode is selected, the voltage unbalance is calculated based on the ratio of the negative-sequence voltage magnitude to the positive-sequence magnitude. When the "Zero to Pos Seq" mode is selected, the voltage unbalance is calculated based on the ratio of the zero-sequence voltage magnitude to the positive-sequence magnitude. When the "Ph vectors Comp" mode is selected, the ratio of the maximum phase voltage magnitude deviation from the mean voltage magnitude to the mean of the phase voltage magnitude is used for voltage unbalance calculation.

The calculated three-second value and ten-minute value are available in the Monitored data view through the outputs `3S_MN_UNB` and `10MN_MN_UNB`.

Voltage unbalance detector

The three-second average value is calculated and compared to the set value *Unbalance pickup val*. If the voltage unbalance exceeds this limit, the MN_UNB_AL output is activated.

The activation of the BLOCK input blocks MN_UNB_AL output.

Percentile calculation

The Percentile calculation module performs the statistics calculation for the level of voltage unbalance value for a settable duration. The operation of the Percentile calculation module can be described with a module diagram.

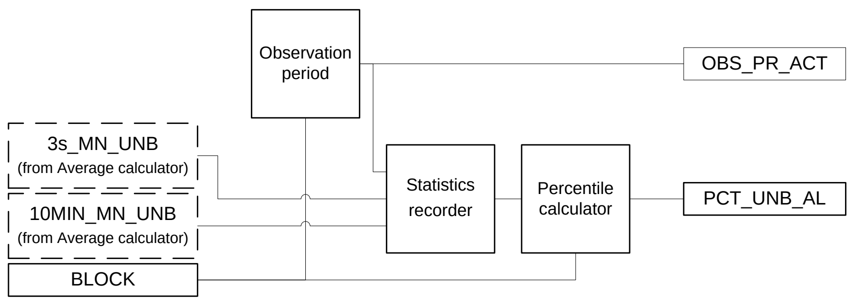


Figure 230: Percentile calculation

Observation period

The Observation period module calculates the length of the observation time for the Statistics recorder sub-module as well as determines the possible start of a new one. A new period can be started by timed activation using settings *Obs period Str time*.

A preferable way of continuous statistics recordings can be selected over a longer period (months, years). With the *Trigger mode* setting, the way the next possible observation time is activated after the former one has finished can be selected. When the trigger mode is selected "Single", it is the single triggering mode, when the trigger mode is selected "Periodic", it is the periodic triggering mode and when the trigger mode is selected "Continuous", it is the continuous triggering mode.

In the single triggering mode, only one period of observation time is activated. In the periodic triggering mode, the time gap between the two trigger signals is seven days. In the continuous triggering mode, the next period starts right after the former observation period is completed.

The length of the period is determined by the settings *Obs period selection* and *User Def Obs period*. The OBS_PR_ACT output is an indication signal which exhibits rising edge

(TRUE) when the observation period starts and falling edge (FALSE) when the observation period ends.

If the *Percentile unbalance*, *Trigger mode* or *Obs period duration* settings change when `OBS_PR_ACT` is active, `OBS_PR_ACT` deactivates immediately.

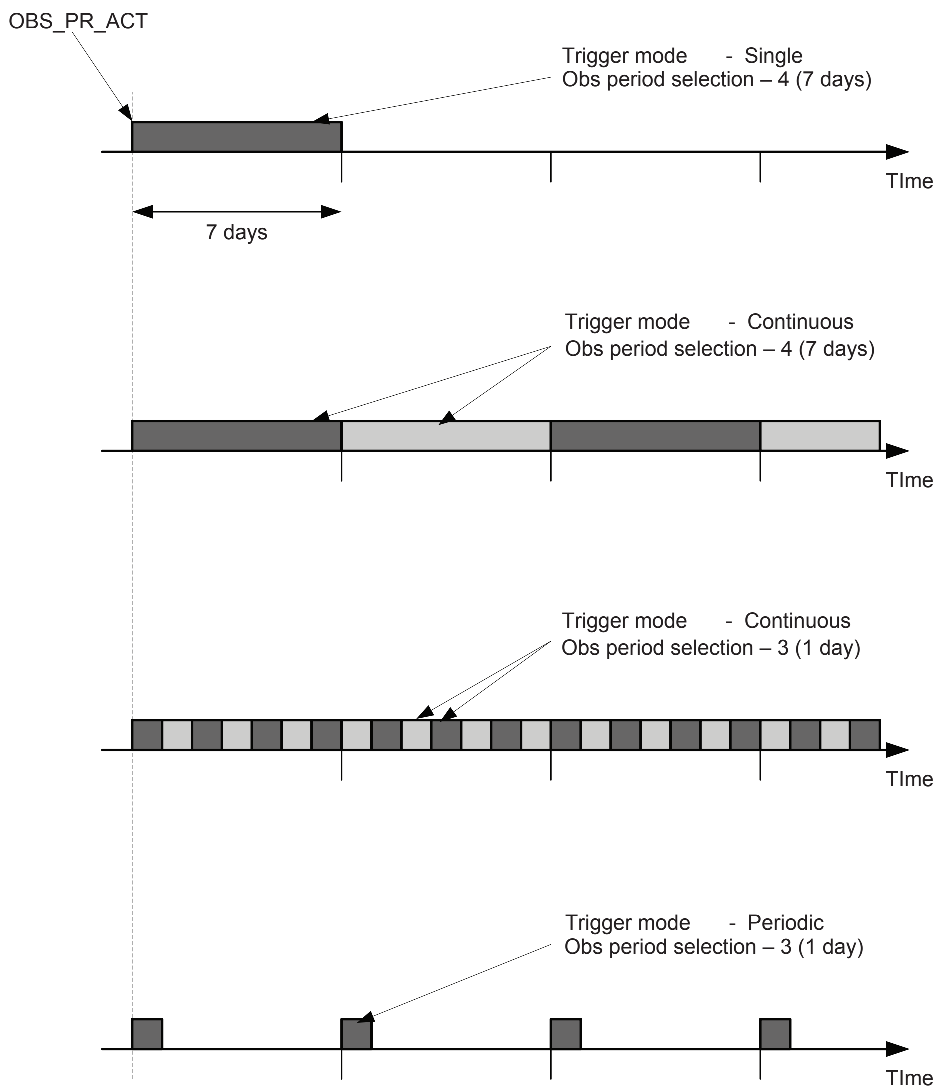


Figure 231: Periods for statistics recorder with different trigger modes and period settings

The BLOCK input blocks the OBS_PR_ACT output, which then disables the maximum value calculation of the Statistics recorder module. If the trigger mode is selected "Periodic" or "Continuous" and the blocking is deactivated before the next observation period is due to start, the scheduled period starts normally.

Statistics recorder

The Statistics recorder module provides readily calculated three-second or ten-minute values of the selected phase to the percentile calculator module based on the length of the active observation period. If the observation period is less than one day, the three-second average values are used. If the observation period is one day or longer, the ten-minute average values are used.

The maximum three-second or ten-minute mean voltage unbalance is recorded during the active observation period. The observation period start time *PR_STR_TIME*, observation period end time *PR_END_TIME*, maximum voltage unbalance value during observation period active, *MAX_UNB_VAL* and time of occurrence *MAX_UNB_TIME* are available through the Monitored data view. These outputs are updated once OBS_PR_ACT deactivates.

Percentile calculator

The purpose of the Percentile calculator module is to find the voltage unbalance level so that during the observation time 95 percent (default value of the *Percentile unbalance* setting) of all the measured voltage unbalance amplitudes are less than or equal to the calculated percentile.

The computed output value PCT_UNB_VAL, below which the percentile of the values lies, is available in the Monitored data view. The PCT_UNB_VAL output value is updated at the end of the observation period.

If the output PCT_UNB_VAL is higher than the defined setting *Unbalance pickup val* at the end of the observation period, an alarm output PCT_UNB_AL is activated. The PCT_UNB_AL output remains active for the whole period before the next period completes.

The BLOCK input blocks the output PCT_UNB_VAL.

Recorded data

The information required for a later fault analysis is stored when the Recorded data module is triggered. This happens when a voltage unbalance is detected by the Voltage unbalance detector module.

Three sets of recorded data are available in total. The sets are saved in data banks 1...3. The data bank 1 holds the most recent recorded data. Older data are moved to the subsequent banks (1 to 2 and 2 to 3) when a voltage unbalance is detected. When all three banks have data and a new variation is detected, the latest data set is placed into bank 1 and the data in bank 3 is overwritten by the data from bank 2.

The recorded data can be reset with the RESET binary input signal by navigating to the HMI reset (**Main menu/Clear/Reset recorded data/PQVUBx**) or through tools via communications.

When voltage unbalance is detected in the system, PQVUB responds with the MN_UNB_AL alarm signal. During the alarm situation, PQVUB stores the maximum magnitude and the time of occurrence and the duration of alarm MN_UNB_AL. The recorded data is stored when MN_UNB_AL is deactivated.

Table 355: Recorded data

Parameter	Description
Alarm high mean Dur	Time duration for alarm high mean unbalance
Max unbalance Volt	Maximum three-second voltage
Time Max Unb Volt	Time stamp of voltage unbalance

8.4.5 Application

Voltage unbalance is one of the basic power quality parameters.

Ideally, in a three-phase or multiphase power system, the frequency and voltage magnitude of all the phases are equal and the phase displacement between any two consecutive phases is also equal. This is called a balanced source. Apart from the balanced source, usually the power system network and loads are also balanced, implying that network impedance and load impedance in each phase are equal. In some cases, the condition of a balance network and load is not met completely, which leads to a current and voltage unbalance in the system. Providing unbalanced supply voltage has a detrimental effect on load operation. For example, a small magnitude of a negative-sequence voltage applied to an induction motor results in a significant heating of the motor.

A balanced supply, balanced network and balanced load lead to a better power quality. When one of these conditions is disturbed, the power quality is deteriorated. PQVUB monitors such voltage unbalance conditions in power transmission and distribution networks. PQVUB calculates two sets of measured values, a three-second and a ten-minute non-sliding average value. The three-second average value is used for continuous monitoring while the ten-minute average value is used for percentile calculation for a longer period of time. It can be applied to identify the network and load unbalance that may cause sustained voltage unbalance. A single-phase or phase-to-phase fault in the network or load side can create voltage unbalance but, as faults are usually isolated in a short period of time, the voltage unbalance is not a sustained one. Therefore, the voltage unbalance may not be covered by PQVUB.

Another major application is the long-term power quality monitoring. This can be used to confirm a compliance to the standard power supply quality norms. The function provides a voltage unbalance level which corresponds to the 95th percentile of the ten minutes' average values of voltage unbalance recorded over a period of up to one week. It means that for 95 percent of time during the observation period the voltage unbalance was less than or equal to the calculated percentile. An alarm can be obtained if this value exceeds the value that can be set.

The function uses five different methods for calculating voltage unbalance.

- Negative-sequence voltage magnitude
- Zero-sequence voltage magnitude
- Ratio of negative-sequence to positive-sequence voltage magnitude
- Ratio of zero-sequence to positive-sequence voltage magnitude
- Ratio of maximum phase voltage magnitude deviation from the mean voltage magnitude to the mean of phase voltage magnitude.

Usually, the ratio of the negative-sequence voltage magnitude to the positive-sequence voltage magnitude is selected for monitoring the voltage unbalance. However, other methods may also be used if required.

8.4.6 Signals

Table 356: PQVUB 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
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage
V_0	SIGNAL	0	Zero sequence voltage
RESET	BOOLEAN	0=False	Resets the registered values of the data banks

Table 357: PQVUB Output signals

Name	Type	Description
MN_UNB_AL	BOOLEAN	Alarm active when 3 sec voltage unbalance exceeds the limit
PCT_UNB_AL	BOOLEAN	Alarm active when percentile unbalance exceeds the limit
OBS_PR_ACT	BOOLEAN	Observation period is active

8.4.7 Settings

Table 358: PQVUB Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Opeartion	1=enable 5=disable			5=disable	Opeartion Enable/Disable
Unb detection method	1=Neg Seq 2=Zero Seq 3=Neg to Pos Seq 4=Zero to Pos Seq 5=Ph vectors Comp			3=Neg to Pos Seq	Set the operation mode for voltage unbalance calculation
Unbalance pickup Val	1...100	%	1	1	Voltage unbalance pickup value
Trigger mode	1=Single 2=Periodic 3=Continuous			3=Continuous	Specifies the observation period triggering mode
Percentile unbalance	1...100	%	1	95	The percent to which percentile value PCT_UNB_VAL is calculated
Obs period selection	1=1 Hour 2=12 Hours 3=1 Day 4=7 Days 5=User defined			5=User defined	Observation period for unbalance calculation
User Def Obs period	1...168	h	1	168	User define observation period for statistic calculation
Obs period Str time	2008010100...2076010100		1	2011010101	Calendar time for observation period start given as YYYYMMDDhh

8.4.8 Monitored data

Table 359: PQVUB Monitored data

Name	Type	Values (Range)	Unit	Description
3S_MN_UNB	FLOAT32	0.00...100.00	%	Non sliding 3 second mean value of voltage unbalance
10MIN_MN_UNB	FLOAT32	0.00...100.00	%	Sliding 10 minutes mean value of voltage unbalance
PCT_UNB_VAL	FLOAT32	0.00...100.00	%	Limit below which percentile unbalance of the values lie
MAX_UNB_VAL	FLOAT32	0.00...100.00	%	Maximum voltage unbalance measured in the observation period
MAX_UNB_TIME	Timestamp			Time stamp at which maximum voltage unbalance measured in the observation period
PR_STR_TIME	Timestamp			Time stamp of starting of the previous observation period
PR_END_TIME	Timestamp			Time stamp of end of previous observation period
Alarm high mean Dur	FLOAT32	0.000...3600.000	s	Time duration for alarm high mean unbalance
Max unbalance Volt	FLOAT32	0.00...100.00	%	Maximum 3 sec voltage
Time Max Unb Volt	Timestamp			Time stamp of voltage unbalance
Alarm high mean Dur	FLOAT32	0.000...3600.000	s	Time duration for alarm high mean unbalance
Max unbalance Volt	FLOAT32	0.00...100.00	%	Maximum 3 sec voltage
Time Max Unb Volt	Timestamp			Time stamp of voltage unbalance
Alarm high mean Dur	FLOAT32	0.000...3600.000	s	Time duration for alarm high mean unbalance
Max unbalance Volt	FLOAT32	0.00...100.00	%	Maximum 3 sec voltage
Time Max Unb Volt	Timestamp			Time stamp of voltage unbalance
PQVUB	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

8.4.9 Technical data

Table 360: PQVUB Technical data

Characteristic	Value
Operation accuracy	±1.5% of the set value or ±0.002 × V_n
Reset ratio	Typically 0.96

Section 9 Control functions

9.1 Circuit breaker control 52

9.1.1 Identification

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

9.1.2 Function block

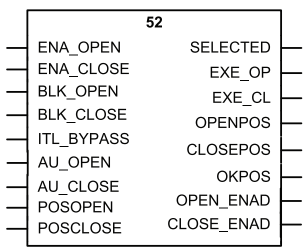


Figure 232: Function block

9.1.3 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 counter value can be read and written remotely from the place of operation or via LHMI.

9.1.4 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 of the apparatus occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 361: 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 autoreclosing functions, for example. There are two blocking principles.

- Enabling the opening command: the function is used to block the operation of the opening command. This block signal also affects the OPEN input of immediate command.
- Enabling the closing command: the function is used to block the operation of the closing command. 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 apparatus 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 the higher priority.

Table 362: *Interlocking conditions for enabling the closing (opening) command*

Inputs			Outputs
INT_BYPASS	ENA_CLOSE (ENA_OPEN)	BLK_CLOSE (BLK_OPEN)	CLOSE_ENAD (OPEN_ENAD)
0 = False	0 = False	0 = False	0 = False
0 = False	0 = False	1 = True	0 = False
0 = False	1 = True	0 = False	1 = True
0 = False	1 = True	1 = True	0 = False
1 = True	0 = False	0 = False	1 = True
1 = True	0 = False	1 = True	0 = False
1 = True	1 = True	0 = False	1 = True
1 = True	1 = True	1 = True	0 = False

Opening and closing operations

The opening and closing operations are available via communication, binary inputs or LHMI commands. As a prerequisite for control commands, there are enabling and blocking functionalities for both opening and closing commands (`CLOSE_ENAD` and `OPEN_ENAD` signals). If the control command is executed against the blocking or if the enabling of the corresponding command is not valid, 52 generates an error message.

Opening and closing 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 apparatus has entered the correct state. If apparatus fails to enter the correct state, the output pulse is deactivated after the set *Operation timeout* setting, and an error message is displayed. When the *Adaptive pulse* is set to “FALSE”, the functions always use 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 apparatus already is in the right position, the maximum pulse length is given.

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 control model setting is only applicable when initiating commands using LHMI or remotely using the IEC 61850 protocol.

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 several 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 canceling: cancels the controlling of a selected object.

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

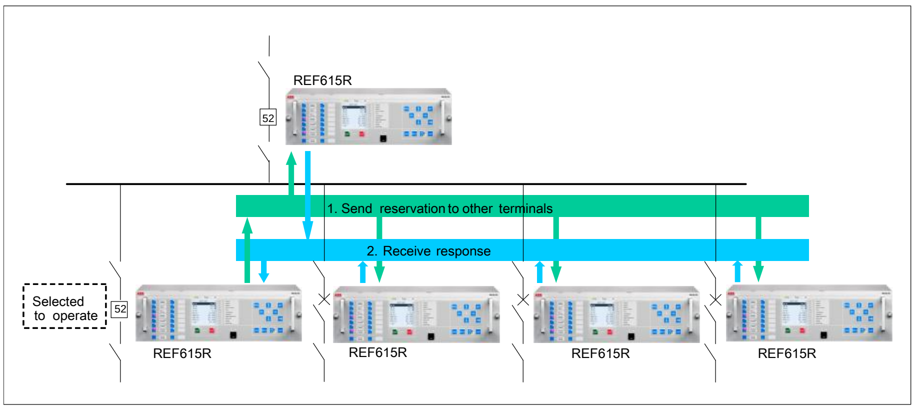


Figure 233: Control procedure in SBO method

9.1.5 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 correct execution sequence of the control commands must be ensured. This can be achieved, for example, with interlocking based on the status indication of the related primary components. The interlocking on substation level can be applied using the IEC 61850 GOOSE messages between feeders.

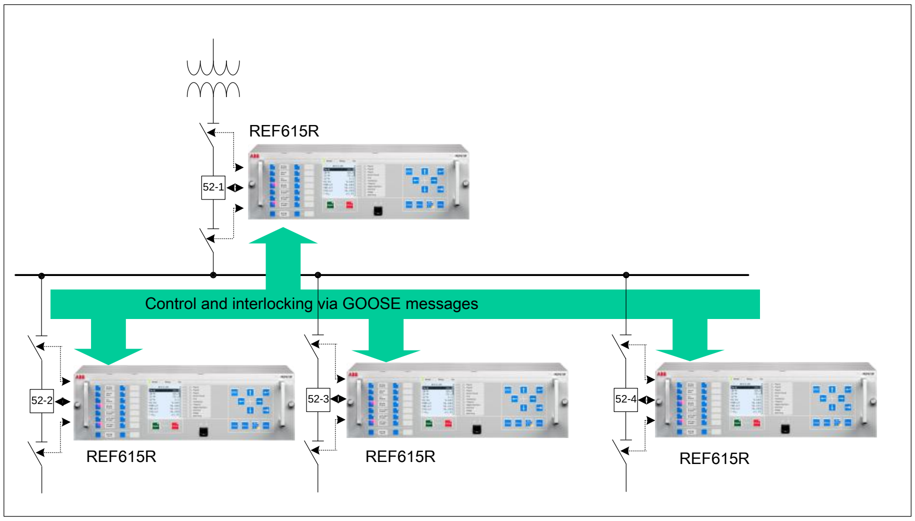


Figure 234: Status indication-based interlocking via the GOOSE messaging

9.1.6 Signals

Table 363: 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 closing
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[1)]
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O[1)]
POSCLOSE	BOOLEAN	0=False	Signal for closed position of apparatus from I/O[1)]

1) Not available for monitoring

Table 364: 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

9.1.7 Settings

Table 365: 52 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation mode disable / disable
Select timeout	10000...300000	ms	10000	60000	Select timeout in ms
Pulse length	10...60000	ms	1	100	Open and close pulse length
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 right position
Event delay	0...10000	ms	1	100	Event delay of the intermediate position
Operation timeout	10...60000	ms		500	Timeout for negative termination

9.1.8 Monitored data

Table 366: 52 Monitored data

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

9.2 Autoreclosing 79

9.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Autoreclosing	DARREC	O -> I	79

9.2.2 Function block

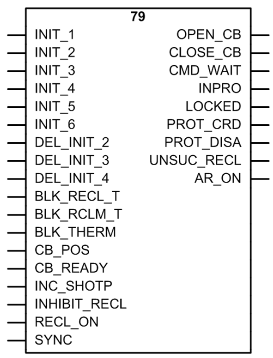


Figure 235: Function block

9.2.3 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 autoreclosing function 79 can be used with any circuit breaker suitable for autoreclosing. The function provides five programmable autoreclosing shots which can perform one to five successive autoreclosings 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 autoreclosing 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.

9.2.3.1 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 367: 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).

9.2.3.2 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.

9.2.3.3 Master and slave scheme

With the cooperation between the AR units in the same protection relay or between protection relays, sequential reclosings of two breakers at a line end in a 1½-breaker, double breaker or ring-bus arrangement can be achieved. 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.

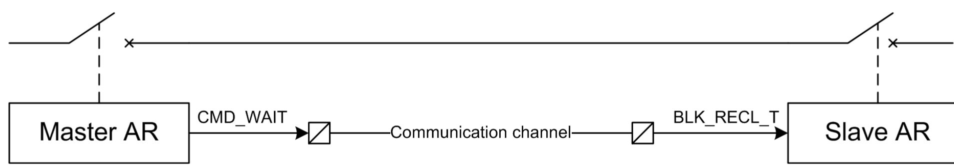


Figure 236: Master and slave scheme

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 autoreclosing shot.

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

9.2.3.4 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.

9.2.4 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 79 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

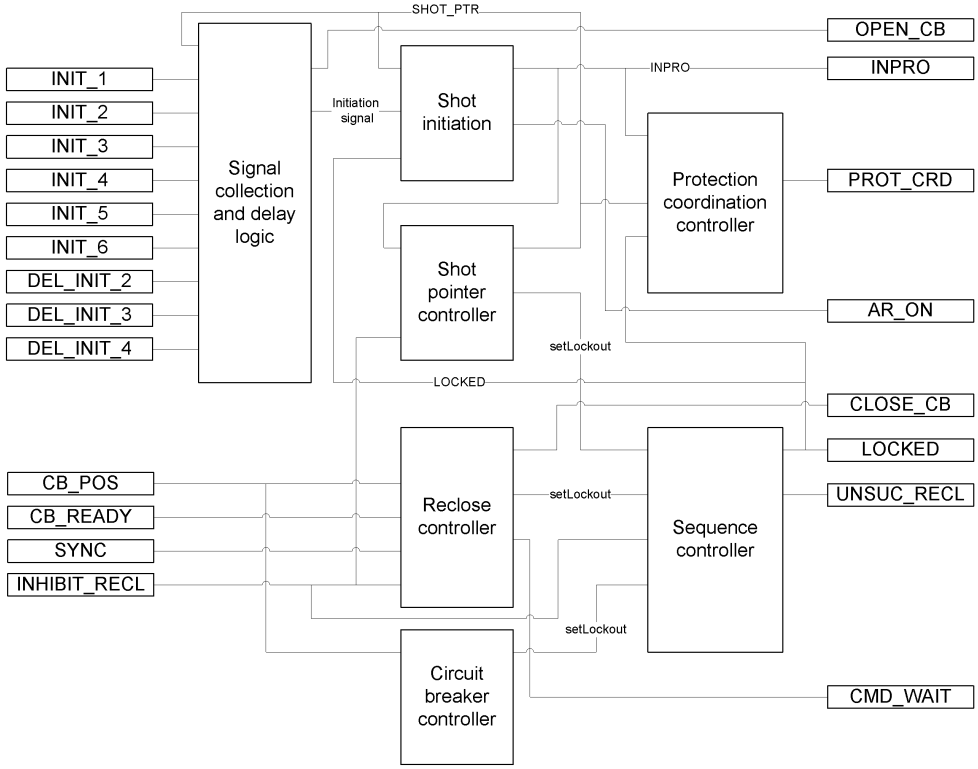


Figure 237: Functional module diagram

9.2.4.1 Signal collection and delay logic

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

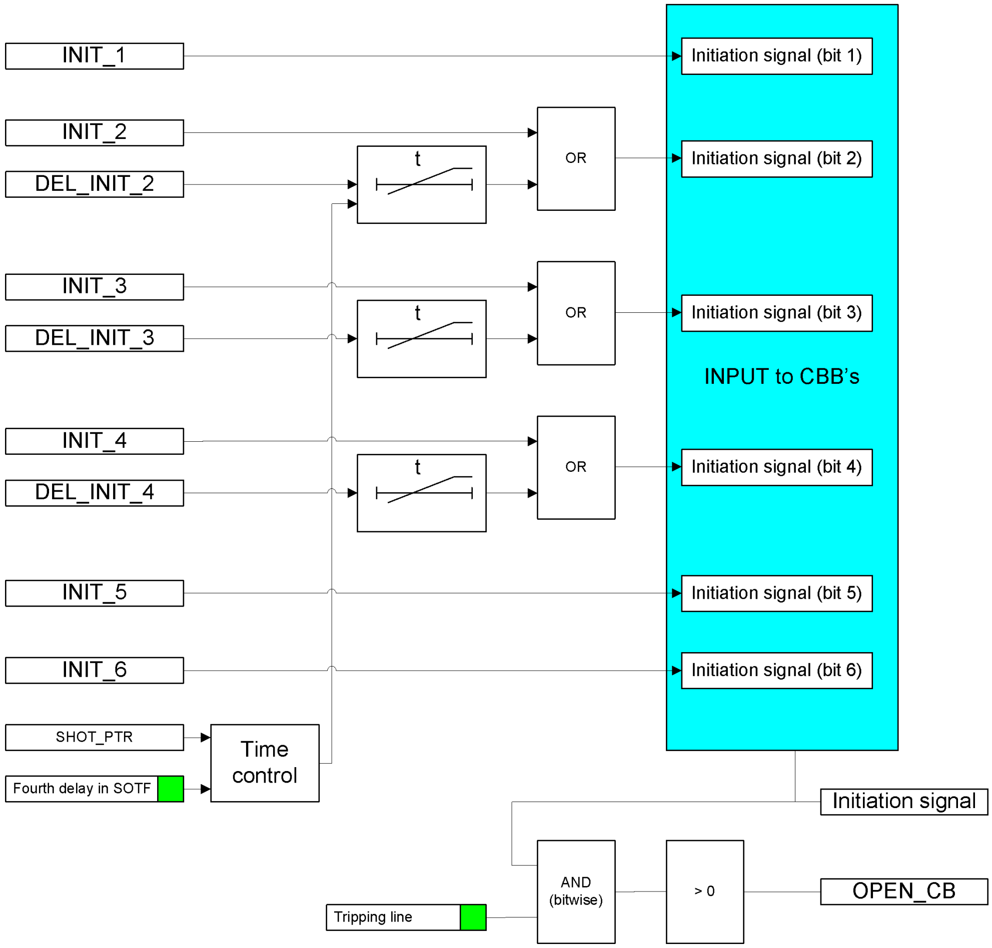


Figure 238: Schematic diagram of delayed initiation input signals

In total, the AR function contains six separate initiation lines used for the initiation or blocking of the autoreclosing 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

- *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

- *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

- *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 reclosing attempts are made. The third and fourth attempts are used to provide the so-called fast final trip to lockout.

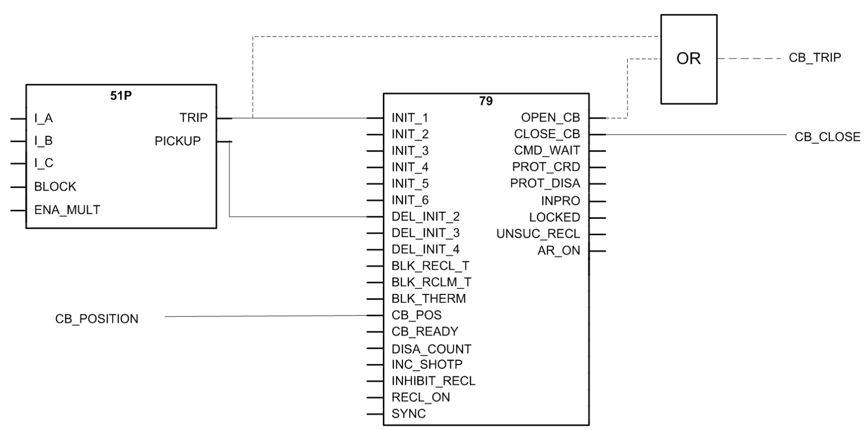


Figure 239: Autoreclosing configuration example

Delayed `DEL_INIT_2...4` signals are used only when the autoreclosing shot is initiated with the pickup signal of a protection stage. After a pickup delay, the AR function opens the circuit breaker and an autoreclosing 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 autoreclosing 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 autoreclosing 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 autoreclosing sequence is successful: the reclaim time elapses and no new sequence is picked up.

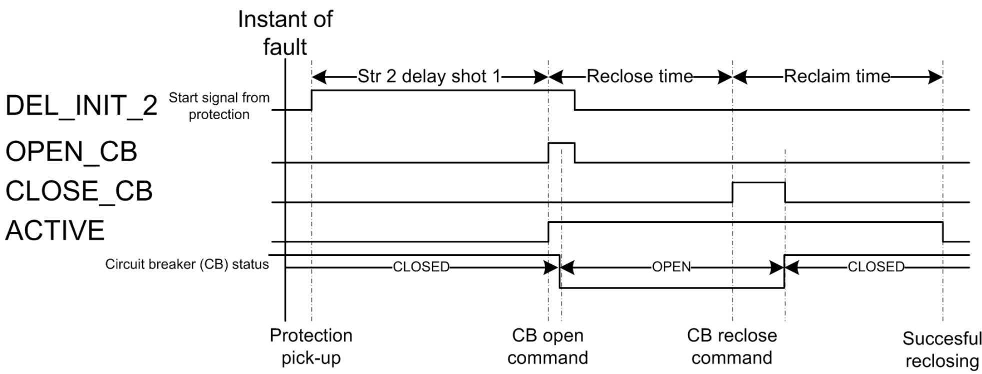


Figure 240: Signal scheme of autoreclosing operation initiated with protection pickup signal

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

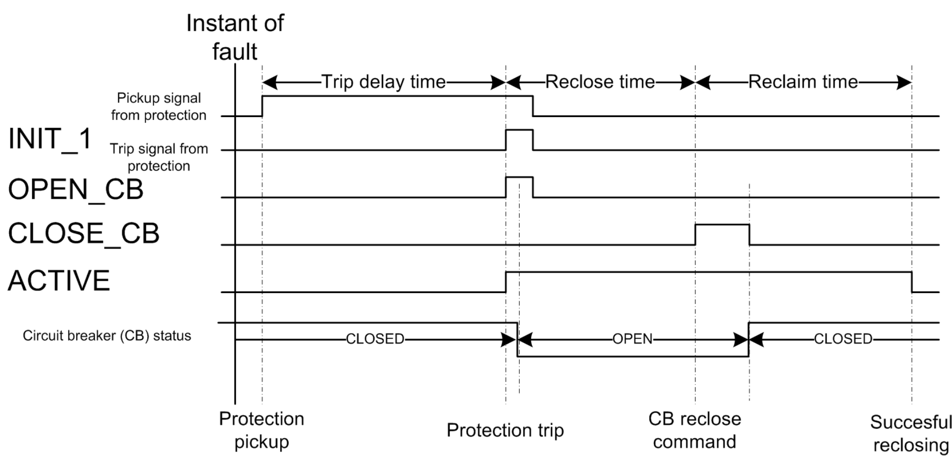


Figure 241: Signal scheme of autoreclosing operation initiated with protection trip signal

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

Normally, all trip and pickup signals are used to initiate an autoreclosing 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.

9.2.4.2 Shot initiation

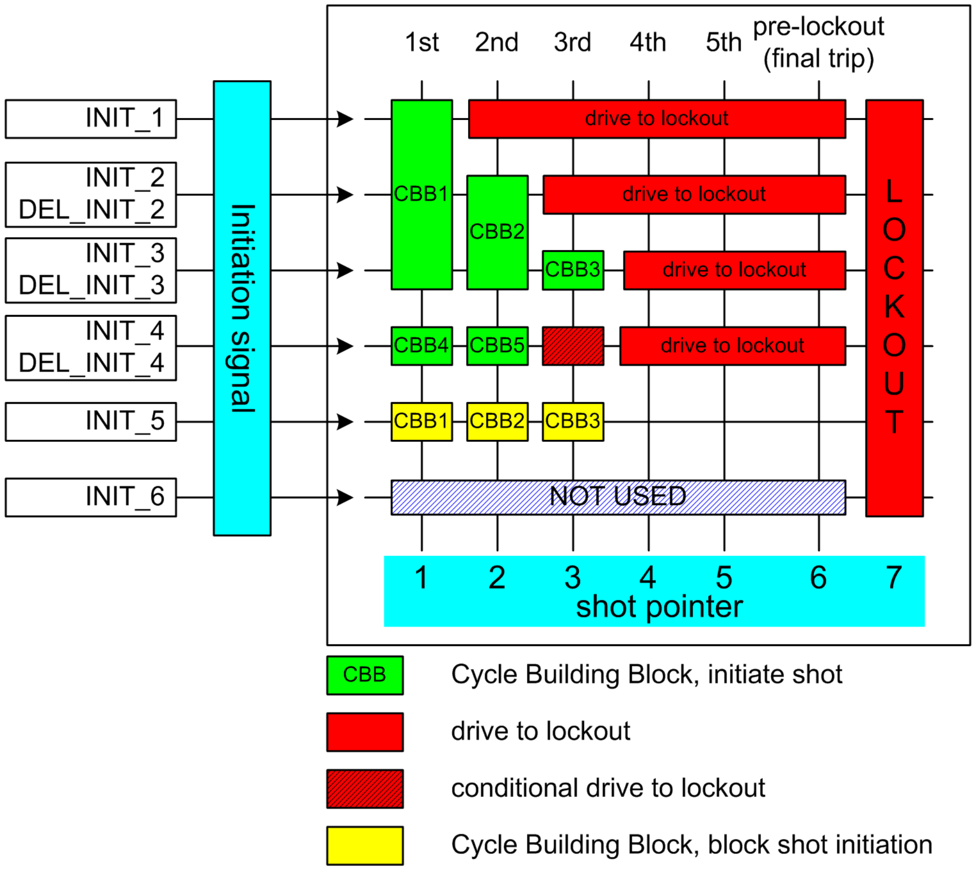


Figure 242: Example of an autoreclosing program with a reclose scheme matrix

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.

When the reclose time of a CBB is set to zero, once its init line is active, it immediately 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.

The existing 79 function does not have a complete zone sequence coordination feature. An external ACT logic needs to be built to drive INC_POINT.

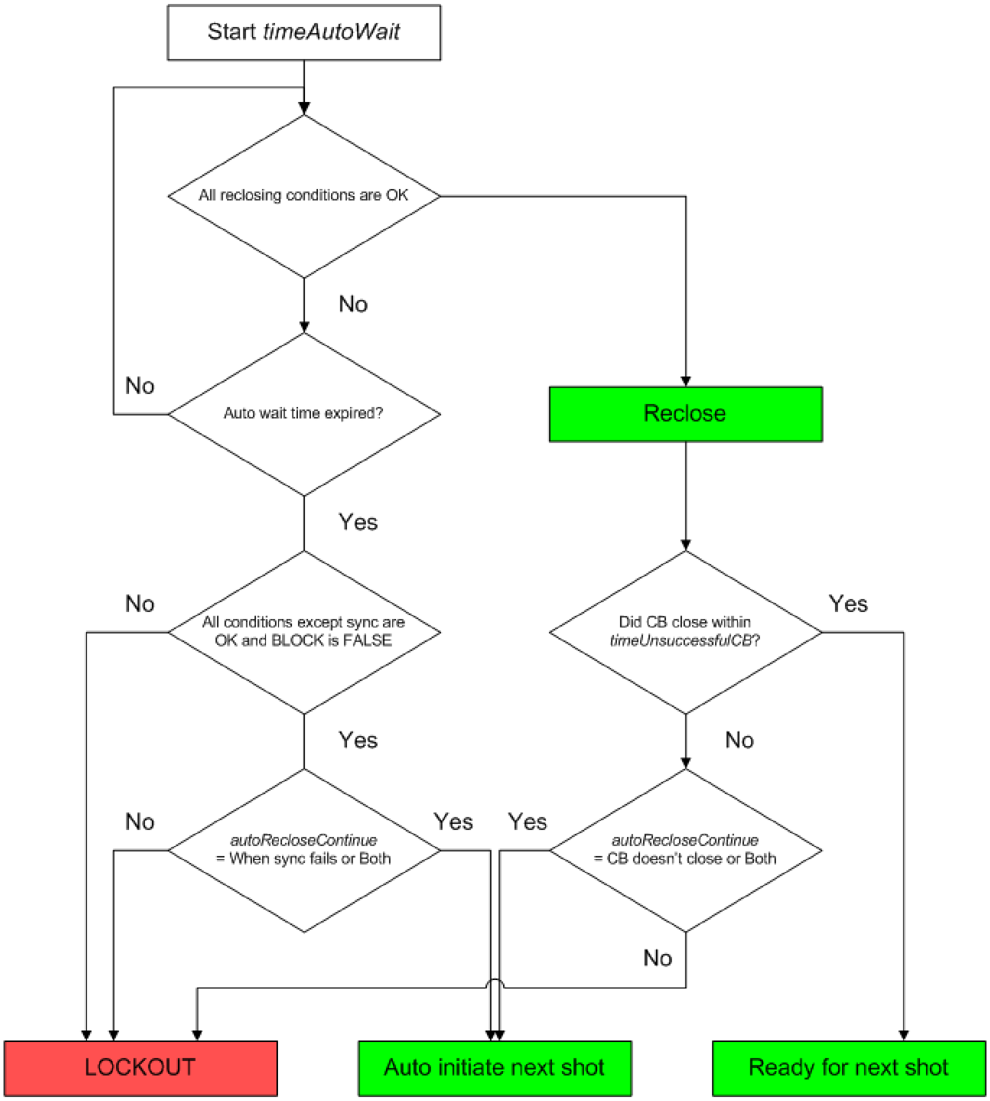


Figure 243: Logic diagram of auto-initiation sequence detection

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.

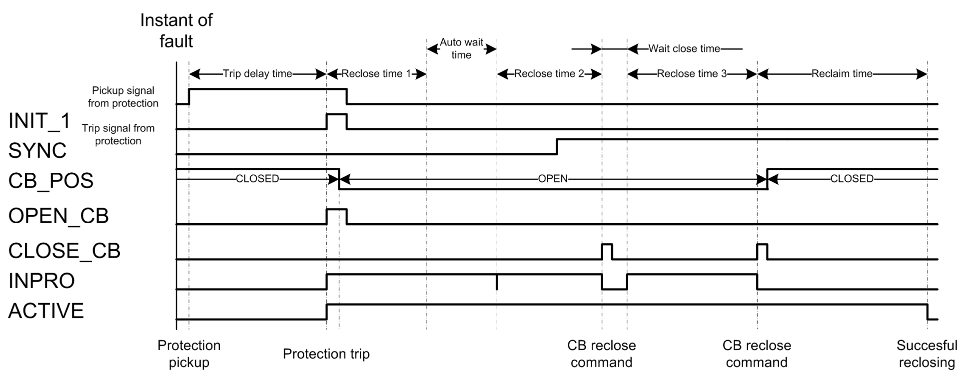


Figure 244: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

9.2.4.3 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.

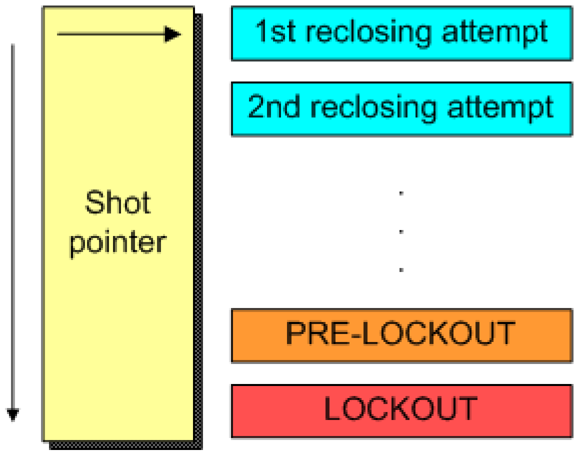


Figure 245: Shot pointer function

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.

9.2.4.4 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.

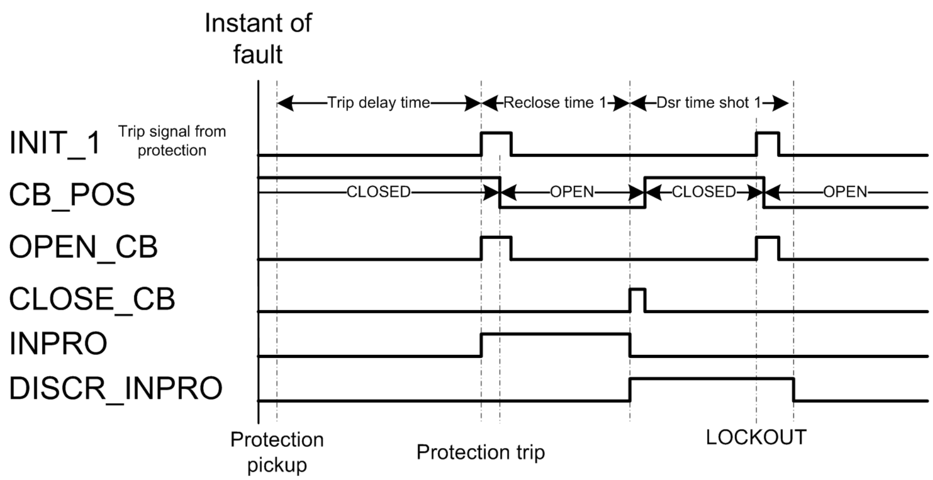


Figure 246: Initiation during discrimination time - AR function goes to lockout

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.

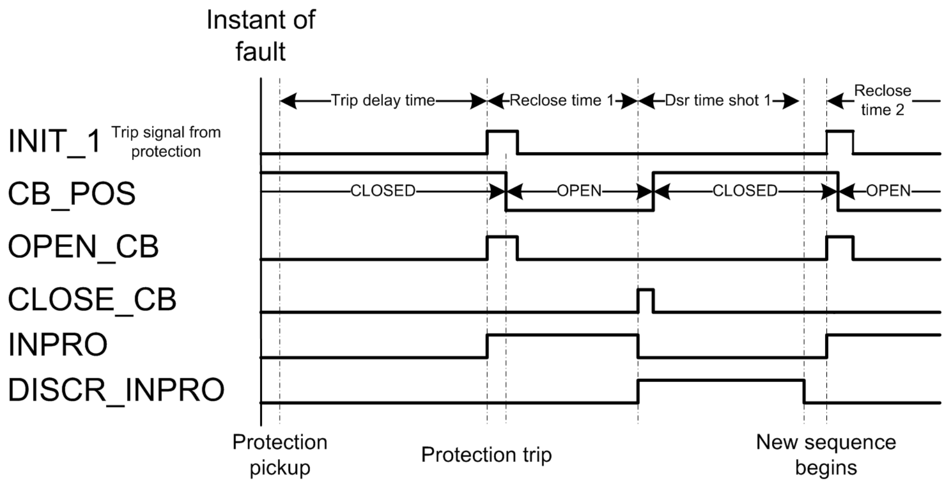


Figure 247: Initiation after elapsed discrimination time - new shot begins

9.2.4.5 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 autoreclosing sequence and the manual close mode is FALSE.

9.2.4.6 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

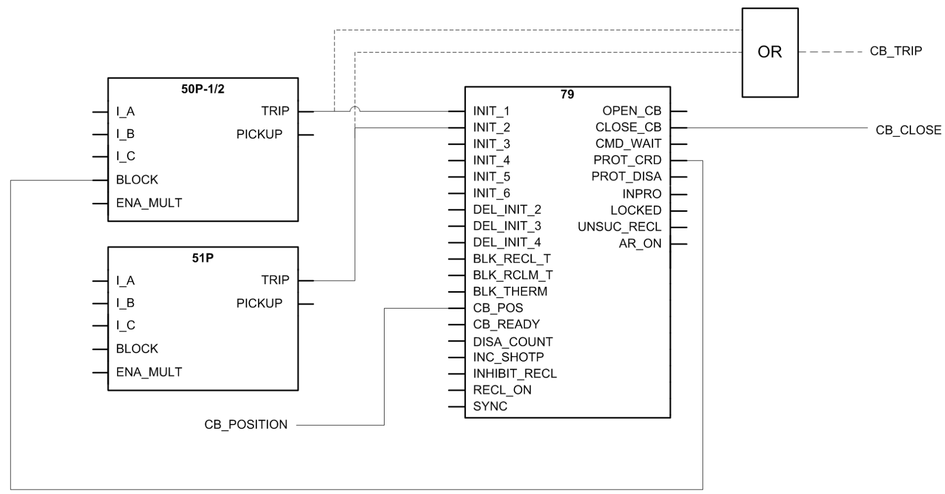


Figure 248: Configuration example of using the `PROT_CRD` output for protection blocking

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.

9.2.4.7 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 autoreclosing 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. 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 autoreclosing 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 autoreclosing 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 autoreclosing 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 autoreclosing function in cases where the fault causes repetitive autoreclosing sequences during a short period of time. For instance, if a tree causes a short circuit and, as a result, there are autoreclosing 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.

9.2.5 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 reclosing command. The counters count the following situations.

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

9.2.6 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 368: 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 auto-reclosing follows, the circuit breaker remains open. This is called final trip or definite trip.

9.2.6.1 Shot initiation

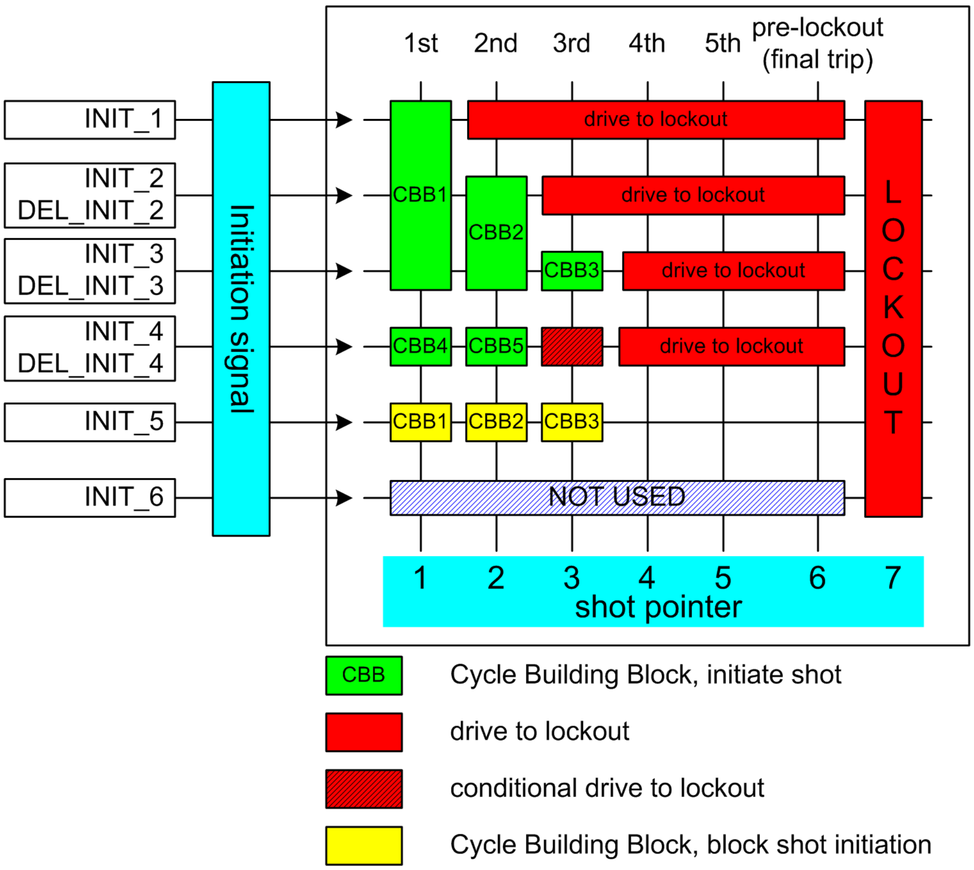


Figure 249: Example of an autoreclosing program with a reclose scheme matrix

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.

When the reclose time of a CBB is set to zero, once its init line is active, it immediately 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.

The existing 79 function does not have a complete zone sequence coordination feature. An external ACT logic needs to be built to drive INC_POINT.

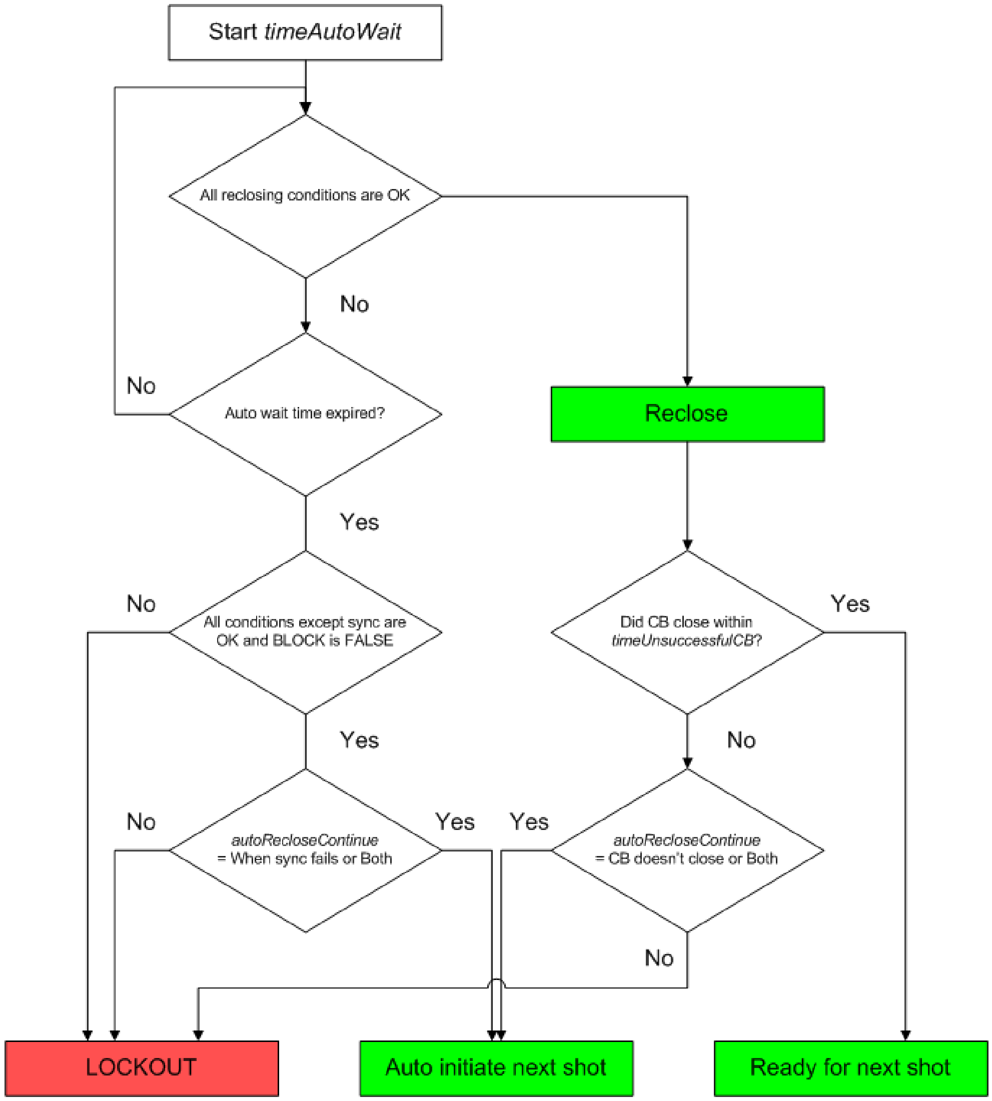


Figure 250: Logic diagram of auto-initiation sequence detection

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.

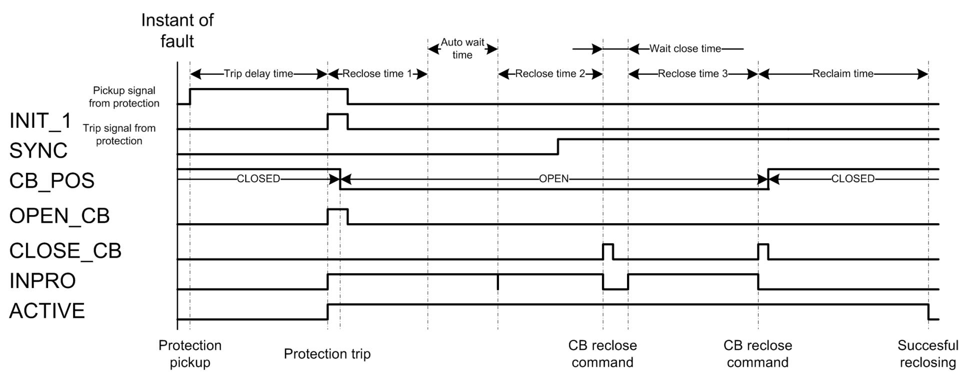


Figure 251: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

9.2.6.2 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.

9.2.6.3 Configuration examples

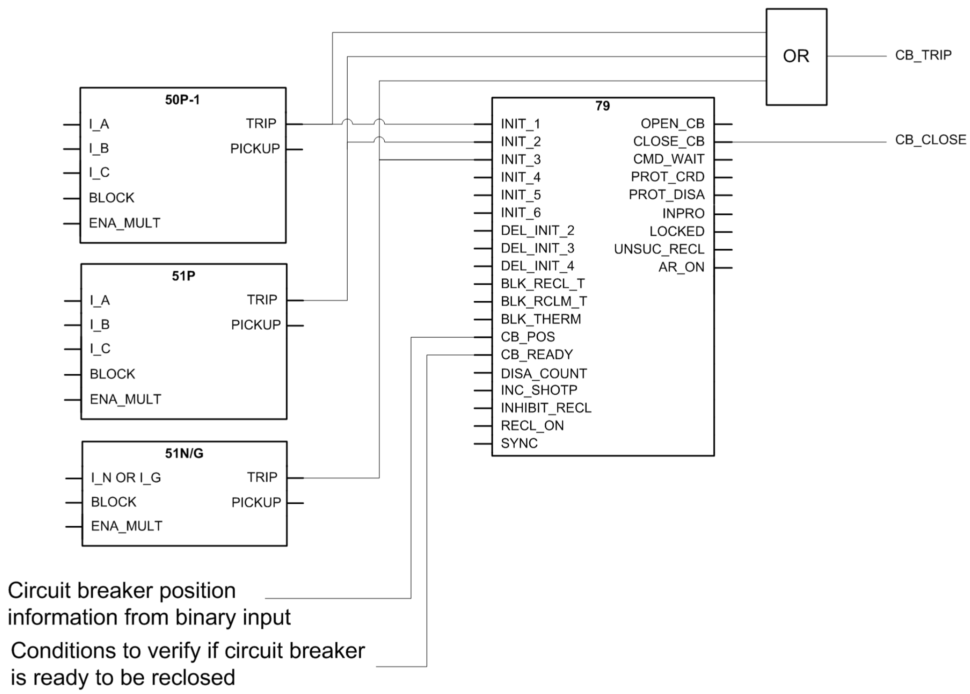


Figure 252: Example connection between protection and autoreclosing functions in protection relay configuration

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.

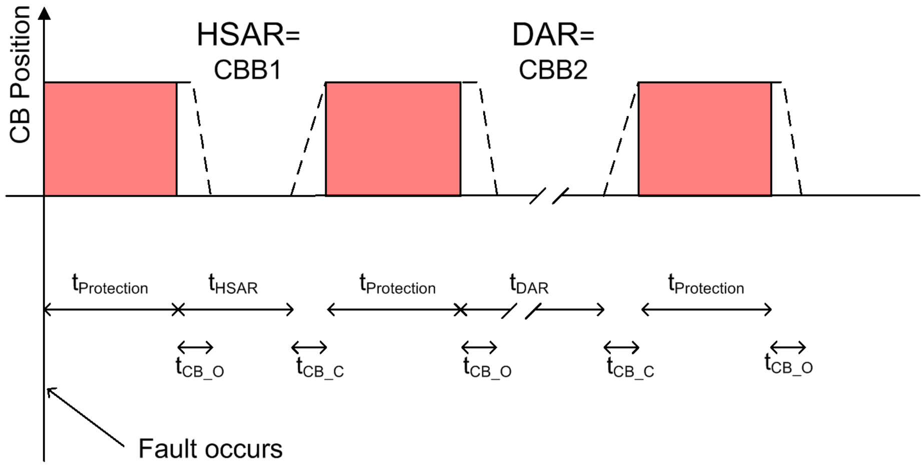


Figure 253: Autoreclosing sequence with two shots

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 described in Table 369 as follows:

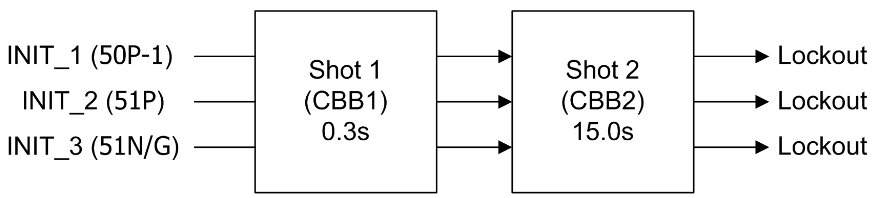


Figure 254: Two shots with three initiation lines

Table 369: 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.

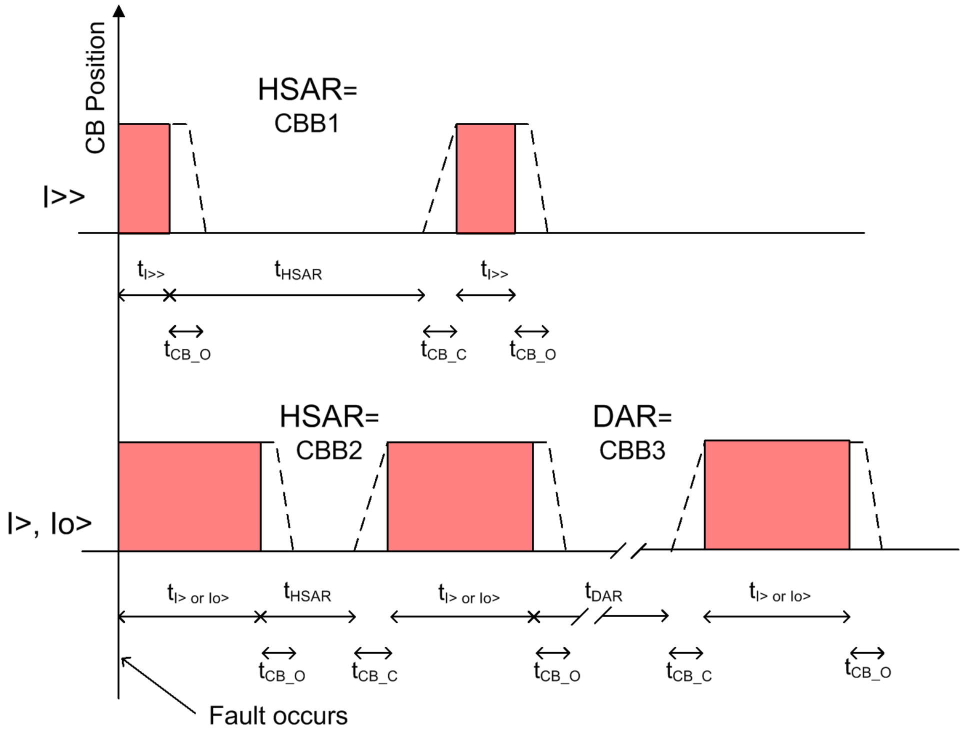


Figure 255: Autoreclosing sequence with two shots with different shot settings according to initiation signal

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.

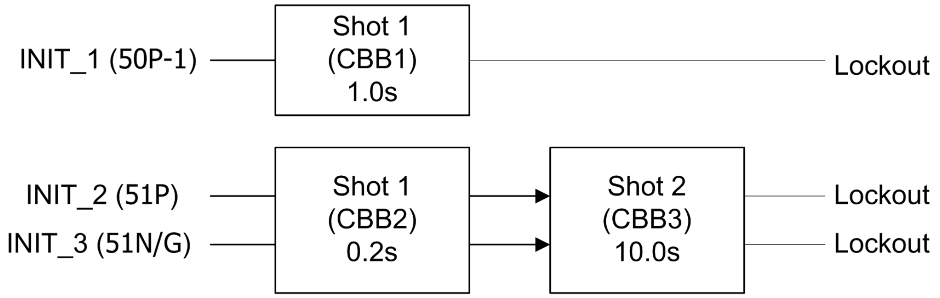


Figure 256: Three shots with three initiation lines

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

Table 370: 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

9.2.6.4 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.

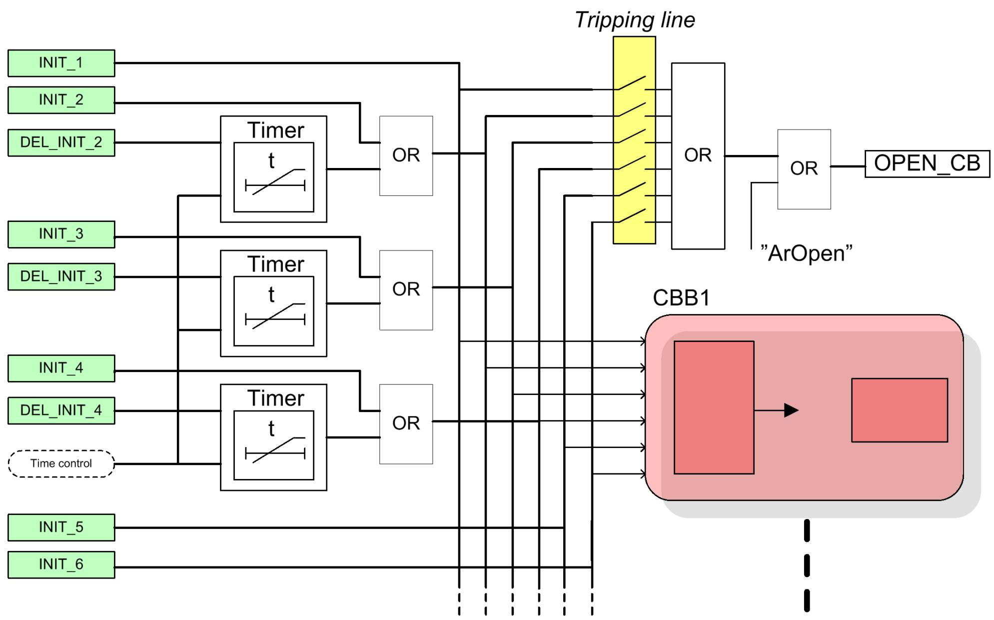


Figure 257: Simplified logic diagram of initiation lines

Each delayed initiation line has four different time settings:

Table 371: 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.

9.2.6.5 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.

9.2.6.6 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.

9.2.7 Signals

Table 372: 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 373: 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 OUT	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

9.2.8 Settings

Table 374: 79 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable/Enable
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
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
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			0=False	Circuit breaker closed position status
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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
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
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

9.2.9 Monitored data

Table 375: 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

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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

9.2.10 Technical data

Table 376: 79 Technical data

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

9.3 Synchronism and energizing check 25

9.3.1 Identification

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

9.3.2 Function block

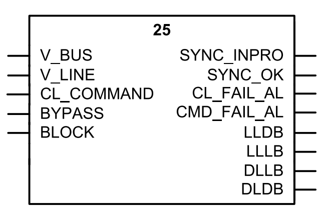


Figure 258: Function block

9.3.3 Functionality

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

9.3.4 Operation principle

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

25 has two parallel functionalities, the synchro check and energizing check functionality. The operation of 25 can be described using a module diagram. All the modules in the diagram are explained in the next sections.

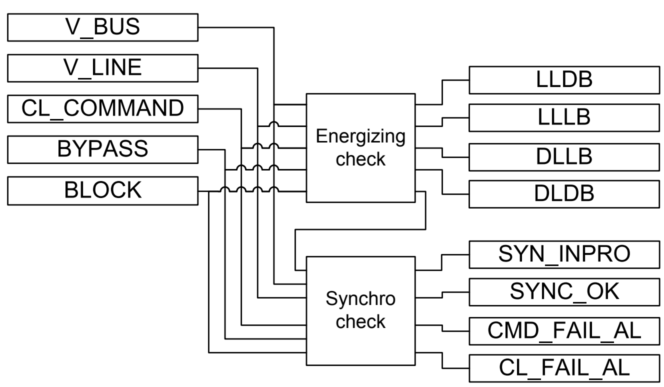


Figure 259: Functional module diagram

The Synchro check function can operate either with the 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 377: 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 ensure 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 operation time, the timer is reset and the procedure is restarted when the conditions allow. 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 a 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 setting parameters.

Synchro check

The Synchro check 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 conditions are simultaneously fulfilled.

- The measured line and bus voltages are higher than the 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 f_n.
- The measured voltages for the line and bus are less than the set value of *Max energizing V*.

In case *Syncro check mode* is set to "Syncronous", 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 f_n.
- The voltage difference must not exceed the 1 percent of the value of V_n.

In case *Syncro check mode* is set to “Asyncronous”, 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*.

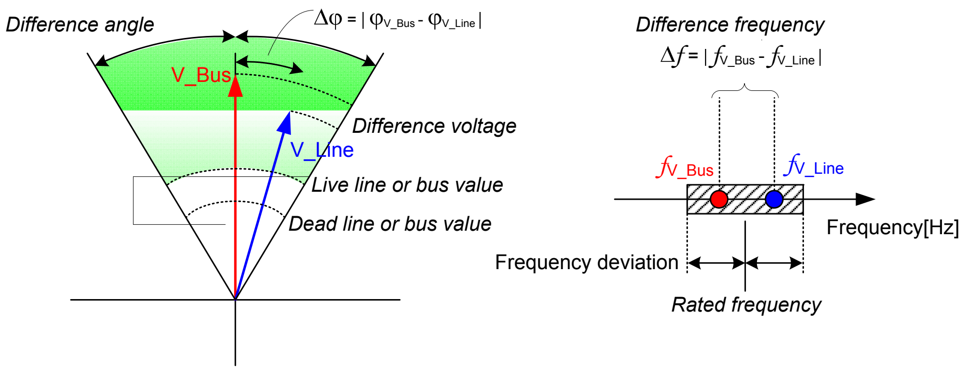


Figure 260: Conditions to be fulfilled when detecting synchronism between systems

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 Synchro check function compensates for the measured slip frequency and the circuit breaker closing delay. The phase angle advance is calculated continuously with the formula.

$$Closing\ angle = \left|(\angle V_{Bus} - \angle V_{Line})° + ((f_{Bus} - f_{line}) \times (T_{CB} + T_{PL}) \times 360°)\right|$$

(Equation 30)

$\angle V_{Bus}$	Measured bus voltage phase angle
$\angle V_{Line}$	Measured line voltage phase angle
f_{Bus}	Measured bus frequency
f_{line}	Measured line frequency
T_{CB}	Total circuit breaker closing delay, including the delay of the protection 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 Synchro check enabled with the *Synchro check mode* setting and the measured ENERG_STATE is "Both Live".

Continuous mode

The continuous mode is activated by setting the parameter *Control mode* to "Continuous". In the continuous control mode, Synchro check is continuously checking the synchronism. When synchronism is detected (according to the settings), the `SYNC_OK` output is set to TRUE (logic '1') and it stays TRUE as long as the conditions are fulfilled. The command input is ignored in the continuous control mode. The mode is used for situations where Synchro check only gives the permission to the control block that executes the CB closing.

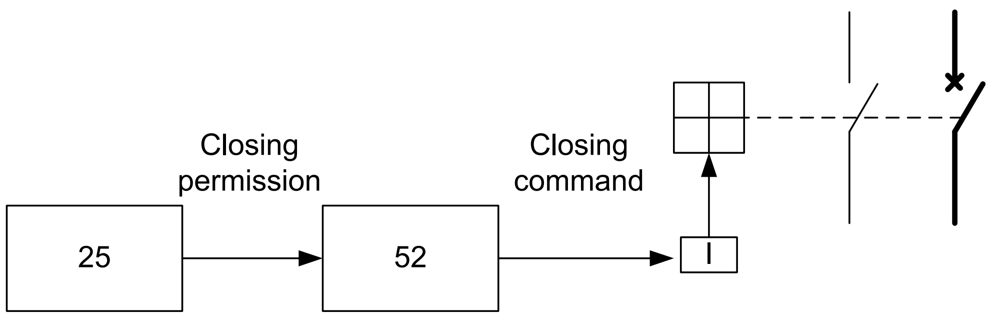


Figure 261: A simplified block diagram of the Synchro check function in the continuous mode operation

Command mode

If *Control mode* is set to "Command", the purpose of the Synchro check 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 such that they can be regarded as live.

In the command 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 Synchro check 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 Synchro check 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*, the Synchro check function delivers a closing signal to the circuit breaker after the command signal is delivered for closing.

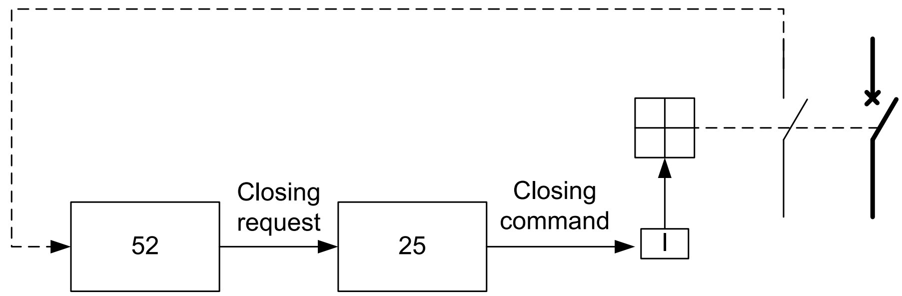


Figure 262: A simplified block diagram of 25 in the command mode operation

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.

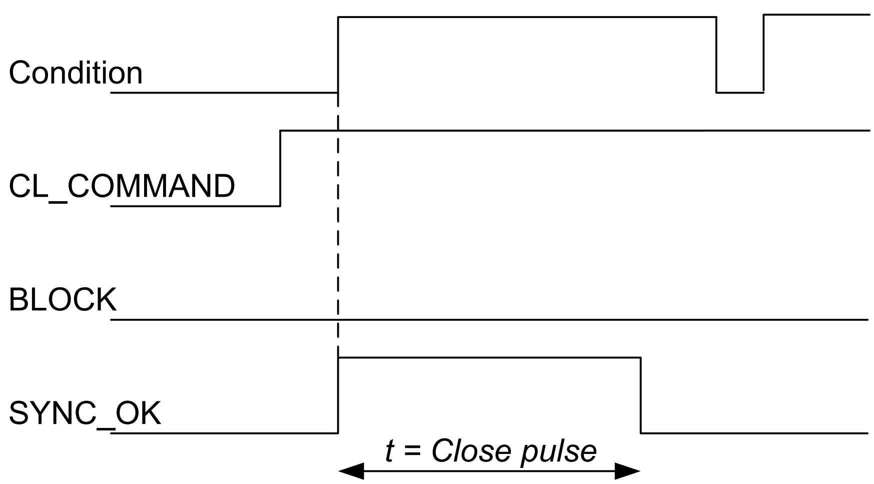


Figure 263: Determination of the pulse length of the closing signal

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 the 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 the closing pulse is given, the alarm timer is reset.

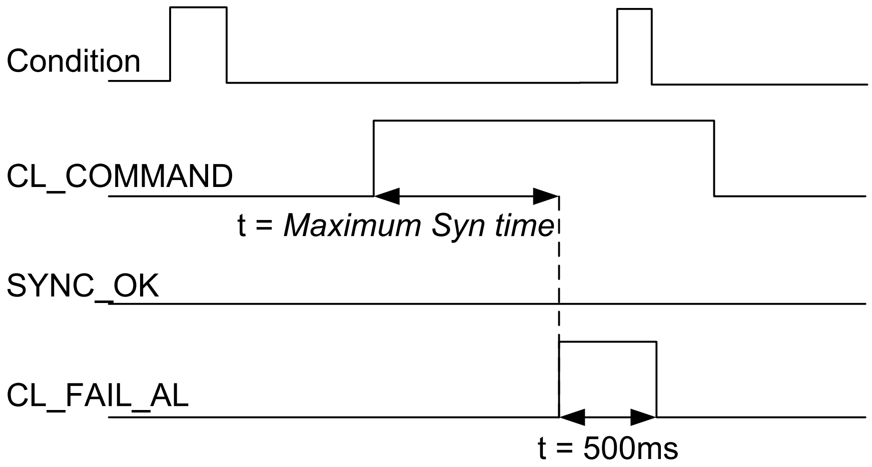


Figure 264: Determination of the checking time for closing

The control module receives information about the circuit breaker status and thus is able to adjust the command signal to be delivered to the Synchro check function. If the external command signal CL_COMMAND is kept active longer than necessary, the `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.

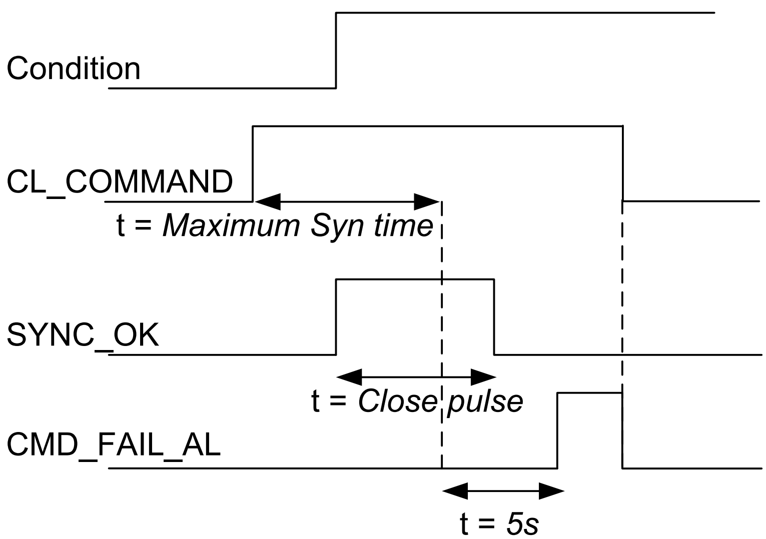


Figure 265: Determination of the alarm limit for a still-active command signal

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 a new closing-command sequence cannot be started until the external command signal is reset and reactivated. 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 to the bypass mode by setting the parameters *Synchro check mode* and *Energizing check mode* to "Off" or alternatively by activating the BYPASS input.

In the bypass mode, the closing conditions are always considered to be fulfilled by 25. 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.

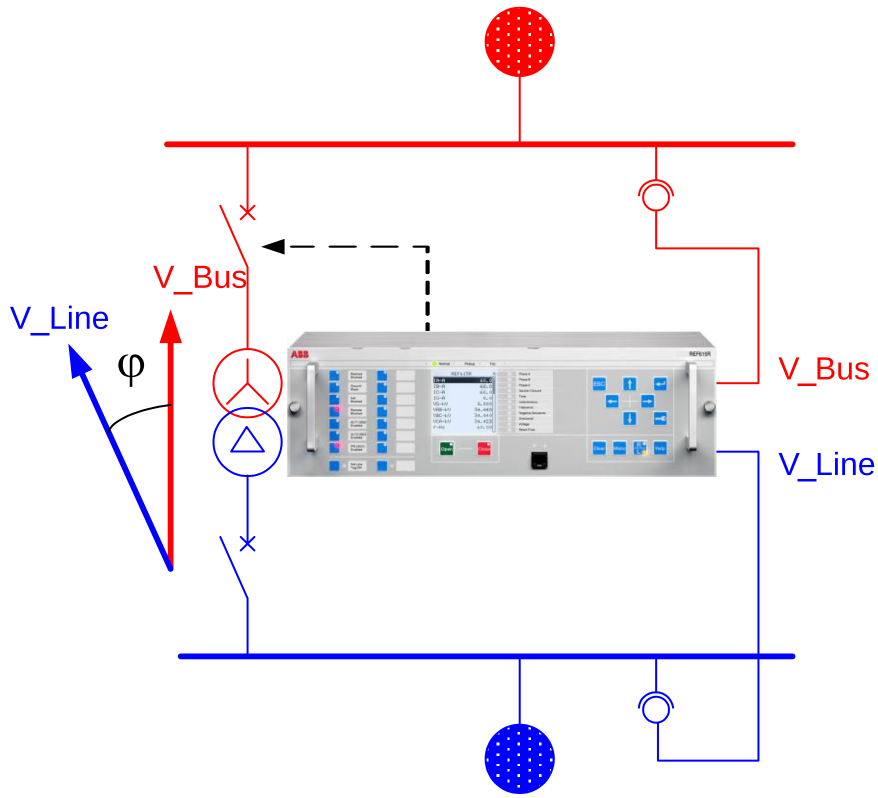


Figure 266:   Status indication-based interlocking via the GOOSE messaging

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 25 with the *Phase shift* setting.

9.3.5 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 Synchro check 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 protection relay 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 79 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 protection relay 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.

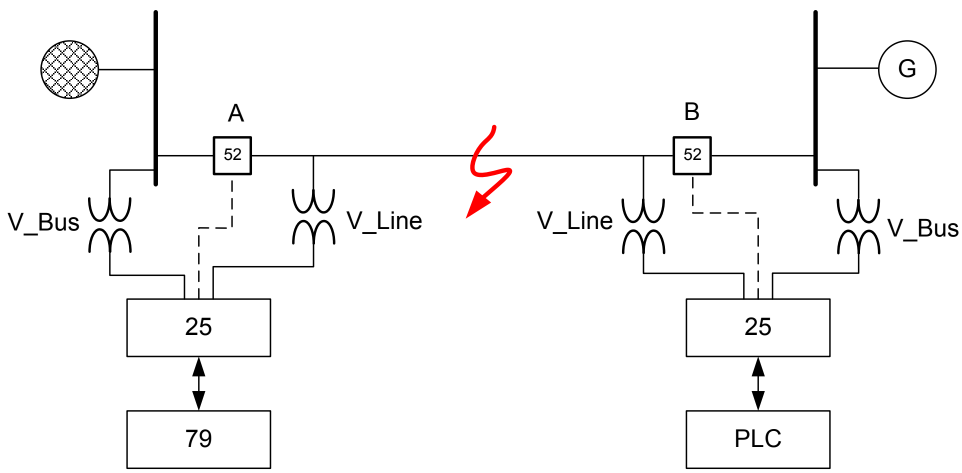


Figure 267: Synchrocheck function 79 checking energizing conditions and synchronism

Connections

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

A faulty wiring of the voltage inputs of the protection relay 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 protection relay 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 protection relay 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 protection relay 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 268 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.

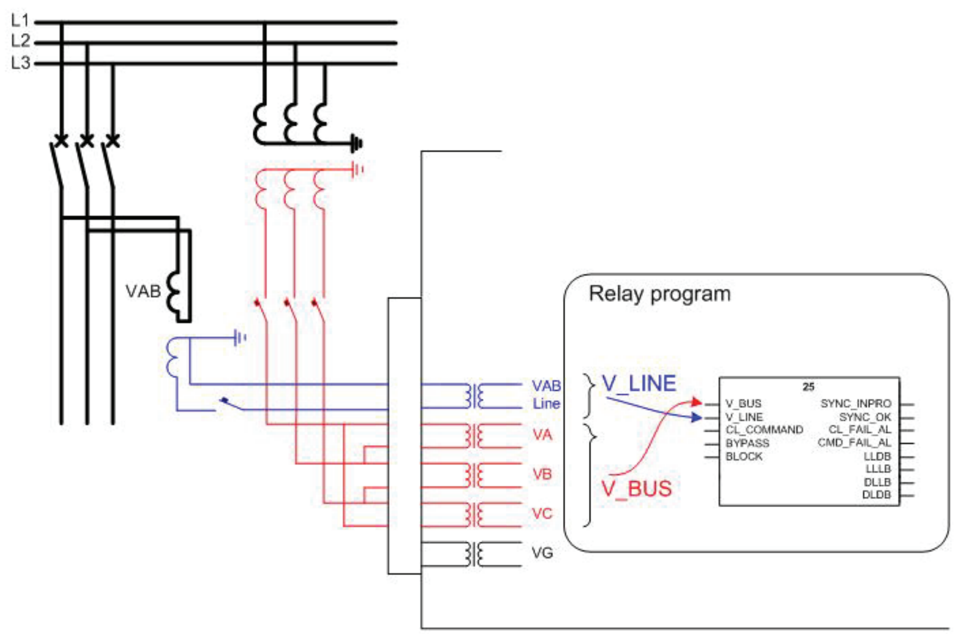


Figure 268: Connection of voltages for the protection relay and signals used in synchrocheck

9.3.6 Signals

Table 378: 25 Input signals

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

Table 379: 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

9.3.7 Settings

Table 380: 25 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Live dead mode	-1=Off 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			1=Both Dead	Energizing check mode
Difference voltage	0.01...0.50	xUn	0.01	0.05	Maximum voltage difference limit
Difference frequency	0.001...0.100	xFn	0.001	0.001	Maximum frequency difference limit
Difference angle	5...90	deg	1	5	Maximum angle difference limit

Table 381: 25 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Synchro check mode	1=Off 2=Synchronous 3=Asynchronous			2=Synchronous	Synchro check operation mode
Control mode	1=Continuous 2=Command			1=Continuous	Selection of synchro check command or Continuous control mode
Dead line value	0.1...0.8	xUn	0.1	0.2	Voltage low limit line for energizing check
Live line value	0.2...1.0	xUn	0.1	0.5	Voltage high limit line for energizing check
Dead bus value	0.1...0.8	xUn	0.1	0.2	Voltage low limit bus for energizing check
Live bus value	0.2...1.0	xUn	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	xUn	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

9.3.8 Monitored data

Table 382: 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	xUn	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

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

9.3.9 Technical data

Table 383: 25 Technical data

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

9.4 Generic up-down counters CTR

9.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Generic up-down counters	UDFCNT	CTR	CTR

9.4.2 Function block

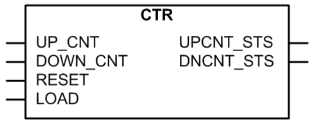


Figure 269: Function block

9.4.3 Functionality

The multipurpose generic up-down counter function CTR counts up or down for each positive edge of the corresponding inputs. The counter value output can be reset to zero or preset to some other value if required.

The function provides up-count and down-count status outputs, which specify the relation of the counter value to a loaded preset value and to zero respectively.

9.4.4 Operation principle

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

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

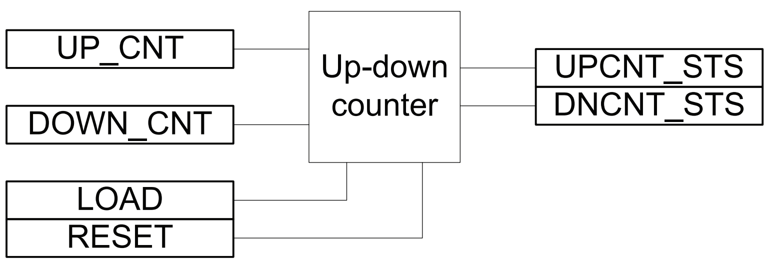


Figure 270: Functional module diagram

Up-down counter

Each rising edge of the `UP_CNT` input increments the counter value `CNT_VAL` by one and each rising edge of the `DOWN_CNT` input decrements the `CNT_VAL` by one. If there is a rising edge at both the inputs `UP_CNT` and `DOWN_CNT`, the counter value `CNT_VAL` is unchanged. The `CNT_VAL` is available in the monitored data view.

The counter value CNT_VAL is stored in a nonvolatile memory. The range of the counter is 0...+2147483647. The count of CNT_VAL saturates at the final value of 2147483647, that is, no further increment is possible.

The value of the setting *Counter load value* is loaded into counter value CNT_VAL either when the LOAD input is set to "True" or when the *Load Counter* is set to "Load" in the LHMI. Until the LOAD input is "True", it prevents all further counting.

The function also provides status outputs UPCNT_STS and DNCNT_STS. The UPCNT_STS is set to "True" when the CNT_VAL is greater than or equal to the setting *Counter load value*. DNCNT_STS is set to "True" when the CNT_VAL is zero.

The RESET input is used for resetting the function. When this input is set to "True" or when *Reset counter* is set to "reset", the CNT_VAL is forced to zero.

9.4.5 Signals

Table 384: CTR Input signals

Name	Type	Default	Description
UP_CNT	BOOLEAN	0=False	Input for up counting
DOWN_CNT	BOOLEAN	0=False	Input for down counting
RESET	BOOLEAN	0=False	Reset input for counter
LOAD	BOOLEAN	0=False	Load input for counter

Table 385: CTR Output signals

Name	Type	Description
UPCNT_STS	BOOLEAN	Status of the up counting
DNCNT_STS	BOOLEAN	Status of the down counting

9.4.6 Settings

Table 386: CTR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Counter load value	0...2147483647		1	10000	Preset counter value
Reset counter	0=Cancel 1=Reset			0=Cancel	Resets counter value
Load counter	0=Cancel 1=Load			0=Cancel	Loads the counter to preset value

9.4.7 Monitored data

Table 387: CTR Monitored data

Name	Type	Values (Range)	Unit	Description
CNT_VAL	INT128	0...2147483647		Output counter value

Section 10 Recording functions

10.1 Disturbance recorder DFR

10.1.1 Functionality

The relay is provided with a disturbance 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 voltages 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 either on the rising or the falling edge of the binary signal or on both.

By default, the binary channels are set to record external or internal relay signals, for example, the pickup or trip signals of the relay stages, or external blocking or control signals. Binary relay signals, such as a protection pickup or trip signal, or an external relay control signal via a binary input, can be set to trigger the recording. Recorded information is stored in a nonvolatile memory and can be uploaded for subsequent fault analysis.

10.1.1.1 Recorded analog inputs

The user can map any analog signal type of the protection relay to each analog channel of the disturbance 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 disturbance recorder by setting the *Operation* parameter of the corresponding analog channel to “Enable” or “Disable”.

All analog channels of the disturbance recorder that are enabled and have a valid signal type mapped are included in the recording.

10.1.1.2 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 disturbance 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 disturbance 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 the Recording started and Recording made events. The Recording made event indicates that the recording has been stored to the non-volatile memory. In addition, every analog channel and binary channel of the disturbance recorder has its own *Channel triggered* parameter. Manual trigger has the *Manual triggering* parameter and periodic trigger has the *Periodic triggering* parameter.

Triggering by binary channels

Input signals for the binary channels of the disturbance 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 disturbance 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 disturbance recorder. The value used for triggering is the calculated peak-to-peak value. Either high or low analog channel trigger can be disabled by setting the corresponding trigger level parameter to zero.

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.

10.1.1.3 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 disturbance 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 disturbance 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.

10.1.1.4 Sampling frequencies

The sampling frequency of the disturbance 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 disturbance 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 388: 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

10.1.1.5 Uploading of recordings

The protection relay stores COMTRADE files to the `C:\COMTRADE\` folder. The files can be uploaded with the PCM600 or any appropriate computer software that can access the `C:\COMTRADE\` folder.

One complete disturbance recording 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.

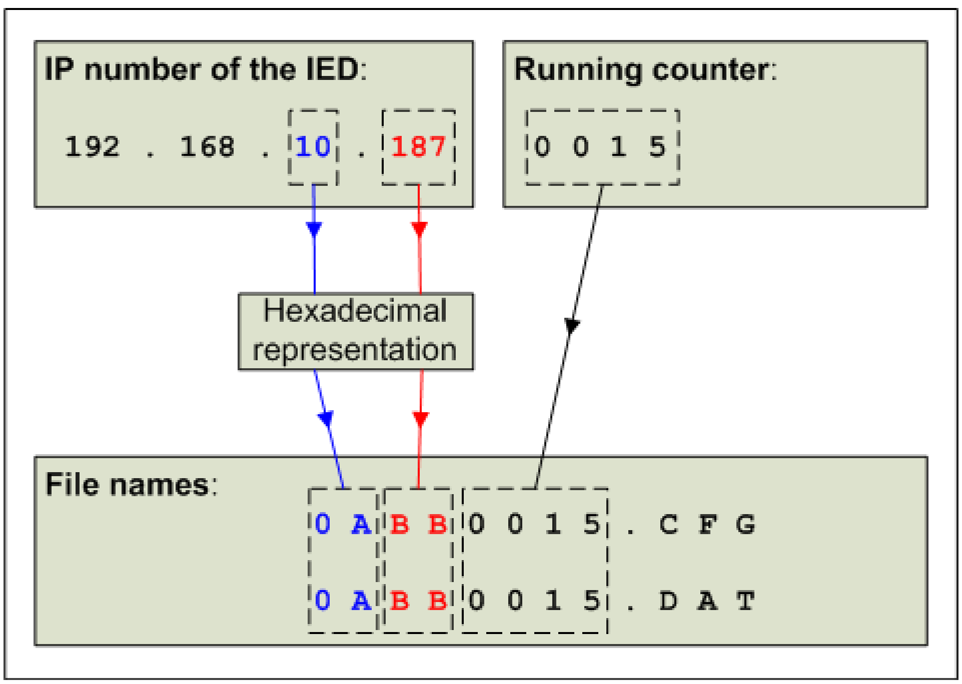


Figure 271: Disturbance recorder file naming

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 protection relay'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.

10.1.1.6 Deletion of recordings

There are several ways to delete disturbance recordings. The recordings can be deleted individually or all at once.

Individual disturbance recordings can be deleted with PCM600 or any appropriate computer software, which can access the protection relay's `C:\COMTRADE` folder. The disturbance recording is not removed from the protection relay's 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 disturbance recordings at once is done either with PCM600 or any appropriate computer software, or from the LHMI via the **Clear/Digital fault recorder** menu. Deleting all disturbance recordings at once also clears the pre-trigger recording in progress.

10.1.1.7 Storage mode

The disturbance 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 disturbance 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*.

10.1.1.8 Pre-trigger and post-trigger data

The waveforms of the disturbance recorder analog channels and the states of the disturbance 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.

10.1.1.9 Operation modes

Disturbance recorder has two operation modes: saturation and overwrite mode. The user can change the operation mode of the disturbance 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.

10.1.1.10 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 disturbance recorder, counting the remaining exclusion time. The user can monitor the remaining exclusion time with the *Exclusion time rem* parameter (only visible via communication, IEC 61850 data ExclTmRmn) of the corresponding analog or binary channel. The *Exclusion time rem* parameter counts downwards.

10.1.2 Configuration

The disturbance recorder can be configured with PCM600 or any tool supporting the IEC 61850 standard.

The disturbance recorder can be enabled or disabled 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. It can be modified 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 protection relay which can be dynamically mapped can be connected to the binary channels of the disturbance recorder. These signals can be, for example, the pickup and trip signals from protection function blocks or the external digital inputs of the protection relay. The connection is made with dynamic mapping to the binary channel of the disturbance recorder using, for example, SMT of PCM600. It is also possible to connect several digital signals to one binary channel of the disturbance recorder. In that case, the signals can be combined with logical functions, for example AND and OR. The name of the binary channel can be configured and modified 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 disturbance 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 disturbance recorder, the *Operation* parameter of the corresponding binary channel is set to “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 `TRIGGERED` output can be used to control the indication LEDs of the protection relay. The `TRIGGERED` output is TRUE due to the triggering of the disturbance recorder, until all the data for the corresponding recording has been recorded.

The IP number of the protection relay and the content of the *Bay name* parameter are both included in the COMTRADE configuration file for identification purposes.

10.1.3 Application

The disturbance recorder is used for post-fault analysis and for verifying the correct operation of protection relays 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 protection relay 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 disturbance recorder. The task execution interval for the disturbance 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 disturbance recorder follows the 1999 version of the COMTRADE standard and uses the binary data file format.

10.1.4 Settings

Table 389: 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 390: 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 Channel 1 5=Disable for channels 2 - 8	Analog channel is enabled or disabled
Channel selection	0=Disabled 1=IG-A 2=IA-A 3=IB-A 4=IC-A 9=VG 10=VA 11=VB 12=VC 14=VSync 17=3I0 18=I1-A1) 19=I2-A1) 20=V0 21=V11) 22=V21) 29=VAB 30=VBC 31=VCA		0	2)	Select the signal to be recorded by this channel. Applicable values for this parameter are product variant dependent. Every product variant includes only the values that are applicable to that particular variant
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) Recordable values are available only in trend mode. In waveform mode, samples for this signal type are constant zeroes. However, these signal types can be used to trigger the recorder on limit violations of the corresponding analog channel.
2) Refer to the application manual for channel allocation for each configuration.

Table 391: 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 392: 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

10.1.5 Monitored data

Table 393: DFR Monitored data

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

10.2 Fault locator FLO

10.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fault location	DRFLO	FLO	FLO

10.2.2 Function block

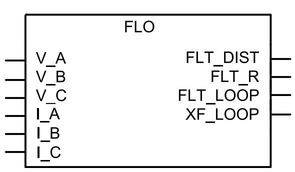


Figure 272: Function block

10.2.3 Functionality

The fault location function FLO 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.

10.2.4 Operation principle

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

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

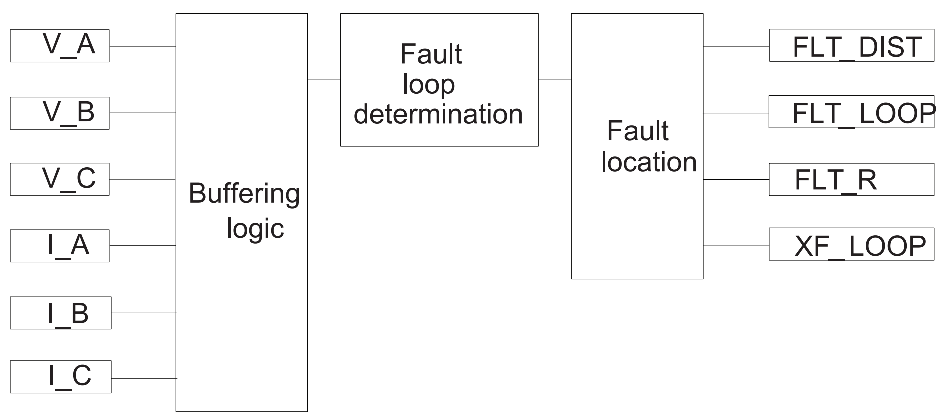


Figure 273: Functional module diagram

Buffering logic

The Buffering logic 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 freezes and the updating of fault buffer is started. The fault buffer freezes once the buffer is updated fully. The fault location algorithm is started only if the 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 to the zero-sequence current.

Fault loop 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, the specific fault loop is determined by comparing all the phase currents to the setting *Phase Level*. Fault loop determination is done in accordance with Table 394.

Table 394: 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, 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 protection relay is ground-compensated by employing the following formula

$$I^*_{rly} = I_{rly} + k * I_0 * (ZL_{Zero} - ZL_{Pos}) / ZL_{Pos}$$

(Equation 31)

where

$$I_0 = (I\_A + I\_B + I\_C) / 3$$

(Equation 32)

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 Km (kilometers) or miles and is provided as a setting.

If *R1*, *X1*, *R0*, *X0* are given in ohm/mile, 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, the length of the line*Line Length* should be given in the unit of Km.

Table 395 describes what are the voltage phasor and current phasor under different fault types.

Table 395: protection relay voltage and current phasor identification

FLTLOOP	Current phasor	Voltage phasor
AG Fault	I_A 1)	V_A
BG Faul	I_B 1)	V_B
CG Fault	I_C 1)	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

1) indicates the respective current is ground-compensated

Fault location

Fault location calculates the distance to fault and fault resistance from the voltage phasor and current phasor selected based on the type of the fault Table 395.

The algorithm uses the fundamental frequency phasor voltages and currents measured at the protection relay terminal before and during the fault.

The algorithm basically is an iterative technique that 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 modified using the correction factors. The corrected values are used to estimate the final `FLT_DIST` and `FLT_R`.

During the autoreclosure sequences, the fault location is done with initial fault conditions.

10.2.5 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 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.

The fault location algorithm is most applicable for radial feeder. The algorithm is based on the system model shown in Figure 274. 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 is not as accurate. Fault location algorithm may not be accurate for the switch-onto-fault condition.

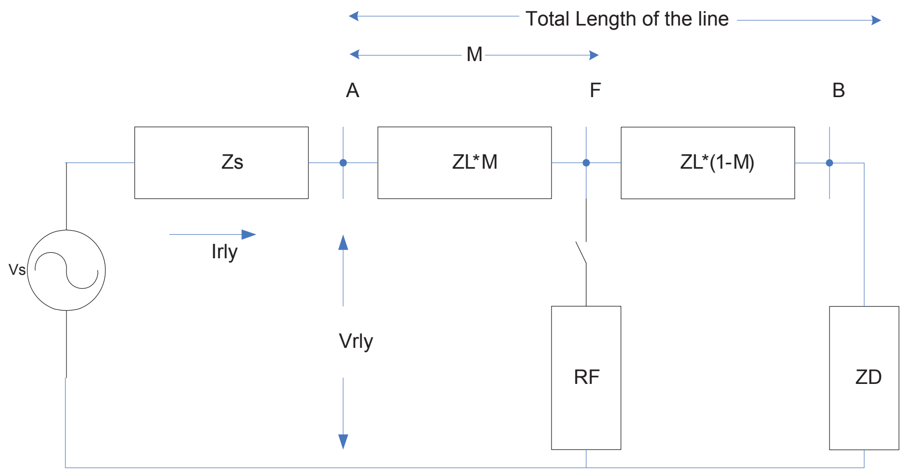


Figure 274: System model considered for fault location

where:

V_s	Source voltage
V_{rly}	Voltage at the protection relay location
I_{rly}	Current in the transmission line at the protection relay location
Z_s	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

10.2.6 Settings

Table 396: FLO Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Phase level	0.05...5.00	xIn	0.01	0.10	Phase Level

Table 397: FLO Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=enable 5=disable			1=enable	Operation Disable / Enable
Line length	0.0...300.0		0.1	100.0	Length of the Line in miles or Km
R1	0.000...20.000	ohm	0.001	1.000	Pos Seq Resistance in ohms/(miles or Km)
X1	0.000...30.000	ohm	0.001	2.000	Pos seq reactance in ohms/(miles or Km)
R0	0.000...20.000	ohm	0.001	0.010	Pos Seq Resistance in ohms/(miles or Km)
X0	0.000...30.000	ohm	0.001	1.000	Zero Seq Reactance in ohms/(miles or Km)

10.2.7 Monitored data

Table 398: FLO Monitored data

Name	Type	Values (Range)	Unit	Description
FLT_DIST	FLOAT32	0.00...9999.00		Fault Distance
FLT_LOOP	Enum	1=AG Fault 2=BG Fault 3=CG Fault 4=AB Fault 5=BC Fault 6=CA Fault 7=ABC Fault -1=ABG Fault -2=BCG Fault -3=CAG Fault -4=ABCG Fault 0=No fault		Fault Loop
FLT_R	FLOAT32	0.00...999.00	ohm	FaultResistance
XF_LOOP	FLOAT32	0.00...9999.00	ohm	Loop Reactance
TIME_FLT_LOC	Timestamp			Time stamp
FLO	Enum	1=Enabled 2=blocked 3=test 4=test/blocked 5=Disabled		Status

Section 11 Other functions

11.1 Minimum pulse timer

11.1.1 Minimum pulse timer TP

11.1.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum pulse timer (2 pcs)	TPGAPC	TP	TP

11.1.1.2 Function block

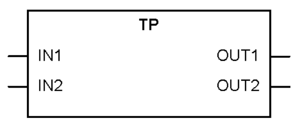


Figure 275: Function block

11.1.1.3 Functionality

The Minimum pulse timer function TP contains two independent timers running in milliseconds. The function has a settable pulse length (in milliseconds). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated the function gives out a pulse (*Pulse time* setting). But if the input remains active longer than the set *Pulse time*, also the output remains active until the input is deactivated.

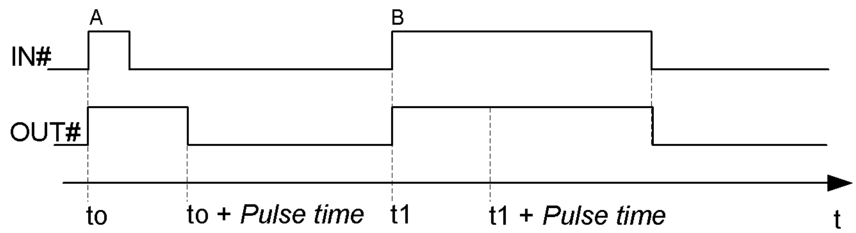


Figure 276: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

11.1.1.4 Signals

Table 399: TP Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status

Table 400: TP Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

11.1.1.5 Settings

Table 401: TP Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...60000	ms	1	150	Minimum pulse time

11.1.2 Minimum second pulse timer 62CLD-1

11.1.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum second pulse timer (2 pcs)	TPSGAPC	TPS	62CLD-1

11.1.2.2 Function block

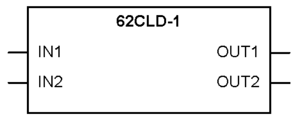


Figure 277: Function block

11.1.2.3 Functionality

The minimum second pulse timer function 62CLD-1 contains two independent timers. The function has a settable pulse length (in seconds). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated the function gives out a pulse (*Cold load time* setting). But if the input remains active longer than the set *Cold load time*, also the output remains active until the input is deactivated.

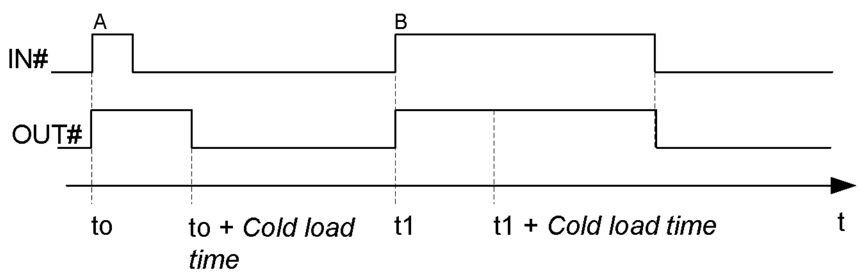


Figure 278: A = Trip pulse is shorter than Cold load time setting, B = Trip pulse is longer than Cold load time setting

11.1.2.4 Signals

Table 402: 62CLD-1 Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status

Table 403: 62CLD-1 Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

11.1.2.5 Settings

Table 404: 62CLD-1 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Cold load time	0...300	s	1	0	Cold load time

11.1.3 Minimum minute pulse timer 62CLD-2

11.1.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum minute pulse timer (2 pcs)	TPMGAPC	TPM	62CLD-2

11.1.3.2 Function block

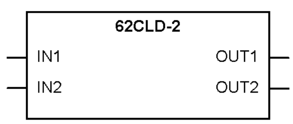


Figure 279: Function block

11.1.3.3 Functionality

The minimum minute pulse timer function 62CLD-2 contains two independent timers. The function has a settable pulse length (in minutes). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated the function gives out a pulse (*Cold load time* setting). But if the input remains active longer than the set *Cold load time*, also the output remains active until the input is deactivated.

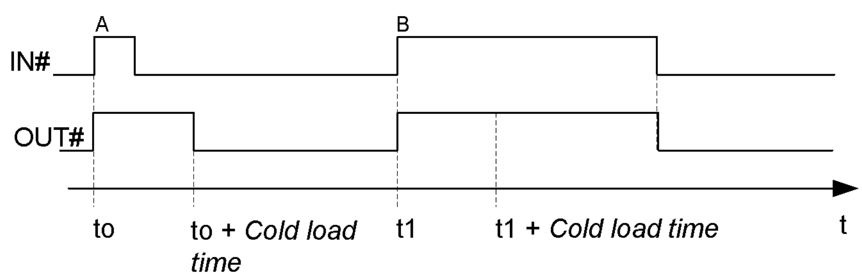


Figure 280: A = Trip pulse is shorter than Cold load time setting, B = Trip pulse is longer than Cold load time setting

11.1.3.4 Signals

Table 405: 62CLD-2 Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status

Table 406: 62CLD-2 Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

11.1.3.5 Settings

Table 407: 62CLD-2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Cold load time	0...300	min	1	0	Cold load time

11.2 Programmable buttons FKEY

11.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Programmable buttons (16 buttons)	FKEYGGIO	FKEY	FKEY

11.2.2 Function block

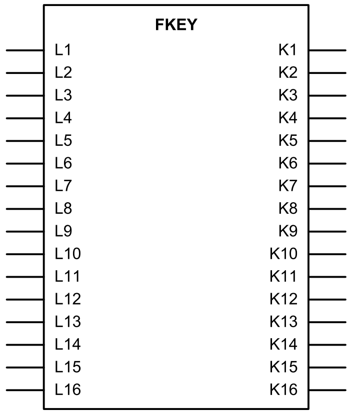


Figure 281: Function block

11.2.3 Functionality

The programmable buttons function FKEY is a simple interface between the panel and the application. The user input from the buttons available on the front panel is transferred to the assigned functionality and the corresponding LED is Enabled or Disabled for indication. The behavior of each function key in the specific application is configured by connection with other application functions. This gives the maximum flexibility.

11.2.4 Operation principle

Inputs `L1`..`L16` represent the LEDs on the protection relay's LHMI. When an input is set to TRUE, the corresponding LED is lit. When a function key on LHMI is pressed, the corresponding output `K1`..`K16` is set to TRUE.

11.2.5 Signals

Table 408: FKEY Input signals

Name	Type	Default	Description
L1	BOOLEAN	0=False	LED 1
L2	BOOLEAN	0=False	LED 2
L3	BOOLEAN	0=False	LED 3
L4	BOOLEAN	0=False	LED 4
L5	BOOLEAN	0=False	LED 5
Table continues on next page			

Name	Type	Default	Description
L6	BOOLEAN	0=False	LED 6
L7	BOOLEAN	0=False	LED 7
L8	BOOLEAN	0=False	LED 8
L9	BOOLEAN	0=False	LED 9
L10	BOOLEAN	0=False	LED 10
L11	BOOLEAN	0=False	LED 11
L12	BOOLEAN	0=False	LED 12
L13	BOOLEAN	0=False	LED 13
L14	BOOLEAN	0=False	LED 14
L15	BOOLEAN	0=False	LED 15
L16	BOOLEAN	0=False	LED 16

Table 409: FKEY Output signals

Name	Type	Description
K1	BOOLEAN	KEY 1
K2	BOOLEAN	KEY 2
K3	BOOLEAN	KEY 3
K4	BOOLEAN	KEY 4
K5	BOOLEAN	KEY 5
K6	BOOLEAN	KEY 6
K7	BOOLEAN	KEY 7
K8	BOOLEAN	KEY 8
K9	BOOLEAN	KEY 9
K10	BOOLEAN	KEY 10
K11	BOOLEAN	KEY 11
K12	BOOLEAN	KEY 12
K13	BOOLEAN	KEY 13
K14	BOOLEAN	KEY 14
K15	BOOLEAN	KEY 15
K16	BOOLEAN	KEY 16

11.3 Move function block MV

11.3.1 Function block

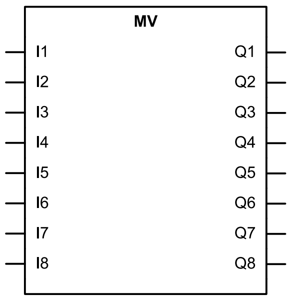


Figure 282: Function block

11.3.2 Functionality

The move (8 pcs) function MV 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.

11.3.3 Signals

Table 410: MV Input signals

Name	Type	Default	Description
I1	BOOLEAN	0=False	I1 status
I2	BOOLEAN	0=False	I2 status
I3	BOOLEAN	0=False	I3 status
I4	BOOLEAN	0=False	I4 status
I5	BOOLEAN	0=False	I5 status
I6	BOOLEAN	0=False	I6 status
I7	BOOLEAN	0=False	I7 status
I8	BOOLEAN	0=False	I8 status

Table 411: MV 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

11.3.4 Settings

Table 412: MV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Description				MVGAPC1 Q1	Output description
Description				MVGAPC1 Q2	Output description
Description				MVGAPC1 Q3	Output description
Description				MVGAPC1 Q4	Output description
Description				MVGAPC1 Q5	Output description
Description				MVGAPC1 Q6	Output description
Description				MVGAPC1 Q7	Output description
Description				MVGAPC1 Q8	Output description

11.4 Pulse timer PT

11.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pulse timer (8 pcs)	PTGAPC	PT	PT

11.4.2 Function block

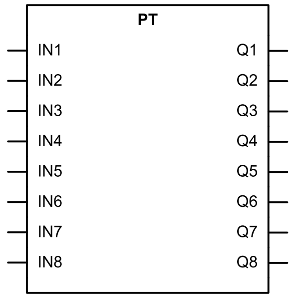


Figure 283: Function block

11.4.3 Functionality

The pulse timer function 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.

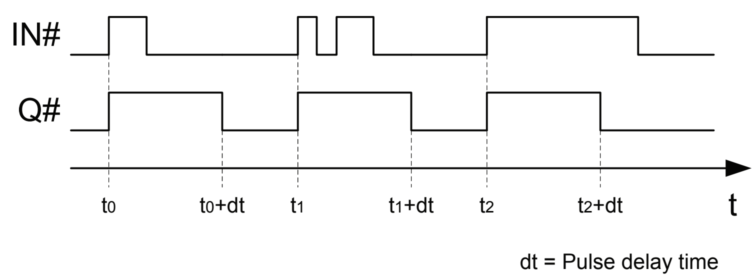


Figure 284: Timer operation

11.4.4 Signals

Table 413: 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
Table continues on next page			

Name	Type	Default	Description
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 414: 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

11.4.5 Settings

Table 415: PT Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
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

11.4.6 Technical data

Table 416: PT Technical data

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

11.5 Generic control points CNTRL

11.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/ IEEEidentification
Generic control points	SPCGGIO	SPC	CNTRL

11.5.2 Function block

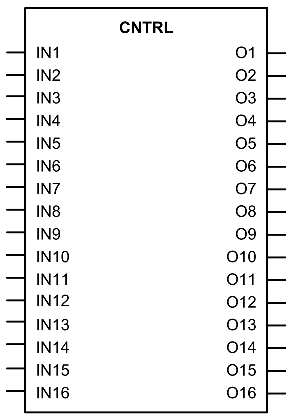


Figure 285: Function block

11.5.3 Functionality

The generic control points function CNTRL can be used in combination with other function blocks such as FKEYGGIO. SPC offers the capability to activate its outputs through a local or remote control. The local control is provided through the buttons in the front panel and the remote control is provided through communications. CNTRL has two modes of operation. In the "Toggle" mode, the block toggles the output signal for every input pulse received. In the "Pulsed" mode, the block generates an output pulse of a preset duration.

11.5.4 Operation principle

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

CNTRL has the *Operation mode*, *Pulse length* and *Description* settings available to control all 16 outputs. By default, the *Operation mode* setting is set to "Off". This disables the controllable signal output. CNTRL also has a general setting *Loc Rem restriction*, which enables or disables the local or remote state functionality.

When the *Operation mode* is set to "Toggle", the corresponding output toggles between "True" and "False" for every input pulse received. The state of the output is stored in a nonvolatile memory and restored if the protection relay is restarted.

When the *Operation mode* is set to "Pulsed", the corresponding output can be used to produce the predefined length of pulses. Once activated, the output remains active for the duration of the set pulse length. When activated, the additional activation command does not extend the length of pulse. Thus, the pulse needs to be ended before the new activation can occur.

The *Description* setting can be used for storing signal names for each output.

Each control point or CNTRL can be accessed locally or remotely through communication or the LHMI control. CNTRL follows the local or remote (L/R) state if the *Loc Rem restriction* setting is "true". If the *Loc Rem restriction* setting is "false", local or remote (L/R) state is ignored, that is, all controls are allowed regardless of the local or remote state.

In case of DNP3, there will be no control remotely if the protection relay is in the local mode and *Loc Rem Restriction* is FALSE. DNP3 controls follow the L/R status irrespective of *Loc Rem Restriction* in SPCGGIO instances.

The `BLOCK` input can be used for blocking the output functionality. The `BLOCK` input operation depends on the *Operation mode* setting. If the *Operation mode* setting is set to "Toggle", the output state cannot be changed when the input `BLOCK` is TRUE. If the *Operation mode* setting is set to "Pulsed", the activation of the `BLOCK` input resets the output to the FALSE state.

From the remote communication point of view, SPCGGIO toggled operation mode is always working as persistent mode. The output `O#` follows the value written to the input `IN#`.

11.5.5 Signals

Table 417: CNTRL Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
I1	BOOLEAN	0=False	Input 1 status
I2	BOOLEAN	0=False	Input 2 status
I3	BOOLEAN	0=False	Input 3 status
I4	BOOLEAN	0=False	Input 4 status
I5	BOOLEAN	0=False	Input 5 status
I6	BOOLEAN	0=False	Input 6 status
I7	BOOLEAN	0=False	Input 7 status
I8	BOOLEAN	0=False	Input 8 status
I9	BOOLEAN	0=False	Input 9 status
I10	BOOLEAN	0=False	Input 10 status
I11	BOOLEAN	0=False	Input 11 status
I12	BOOLEAN	0=False	Input 12 status
I13	BOOLEAN	0=False	Input 13 status
I14	BOOLEAN	0=False	Input 14 status
I15	BOOLEAN	0=False	Input 15 status
I16	BOOLEAN	0=False	Input 16 status

Table 418: CNTRL Output signals

Name	Type	Description
O1	BOOLEAN	Output 1 status
O2	BOOLEAN	Output 2 status
O3	BOOLEAN	Output 3 status
O4	BOOLEAN	Output 4 status
O5	BOOLEAN	Output 5 status
O6	BOOLEAN	Output 6 status
O7	BOOLEAN	Output 7 status
O8	BOOLEAN	Output 8 status
O9	BOOLEAN	Output 9 status
O10	BOOLEAN	Output 10 status
O11	BOOLEAN	Output 11 status
O12	BOOLEAN	Output 12 status
O13	BOOLEAN	Output 13 status

Table continues on next page

Name	Type	Description
O14	BOOLEAN	Output 14 status
O15	BOOLEAN	Output 15 status
O16	BOOLEAN	Output 16 status

11.5.6 Settings

Table 419: CNTRL Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Loc Rem restriction	0=False 1=True			1=True	Local remote switch restriction
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 1	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 2	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 3	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 4	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 5	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 6	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 7	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 8	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 9	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 10	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 11	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 12	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 13	Generic control point description

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 14	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 15	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCGGIO1 Output 16	Generic control point description

11.6 Remote generic control points RCNTRL

11.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/ IEEEidentification
Remote generic control points	SPCRGGIO	SPCR	RCNTRL

11.6.2 Function block

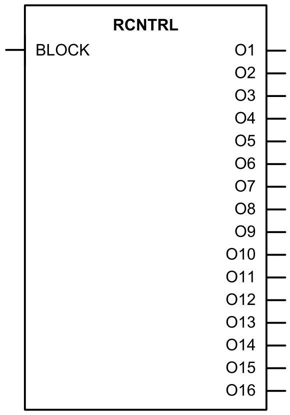


Figure 286: Function block

11.6.3 Functionality

The remote generic control points function RCNTRL is dedicated only for remote controlling, that is, RCNTRL cannot be controlled locally. The remote control is provided through communications.

11.6.4 Operation principle

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

RCNTRL has the *Operation mode*, *Pulse length* and *Description* settings available to control all 16 outputs. By default, the *Operation mode* setting is set to "Off". This disables the controllable signal output. RCNTRL also has a general setting *Loc Rem restriction*, which enables or disables the local or remote state functionality.

When the *Operation mode* is set to "Toggle", the corresponding output toggles between "True" and "False" for every input pulse received. The state of the output is stored in a nonvolatile memory and restored if the protection relay is restarted.

When the *Operation mode* is set to "Pulsed", the corresponding output can be used to produce the predefined length of pulses. Once activated, the output remains active for the duration of the set pulse length. When activated, the additional activation command does not extend the length of pulse. Thus, the pulse needs to be ended before the new activation can occur.

The *Description* setting can be used for storing signal names for each output.

Each control point or RCNTRL can only be accessed remotely through communication. RCNTRL follows the local or remote (L/R) state if the setting *Loc Rem restriction* is "true". If the *Loc Rem restriction* setting is "false", local or remote (L/R) state is ignored, that is, all controls are allowed regardless of the local or remote state.

The `BLOCK` input can be used for blocking the output functionality. The `BLOCK` input operation depends on the *Operation mode* setting. If the *Operation mode* setting is set to "Toggle", the output state cannot be changed when the input `BLOCK` is TRUE. If the *Operation mode* setting is set to "Pulsed", the activation of the `BLOCK` input resets the output to the FALSE state.

From the remote communication point of view, SPCGGIO toggled operation mode is always working as persistent mode. The output `O#` follows the value written to the input `IN#`.

11.6.5 Signals

Table 420: RCNTRL Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 421: RCNTRL Output signals

Name	Type	Description
O1	BOOLEAN	Output 1 status
O2	BOOLEAN	Output 2 status
O3	BOOLEAN	Output 3 status
O4	BOOLEAN	Output 4 status
O5	BOOLEAN	Output 5 status
O6	BOOLEAN	Output 6 status
O7	BOOLEAN	Output 7 status
O8	BOOLEAN	Output 8 status
O9	BOOLEAN	Output 9 status
O10	BOOLEAN	Output 10 status
O11	BOOLEAN	Output 11 status
O12	BOOLEAN	Output 12 status
O13	BOOLEAN	Output 13 status
O14	BOOLEAN	Output 14 status
O15	BOOLEAN	Output 15 status
O16	BOOLEAN	Output 16 status

11.6.6 Settings

Table 422: RCNTRL Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Loc Rem restriction	0=False 1=True			1=True	Local remote switch restriction
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 1	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 2	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 3	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 4	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 5	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 6	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 7	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 8	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 9	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 10	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 11	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 12	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 13	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 14	Generic control point description

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 15	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCRGGIO1 Output 16	Generic control point description

11.7 Local generic control points LCNTRL

11.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/ IEEEidentification
Local generic control points	SPCLGGIO	SPCL	LCNTRL

11.7.2 Function block

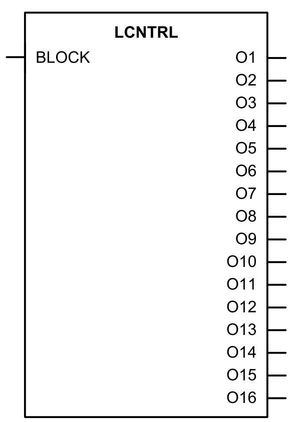


Figure 287: Function block

11.7.3 Functionality

The local generic control points function LCNTRL is dedicated only for local controlling, that is, LCNTRL cannot be controlled remotely. The local control is done through the buttons in the front panel.

11.7.4 Operation principle

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

LCNTRL has the *Operation mode*, *Pulse length* and *Description* settings available to control all 16 outputs. By default, the *Operation mode* setting is set to "Off". This disables the controllable signal output. LCNTRL also has a general setting *Loc Rem restriction*, which enables or disables the local or remote state functionality.

When the *Operation mode* is set to "Toggle", the corresponding output toggles between "True" and "False" for every input pulse received. The state of the output is stored in a nonvolatile memory and restored if the protection relay is restarted.

When the *Operation mode* is set to "Pulsed", the corresponding output can be used to produce the predefined length of pulses. Once activated, the output remains active for the duration of the set pulse length. When activated, the additional activation command does not extend the length of pulse. Thus, the pulse needs to be ended before the new activation can occur.

The *Description* setting can be used for storing signal names for each output.

Each control point or LCNTRL can only be accessed through the LHMI control. LCNTRL follows the local or remote (L/R) state if the *Loc Rem restriction* setting is "true". If the *Loc Rem restriction* setting is "false", local or remote (L/R) state is ignored, that is, all controls are allowed regardless of the local or remote state.

The `BLOCK` input can be used for blocking the output functionality. The `BLOCK` input operation depends on the *Operation mode* setting. If the *Operation mode* setting is set to "Toggle", the output state cannot be changed when the input `BLOCK` is TRUE. If the *Operation mode* setting is set to "Pulsed", the activation of the `BLOCK` input resets the output to the FALSE state.

From the remote communication point of view, SPCGGIO toggled operation mode is always working as persistent mode. The output `O#` follows the value written to the input `IN#`.

11.7.5 Signals

Table 423: LCNTRL Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 424: LCNTRL Output signals

Name	Type	Description
O1	BOOLEAN	Output 1 status
O2	BOOLEAN	Output 2 status
O3	BOOLEAN	Output 3 status
O4	BOOLEAN	Output 4 status
O5	BOOLEAN	Output 5 status
O6	BOOLEAN	Output 6 status
O7	BOOLEAN	Output 7 status
O8	BOOLEAN	Output 8 status
O9	BOOLEAN	Output 9 status
O10	BOOLEAN	Output 10 status
O11	BOOLEAN	Output 11 status
O12	BOOLEAN	Output 12 status
O13	BOOLEAN	Output 13 status
O14	BOOLEAN	Output 14 status
O15	BOOLEAN	Output 15 status
O16	BOOLEAN	Output 16 status

11.7.6 Settings

Table 425: LCNTRL Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Loc Rem restriction	0=False 1=True			1=True	Local remote switch restriction
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 1	Generic control point description
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 2	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 3	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Operation mode	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 4	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 5	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 6	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 7	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 8	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 9	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 10	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 11	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 12	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 13	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 14	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 15	Generic control point description
Operation mode	0=Pulsed 1=Toggle -1=Off			-1=Off	Operation mode for generic control point
Pulse length	10...3600000	ms	10	1000	Pulse length for pulsed operation mode
Description				SPCLGGIO1 Output 16	Generic control point description

11.8 Set reset SR

11.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Set reset (8 pcs)	SRGAPC	SR	SR

11.8.2 Function block

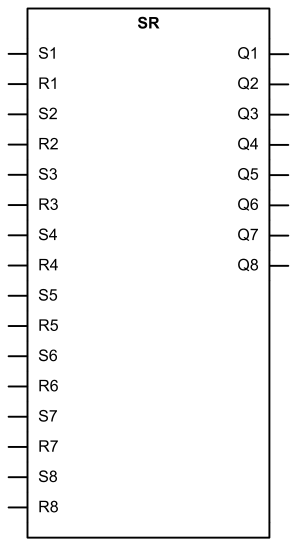


Figure 288: Function block

11.8.3 Functionality

The set-reset (8 pcs) function SR 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. The function 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 426: Truth table for SR

S#	R#	Q#
0	0	0[1]
0	1	0
1	0	1
1	1	1

1) Keep state/no change

11.8.4 Signals

Table 427: SR 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 428: SR 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

Table continues on next page

Name	Type	Description
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

11.8.5 Settings

Table 429: SR 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

11.9 Time delay off TOF

11.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time delay off (8 pcs)	TOFGAPC	TOF	TOF

11.9.2 Function block

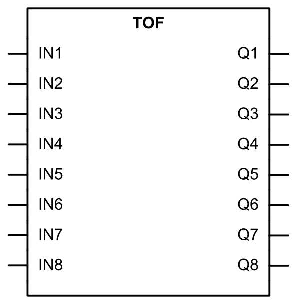


Figure 289: Function block

11.9.3 Functionality

The time delay off (8 pcs) function TOF can be used, for example, for a drop-off-delayed output related to the input signal. The function 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.

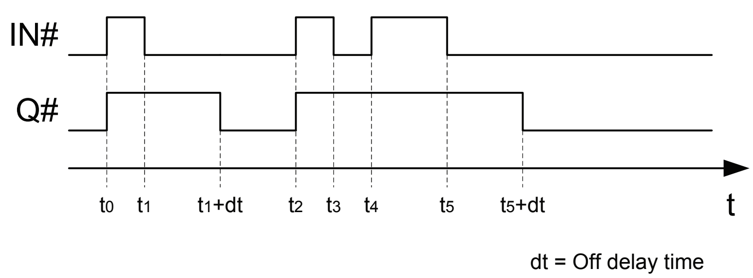


Figure 290: Timer operation

11.9.4 Signals

Table 430: TOF 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
Table continues on next page			

Name	Type	Default	Description
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 431: TOF 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

11.9.5 Settings

Table 432: TOF 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

11.9.6 Technical data

Table 433: TOF Technical data

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

11.10 Time delay on TON

11.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time delay on (8 pcs)	TONGAPC	TON	TON

11.10.2 Function block

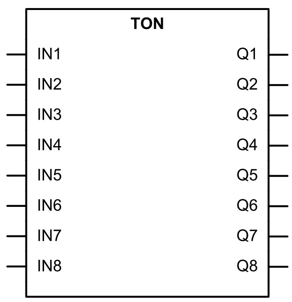


Figure 291: Function block

11.10.3 Functionality

The time delay on (8 pcs) function TON can be used, for example, for time-delaying the output related to the input signal. TON 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.

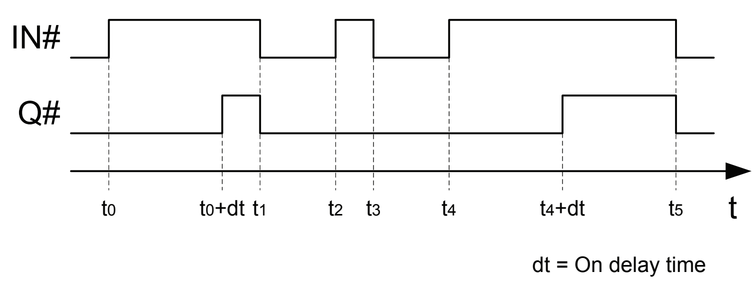


Figure 292: Timer operation

11.10.4 Signals

Table 434: TON 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 435: TON 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

11.10.5 Settings

Table 436: TON 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

11.10.6 Technical data

Table 437: TON Technical data

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

Section 12 General function block features

12.1 Definite time characteristics

12.1.1 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.

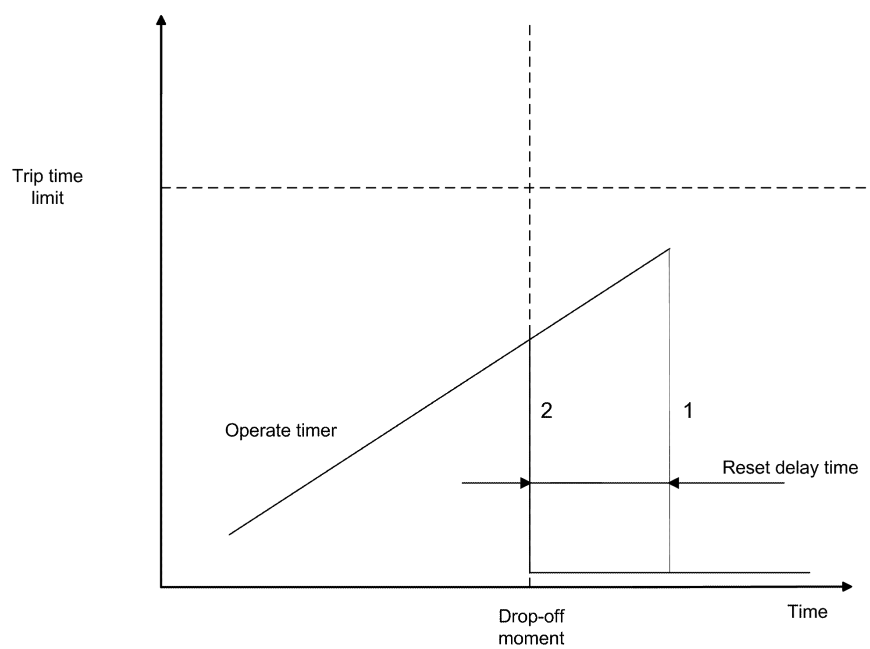


Figure 293: Operation of the counter in drop-off

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.

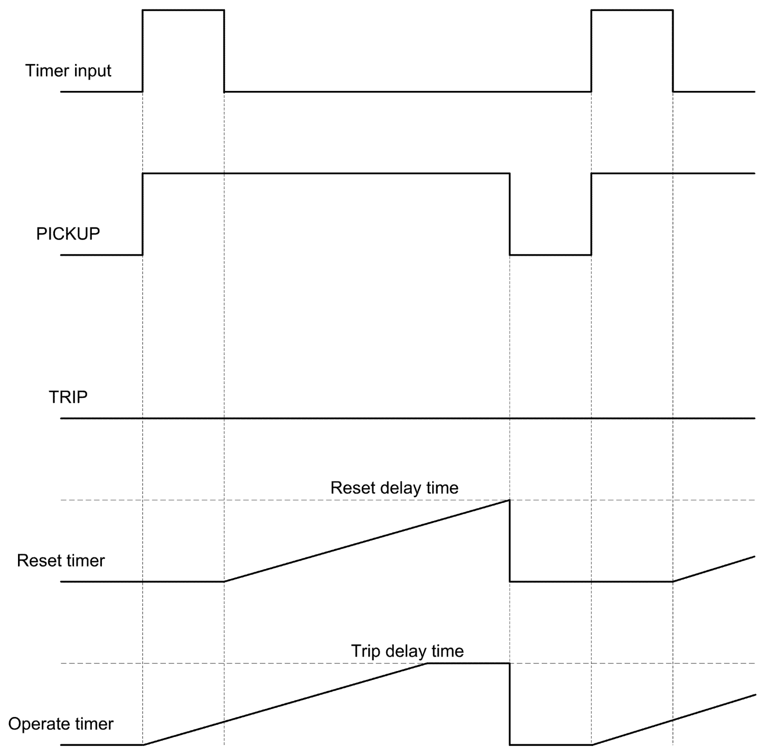


Figure 294: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 294, 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 operation 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 operation timer is reset. Since this happens before another pickup occurs, the `TRIP` output is not activated.

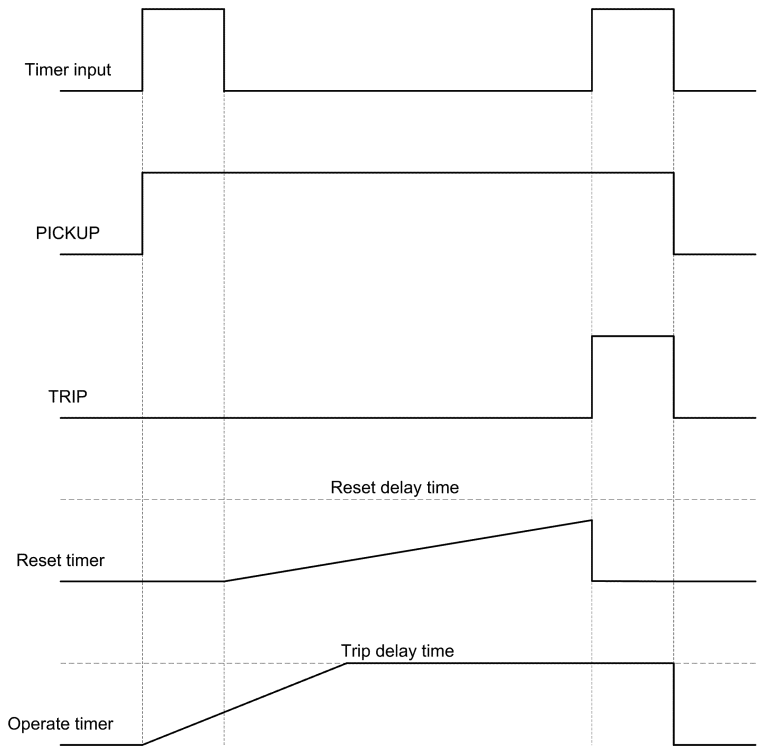


Figure 295: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 295, 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 operation 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 operation timer already has elapsed.

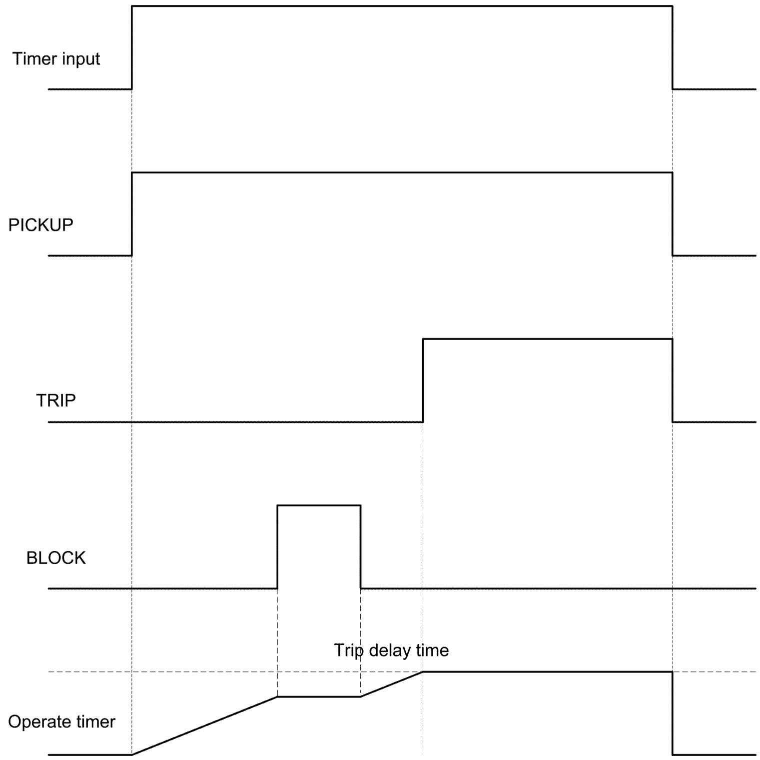


Figure 296: Operating effect of the `BLOCK` *input when the selected blocking mode is "Freeze timer"*

If the `BLOCK` input is activated when the operation timer is running, as described in Figure 296, 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 operation timer is reset in the same way as described in Figure 294, regardless of the `BLOCK` input.

The selected blocking mode is "Freeze timer".

12.2 Current based inverse definite minimum time characteristics

12.2.1 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 curve scaling is determined with the *Time multiplier* setting.

There are two methods to level out the inverse-time characteristic.

- The *Minimum trip time* setting defines the minimum operating time for the IDMT curve, that is, the operation time is always at least the *Minimum trip time* setting.
- Alternatively, the *IDMT Sat point* is used for giving the leveling-out point as a multiple of the *Pickup value* setting. (Global setting: **Configuration/System/*IDMT Sat point***). The default parameter value is 50. This setting affects only the overcurrent and ground-fault IDMT timers.

IDMT operation time at currents over 50 x In is not guaranteed.

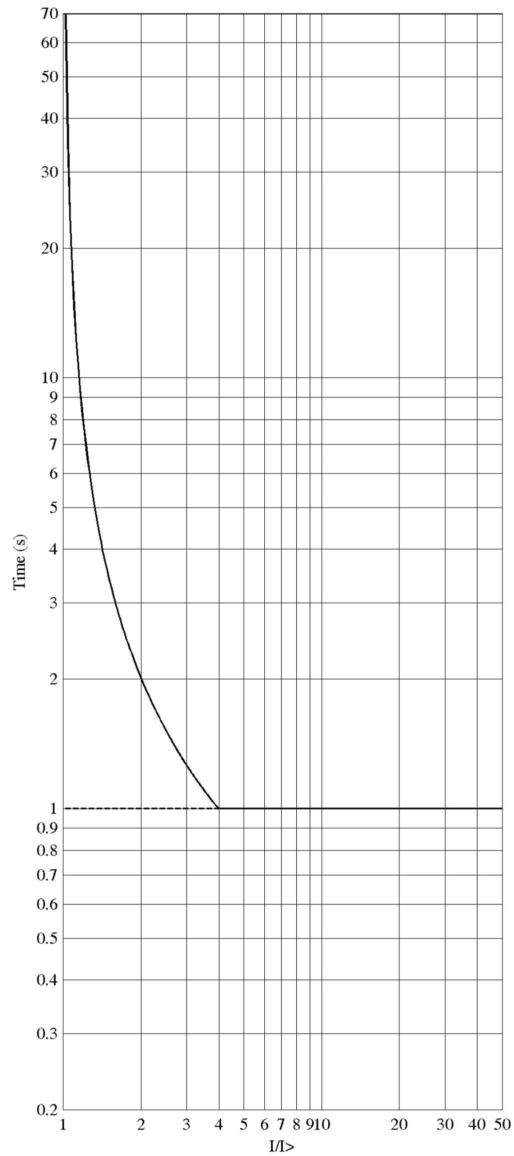


Figure 297: Operation time curve based on the IDMT characteristic leveled out with the Minimum trip time setting is set to 1000 milliseconds (the IDMT Sat point setting is set to maximum).

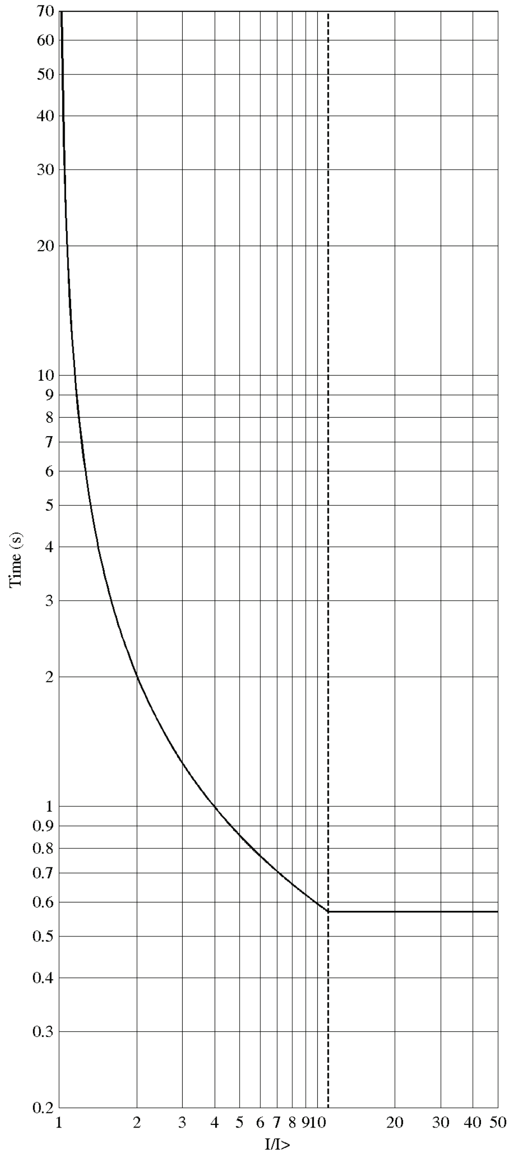


Figure 298: Operation time curve based on the IDMT characteristic leveled out with IDMT Sat point setting value “11” (the Minimum trip time setting is set to minimum).

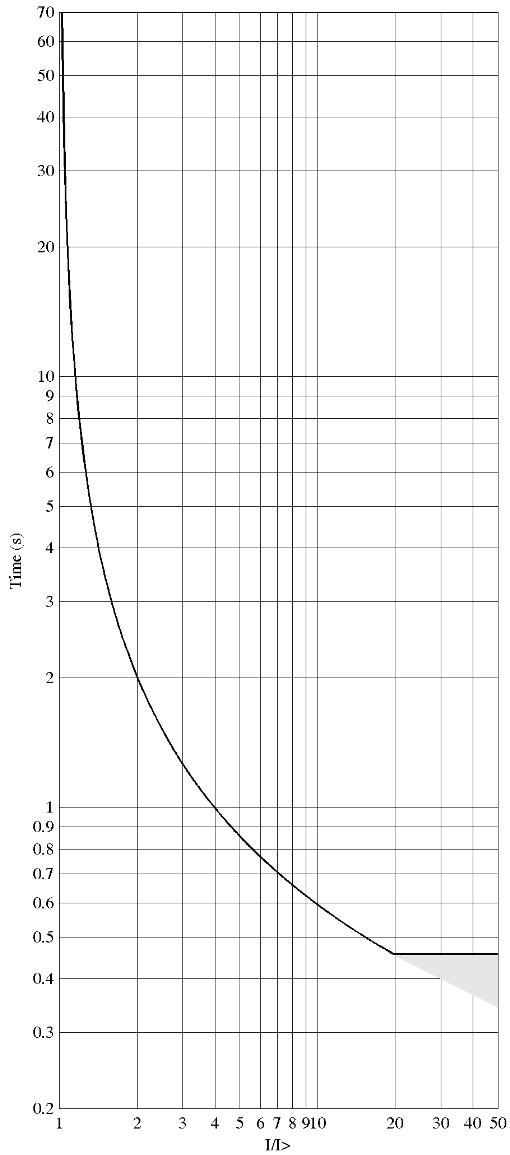


Figure 299: Example of how the inverse time characteristic is leveled out with currents over 50 x In and the Setting Pickup value setting "2.5 x In". (the IDMT Sat point setting is set to maximum and the Minimum trip time setting is set to minimum).

The grey zone in Figure 299 shows the behavior of the curve in case the measured current is outside the guaranteed measuring range. Also, the maximum measured current of 50 x In gives the leveling-out point 50/2.5 = 20 x I/I>.

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.

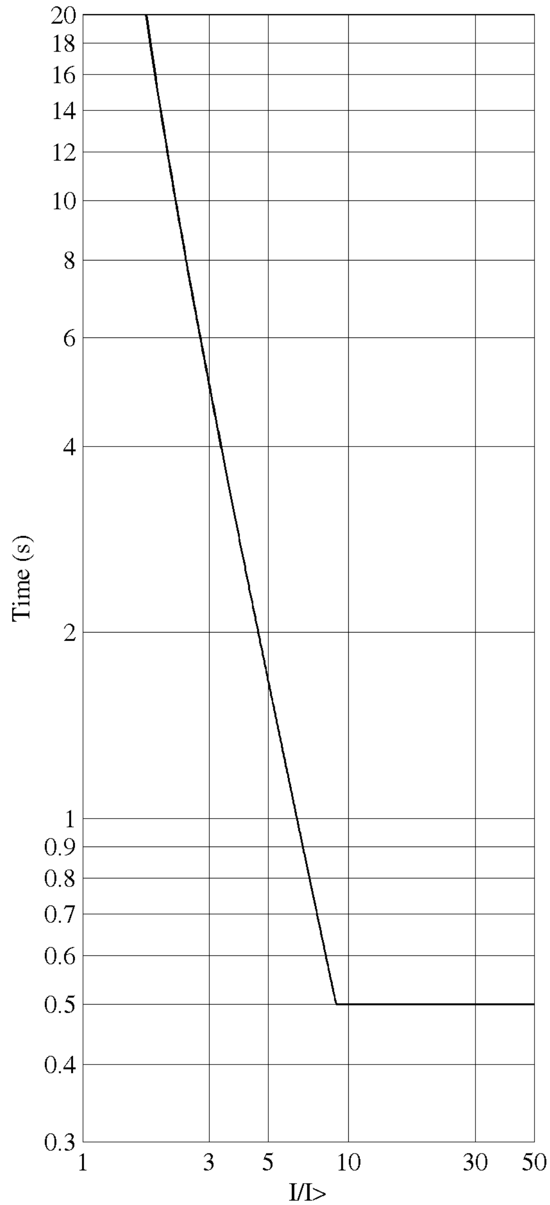


Figure 300: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 0.5 second

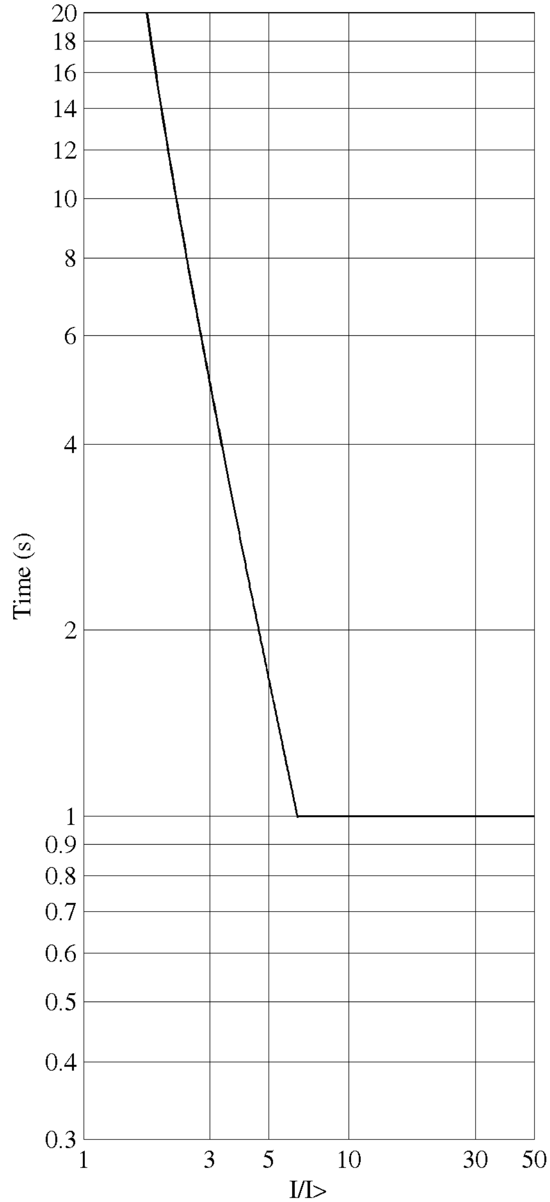


Figure 301: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 1 second

12.2.1.1 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 33)

t[s]	t[s] = Trip time in seconds
I	measured current
I>	set *Pickup value*
k	set *Time multiplier*

Table 438: 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

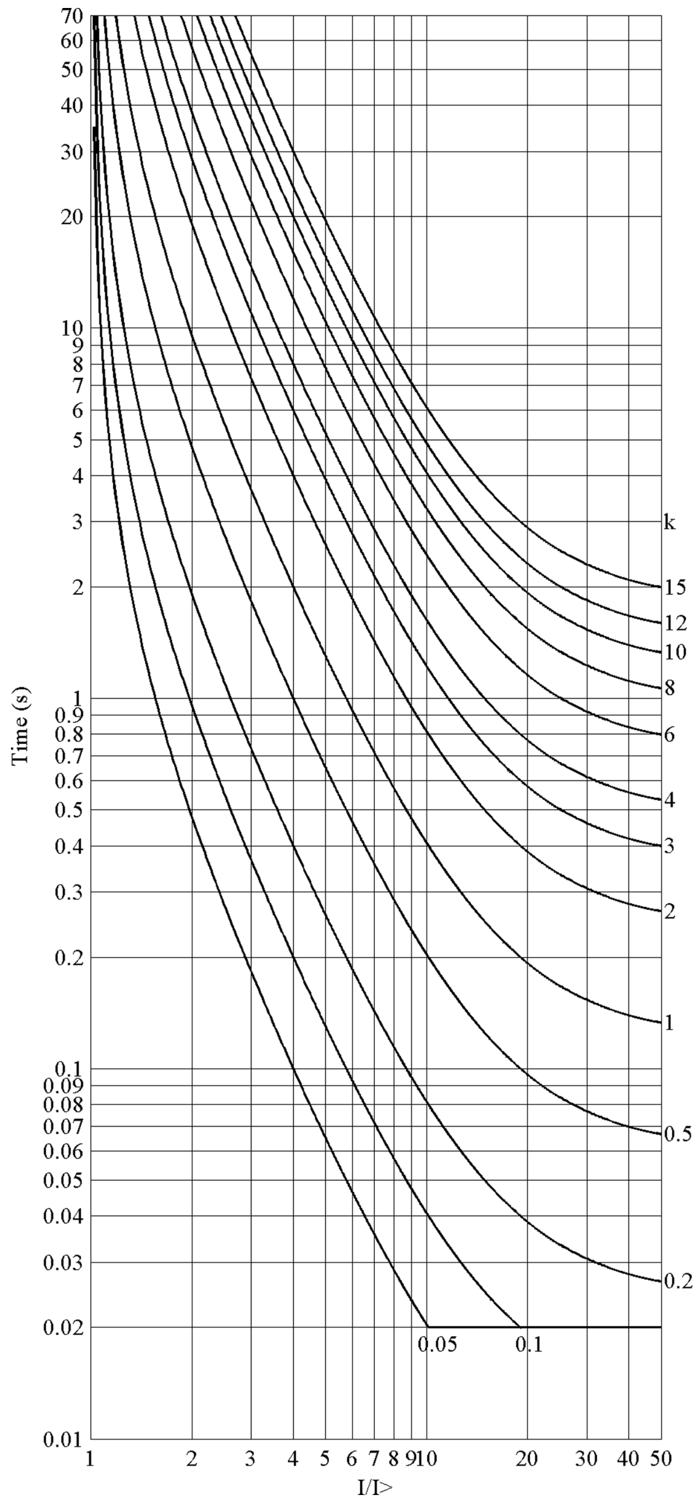


Figure 302: ANSI extremely inverse-time characteristics

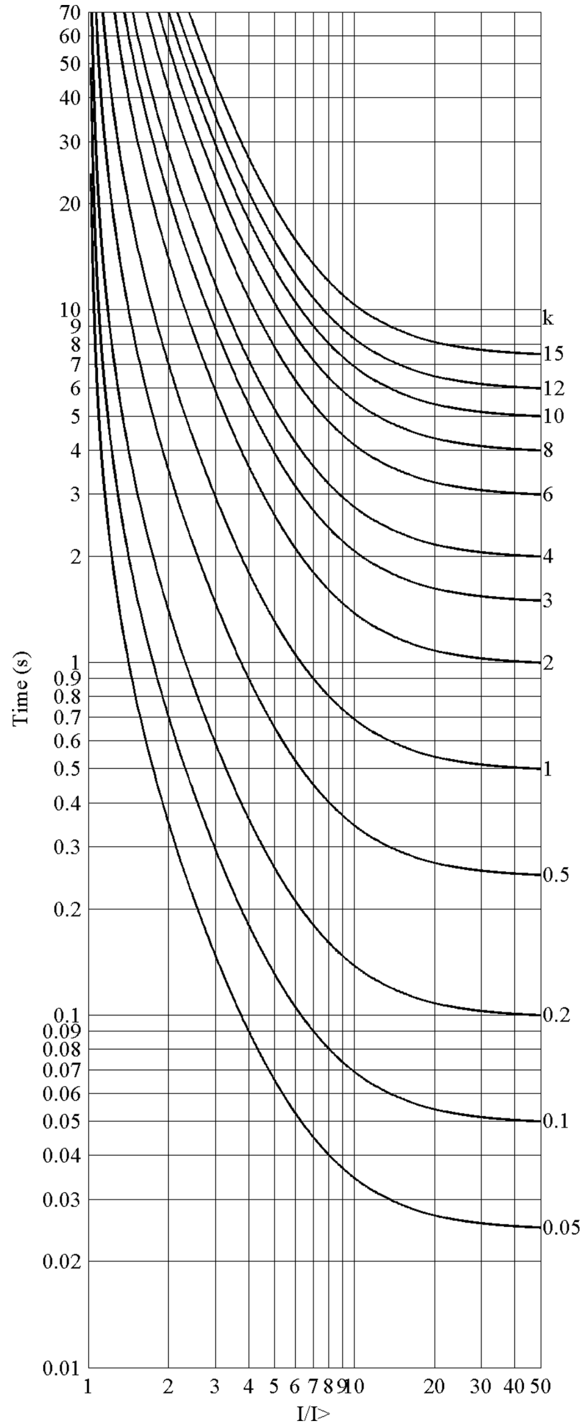


Figure 303: ANSI very inverse-time characteristics

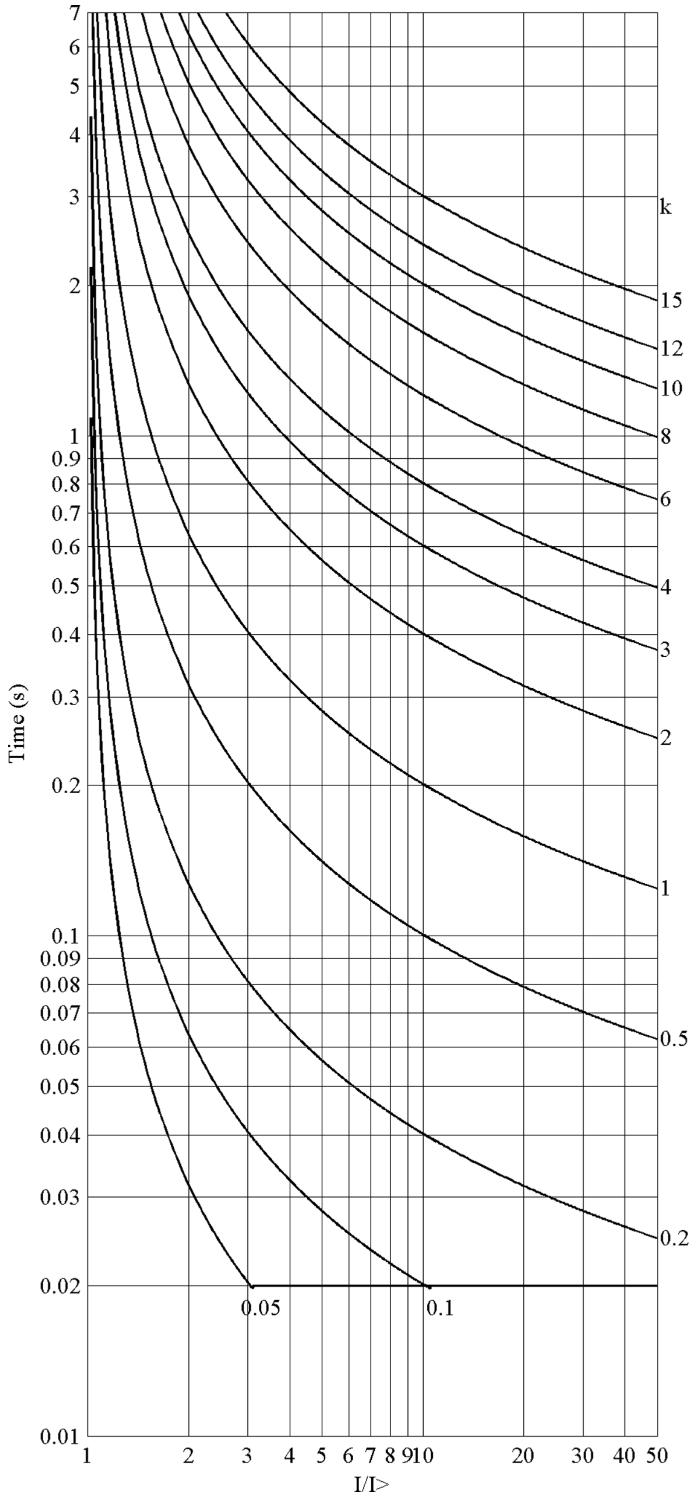


Figure 304: ANSI normal inverse-time characteristics

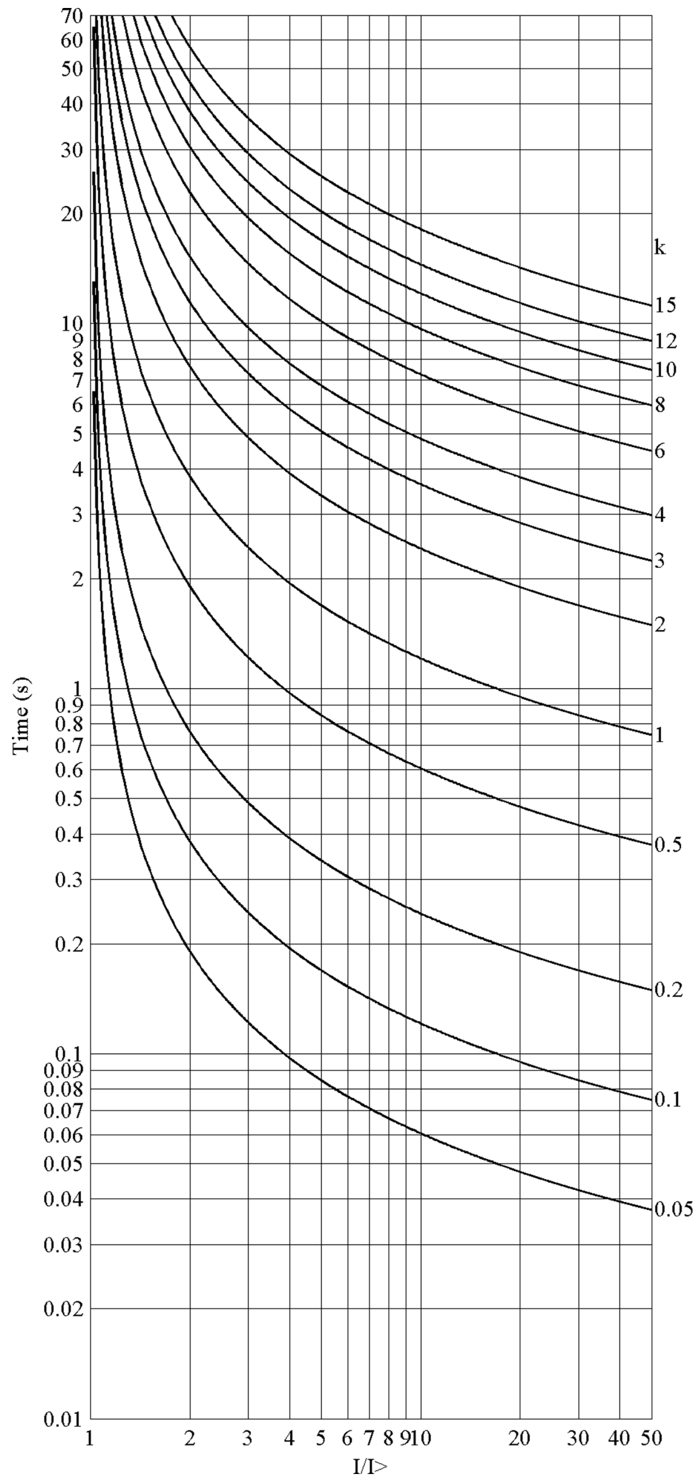


Figure 305: ANSI moderately inverse-time characteristics

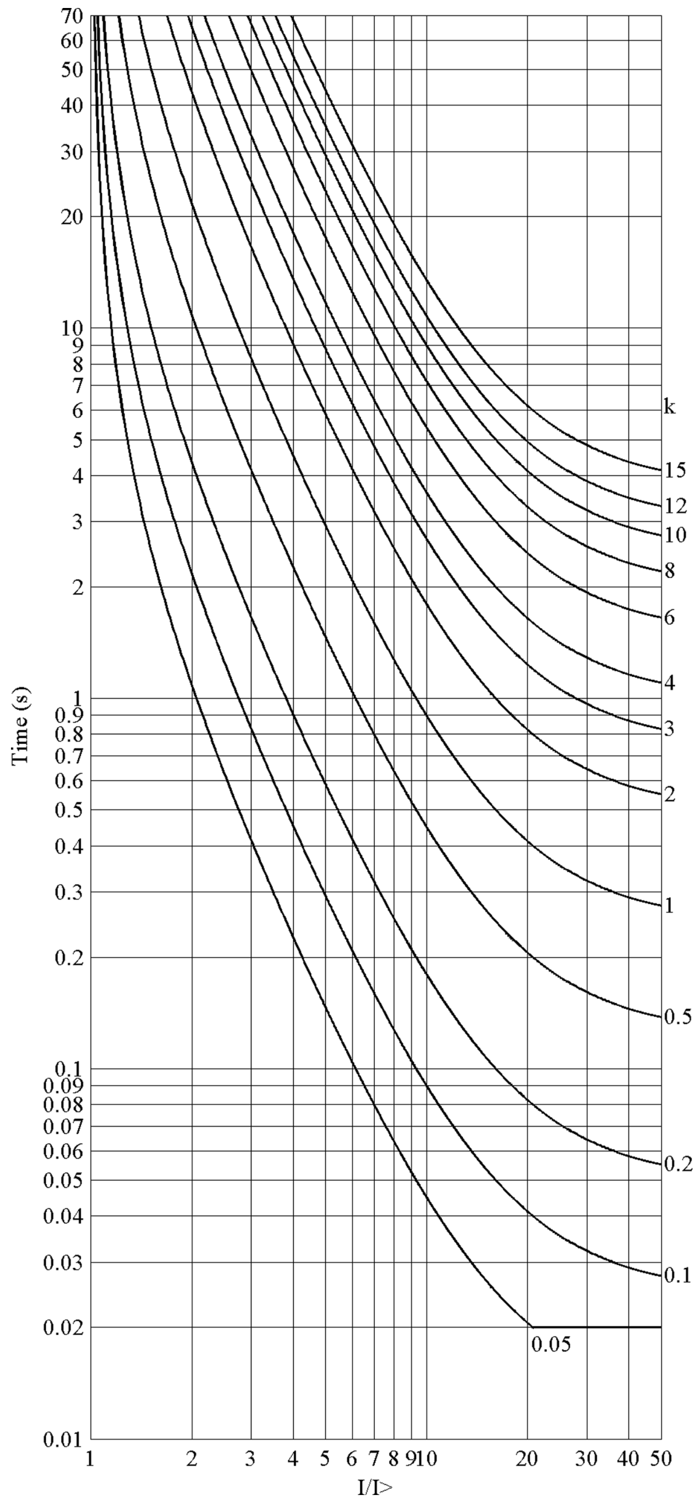


Figure 306: ANSI long-time extremely inverse-time characteristics

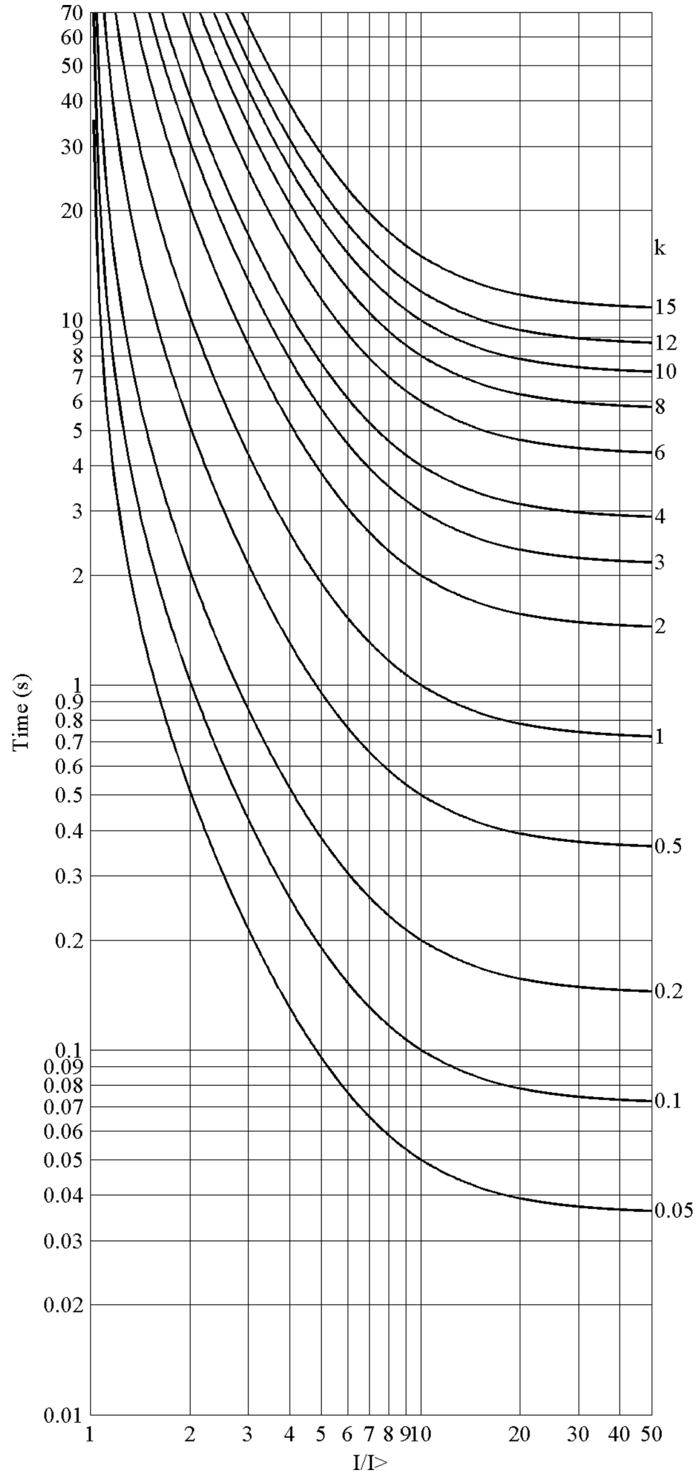


Figure 307: ANSI long-time very inverse-time characteristics

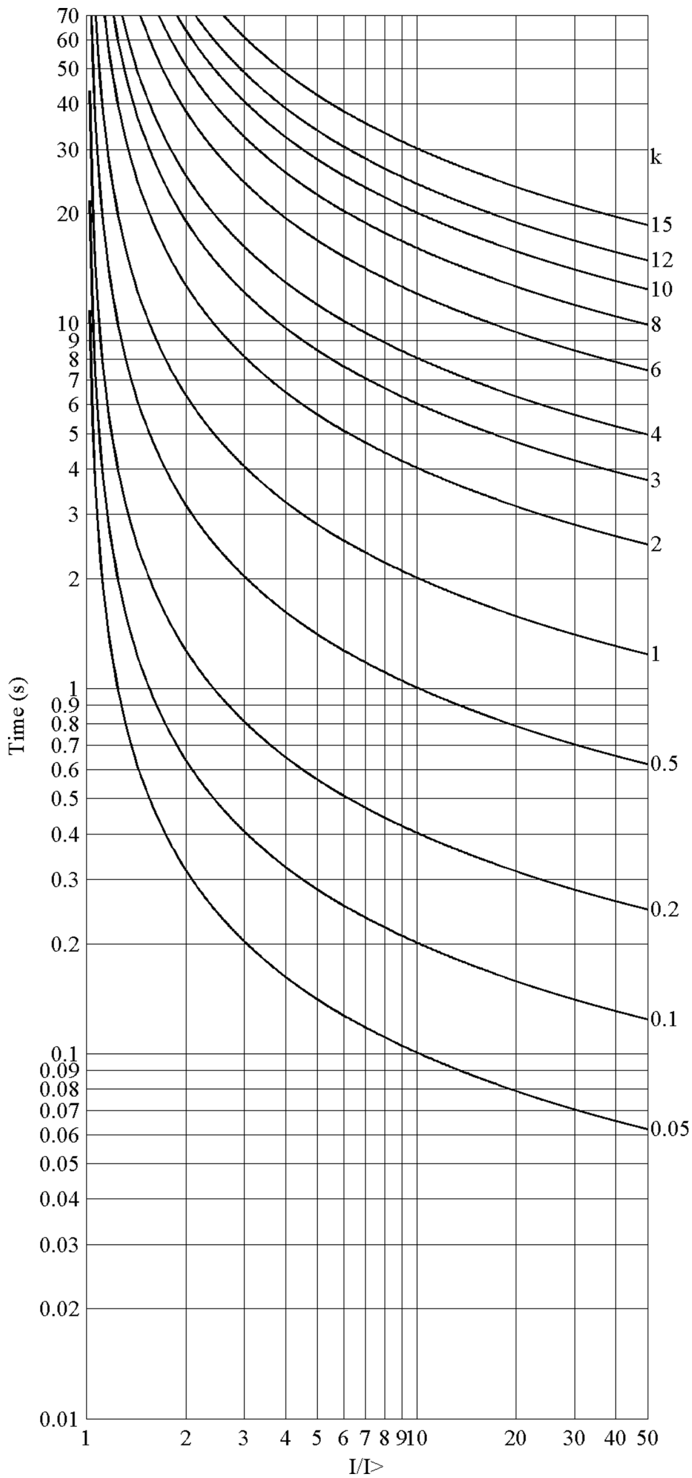


Figure 308: ANSI long-time inverse-time characteristics

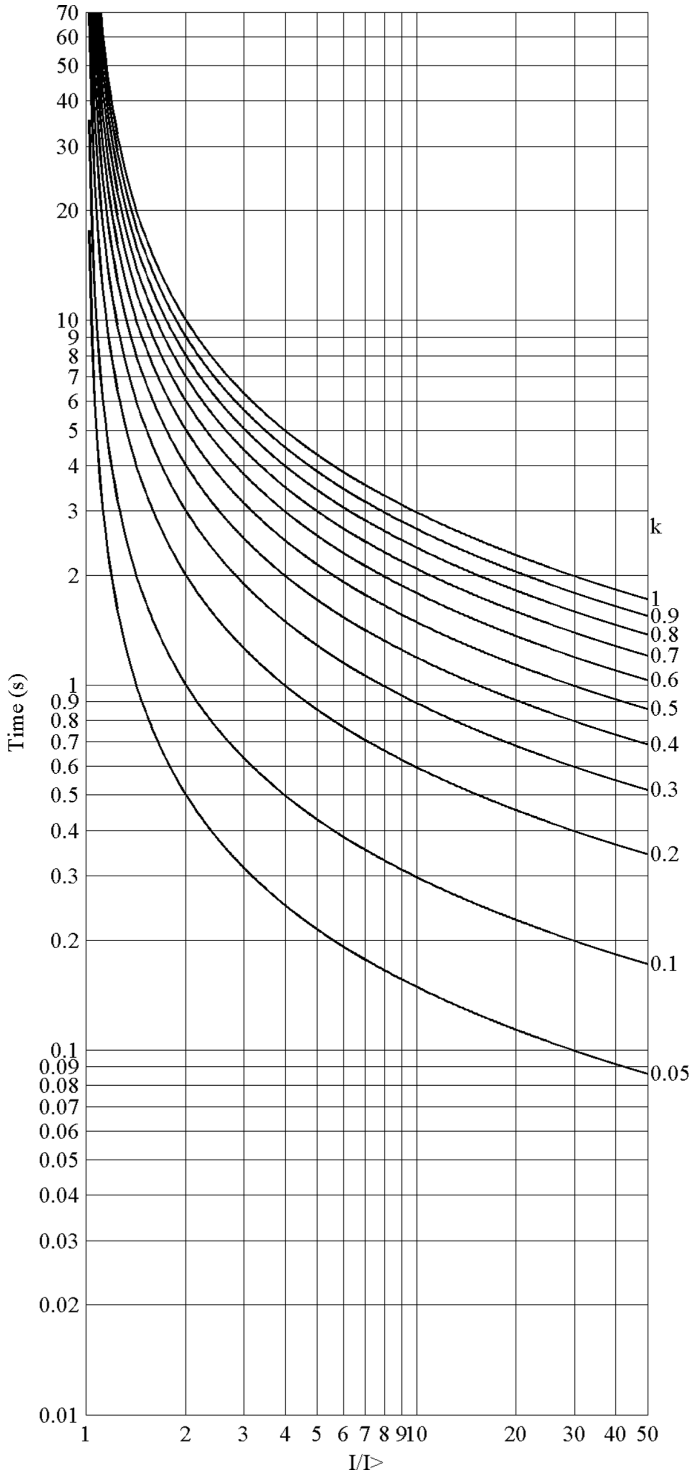


Figure 309: IEC normal inverse-time characteristics

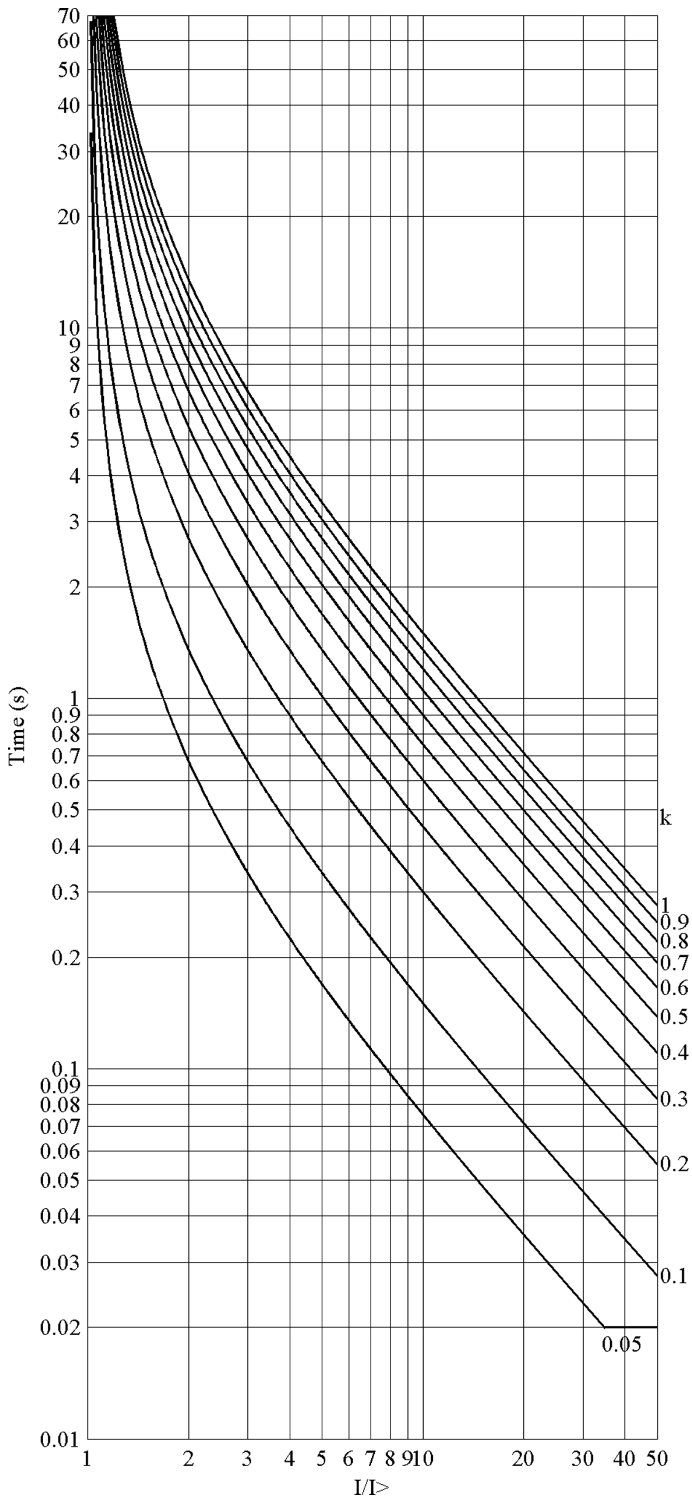


Figure 310: IEC very inverse-time characteristics

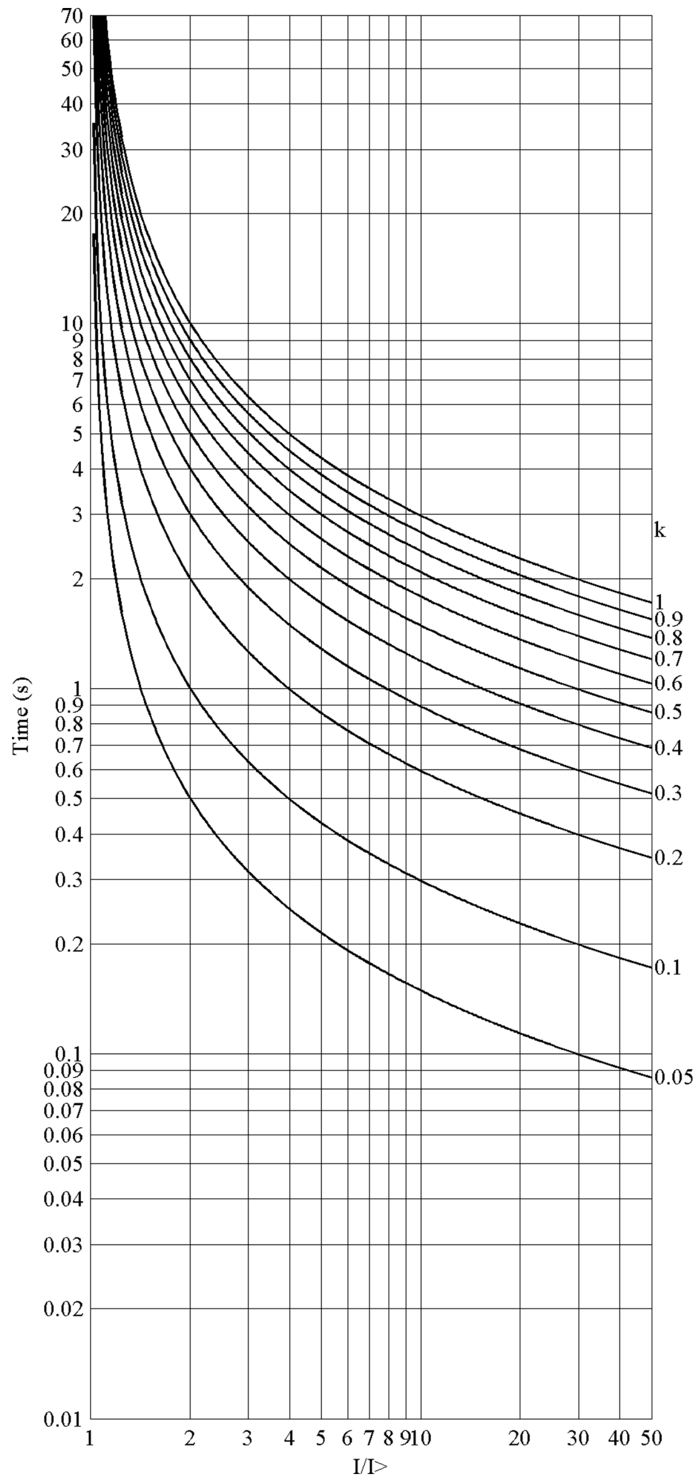


Figure 311: IEC inverse-time characteristics

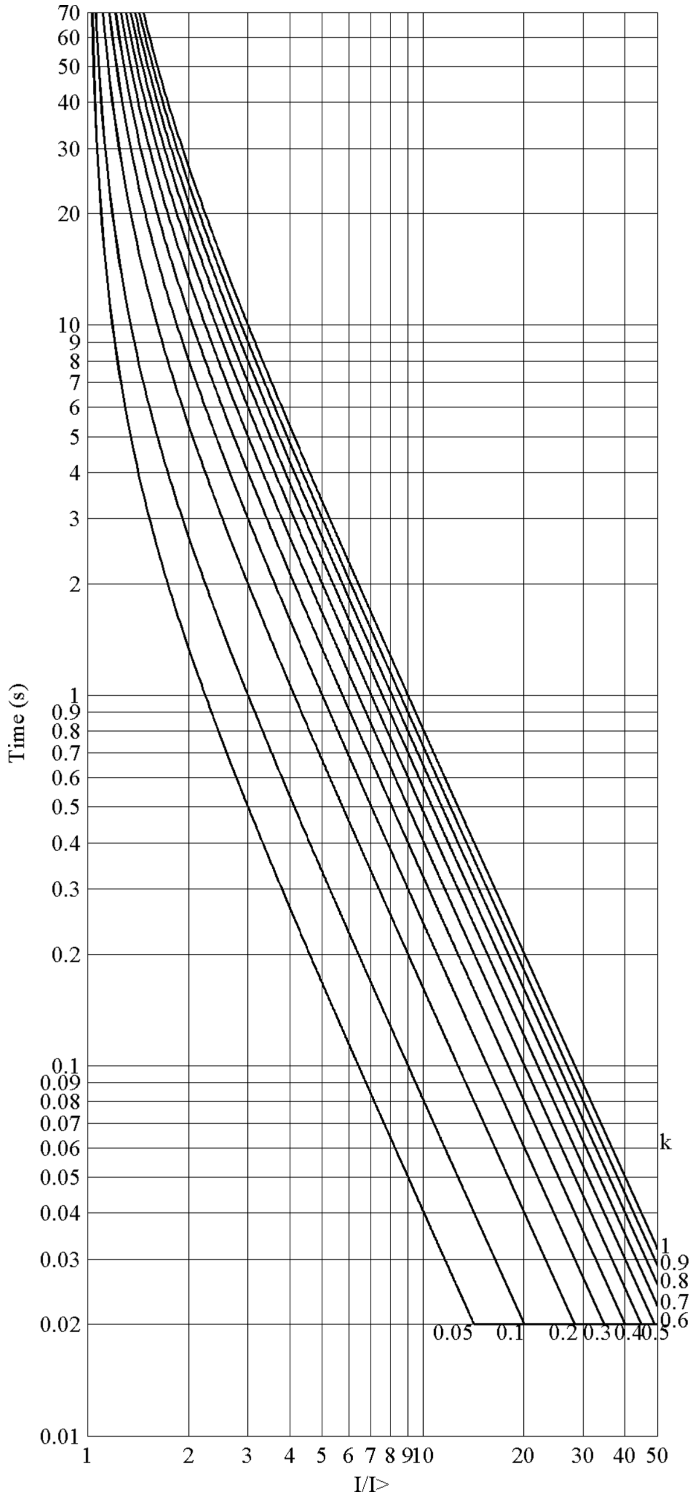


Figure 312: IEC extremely inverse-time characteristics

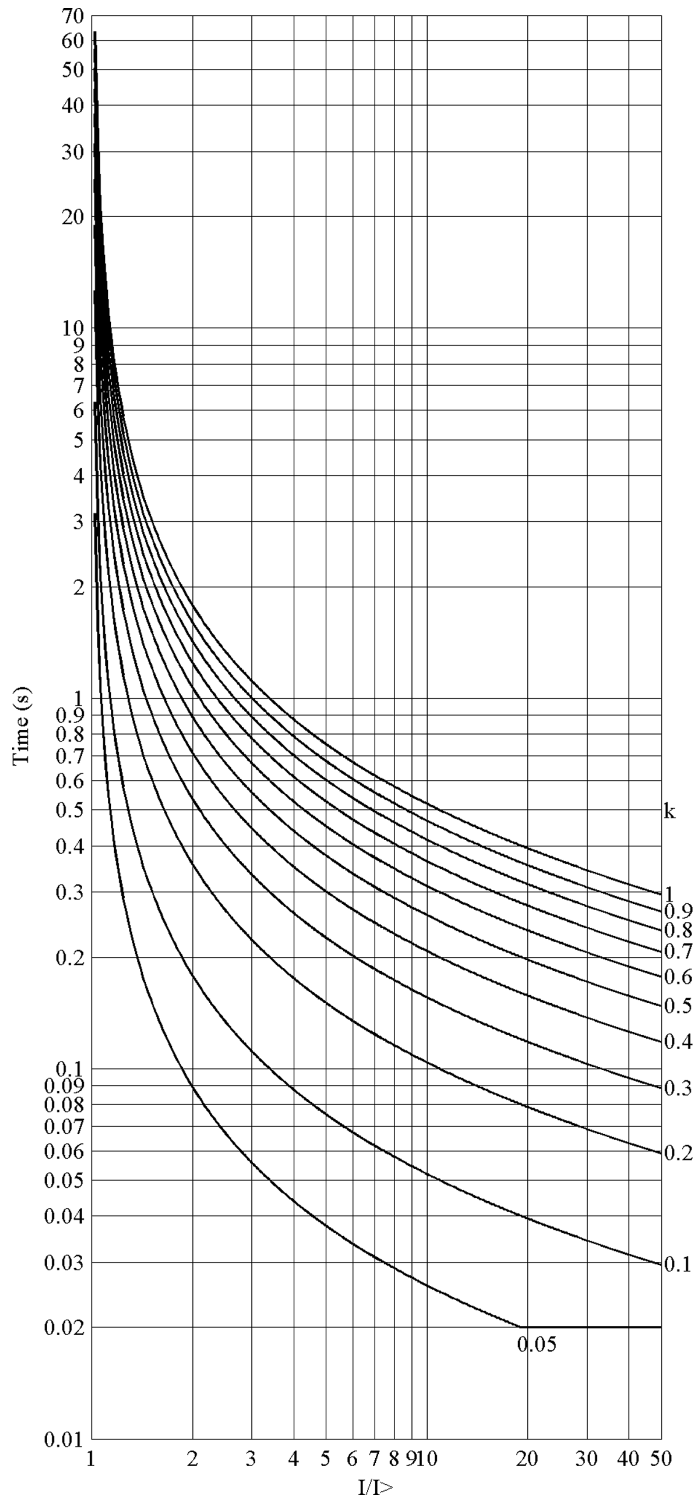


Figure 313: IEC short-time inverse-time characteristics

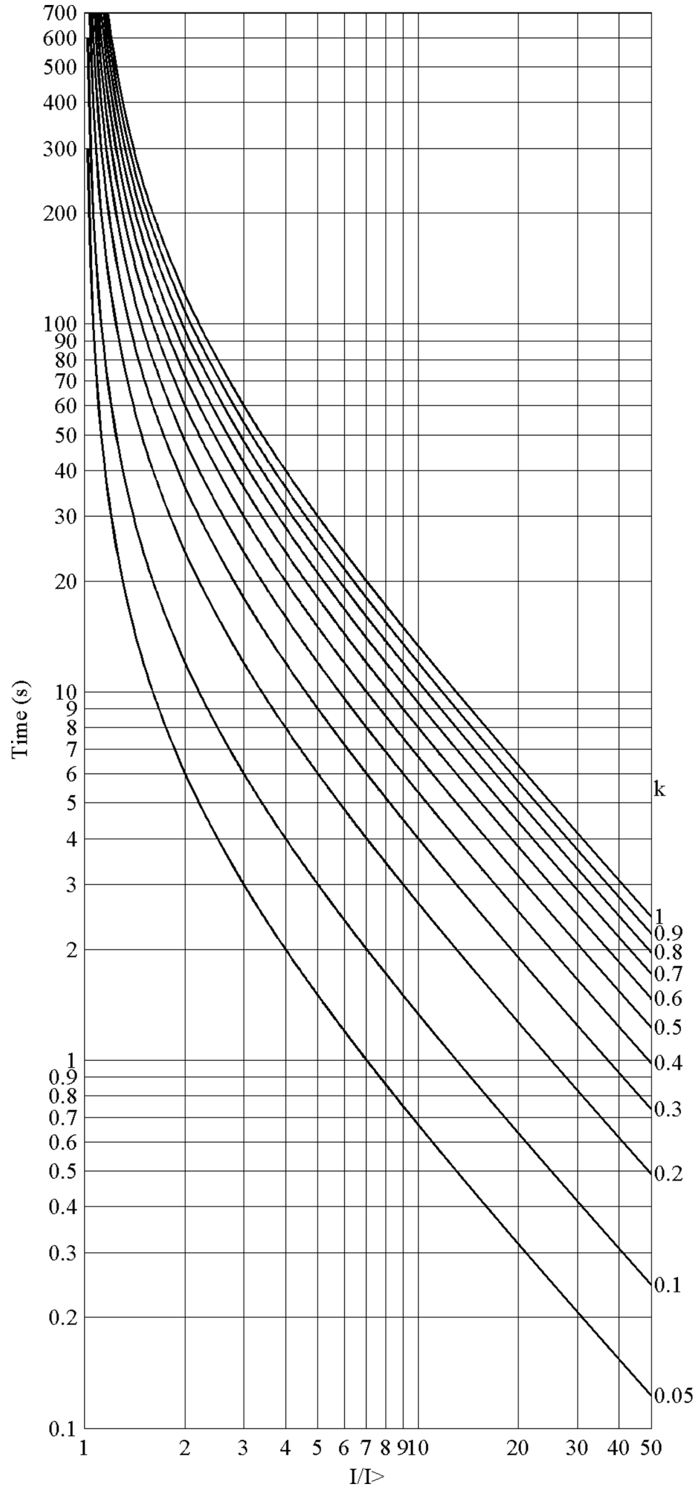


Figure 314: IEC long-time inverse-time characteristics

12.2.1.2 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 34)

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*

12.2.1.3 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 35)

The RD-type is calculated using the formula

$$t[s] = 5.8 - 1.35 \times \mathrm{In}\left(\frac{I}{k \times I>} \right)$$

(Equation 36)

t[s]	Trip time (in seconds)
k	set *Time multiplier*
I	Measured current
I>	set *Pickup value*

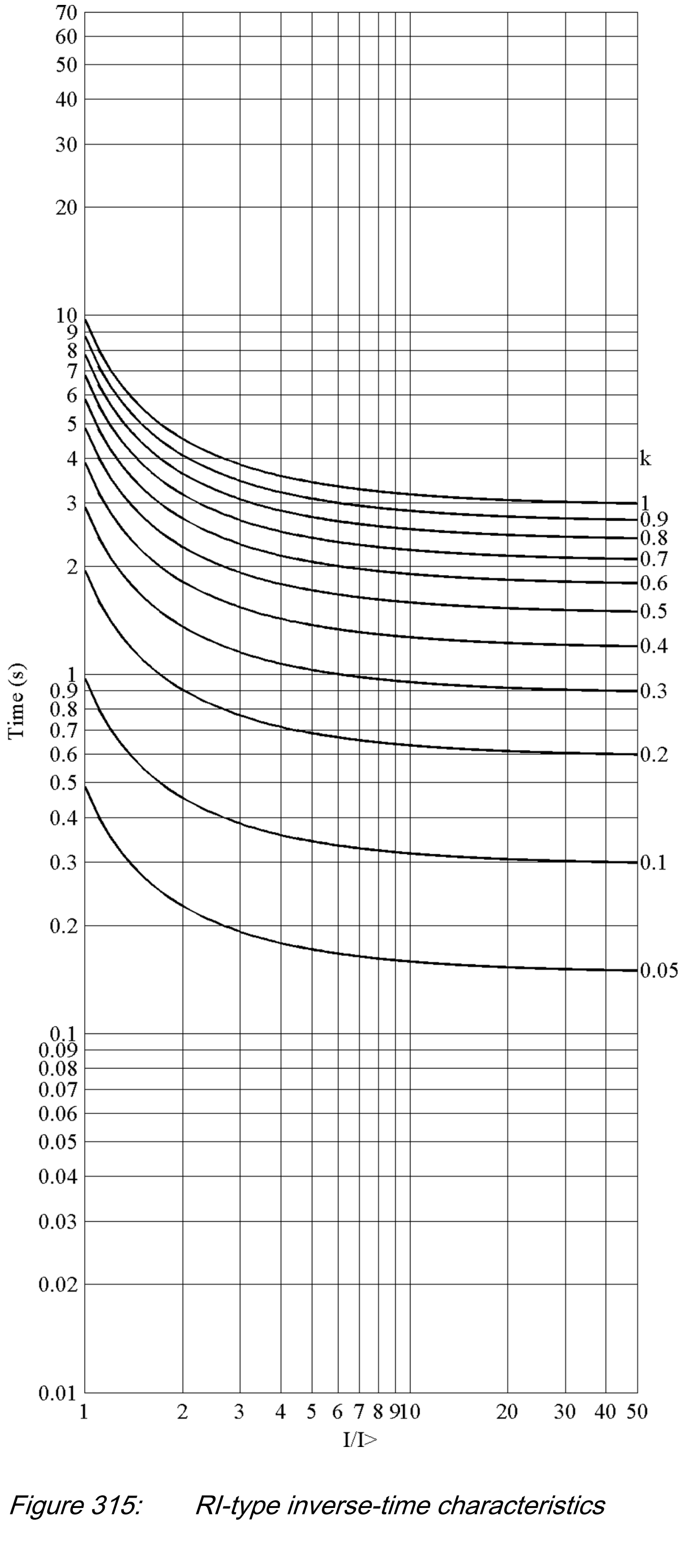


Figure 315: RI-type inverse-time characteristics

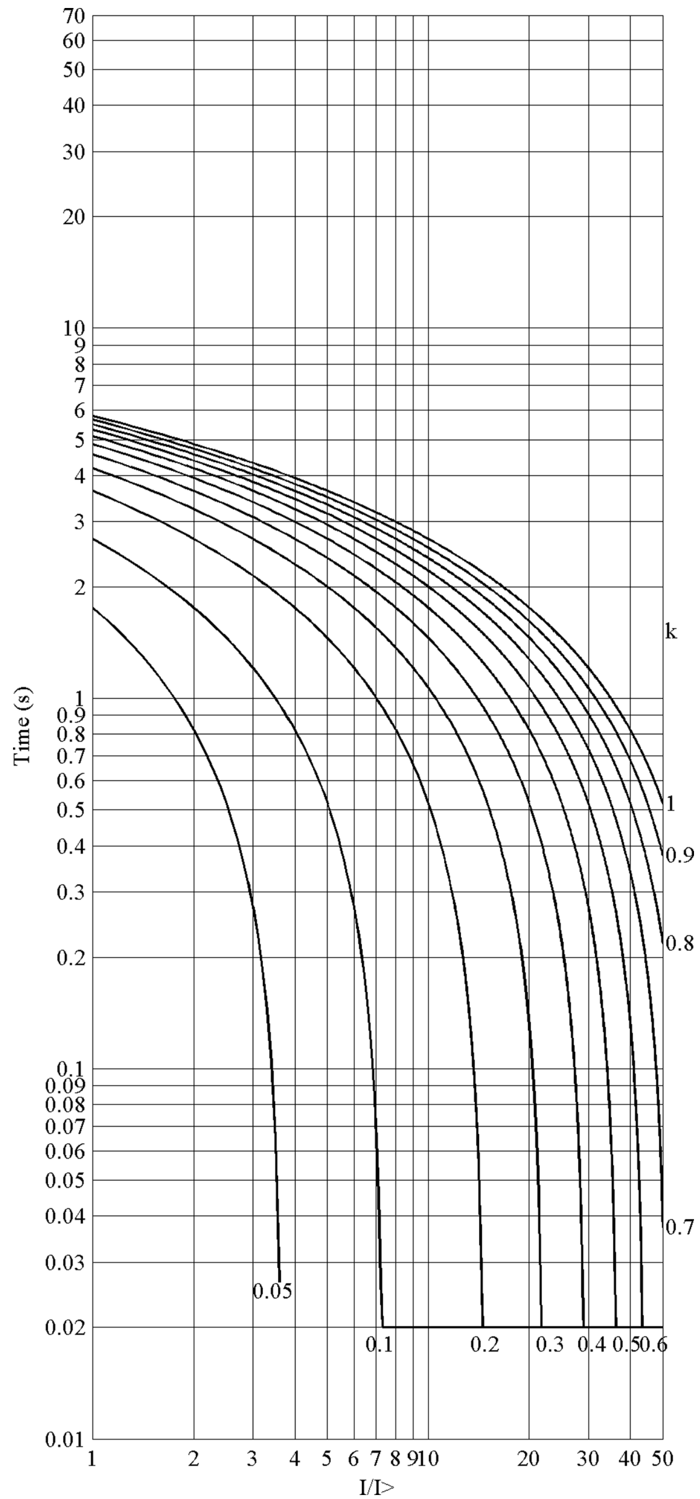


Figure 316: RD-type inverse-time characteristics

12.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting.

Table 439: 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 37)

t[s] Reset time (in seconds)

k set *Time multiplier*

I Measured current

I> set *Pickup value*

Table 440: 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

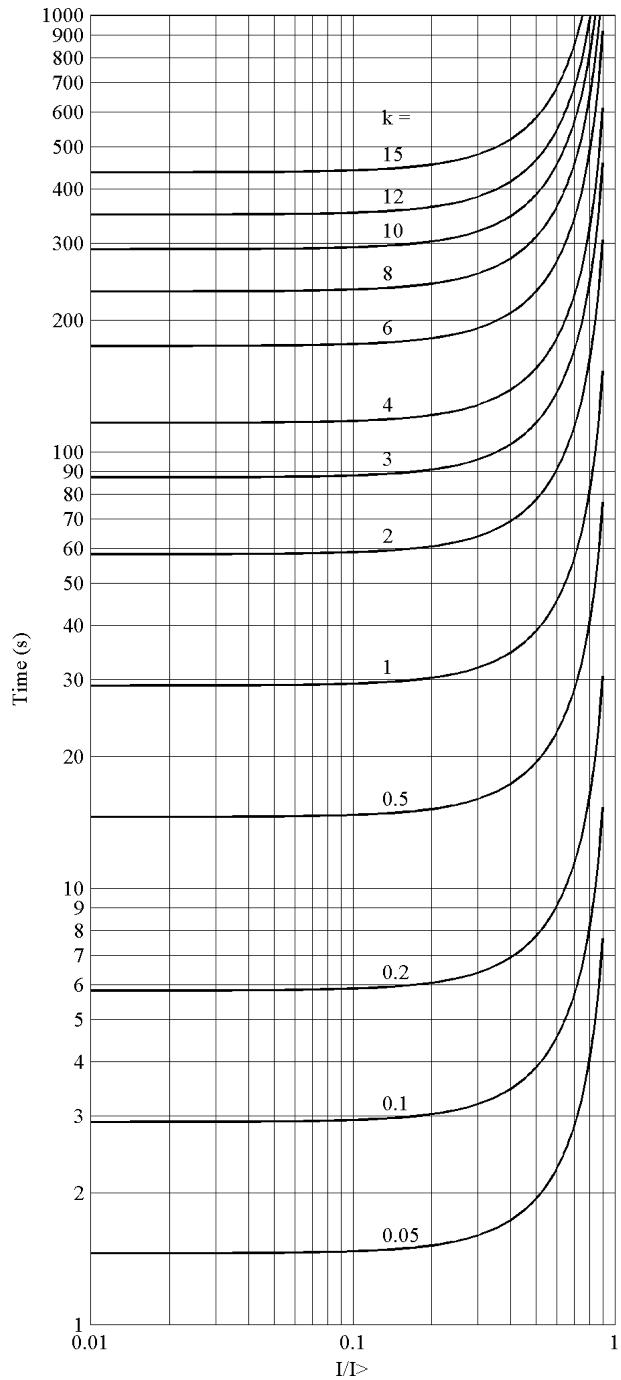


Figure 317: ANSI extremely inverse reset time characteristics

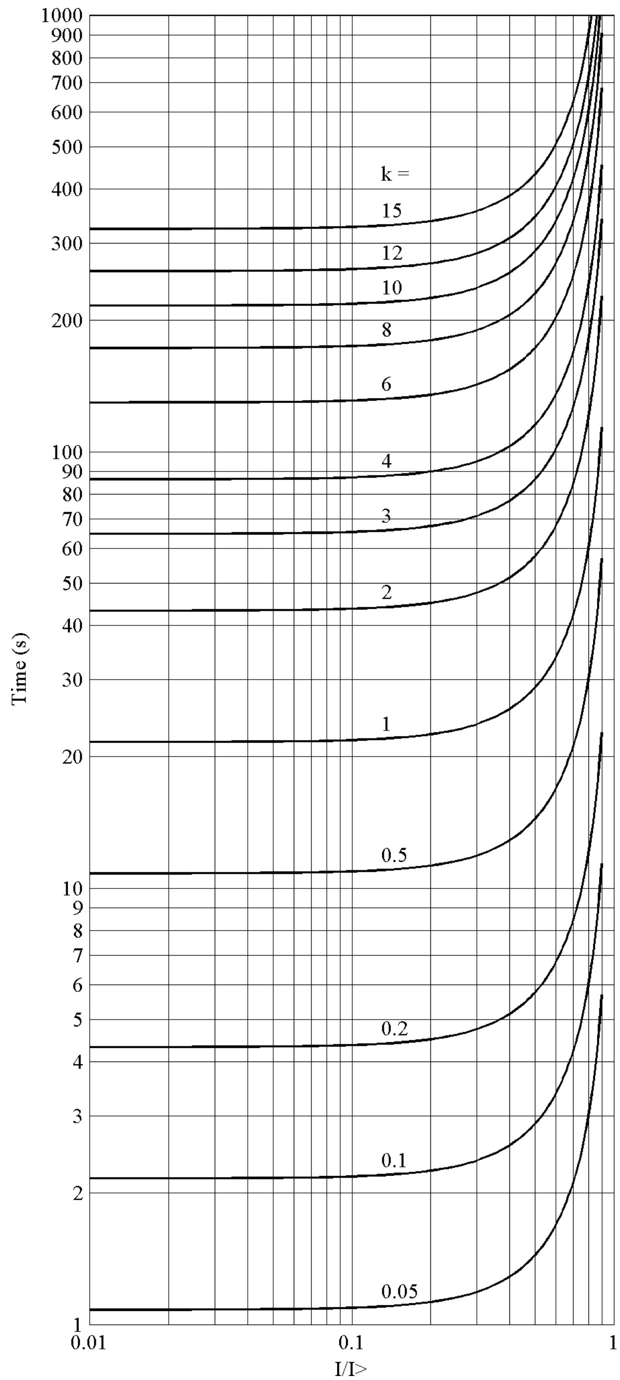


Figure 318: ANSI very inverse reset time characteristics

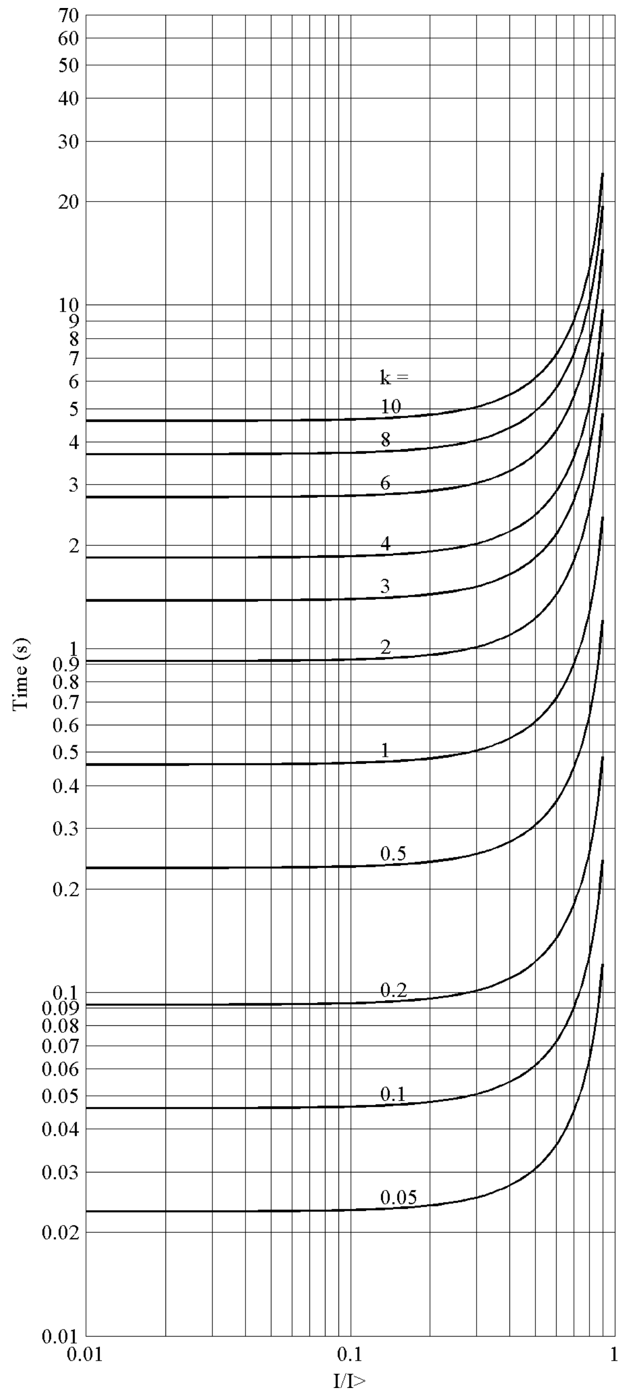


Figure 319: ANSI normal inverse reset time characteristics

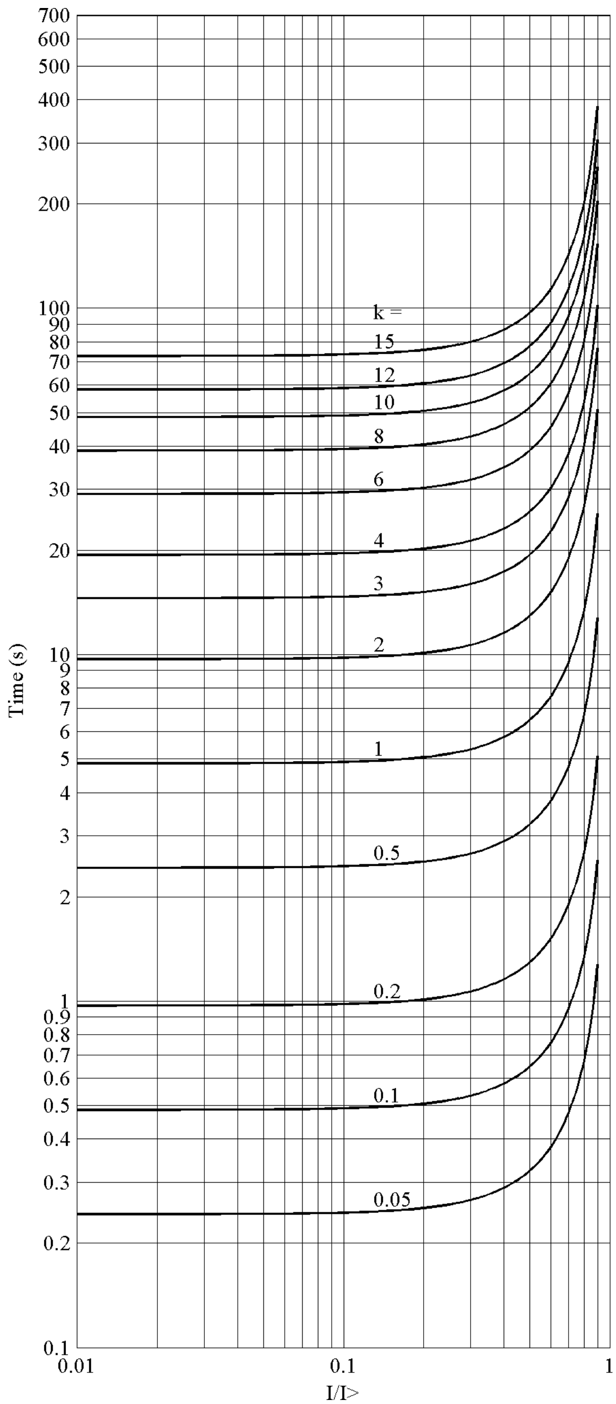


Figure 320: ANSI moderately inverse reset time characteristics

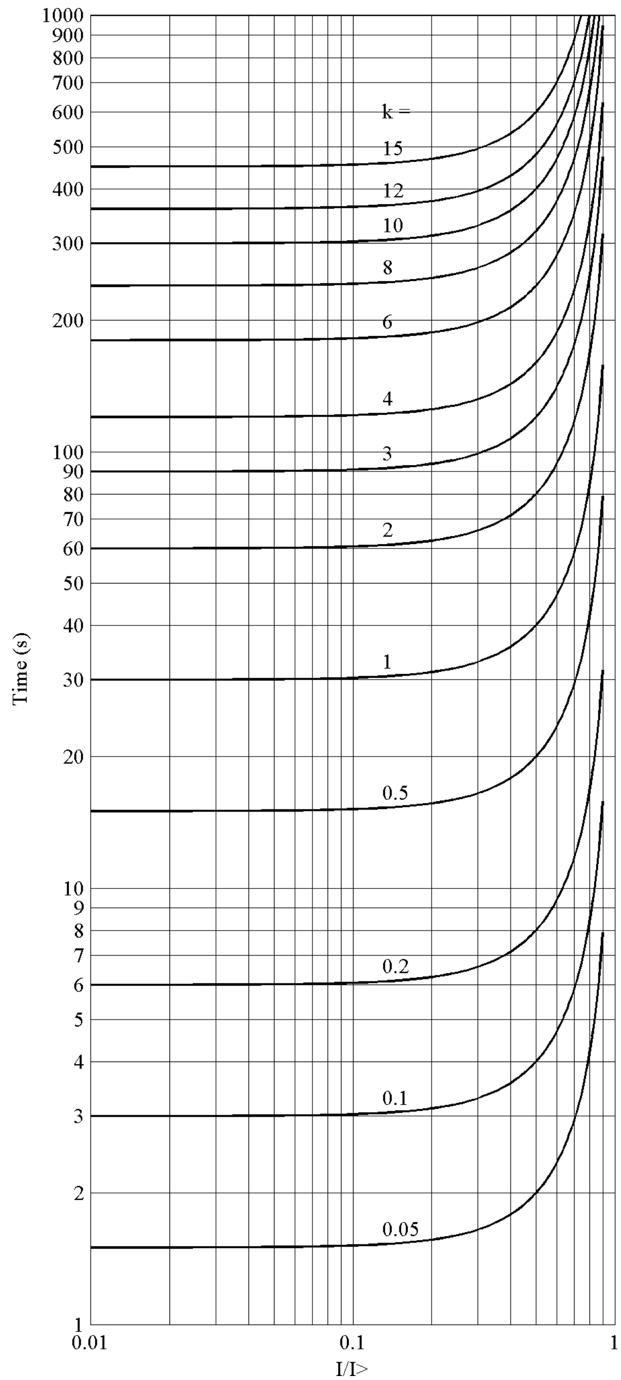


Figure 321: ANSI long-time extremely inverse reset time characteristics

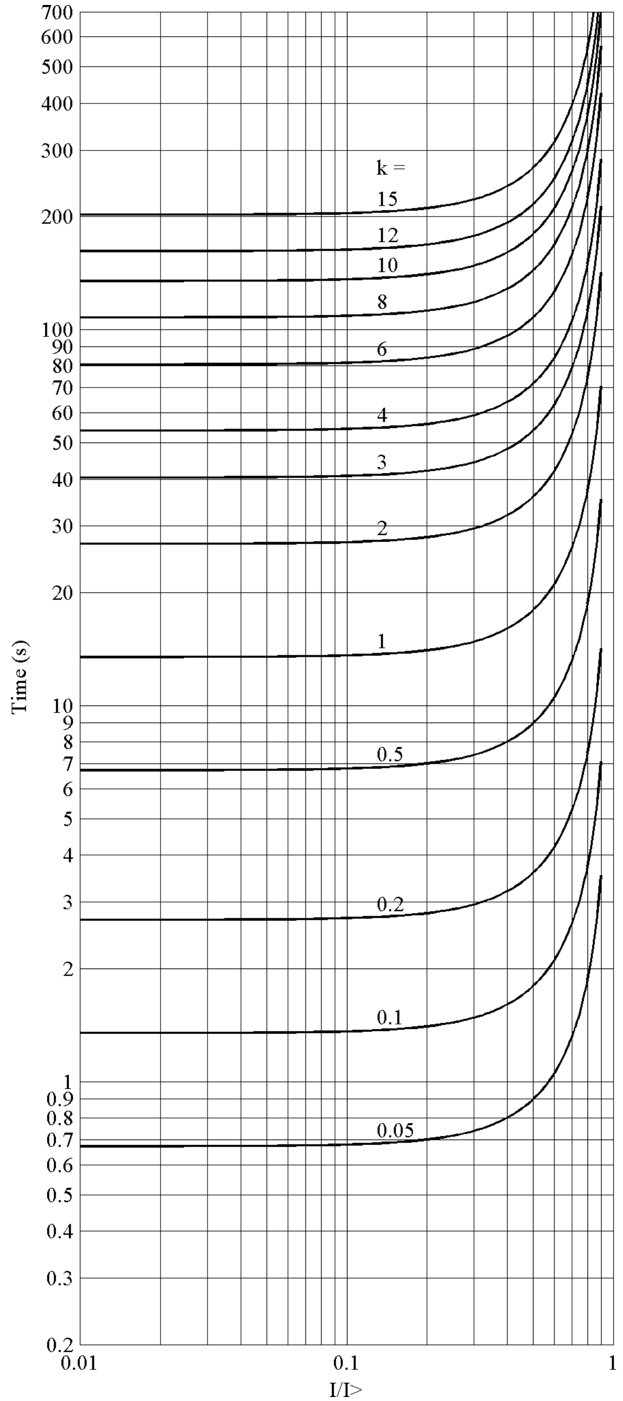


Figure 322: ANSI long-time very inverse reset time characteristics

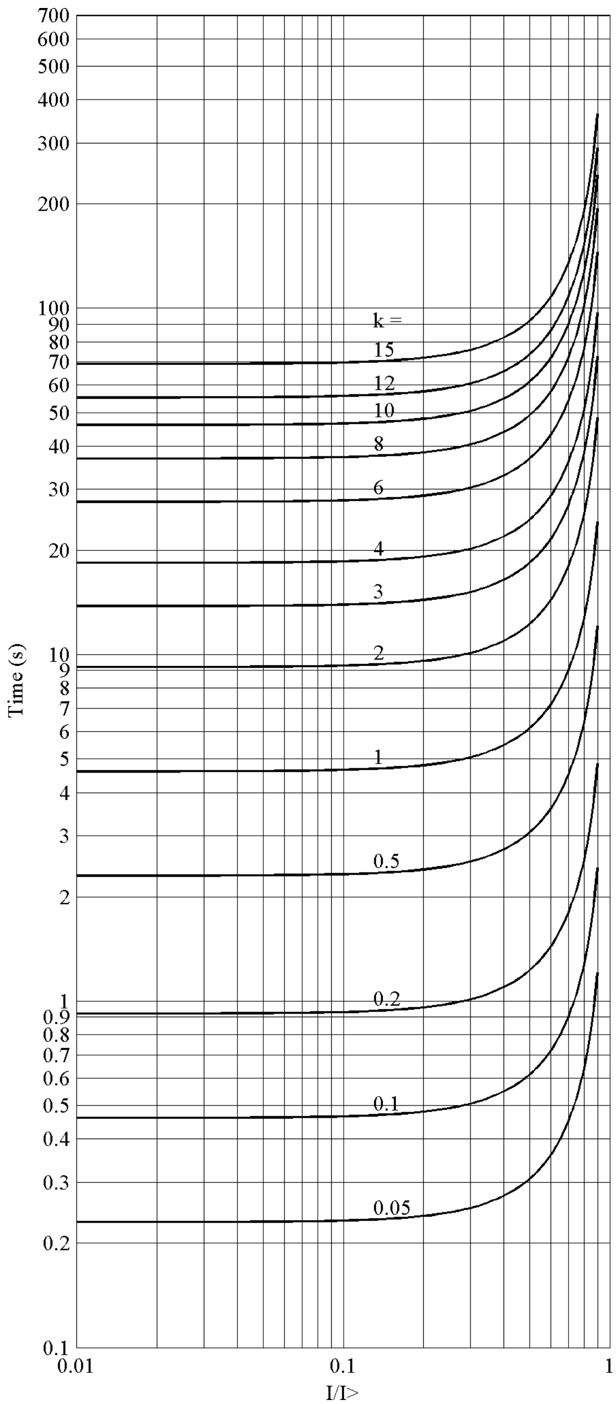


Figure 323: ANSI long-time inverse reset time characteristics

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 38)

t[s]	Reset time (in seconds)
k	set *Time multiplier*
D	set *Curve parameter D*
I	Measured current
I>	set *Pickup value*

12.2.3 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 a protection relay needs to be blocked to enable the definite-time operation of another protection relay 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.

12.3 Voltage based inverse definite minimum time characteristics

12.3.1 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:

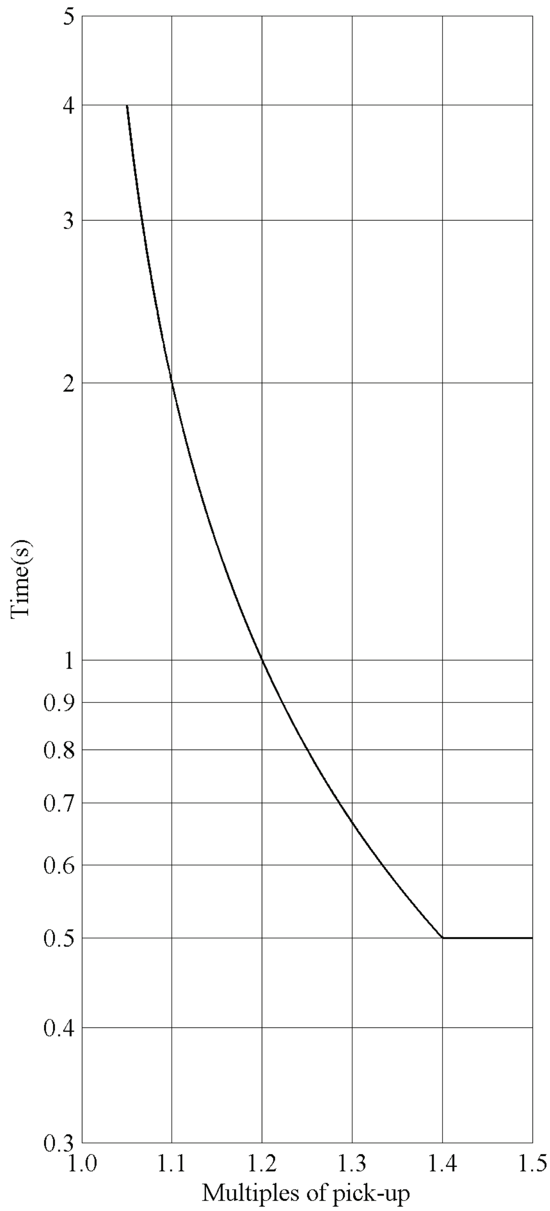


Figure 324: Trip time curve based on IDMT characteristic with Minimum trip time set to 0.5 second

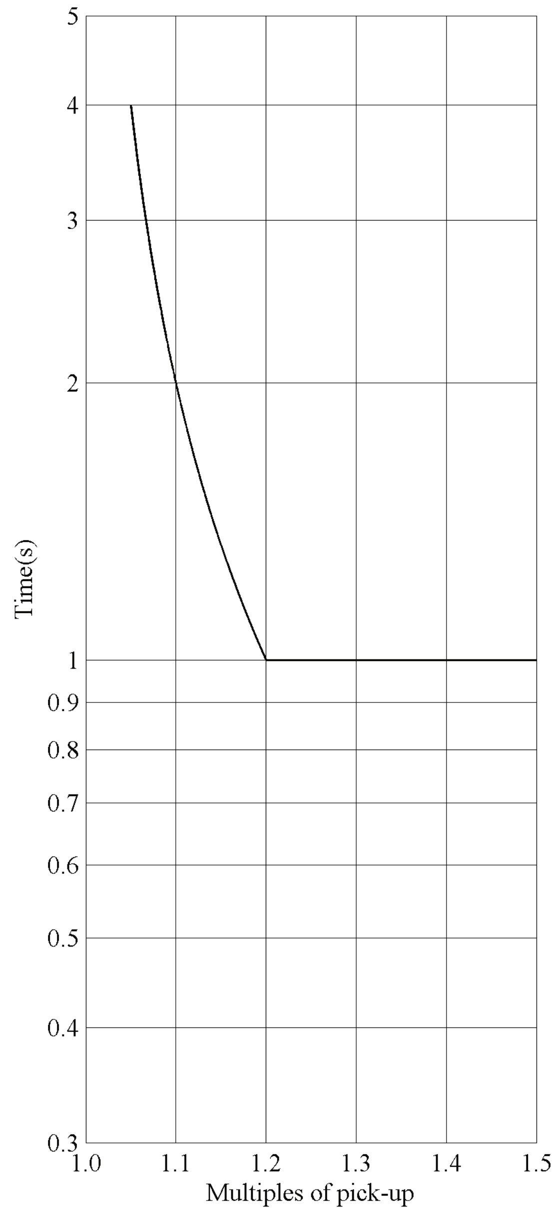


Figure 325: Trip time curve based on IDMT characteristic with Minimum trip time set to 1 second

12.3.1.1 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 39)

t [s] trip time in seconds

V measured voltage

V> the set value of *Pickup value*

k the set value of *Time multiplier*

Table 441: 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

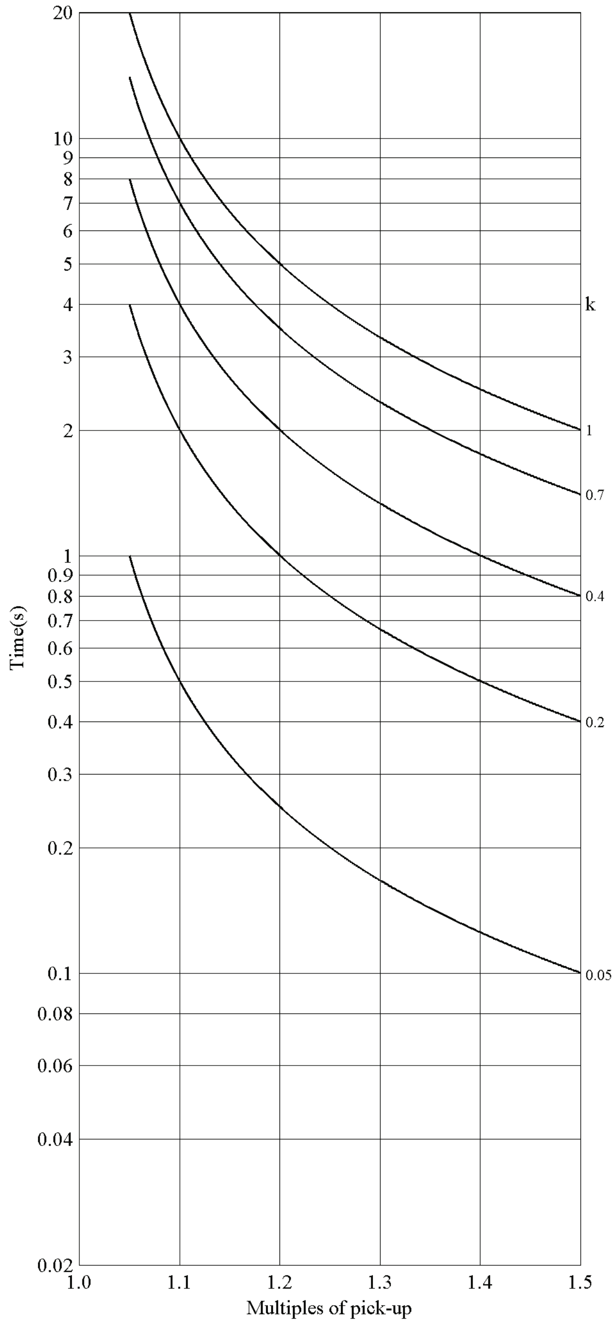


Figure 326: Inverse curve A characteristic of overvoltage protection

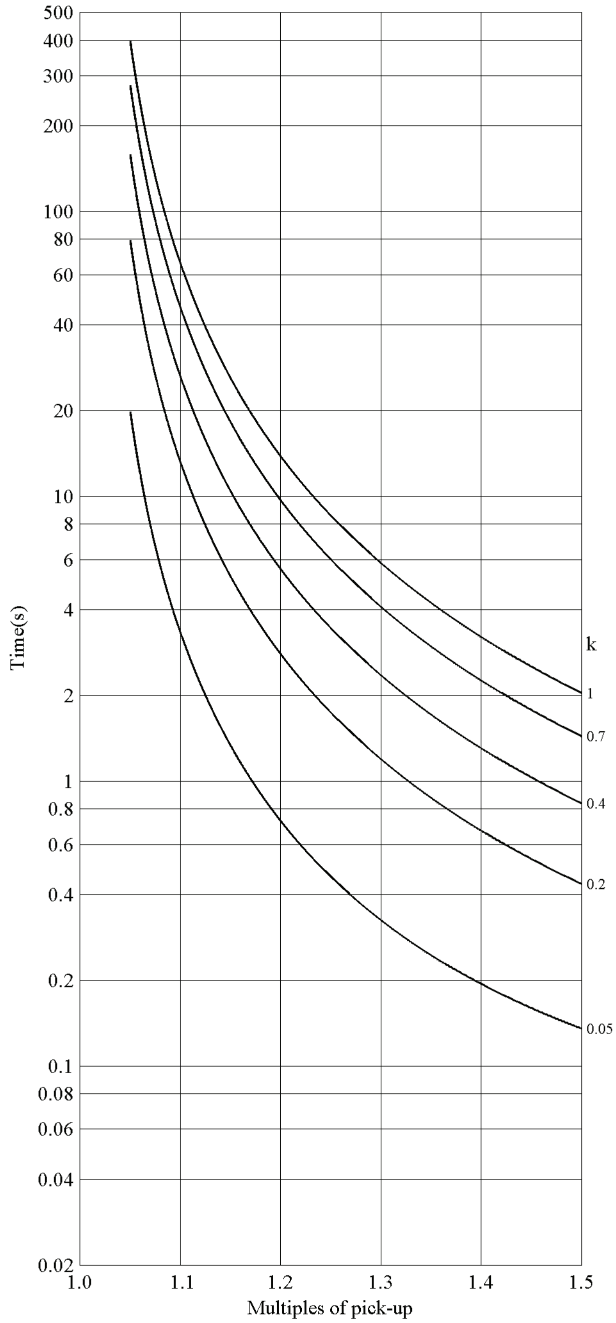


Figure 327: Inverse curve B characteristic of overvoltage protection

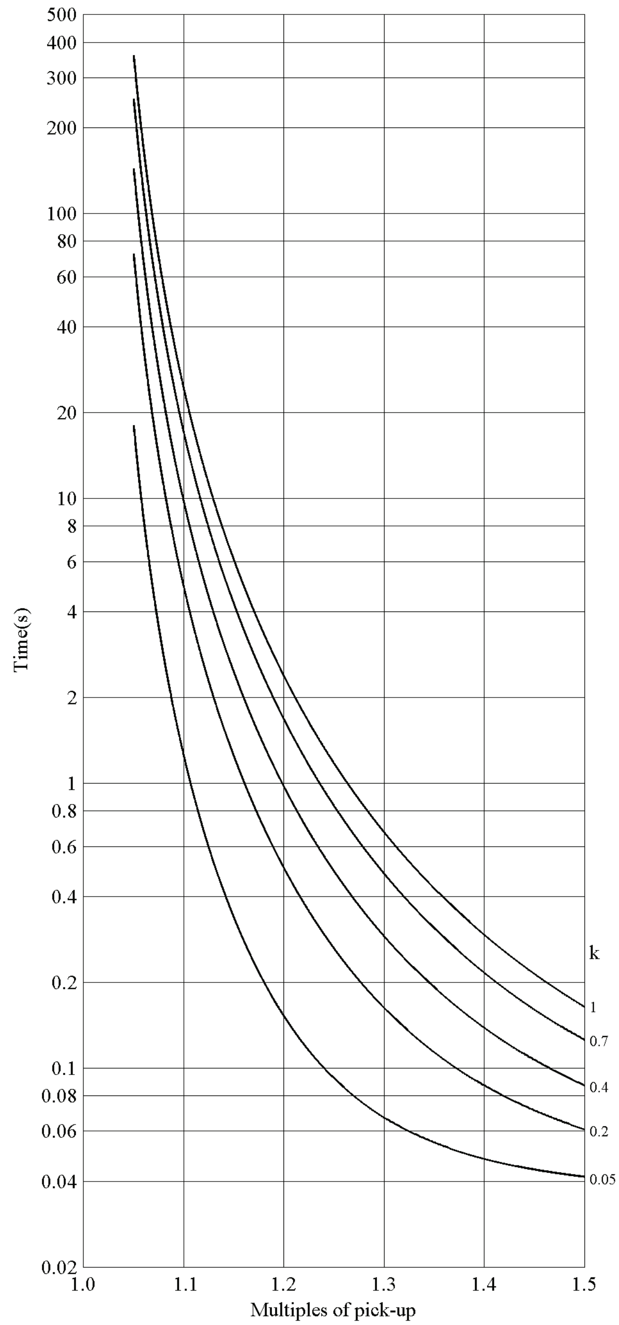


Figure 328: Inverse curve C characteristic of overvoltage protection

12.3.1.2 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 40)

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*

12.3.1.3 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.

12.3.2 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.

12.3.2.1 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 41)

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 442: 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

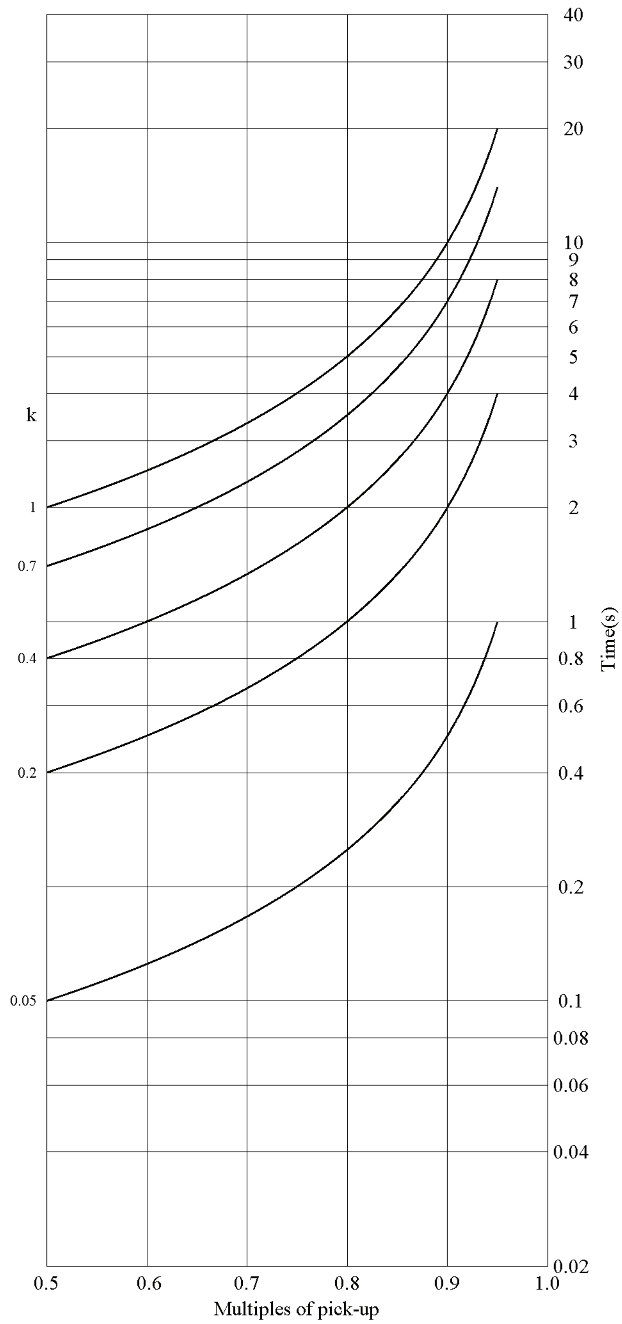


Figure 329: : Inverse curve A characteristic of undervoltage protection

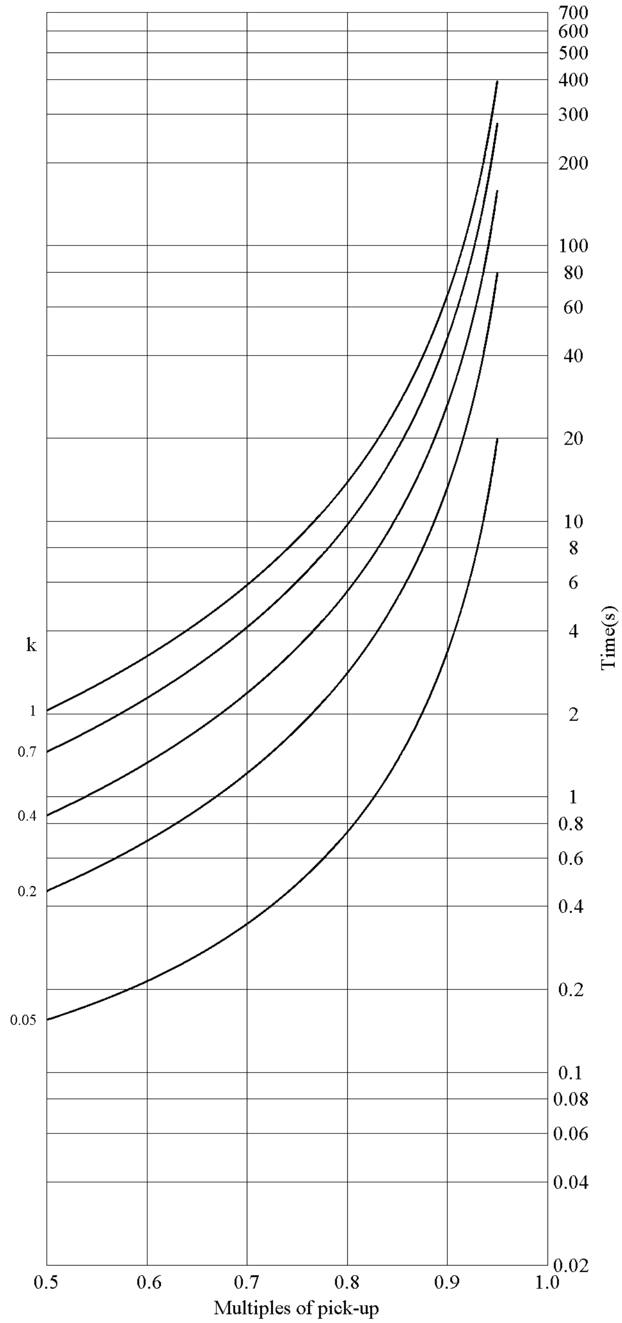


Figure 330: Inverse curve B characteristic of undervoltage protection

12.3.2.2 User-programmable inverse-time characteristics for undervoltage protection

The user can define curves by entering parameters into the standard formula:

$$t[s] = \frac{k \cdot A}{\left(B \times \frac{V< - V}{V<} - C \right)^{E}} + D$$

(Equation 42)

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*

12.3.2.3 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.

12.4 Frequency measurement and protection

All the function blocks that use frequency quantity as their input signal share the common features related to the frequency measurement algorithm. The frequency estimation is done from one phase (phase-to-phase or phase voltage) or from the positive phase sequence (PPS). The voltage groups with three-phase inputs use PPS as the source. The frequency measurement range is 0.6...1.5 × F_n. When the frequency exceeds these limits, it is regarded as out of range and a minimum or maximum value is held as the measured value respectively with appropriate quality information. The frequency estimation requires 160 ms to stabilize after a bad quality signal. Therefore, a delay of 160 ms is added to the transition from the bad quality. The bad quality of the signal can be due to restrictions like:

- The source voltage is below 0.02 × Vn at f_n.
- The source voltage waveform is discontinuous.
- The source voltage frequency rate of change exceeds 15 Hz/s (including stepwise frequency changes).

When the bad signal quality is obtained, the nominal frequency value is shown with appropriate quality information in the measurement view. The frequency protection functions are blocked when the quality is bad, thus the timers and the function outputs are reset. When the frequency is out of the function block's setting range but within the measurement range, the protection blocks are running. However, the `TRIP` outputs are blocked until the frequency restores to a valid range.

12.5 Measurement modes

In many current or voltage dependent function blocks, there are various 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 operation 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:

$$I_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_i^2}$$

(Equation 43)

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 protection relay 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.

12.6 Calculated measurements

Calculated residual current and voltage

The residual current is calculated from the phase currents according to equation:

$$\overline{Io} = -(\overline{I}_A + \overline{I}_B + \overline{I}_C)$$

(Equation 44)

The residual voltage is calculated from the phase-to-ground voltages when the VT connection is selected as “Wye” with the equation:

$$\overline{Vo} = (\overline{V}_A + \overline{V}_B + \overline{V}_C)$$

(Equation 45)

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 46)

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

(Equation 47)

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

(Equation 48)

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

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

(Equation 49)

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

(Equation 50)

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

(Equation 51)

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 equations:

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

(Equation 52)

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

(Equation 53)

The phase-to-ground voltages are calculated from the phase-to-phase voltages when *VT connection* is selected as "Delta" according to the equations.

$$\overline{V}_A = \overline{V}_0 + \left(\overline{V}_{AB} - \overline{V}_{CA}\right)/3$$

(Equation 54)

$$\overline{V}_B = \overline{V}_0 + \left(\overline{V}_{BC} - \overline{V}_{AB}\right)/3$$

(Equation 55)

$$\overline{V}_C = \overline{V}_0 + \left(\overline{V}_{CA} - \overline{V}_{BC}\right)/3$$

(Equation 56)

If the $\overline{V}o$ channel is not valid, it is assumed to be zero.

The phase-to-phase voltages are calculated from the phase-to-ground voltages when *VT connection* is selected as "Wye" according to the equations.

$$\overline{V}_{AB} = \overline{V}_A - \overline{V}_B$$

(Equation 57)

$$\overline{V}_{BC} = \overline{V}_B - \overline{V}_C$$

(Equation 58)

$$\overline{V}_{CA} = \overline{V}_C - \overline{V}_A$$

(Equation 59)

Section 13 Requirements for measurement transformers

13.1 Current transformers

13.1.1 Current transformer requirements for overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden. The protection settings of the protection relay should be defined in accordance with the CT performance as well as other factors.

For all ANSI applications, details are available in C37.110-2007, IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes with all other reference documents listed therein. The application manual of REF615R provides a brief introduction on CT requirements.

The following section provides basic inputs on CT requirements when CTs with IEC standards are specified.

13.1.1.1 Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (F_n) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection).

Table 443: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The 5P class provides a better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering, and so on) of the protection relay.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it might have severe effects on the performance of the protection relay.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

13.1.1.2 Non-directional overcurrent protection

The current transformer selection

Non-directional overcurrent protection does not set high requirements on the accuracy class or on the actual accuracy limit factor (F_a) of the CTs. It is, however, recommended to select a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the protection relay is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$,

I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the protection relay. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended pickup current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to trip, the pickup current should be set using the formula:

Current pickup value $< 0.7 \times (I_{kmin} / I_{1n})$

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection relay inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The trip time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a.

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the pickup current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed protection relay operation. To ensure the time selectivity, the delay must be taken into account when setting the trip times of successive protection relays.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time constant of the DC component of the fault current, when the current is only slightly higher than the pickup current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the trip time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the pickup current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

$F_a > 20 \times$ *Current pickup value* $/ I_{1n}$

The *Current pickup value* is the primary pickup current setting of the protection relay.

13.1.1.3 Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three-stage definite time non-directional overcurrent protection.

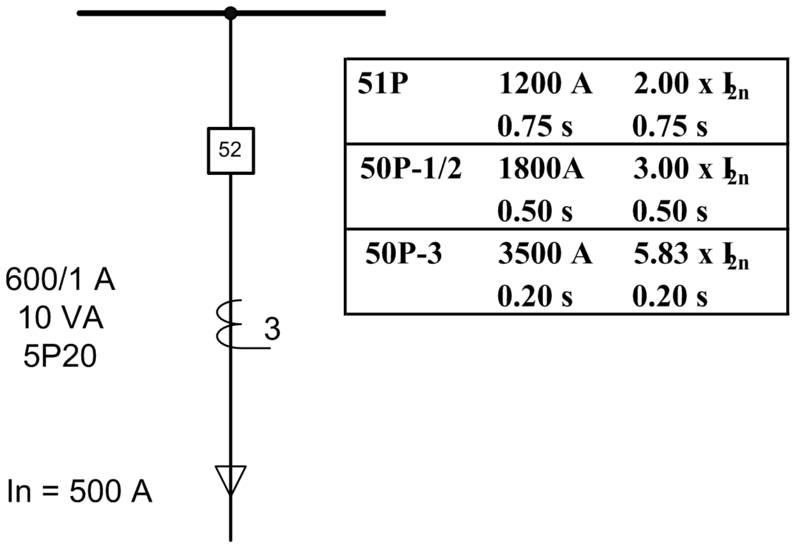


Figure 331: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next protection relay (not visible in Figure 331). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the pickup current settings have to be defined so that the protection relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in Figure 331.

For the application point of view, the suitable setting for instantaneous stage (50P-3) in this example is 3 500 A (5.83 × I_{2n}). I_{2n} is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 14 Protection relay's physical connections

14.1 Connections to the rear panel terminals

All external circuits are connected to the terminals on the rear panel of the protection relay.

- Each signal connector terminal is connected with one 14 or 16 Gauge wire. For CB trip circuit, 12 or 14 Gauge wire is used.
- Each ring-lug terminal for signal connector is connected with one of maximum 14 or 16 Gauge wire.
- Each ring-lug terminal for CTs/VTs is connected with one 12 Gauge wire.

14.2 Protective ground connections

The protective ground screw is located at the rear of the protection relay.

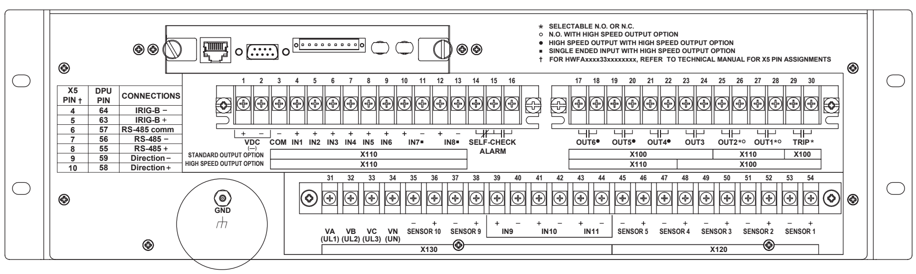


Figure 332: Protective ground screw

The ground lead must be at least a 10 Gauge wire. If the length of the ground lead is long, the cross section of the wire must be increased.

14.3 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

14.3.1 Ethernet RJ-45 front connection

The protection relay 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 the protection relay 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 protection relay 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.

14.3.2 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 (≤ 2 km) with LC type connections.

In addition, communication modules with multiple Ethernet connectors enable the forwarding of Ethernet traffic. The variants include an internal switch that handles the Ethernet traffic between a protection relay and a station bus. In this case, the used network can be a ring or daisy-chain type of network topology. In loop type topology, a self-healing Ethernet loop is closed by a managed switch supporting rapid spanning tree protocol. In daisy-chain type of topology, the network is bus type and it is either without switches, where the station bus starts from the station client, or with a switch to connect some devices and the REF615R protection relay chain to the same network.

Communication modules including Ethernet connectors X1, X2, and X3 can utilize the third port for connecting any other device (for example, an SNTP server, that is visible for the whole local subnet) to a station bus.

The protection relay's default IP address through this port is 192.168.2.10 with the TCP/IP protocol. The data transfer rate is 100 Mbps.

14.3.3 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.

14.3.4 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 protection relay is used is 32, and the maximum length of the bus is 1312 yards (1200 meters).

14.3.5 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.

14.3.6 Communication interfaces and protocols

The communication protocols supported depend on the optional rear communication module.

Table 444: Supported station communication interfaces and protocols

Interfaces/Protocols	Ethernet		Serial	
	100BASE-TX RJ-45	100BASE-FX LC	EIA-232/EIA-485	Fibre-optic ST
IEC 61850	●	●	-	-
MODBUS RTU/ ASCII	-	-	●	●
MODBUS TCP/IP	●	●	-	-
DNP3 (serial)	-	-	●	●
DNP3 TCP/IP	●	●	-	-
● = Supported				

14.3.7 Rear communication modules

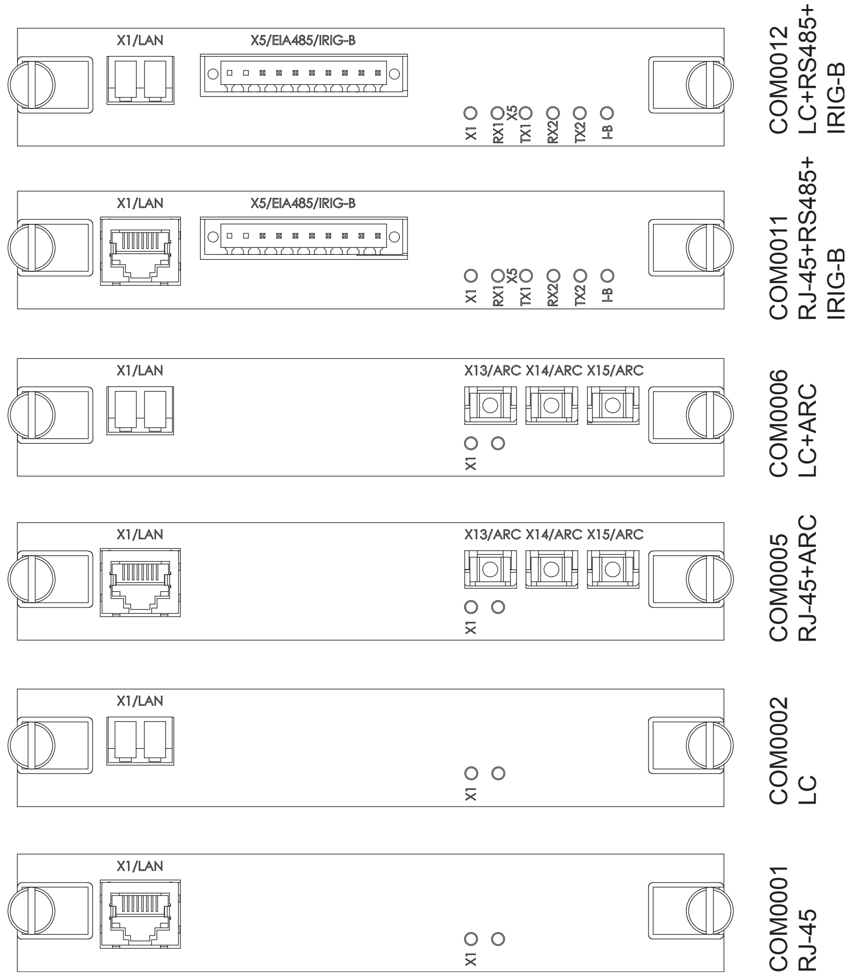


Figure 333: Communication module options COM0001…COM0012

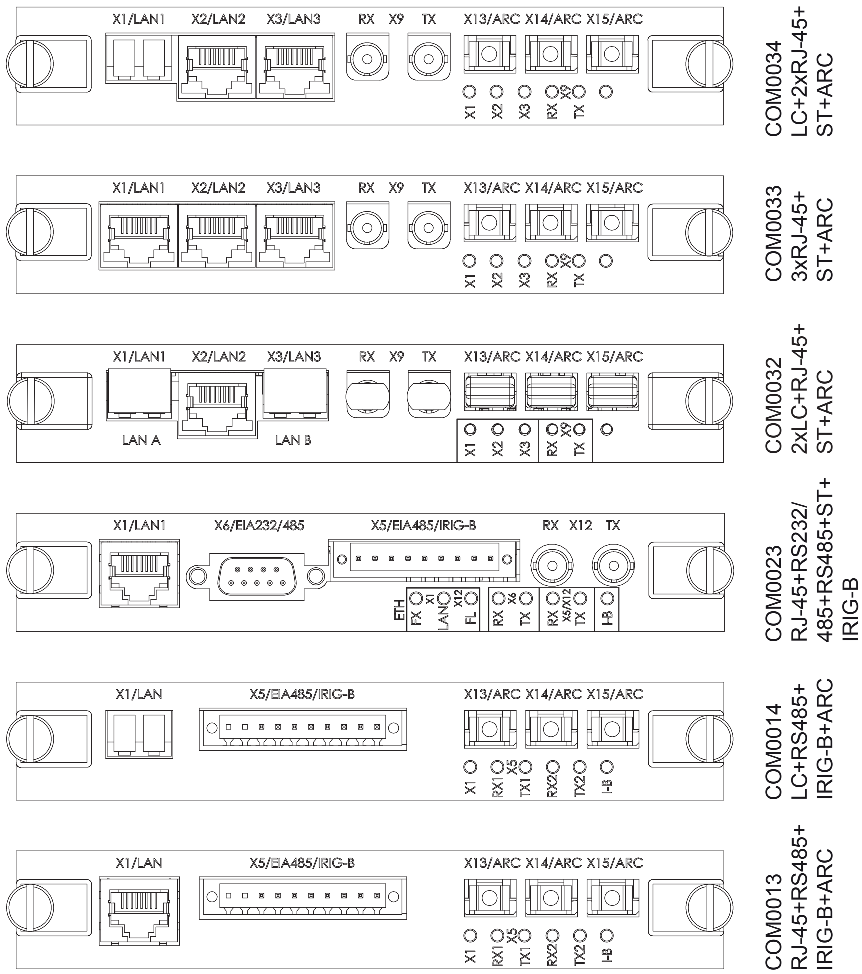


Figure 334: Communication module options COM00013…COM0034

Table 445: Station bus communication interfaces included in communication modules

Module ID	RJ-45	LC	EIA-485	EIA-232	ST
COM0001	1	-	-	-	-
COM0002	-	1	-	-	-
COM0005	1	-	-	-	-
COM0006	-	1	-	-	-
COM0011	1	-	1	-	-
COM0012	-	1	1	-	-
COM0013	1	-	1	-	-
COM0014	-	1	1	-	-
COM0023	1	-	1	1	1
Table continues on next page					

Module ID	RJ-45	LC	EIA-485	EIA-232	ST
COM0032	1	2	-	-	1
COM0033	3	-	-	-	1
COM0034	2	1	-	-	1

Table 446: LED descriptions for COM0001-COM0014

LED	Connector	Description1)
LAN	X1	LAN link status and activity (RJ-45 and LC)
RX1	X2	COM2 2-wire/4-wire receive activity
TX1	X3	COM2 2-wire/4-wire transmit activity
RX2	X4	COM1 2-wire receive activity
TX2	X5	COM1 2-wire transmit activity
I-B	X6	IRIG-B signal activity

1) Depending on the COM module and jumper configuration

Table 447: LED descriptions for COM0023

LED	Connector	Description1)
FX	X12	Not used by COM23A
LAN	X1	LAN Link status and activity (RJ-45 and LC)
FL	X12	Not used by COM23A
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 fibre-optic receive activity
TX	X5 / X12	COM2 2-wire / 4-wire or fibre-optic transmit activity
I-B	X5	IRIG-B Signal activity

1) Depending on the jumper configuration

Table 448: LED descriptions for COM0032, 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

14.3.7.1 COM0001-COM0014 jumper locations and connections

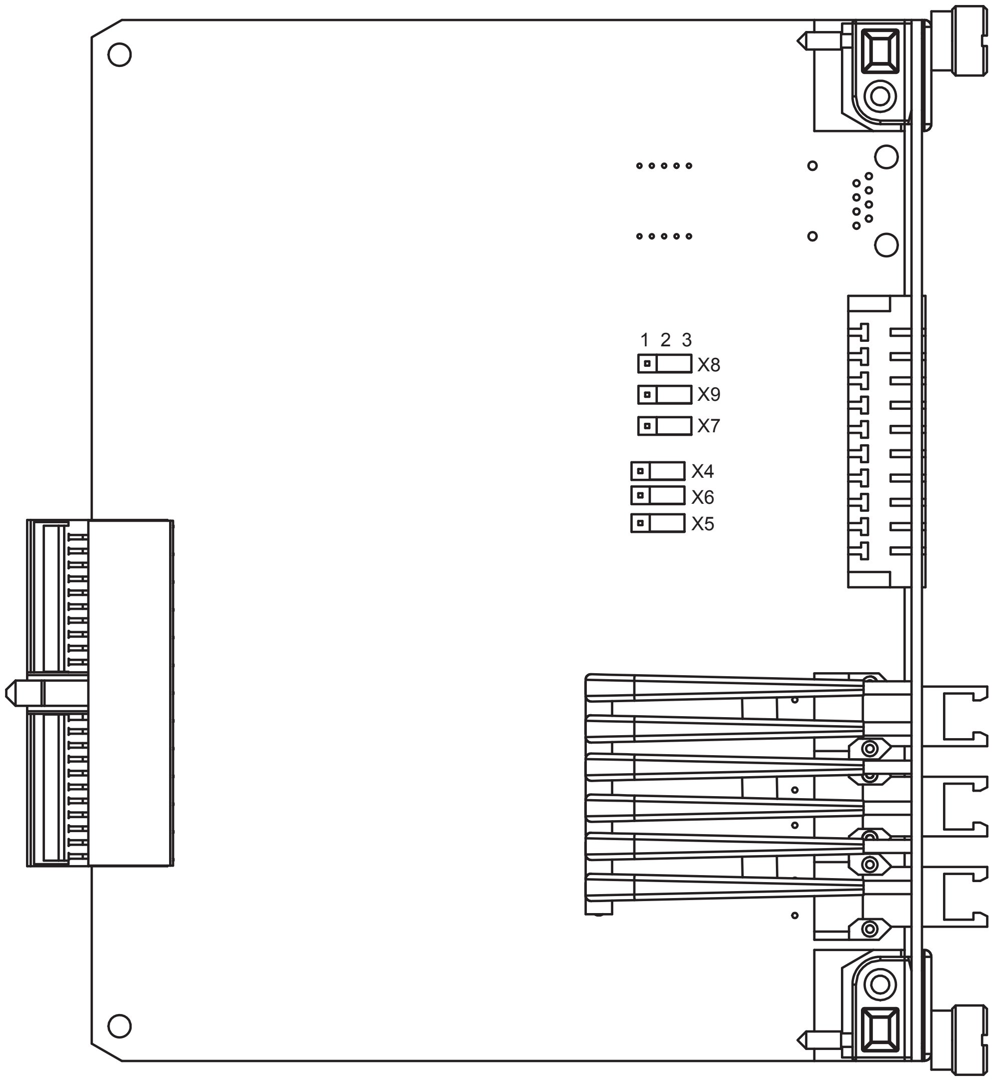


Figure 335: Jumper connectors on communication module

Table 449: 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 450: 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[1)]	
X6	1-2	Bus termination enabled	
	2-3	Bus termination disabled[1)]	
X7	1-2	B- bias enabled	COM2 4-wire RX channel
	2-3	B- bias disabled[1)]	
X8	1-2	A+ bias enabled	
	2-3	A+ bias disabled[1)]	
X9	1-2	Bus termination enabled	
	2-3	Bus termination disabled[1)]	

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 fiber-optic ST connection uses the COM1 port.

Table 451: EIA-485 connections for COM0001-COM0014

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)			

14.3.7.2 COM0023 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 called 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 452: 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)

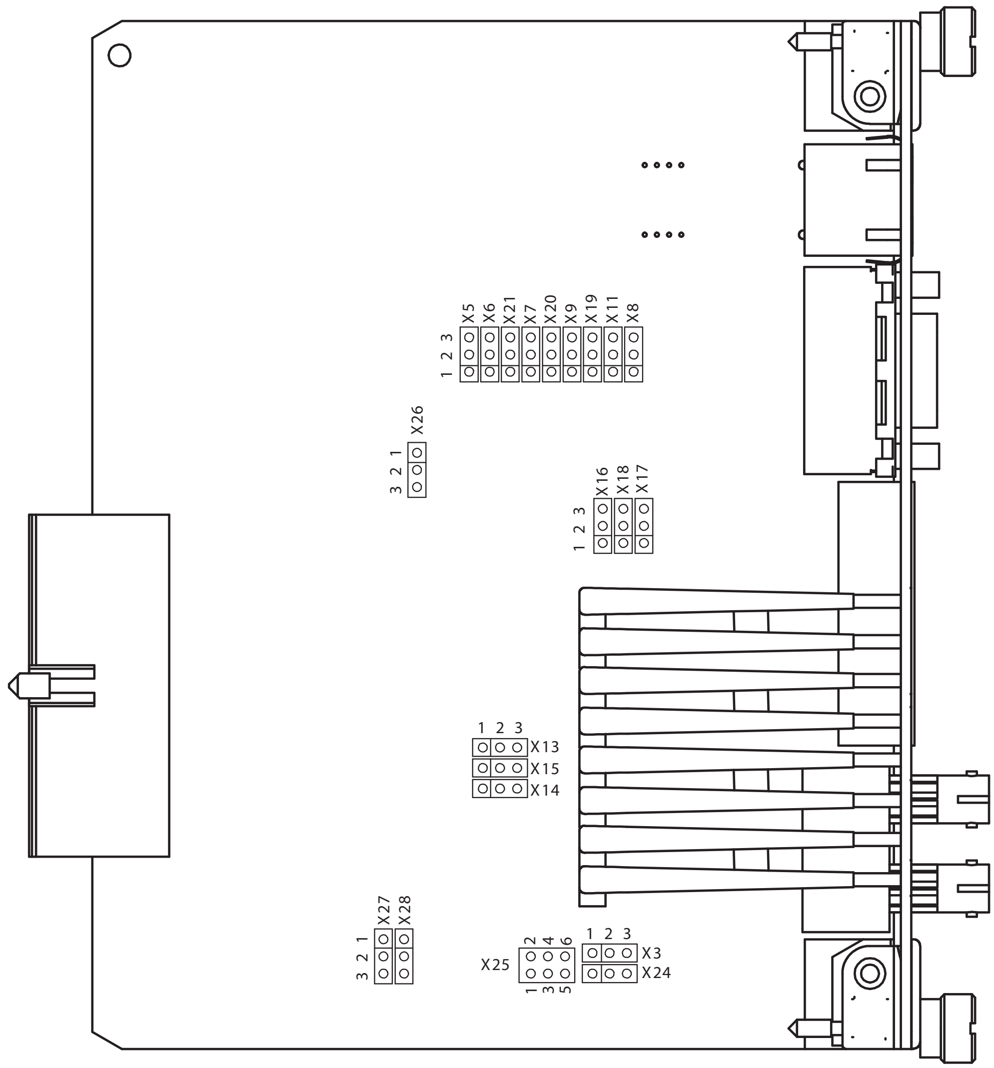


Figure 336: Jumper connections on communication module COM0023

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 453: 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 the enabled position. The bus termination is selected by setting jumpers X7, X11 to the enabled position.

The jumpers have been set to no termination and no biasing as default.

Table 454: 2-wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1–2 2–3	A+ bias enabled A+ bias disabled1)	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 455: 4–wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1–2 2–3	A+ bias enabled A+ bias disabled1)	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	

Table continues on next page

Group	Jumper connection	Description	Notes
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 456: 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 457: 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 458: 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	
X16	1–2 2–3	B- bias enabled B- bias disabled	4-wire RX channel
X17	1–2 2–3	A+ bias enabled A+ bias disabled	
X18	1–2 2–3	Bus termination enabled Bus termination disabled	

Table 459: 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 460: EIA-232 connections for COM0023 (X6)

Pin	EIA-232
1	DCD
2	RxD
3	TxD
4	DTR
5	AGND
6	-
7	RTS
8	CTS

Table 461: EIA-485 connections for COM0023 (X6)

Pin	2-wire mode	4-wire mode
1	-	Rx/+
6	-	Rx/-
7	B/-	Tx/-
8	A/+	Tx/+

Table 462: EIA-485 connections for COM0023 (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)	

14.3.7.3 COM0032-COM0034 jumper locations and connections

The optional communication modules include support for optical ST serial communication (X9 connector). The fibre-optic ST connection uses the COM1 port.

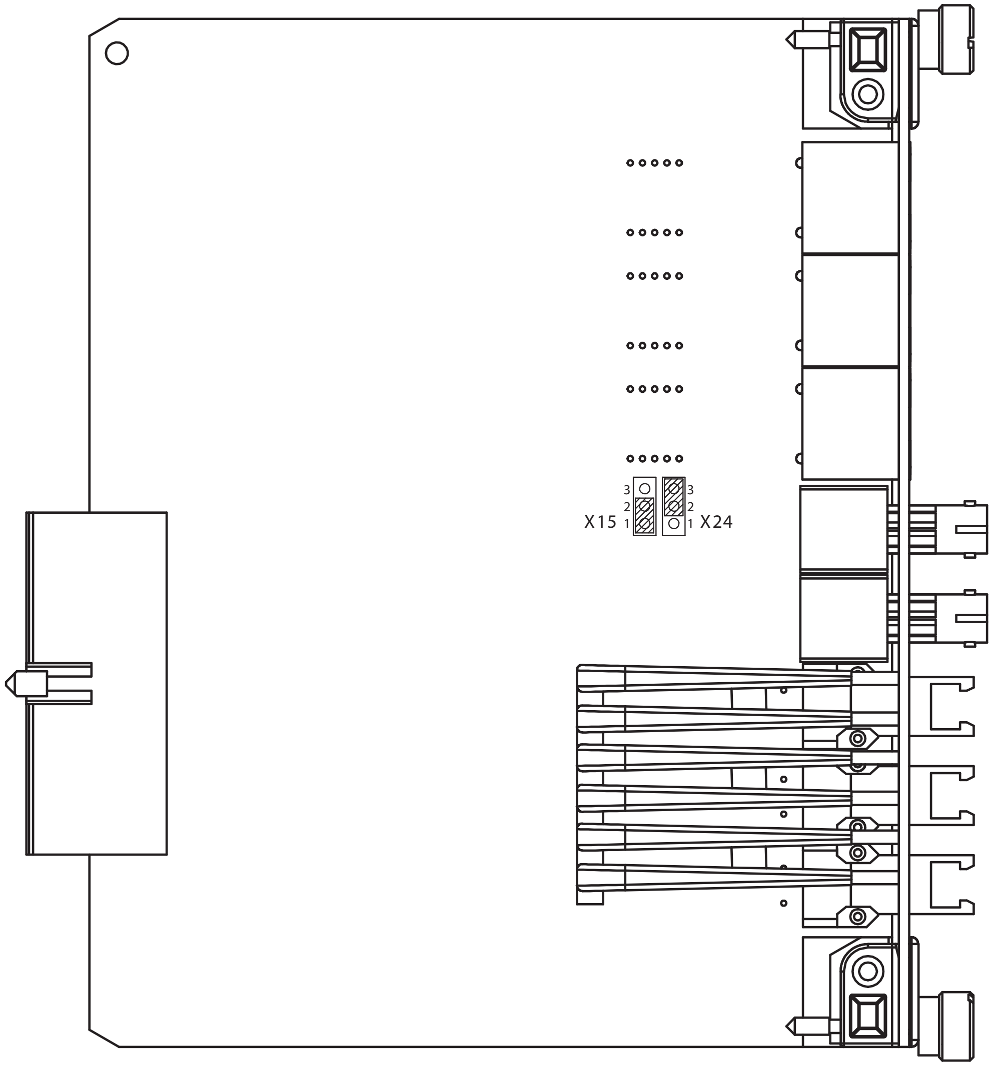


Figure 337: Jumper connections on communication module COM0033

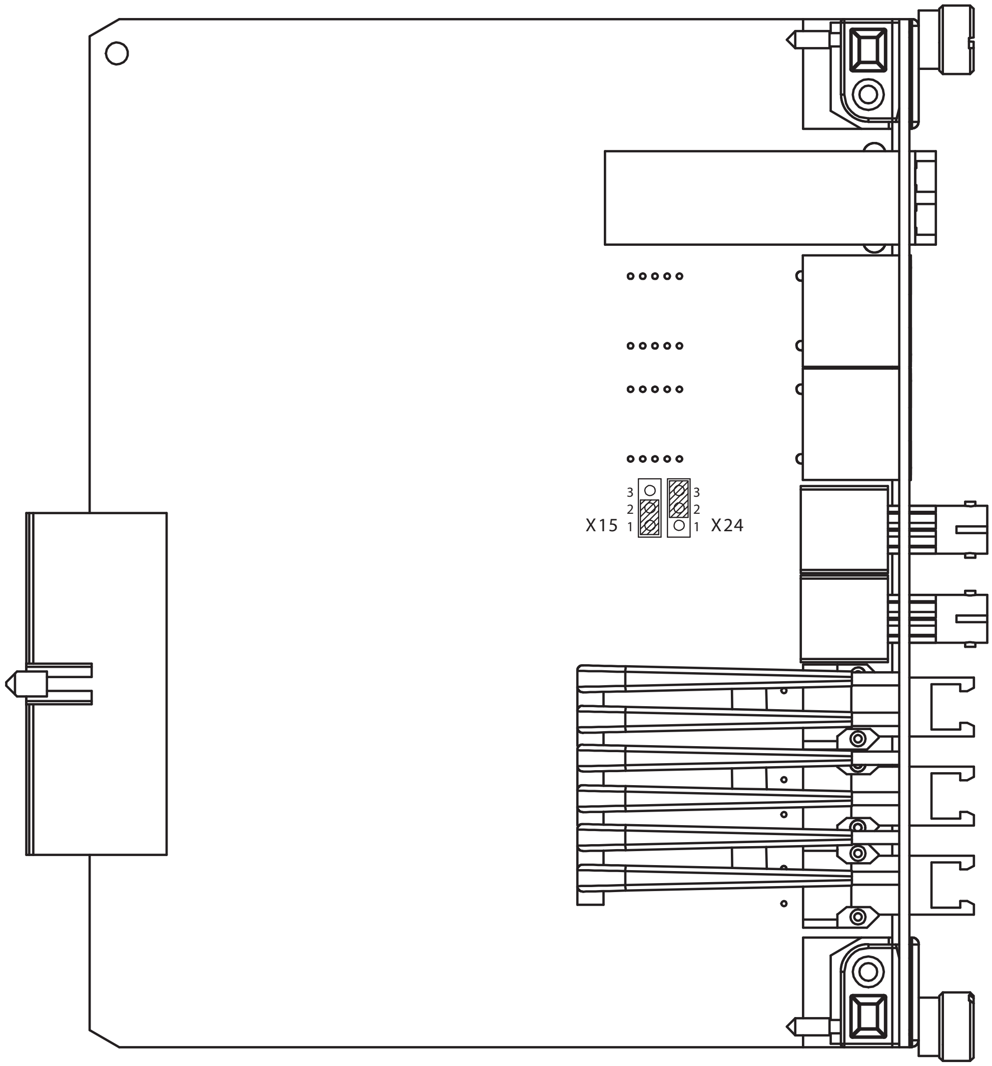


Figure 338: Jumper connections on communication module COM0034

Table 463: X9 Optical ST jumper connectors

Group	Jumper connection	Description
X15	1-2 2-3	Star topology Loop topology
X24	1-2 2-3	Idle state = Light on Idle state = Light off

Section 15 Technical data

Table 464: Dimensions

Description	Value	
Width	With mounting ears	19 in. (482.6 mm)
	Without mounting ears	17.12 in. (434.8 mm)
Height		5.22 in. (132.6 mm)
Depth		9.08 in. (230.7 mm)
Weight	Complete protection relay	11.9 lb (5.4 kg)
	Plug-in unit (inner chassis) only	5.1 lb (2.31 kg)

Table 465: 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 protection relay	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 <15 W (nominal)/ <20 W (max) and AC <17 W (nominal)/ <22 W (max)	DC <15 W (nominal)/ <20 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 466: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz	
Current inputs	Rated current, I_n	0.2/1 A[1)]	1/5 A[2)]
	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	 240 V AC 360 V AC	
	Burden at rated voltage	< 0.05 VA	

1) Ordering option for ground current input
2) Ground current and/or phase current

Table 467: 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 468: Trip outputs (TO)

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	15 A
Table continues on next page	

Description	Value
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R <40 ms at 48V/110V/220V	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 469: 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 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 470: Trip output HSTO

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	1 ms
Dropout	20 ms, resistive load

Table 471: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front	TCP/IP	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s
Rear	TCP/IP	Shielded twisted pair CAT 5e cable with RJ-45 connector or fiber-optic cable with LC connector	100 MBits/s

Table 472: Serial rear interface

Type	Counter connector
Serial port (X5)	10-pin counter connector Weidmüller BL 3.5/10/180F AU OR BEDR or 9-pin counter connector Weidmüller BL 3.5/9/180F AU OR BEDR[1)]
Serial port (X16)	9-pin D-sub connector DE-9
Serial port (X12)	Optical ST-connector

1) Depending on the optional communication module

Table 473: Fibre-optic communication link

Connector	Fibre type	Wave length	Max. distance	Permitted path attenuation[1)]
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 474: IRIG-B

Description	Value
IRIG time code format	B004,B005[1)]
Isolation	500 V, 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 475: Lens sensor and optical fibre for arc flash detector

Description	Value
Fibre-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 fibre	3.94 inches (100 mm)

Table 476: Measuring range

Description	Value
Measured currents on phases IA, IB and IC as multiples of the rated currents of the analog inputs	0...50 × 1_n
Graound current as a multiple of the rated current of the analog input	0...50 × 1_n

Table 477: Degree of protection of flush-mounted protection relay

Description	Value
Front side (with dust cover accessory)	IP 54

Table 478: Environmental conditions

Description	Value
Continuous operating temperature range	-25ºC...+55ºC
Short-term operating temperature range	-40ºC...+85ºC (< 16h)[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	-40ºC...+85ºC

1) Degradation in MTBF and LHMI performance outside the temperature range of -25ºC to +55ºC.
2) For protection relays with an LC communication interface, the maximum operating temperature is +70ºC.

Section 16 Protection relay and functionality tests

Table 479: Electromagnetic compatibility tests

Description	Requirement	Reference
1 MHz/100 kHz burst disturbance test, all ports • Differential mode • Common mode	 ±2.5 kV ±2.5 kV	IEC60255-22-1, Class III IEC61000-4-18 IEEE37.90.1-2002
3 MHz/10 MHz/30 MHz burst disturbance test, all ports • Common mode	 ±2.5 kV	IEC61000-4-18, Level 3
Fast transient disturbance test, all ports • Common mode/differential mode	 ±4 kV	IEC60255-22-4, Class A IEC61000-4-4 IEEE37.90.1-2002
Radio frequency interference tests	10 V/m (prior to modulation) f = 80...2700 MHz (sweep and keying test)	IEC60255-22-3 IEC61000-4-3
	20 V/m (prior to modulation) f = 80...1000 MHz (sweep and keying test)	IEEE C37.90.2-2004
Electrostatic discharge test • Contact discharge • Air discharge	 ±8 kV ±15 kV	IEC60255-22-2 IEC61000-4-2, Class 4 IEEE C37.90.3-2001
Surge immunity test • Communication • Other ports	 1 kV, line-to-earth 4 kV, line-to-earth 2 kV, line-to-line	IEC 61000-4-5 IEC 60255-22-5
Power frequency magnetic field	300 A/m, >300 s 1000 A/m, 3 s	IEC 61000-4-8
Voltage dips and short interruptions	30%/10 ms 60%/100 ms 60%/1000 ms >95%/5000 ms	IEC 61000-4-11
Power frequency immunity test, binary inputs	150 V_{rms}, differential mode 300 V_{rms}, common mode	IEC 61000-4-16 IEC 60255-22-7, class A

Table continues on next page

Description	Requirement	Reference
Emission tests • Conducted • Radiated	 0.15…0.50 MHz • <79 dB (µV) quasi peak • <66 dB (µV) average 0.5…30 MHz • <73 dB (µV) quasi peak • <60 dB (µV) average 30…230 MHz • <40 dB (µV/m) quasi peak, measured at a distance of 10 m 230…1000 MHz • <47 dB (µV/m) quasi peak, measure at a distance of 10 m	IEC 60255-25 EN 55011, class A
Pulse magnetic field immunity test	100 A/m (test level) 6.4 / 16µs (pulse waveform)	IEC 61000-4-9
Damped oscillatory magnetic field immunity test	400 transients/s at 1 MHz (repetition rate) 100 A/m for 2 s	IEC 61000-4-10

Table 480: Mechanical tests

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 protection relay setting controls	IEEE C37.90-2005

Table 481: Insulation tests

Description	Requirement	Reference
Dielectric tests	2.8 kV DC, 1 min 700 V, DC, 1 min for signal circuit and communication	IEEE C37.90-2005
	2 kV AC 50 Hz, 1 min 500 V AC 50 Hz, 1 min for communication	IEC 60255-5
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J	IEEE C37.90-2005
Insulation resistance measurement	>100 MΩ, 500 V_{DC}	IEC 60255-5
Protective bonding resistance	<0.1 Ω, 4 A, 60 s	IEC 60255-27

Table 482: Environmental tests

Description	Requirement	Reference
Damp heat test	+55°C, Rh = 95%, 96 h	IEEE C37.90-2005
	6 test cycles (12 h + 12 h), +25… +55°C, Rh = 95% 1)	IEC 60068-2-30
Dry heat test	+85°C 12h 2)3)4)	IEEE C37.90-2005
	+85°C 16 h 3)4) +55°C 96h	IEC 60068-2-2
Dry cold test	-40°C 12 h 2)3)	IEEE C37.90-2005
	-40°C 16 h 3) -25°C 96 h	IEC 60068-2-1
Storage temperature test	+85°C 96 h, -40°C 96 h	IEEE C37.90-2005 IEC 60068-2-1,-2
Change temperature test	5 test cycles (3 h + 3 h) at -25°C and +55°C 5)	IEC 60068-2-14

1) The auxiliary voltage was disconnected during the first 5 cycles of the test. The auxiliary voltage was switched on during the sixth cycle when the temperature was +55°C and the humidity 95% Rh.
2) Protection relay was soaked unpowered for 12 hours and then checked for functionality.
3) LCD may be unreadable, but the protection relay is still operational.
4) For protection relays with an LC communication interface, the maximum operating temperature is +70°C.
5) Protection relay was energized.

Section 17 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

Section 18 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium 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
AC	Alternating current
ACT	1. Application Configuration tool in PCM600 2. Trip status in IEC 61850
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
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
CPU	Central processing unit
CT	Current transformer
CTS	Clear to send
DC	1. Direct current 2. Disconnector 3. Double command
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.

DPU2000R	ABB's Distribution Protection Unit 2000R, an advanced microprocessor-based relay that protects electrical power subtransmission and distribution systems
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
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FPGA	Field-programmable gate array
GND	Ground/earth
GOOSE	Generic Object-Oriented Substation Event
GPS	Global Positioning System
HMI	Human-machine interface
IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IEC 61850	International standard for substation communication and modeling
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.
IRF	1. Internal fault 2. Internal relay fault
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
NC	Normally closed
NO	Normally open
PC	1. Personal computer 2. Polycarbonate
PCM600	Protection and Control IED Manager
Peak-to-peak	1. The amplitude of a waveform between its maximum positive value and its maximum negative value 2. 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
PLC	Programmable logic controller
PPS	Pulse per second
RAM	Random access memory
RCA	Also known as MTA or base angle. Characteristic angle.
REF615R	Wire-alike replacement option for DPU2000R with the same form factor
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
ROM	Read-only memory
RSTP	Rapid spanning tree protocol
RTC	Real-time clock

RTS	Ready to send
SBO	Select-before-operate
SCL	XML-based substation description configuration language defined by IEC 61850
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SMT	Signal Matrix tool in PCM600
SNTP	Simple Network Time Protocol
SOTF	Switch onto fault
ST	Connector type for glass fiber cable
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TO	Time-out
UL	Underwriters Laboratories
UTC	Coordinated universal time
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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