RELION® PROTECTION AND CONTROL

611 series

Technical Manual

Document ID: 1MRS757454
Issued: 2019-04-10
Revision: D
Product version: 2.0

Copyright

Trademarks

Warranty

Please inquire about the terms of warranty from your nearest ABB representative.

www.abb.com/relion

Disclaimer

The data, examples and diagrams in this manual are included solely for the concept or product description and are not to be deemed as a statement of guaranteed properties. All persons responsible for applying the equipment addressed in this manual must satisfy themselves that each intended application is suitable and acceptable, including that any applicable safety or other operational requirements are complied with. In particular, any risks in applications where a system failure and/or product failure would create a risk for harm to property or persons (including but not limited to personal injuries or death) shall be the sole responsibility of the person or entity applying the equipment, and those so responsible are hereby requested to ensure that all measures are taken to exclude or mitigate such risks.

This product has been designed to be connected and communicate data and information via a network interface which should be connected to a secure network. It is the sole responsibility of the person or entity responsible for network administration to ensure a secure connection to the network and to take the necessary measures (such as, but not limited to, installation of firewalls, application of authentication measures, encryption of data, installation of anti virus programs, etc.) to protect the product and the network, its system and interface included, against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB is not liable for any such damages and/or losses.

This document has been carefully checked by ABB but deviations cannot be completely ruled out. In case any errors are detected, the reader is kindly requested to notify the manufacturer. Other than under explicit contractual commitments, in no event shall ABB be responsible or liable for any loss or damage resulting from the use of this manual or the application of the equipment.

Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2014/30/EU) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2014/35/EU). This conformity is the result of tests conducted by ABB in accordance with the product standard EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

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

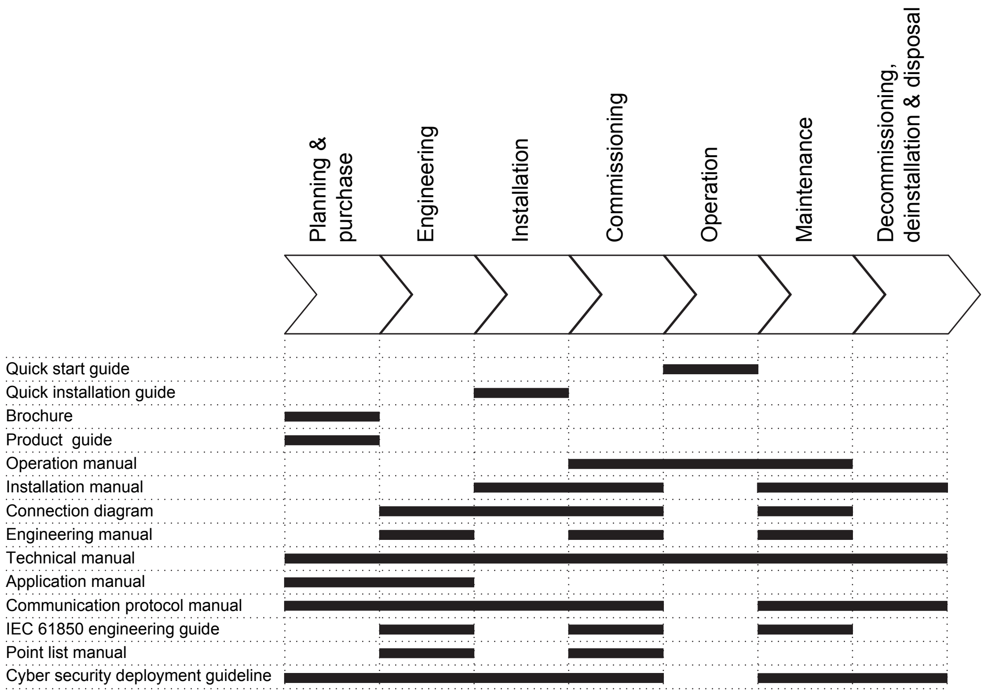


Figure 1: The intended use of manuals in different lifecycles

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

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2011-11-18	1.0	First release
B/2016-02-22	2.0	Content updated to correspond to the product series version
C/2017-10-31	2.0	Content updated
D/2019-04-10	2.0	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**.
- 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 "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to all products.

Table 1: Functions included in the relays

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67-1(1)
Three-phase directional overcurrent protection, low stage, instance 2	DPHLPDOC2	3I> -> (2)	67-1(2)
Three-phase directional overcurrent protection, high stage, instance 1	DPHHPDOC1	3I>> -> (1)	67-2(1)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Negative-sequence overcurrent protection for machines, instance 1	MNSPTOC1	I2>M (1)	46M (1)
Negative-sequence overcurrent protection for machines, instance 2	MNSPTOC2	I2>M (2)	46M (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27(1)
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27(2)
Three-phase undervoltage protection, instance 3	PHPTUV3	3U< (3)	27(3)
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59(1)
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59(2)
Three-phase overvoltage protection, instance 3	PHPTOV3	3U> (3)	59(3)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+(1)
Positive-sequence undervoltage protection, instance 2	PSPTUV2	U1< (2)	47U+(2)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O-(1)
Negative-sequence overvoltage protection, instance 2	NSPTOV2	U2> (2)	47O-(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)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
High-impedance differential protection for phase A, instance 1	HIAPDIF1	dHi>(1)	87(1)
High-impedance differential protection for phase B, instance 2	HIBPDIF1	dHi>(2)	87(2)
High-impedance differential protection for phase C, instance 3	HICPDIF1	dHi>(3)	87(3)
Switch onto fault	CBPSOF1	SOTF	SOTF
Other			
Input switch group	ISWGAPC	ISWGAPC	ISWGAPC
Output switch group	OSWGAPC	OSWGAPC	OSWGAPC
Selector	SELGAPC	SELGAPC	SELGAPC
Minimum pulse timer (2 pcs)	TPGAPC	TP	TP
Minimum pulse timer (2 pcs, second resolution), instance 1	TPSGAPC	TPS (1)	TPS (1)
Move (8 pcs), instance 1	MVGAPC	MV (1)	MV (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Emergency start-up	ESMGAPC1	ESTART	ESTART
Autoreclosing	DARREC1	O -> I	79
Condition monitoring and supervision			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Phase segregated CT supervision function for phase A, instance 1	HZCCASPVC1	MCS 1I(1)	MCS 1I(1)
Phase segregated CT supervision function for phase B, instance 2	HZCCBSPVC1	MCS 1I(2)	MCS 1I(2)
Phase segregated CT supervision function for phase C, instance 3	HZCCCSPVC1	MCS 1I(3)	MCS 1I(3)
Logging			

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Disturbance recorder	RDRE1	DR (1)	DFR(1)
Fault recorder	FLTRFRC1	-	FR
Measurement			
Three-phase current measurement, instance 1[1)]	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement, instance 1	VMMXU1	3U	3U
Three-phase voltage measurement, instance 2	VMMXU2	3U(B)	3U(B)
Sequence voltage measurement, instance 1	VSMSQI1	U1, U2, U0	U1, U2, U0
Residual voltage measurement	RESVMMXU1	Uo	Vn
Frequency measurement, instance 1	FMMXU1	f	f
Three-phase power and energy measurement, instance 1	PEMMXU1	P, E	P, E

1) In REB611, CMMXU is used for measuring differential phase currents

Section 2 611 series overview

2.1 Overview

The 611 series is part of ABB’s Relion® product family. The 611 series protection relays offer functionality within basic protection and control configurations. There are product variants for feeder, motor, busbar and voltage protection applications. The relays, characterized by their compactness and withdrawable-unit design, are designed for most utility substations and industrial power systems including radial, looped and meshed distribution networks that may also involve distributed power generation.

The 611 series relays support the Edition 1 and Edition 2 versions of the IEC 61850 standard for communication and interoperability of substation automation devices, including fast GOOSE messaging. The 611 series relays are able to use IEC 61850 and Modbus® communication protocols simultaneously. The relays also support the parallel redundancy protocol PRP and the high-availability seamless redundancy HSR protocol. IEEE 1588 v2 is available for high-accuracy time synchronization in all variants with an optional redundant Ethernet communication module.

2.1.1 Product series version history

Product series version	Product series history
1.0	First products from 611 series released • REB611 with configuration A • REF611 with configurations A and B • REM611 with configuration A
2.0	New product • REU611 with configuration A New configurations • REF611 configuration C REF611 enhancements • Switch onto fault REM611 enhancements • Analog GOOSE support Platform enhancements • High-availability seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • Two selectable indication colors for LEDs (red or green) • Online binary signal monitoring with PCM600 • IEEE 1588 v2 time synchronization • Profibus adapter support • Import/export of settings via WHMI • Setting usability improvements • HMI event filtering tool • IEC 61850 Edition 2 • Support for configuration migration (starting from Ver.1.0 to Ver.2.0) • Software closable Ethernet ports • Report summary via WHMI

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.7 or later
- REB611 Connectivity Package Ver.2.0 or later
- REF611 Connectivity Package Ver.2.0 or later
- REM611 Connectivity Package Ver.2.0 or later
- REU611 Connectivity Package Ver.2.0 or later

Download connectivity packages from the ABB Web site http://www.abb.com/substationautomation or directly with Update Manager in PCM600.

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.

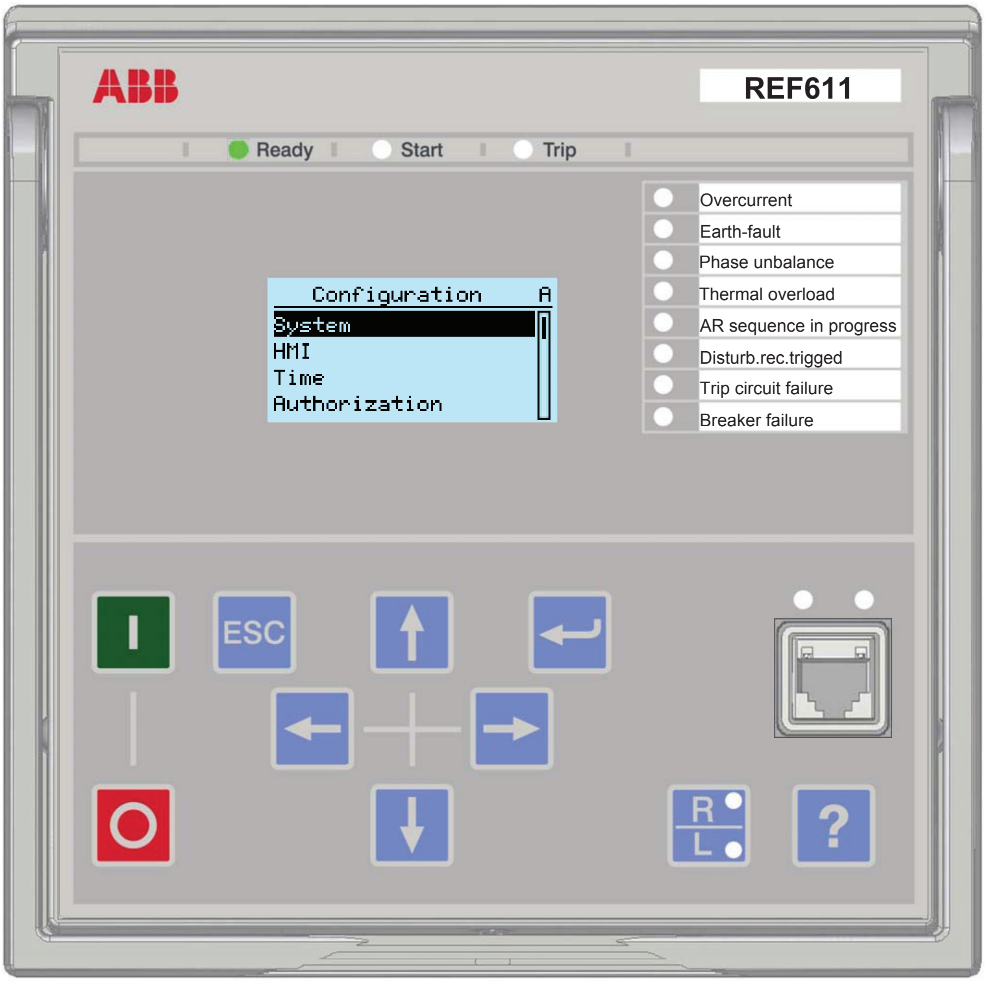


Figure 2: Example of the LHMI

2.2.1 Display

The LHMI includes a graphical display that supports two character sizes. The character size depends on the selected language. The amount of characters and rows fitting the view depends on the character size.

Table 2: Small display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

1) Depending on the selected language

The display view is divided into four basic areas.

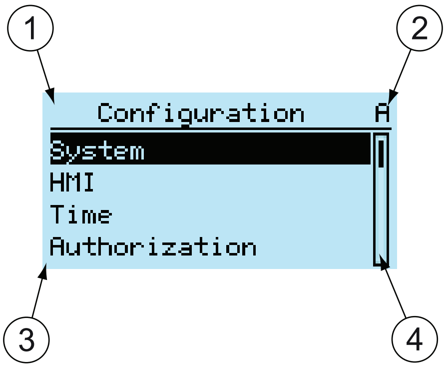


Figure 3: Display layout

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: Ready, Start and Trip.

There are also 8 programmable LEDs on front of the LHMI. The LEDs can be configured with the LHMI, WHMI or PCM600.

2.2.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. With the push buttons you can give open or close commands to one object 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.

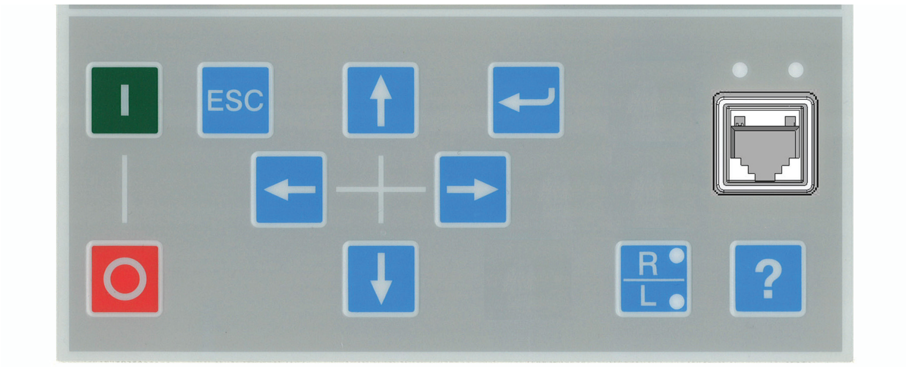


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.3 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. When the *Secure Communication* parameter in the protection relay is activated, the Web server is forced to take a secured (HTTPS) connection to WHMI using TLS encryption.The WHMI is verified with Internet Explorer 8.0, 9.0, 10.0 and 11.0.

WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Fault records
- Phasor diagram
- Signal configuration
- Importing/Exporting parameters
- Report summary

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

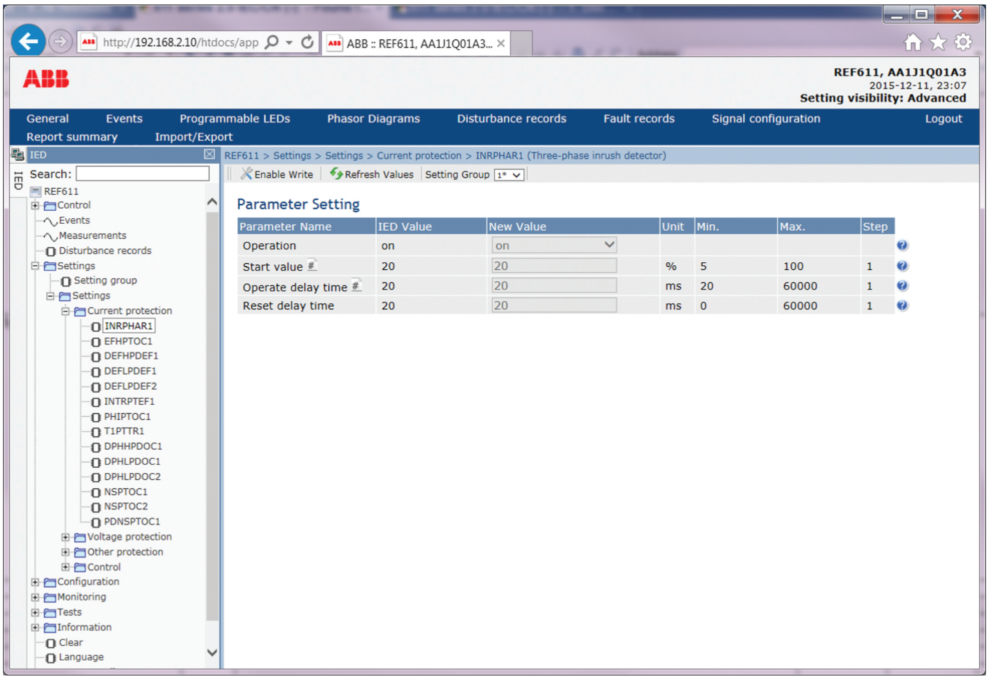


Figure 5: Example view of the WHMI

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.

2.3.1 Command buttons

Command buttons can be used to edit parameters and control information via the WHMI.

Table 3: Command buttons

Name	Description
Enable Write	Enabling parameter editing
Disable Write	Disabling parameter editing
Write to IED	Writing parameters to the protection relay
Refresh Values	Refreshing parameter values
Print	Printing out parameters
Commit	Committing changes to protection relay's nonvolatile flash memory

Table continues on next page

Name	Description
Reject	Rejecting changes
	Showing context sensitive help messages
	Error icon
Clear events	Clearing events
Manual trigger	Triggering the disturbance recorder manually
Save	Saving values to TXT or CSV file format
Freeze	Freezing the values so that updates are not displayed
Continue	Receiving continuous updates to the monitoring view
Delete	Deleting the disturbance record
Delete all	Deleting all disturbance records
	Saving the disturbance record files
View all	Viewing all fault records
Clear records	Clearing all fault records
Import Settings	Importing settings
Export Settings	Exporting settings
Select all	Selecting all
Clear all	Clearing all selections
Refresh	Refreshing the parameter list view

2.4 Authorization

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

The default passwords in the protection relay delivered from the factory can be changed with Administrator user rights.

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

Table 4: 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 disturbance records • Changing system settings such as IP address, serial baud rate or disturbance recorder settings • Setting the protection relay to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.4.1 Audit trail

The protection relay offers a large set of event-logging functions. Critical system and protection relay security-related events are logged to a separate nonvolatile audit trail for the administrator.

Audit trail is a chronological record of system activities that allows the reconstruction and examination of the sequence of system and security-related events and changes in the protection relay. Both audit trail events and process related events can be examined and analyzed in a consistent method with the help of Event List in LHMI and WHMI and Event Viewer in PCM600.

The protection relay stores 2048 audit trail events to the nonvolatile audit trail. Additionally, 1024 process events are stored in a nonvolatile event list. Both the audit trail and event list work according to the FIFO principle. Nonvolatile memory is based on a memory type which does not need battery backup nor regular component change to maintain the memory storage.

Audit trail events related to user authorization (login, logout, violation remote and violation local) are defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined user names or user categories. The user audit trail events are accessible with IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 5: Audit trail events

Audit trail event	Description
Configuration change	Configuration files changed
Firmware change	Firmware changed
Firmware change fail	Firmware change failed
Attached to retrofit test case	Unit has been attached to retrofit case
Removed from retrofit test case	Removed from retrofit test case
Setting group remote	User changed setting group remotely
Setting group local	User changed setting group locally
Control remote	DPC object control remote
Control local	DPC object control local
Test on	Test mode on
Test off	Test mode off
Reset trips	Reset latched trips (TRPPTRC*)
Setting commit	Settings have been changed
Time change	Time changed directly by the user. Note that this is not used when the protection relay is synchronised properly by the appropriate protocol (SNTP, IRIG-B, IEEE 1588 v2).
View audit log	Administrator accessed audit trail
Login	Successful login from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Logout	Successful logout from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Password change	Password changed
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period
Violation remote	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Violation local	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.

PCM600 Event Viewer can be used to view the audit trail events and process related events. Audit trail events are visible through dedicated Security events view. Since only the administrator has the right to read audit trail, authorization must be used in PCM600. The audit trail cannot be reset, but PCM600 Event Viewer can filter data. Audit trail events can be configured to be visible also in LHMI/WHMI Event list together with process related events.

To expose the audit trail events through Event list, define the *Authority logging* level parameter via **Configuration/ Authorization/Security**. This exposes audit trail events to all users.

Table 6: Comparison of authority logging levels

Audit trail event	Authority logging level					
	None	Configuration change	Setting group	Setting group, control	Settings edit	All
Configuration change		•	•	•	•	•
Firmware change		•	•	•	•	•
Firmware change fail		•	•	•	•	•
Attached to retrofit test case		•	•	•	•	•
Removed from retrofit test case		•	•	•	•	•
Setting group remote			•	•	•	•
Setting group local			•	•	•	•
Control remote				•	•	•
Control local				•	•	•
Test on				•	•	•
Test off				•	•	•
Reset trips				•	•	•
Setting commit					•	•
Time change						•
View audit log						•
Login						•
Logout						•
Password change						•
Firmware reset						•
Violation local						•
Violation remote						•

2.5 Communication

The protection relay supports a range of communication protocols including IEC 61850 and Modbus®. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices (so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. 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 support five simultaneous clients. If PCM600 reserves one client connection, only four client connections are left, for example, for IEC 61850 and Modbus.

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). An optional serial interface is available for RS-485 communication.

2.5.1 Self-healing Ethernet ring

For the correct operation of self-healing 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 the MAC addresses, and the link-up/link-down events can cause temporary breaks in communication. For a 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. A self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all protection relays.

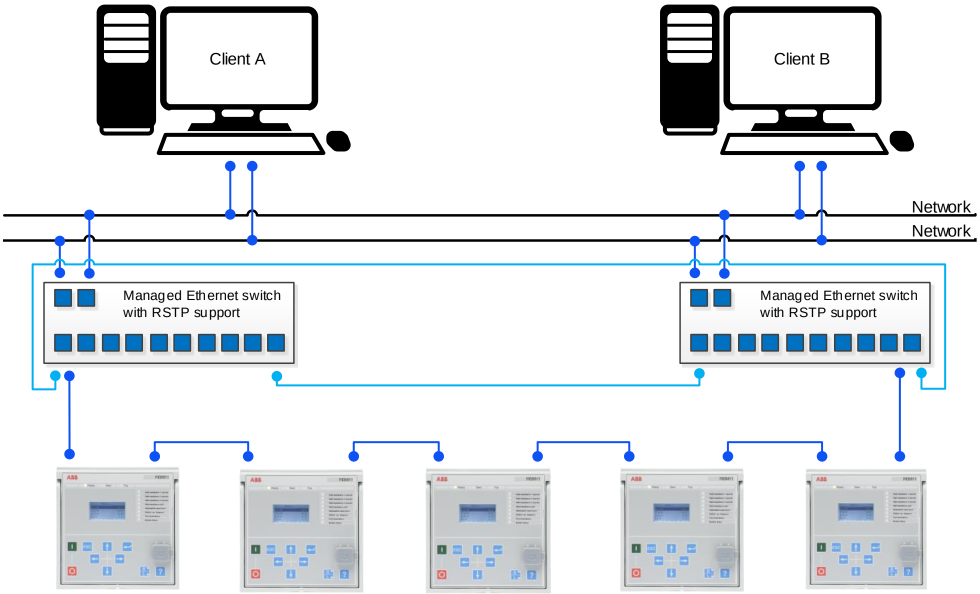


Figure 6: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to 30 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. Each protection relay has a 50-μs store-and-forward delay, and to fulfil the performance requirements for fast horizontal communication, the ring size is limited to 30 protection relays.

2.5.2 Ethernet redundancy

IEC 61850 specifies a network redundancy scheme that improves the system availability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3:2012 standard: parallel redundancy protocol PRP and high-availability seamless redundancy HSR protocol. Both protocols rely on the duplication of all transmitted information via two Ethernet ports for one logical network connection. Therefore, both are able to overcome the failure of a link or switch with a zero-switchover time, thus fulfilling the stringent real-time requirements for the substation automation horizontal communication and time synchronization.

PRP specifies that each device is connected in parallel to two local area networks. HSR applies the PRP principle to rings and to the rings of rings to achieve cost-effective redundancy. Thus, each device incorporates a switch element that forwards frames from port to port. The HSR/PRP option is available for all 611 series protection relays.

IEC 62439-3:2012 cancels and replaces the first edition published in 2010. These standard versions are also referred to as IEC 62439-3 Edition 1 and IEC 62439-3 Edition 2. The protection relay supports IEC 62439-3:2012 and it is not compatible with IEC 62439-3:2010.

PRP

Each PRP node, called a double attached node with PRP (DAN), is attached to two independent LANs operated in parallel. These parallel networks in PRP are called LAN A and LAN B. The networks are completely separated to ensure failure independence, and they can have different topologies. Both networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid communication failures. Non-PRP nodes, called single attached nodes (SANs), are either attached to one network only (and can therefore communicate only with DANs and SANs attached to the same network), or are attached through a redundancy box, a device that behaves like a DAN.

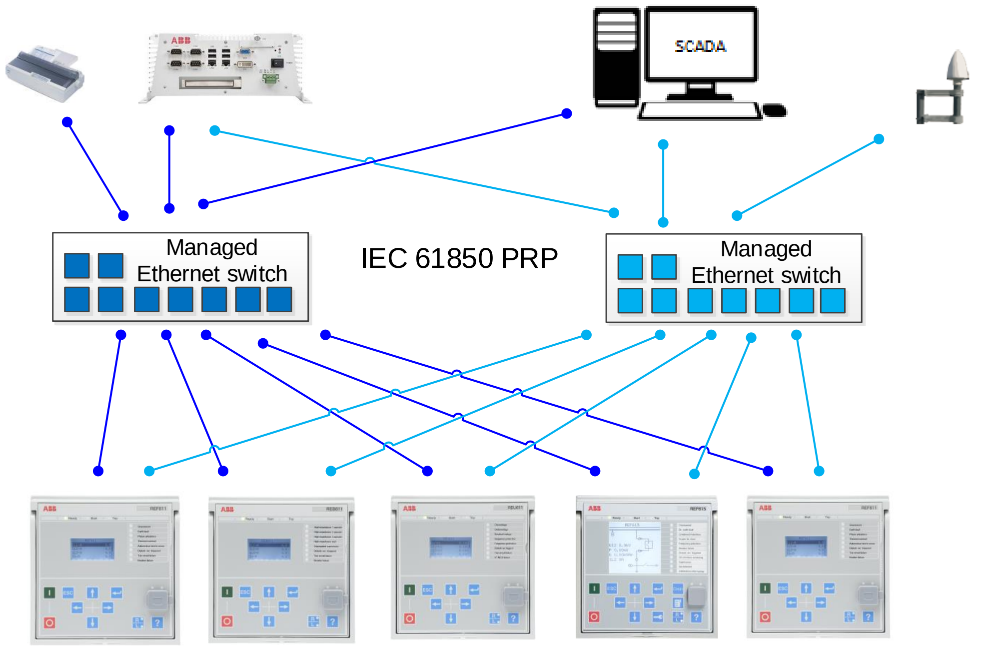


Figure 7: PRP solution

In case a laptop or a PC workstation is connected as a non-PRP node to one of the PRP networks, LAN A or LAN B, it is recommended to use a redundancy box device or an Ethernet switch with similar functionality between the PRP network and SAN to remove additional PRP information from the Ethernet frames. In some cases, default PC workstation adapters are not able to handle the maximum-length Ethernet frames with the PRP trailer.

There are different alternative ways to connect a laptop or a workstation as SAN to a PRP network.

- Via an external redundancy box (RedBox) or a switch capable of connecting to PRP and normal networks
- By connecting the node directly to LAN A or LAN B as SAN
- By connecting the node to the protection relay's interlink port

HSR

HSR applies the PRP principle of parallel operation to a single ring, treating the two directions as two virtual LANs. For each frame sent, a node, DAN, sends two frames, one over each port. Both frames circulate in opposite directions over the ring and each node forwards the frames it receives, from one port to the other. When the originating node receives a frame sent to itself, it discards that to avoid loops; therefore, no ring protocol is needed. Individually attached nodes, SANs, such as laptops and printers, must be attached through a “redundancy box” that acts as a ring element. For example, a 615 or 620 series protection relay with HSR support can be used as a redundancy box.

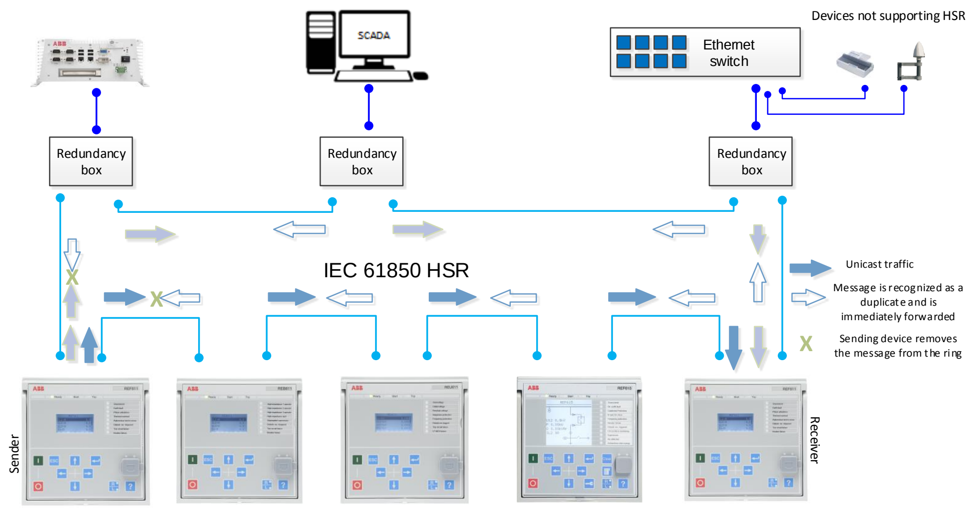


Figure 8: HSR solution

2.5.3 Secure communication

The protection relay supports secure communication for WHMI and file transfer protocol. If the *Secure Communication* parameter is activated, protocols require TLS based encryption method support from the clients. In this case WHMI must be connected from a Web browser using the HTTPS protocol and in case of file transfer the client must use FTPS.

As a factory default, *Secure Communication* is “ON”.

Section 3 Basic functions

3.1 General parameters

Table 7: Analog input settings, phase currents

Parameter	Values (Range)	Unit	Step	Default	Description
Primary current	1.0...6000.0	A	0.1	100.0	Rated primary current
Secondary current	2=1A 3=5A			2=1A	Rated secondary current
Amplitude Corr A	0.9000...1.1000		0.0001	1.0000	Phase A amplitude correction factor
Amplitude Corr B	0.9000...1.1000		0.0001	1.0000	Phase B amplitude correction factor
Amplitude Corr C	0.9000...1.1000		0.0001	1.0000	Phase C amplitude correction factor
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the phase CTs
Angle Corr A	-20.0000...20.0000	deg	0.0001	0.0000	Phase A angle correction factor
Angle Corr B	-20.0000...20.0000	deg	0.0001	0.0000	Phase B angle correction factor
Angle Corr C	-20.0000...20.0000	deg	0.0001	0.0000	Phase C angle correction factor

Table 8: Analog input settings, residual current

Parameter	Values (Range)	Unit	Step	Default	Description
Primary current	1.0...6000.0	A	0.1	100.0	Primary current
Secondary current	1=0.2A 2=1A 3=5A			2=1A	Secondary current
Amplitude Corr	0.9000...1.1000		0.0001	1.0000	Amplitude correction
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the residual CT
Angle correction	-20.0000...20.0000	deg	0.0001	0.0000	Angle correction factor

Table 9: 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 2=Delta 3=U12 4=UL1			2=Delta	Voltage transducer measurement connection

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Amplitude Corr A	0.9000...1.1000		0.0001	1.0000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Amplitude Corr B	0.9000...1.1000		0.0001	1.0000	Phase B Voltage phasor magnitude correction of an external voltage transformer
Amplitude Corr C	0.9000...1.1000		0.0001	1.0000	Phase C Voltage phasor magnitude correction of an external voltage transformer
Voltage input type	1=Voltage trafo			1=Voltage trafo	Type of the voltage input
Angle Corr A	-20.0000...20.0000	deg	0.0001	0.0000	Phase A Voltage phasor angle correction of an external voltage transformer
Angle Corr B	-20.0000...20.0000	deg	0.0001	0.0000	Phase B Voltage phasor angle correction of an external voltage transformer
Angle Corr C	-20.0000...20.0000	deg	0.0001	0.0000	Phase C Voltage phasor angle correction of an external voltage transformer

Table 10: Analog input settings, residual voltage

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.100...440.000	kV	0.001	11.547	Primary voltage
Secondary voltage	60...210	V	1	100	Secondary voltage
Amplitude Corr	0.9000...1.1000		0.0001	1.0000	Amplitude correction
Angle correction	-20.0000...20.0000	deg	0.0001	0.0000	Angle correction factor

Table 11: Authorization settings

Parameter	Values (Range)	Unit	Step	Default	Description
Remote Update	0=Disable 1=Enable			0=Disable	Remote update
Secure Communication	0=False 1=True			1=True	Secure Communication
Authority logging	1=None 2=Configuration change 3=Setting group 4=Setting group, control 5=Settings edit 6=All			1=None	Authority logging level
Remote override	0=False [1)] 1=True [2)]			1=True	Disable authority
Remote viewer				0	Set password
Remote operator				0	Set password
Remote engineer				0	Set password
Remote administrator				0	Set password
Local override	0=False [3)] 1=True [4)]			1=True	Disable authority

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Local viewer				0	Set password
Local operator				0	Set password
Local engineer				0	Set password
Local administrator				0	Set password

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

Table 12: Binary input settings

Parameter	Values (Range)	Unit	Step	Default	Description
Threshold voltage	16...176	Vdc	2	16 [1)]	Binary input threshold voltage
Input osc. level	2...50	events/s	1	30	Binary input oscillation suppression threshold
Input osc. hyst	2...50	events/s	1	10	Binary input oscillation suppression hysteresis

1) For Chinese configurations 78

Table 13: Binary input signals in card location Xnnn

Name	Type	Description
Xnnn-Input m [1)2)]	BOOLEAN	See the application manual for terminal connections

1) Xnnn = Slot ID, for example, X120, X130, as applicable
2) m =For example, 1, 2, depending on the serial number of the binary input in a particular BIO or AIM card

Table 14: Binary output signals in card location Xnnn

Name	Type	Default	Description
Xnnn-Pmm[1)2)]	BOOLEAN	0=False	See the application manual for terminal connections

1) Xnnn = Slot ID, for example, X100, X130, as applicable
2) Pmm = For example, PO1, PO2, SO1, SO2, as applicable

Table 15: Binary input settings in card location Xnnn

Name [1)]	Value	Unit	Step	Default
Input m[2)] filter time	5…1000	ms		5
Input m inversion	0= False 1= True			0=False

1) Xnnn = Slot ID, for example, X120, X130, as applicable
2) m = For example, 1, 2, depending on the serial number of the binary input in a particular BIO or AIM card

Table 16: 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 17: 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 18: 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 OPERATE output			1=Freeze timer	Behaviour for function BLOCK inputs
Bay name				REF611[1)]	Bay name in system
IDMT Sat point	10...50	I/I>	1	50	Overcurrent IDMT saturation point

1) Depending on the product variant

Table 19: 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 IED
Default view	1=Measurements 2=Main menu 3=SLD			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			2=Active	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
Setting visibility	1=Basic 2=Advanced			2=Advanced	Setting visibility for HMI

Table 20: IEC 61850-8-1 MMS settings

Parameter	Values (Range)	Unit	Step	Default	Description
Unit mode	1=Primary[1)] 0=Nominal[2)] 2=Primary-Nominal[3)]			0=Nominal	IEC 61850-8-1 unit mode

1) MMS client expects primary values from event reporting and data attribute reads
2) MMS client expects nominal values from event reporting and data attribute reads; this is the default for PCM600
3) For PCM600 use only, When *Unit mode* is set to "Primary", the PCM600 client can force its session to "Nominal" by selecting "Primary-Nominal" and thus parameterizing in native form. The selection is not stored and is therefore effective only for one session. This value has no effect if selected via the LHMI.

Table 21: Modbus settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			5=off	Enable or disable this protocol instance
Port [1)]	1=COM 1 2=COM 2 3=Ethernet - TCP 1			3=Ethernet - TCP 1	Port selection for this protocol instance. Select between serial and Ethernet based communication.
Mapping selection	1...2		1	1	Chooses which mapping scheme will be used for this protocol instance.
Address	1...254		1	1	Unit address
Link mode	1=RTU 2=ASCII			1=RTU	Selects between ASCII and RTU mode. For TCP, this should always be RTU.
TCP port	1...65535		1	502	Defines the listening port for the Modbus TCP server. Default = 502.
Parity	0=none 1=odd 2=even			2=even	Parity for the serial connection.
Start delay	0...20		1	4	Start delay in character times for serial connection
End delay	0...20		1	4	End delay in character times for serial connections
CRC order	0=Hi-Lo 1=Lo-Hi			0=Hi-Lo	Selects between normal or swapped byte order for checksum for serial connection. Default: Hi-Lo.
Client IP				0.0.0.0	Sets the IP address of the client. If set to zero, connection from any client is accepted.
Write authority	0=Read only 1=Disable 0x write 2=Full access			2=Full access	Selects the control authority scheme
Time format	0=UTC 1=Local			1=Local	Selects between UTC and local time for events and timestamps.
Event ID selection	0=Address 1=UID			0=Address	Selects whether the events are reported using the MB address or the UID number.
Event buffering	0=Keep oldest 1=Keep newest			0=Keep oldest	Selects whether the oldest or newest events are kept in the case of event buffer overflow.

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Event backoff	1...500		1	200	Defines how many events have to be read after event buffer overflow to allow new events to be buffered. Applicable in "Keep oldest" mode only.
ControlStructPWd 1				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 2				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 3				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 4				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 5				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 6				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 7				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 8				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.

1) Dependent on the COM card selection

Table 22: COM1 serial communication settings

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

Table 23: COM2 serial communication settings

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

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, relay protection operation is disabled, the green Ready 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 the 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 Ready 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 protection relay is energized and the contact gaps 3-5 in slot X100 is closed. If the auxiliary power supply fails or an internal fault is detected, the contact gaps 3-5 are opened.

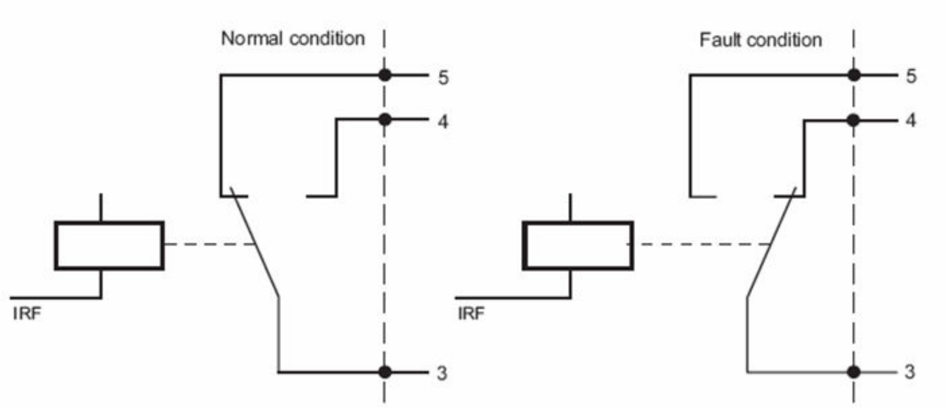


Figure 9: Output contact

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

Table 24: 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.
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.
Table continues on next page		

Fault indication	Fault code	Additional information
Internal Fault PO-relay(s),X100	53	Faulty Power Output relay(s) in card located in slot X100.
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 Conf. error,X000	62	Card in slot X000 is wrong type, is missing, does not belong to original configuration or card firmware is faulty.
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,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,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.
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.
Internal Fault COM card error	116	Error in the COM 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 Ready 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 25: Warning indications and codes

Warning indication	Warning code	Additional information
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 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).
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.
Warning GOOSE Rx. error	32	Error in the GOOSE message receiving.
Warning AFL error	33	Analog channel configuration error.
Warning Comm. channel down	35	Redundant Ethernet (HSR/PRP) communication interrupted.
Warning Unack card comp.	40	A new composition has not been acknowledged/accepted.
Warning Protection comm.	50	Error in protection communication.

Further information on warning indications can be found in the operation manual.

3.3 LED indication control

3.3.1 Function block

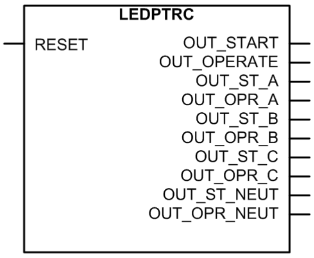


Figure 10: Function block

3.3.2 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 TRPPTRC available in the relay configuration.

LED indication control is preconfigured in a such way that all the protection function general start and operate signals are combined with this function (available as output signals `OUT_START` and `OUT_OPERATE`). These signals are always internally connected to Start 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 earth fault information collected from all the earth-fault functions available in the relay configuration (available as output signals `OUT_ST_NEUT` and `OUT_OPR_NEUT`).

3.4 Programmable LEDs

3.4.1 Function block

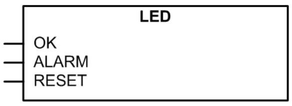


Figure 11: Function block

3.4.2 Functionality

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

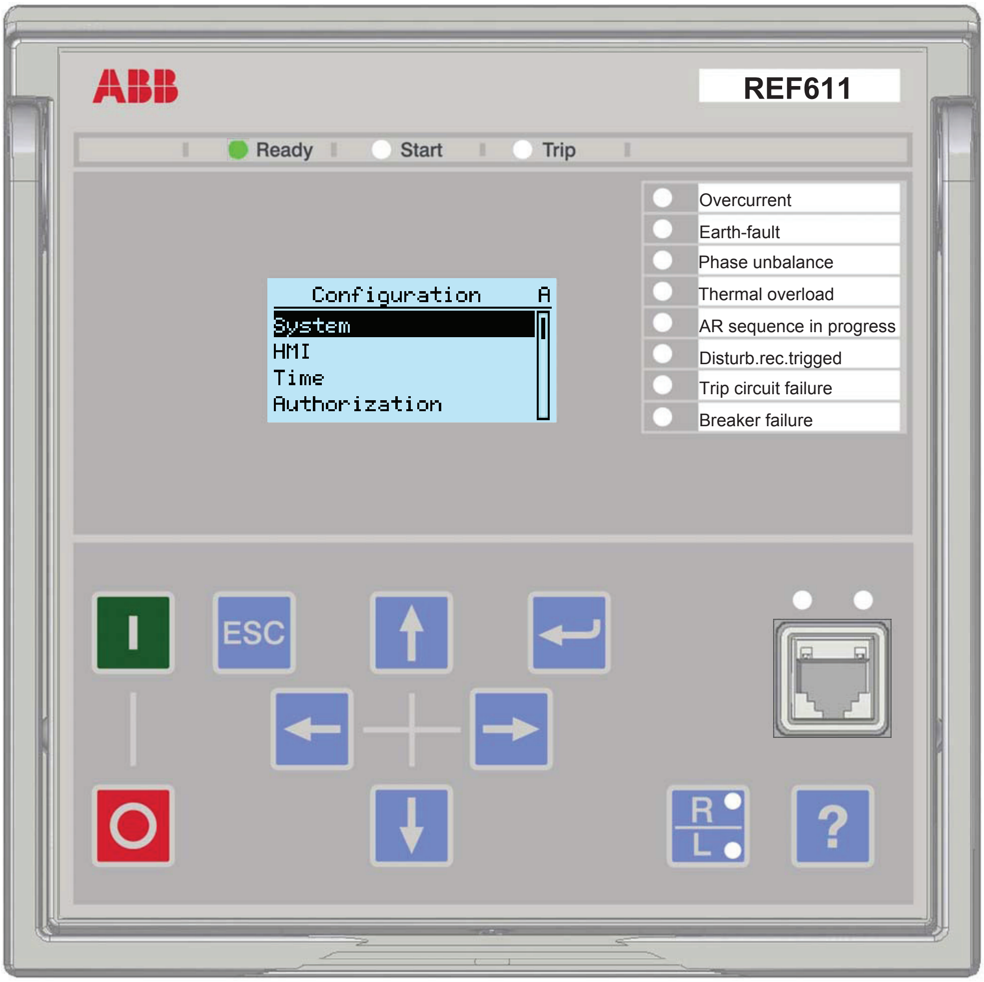


Figure 12: Programmable LEDs on the right side of the display

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 has two control inputs, `ALARM` and `OK`. The color setting is common for all the LEDs. It is controlled with the *Alarm colour* setting, the default value being "Red". The `OK` input corresponds to the color that is available, with the default value being "Green".

Changing the *Alarm colour* setting to "Green" changes the color behavior of the `OK` inputs to red.

The `ALARM` input has a higher priority than the `OK` input.

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

The menu structure for the programmable LEDs is presented in Figure 13. 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.

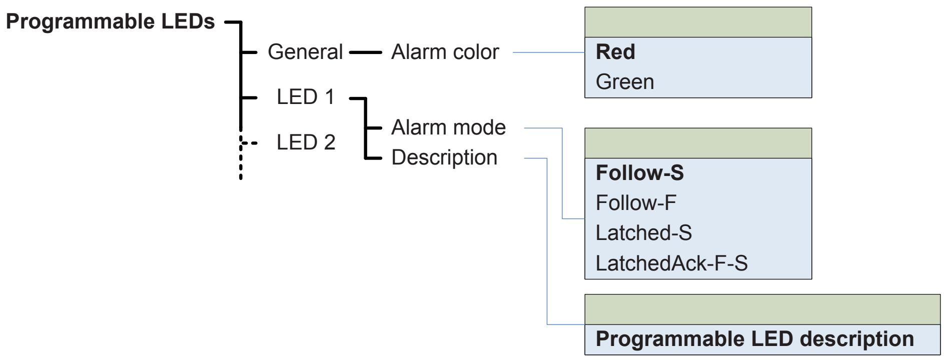


Figure 13: Menu structure

Alarm mode alternatives

The `ALARM` input behavior can be selected with the alarm mode settings from the alternatives "Follow-S", "Follow-F", "Latched-S" and "LatchedAck-F-S". The `OK` input behavior is always according to "Follow-S". The alarm input latched modes can be cleared with the reset input in the application logic.

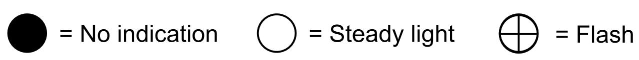


Figure 14: Symbols used in the sequence diagrams

"Follow-S": Follow Signal, ON

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

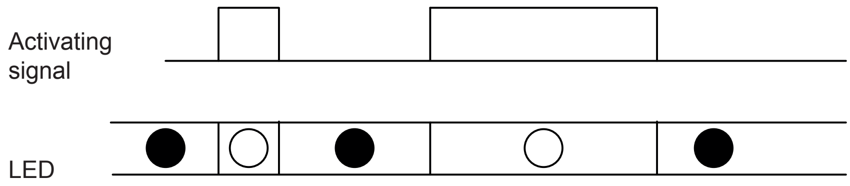


Figure 15: Operating sequence "Follow-S"

"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.

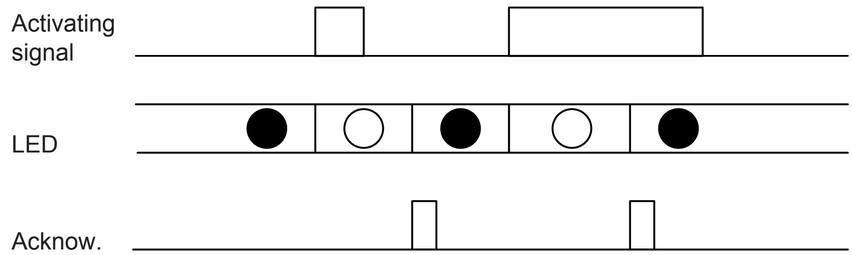


Figure 16: Operating sequence "Latched-S"

"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.

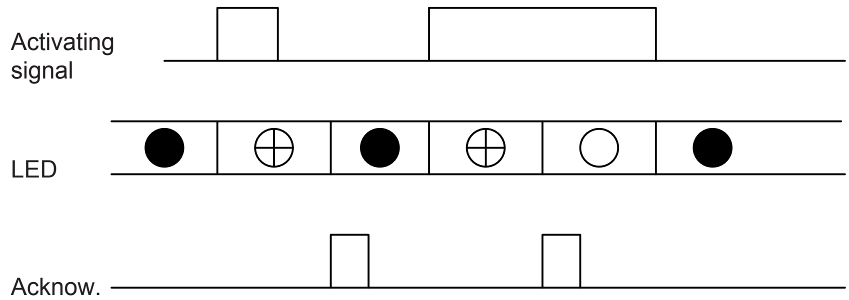


Figure 17: Operating sequence "LatchedAck-F-S"

3.4.3 Signals

Table 26: 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
ALARM	BOOLEAN	0=False	Alarm input for LED 8
RESET	BOOLEAN	0=False	Reset input for LED 8

3.4.4 Settings

Table 27: LED settings

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm colour	1=Green 2=Red			2=Red	Colour 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
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 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
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

3.4.5 Monitored data

Table 28: 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

3.5 Time synchronization

3.5.1 Time master supervision GNRLLTMS

3.5.1.1 Function block

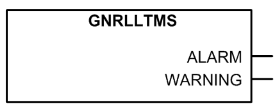


Figure 18: Function block

3.5.1.2 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. IEEE 1588 v2 and SNTP provide time master redundancy.

The protection relay supports SNTP, IRIG-B, IEEE 1588 v2 and Modbus to update the real-time clock. IEEE 1588 v2 with GPS grandmaster clock provides the best accuracy ±1 µs. The accuracy using IRIG-B and SNTP is ±1 ms.

The protection relay's 1588 time synchronization complies with the IEEE C37.238-2011 Power Profile, interoperable with IEEE 1588 v2. According to the power profile, the frame format used is IEEE 802.3 Ethernet frames with 88F7 Ethertype as communication service and the delay mechanism is P2P. *PTP announce mode* determines the format of PTP announce frames sent by the protection relay when acting as 1588 master, with options “Basic IEEE1588” and “Power Profile”. In the “Power Profile” mode, the TLVs required by the IEEE C37.238-2011 Power Profile are included in announce frames.

IEEE 1588 v2 time synchronization requires a communication card with redundancy support (COM0031).

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

With the legacy protocols, the synchronization message must be received within four minutes from the previous synchronization. Otherwise bad synchronization status is raised for the protection relay. With SNTP, it is required that the SNTP server responds to a request within 12 ms, otherwise the response is considered invalid.

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. Supported SNTP versions are 3 and 4.

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.

IRIG-B time synchronization requires a COM card with an IRIG-B input.

3.5.1.3 Signals

Table 29: GNRLLTMS output signals

Name	Type	Description
ALARM	BOOLEAN	Time synchronization alarm
WARNING	BOOLEAN	Time synchronization warning

3.5.1.4 Settings

Table 30: Time format

Parameter	Values (Range)	Unit	Step	Default	Description
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

Table 31: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Synch source	0=None 1=SNTP 2=Modbus 3=IEEE 1588 5=IRIG-B			1=SNTP	Time synchronization source
PTP domain ID	0...255		1	0	The domain is identified by an integer, the domainNumber, in the range of 0 to 255.
PTP priority 1	0...255		1	128	PTP priority 1, in the range of 0 to 255.
PTP priority 2	0...255		1	128	PTP priority 2, in the range of 0 to 255.
PTP announce mode	1=Basic IEEE1588 2=Power Profile			1=Basic IEEE1588	PTP announce frame mode

Table 32: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Date				0	Date
Time				0	Time
Local time offset	-840...840	min	1	0	Local time offset in minutes

Table 33: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
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

Table 34: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
DST in use	0=False 1=True			1=True	DST in use setting
DST on time (hours)	0...23	h		2	Daylight saving time on, time (hh)
DST on time (minutes)	0...59	min		0	Daylight saving time on, time (mm)
DST on date (day)	1...31			1	Daylight saving time on, date (dd:mm)
DST on date (month)	1=January 2=February 3=March 4=April 5=May 6=June 7=July 8=August 9=September 10=October 11=November 12=December			5=May	Daylight saving time on, date (dd:mm)
DST on day (weekday)	0=reserved 1=Monday 2=Tuesday 3=Wednesday 4=Thursday 5=Friday 6=Saturday 7=Sunday			0=reserved	Daylight saving time on, day of week
DST off time (hours)	0...23	h		2	Daylight saving time off, time (hh)
DST off time (minutes)	0...59	min		0	Daylight saving time off, time (mm)
DST off date (day)	1...31			25	Daylight saving time off, date (dd:mm)
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
DST off date (month)	1=January 2=February 3=March 4=April 5=May 6=June 7=July 8=August 9=September 10=October 11=November 12=December			9=September	Daylight saving time off, date (dd:mm)
DST off day (weekday)	0=reserved 1=Monday 2=Tuesday 3=Wednesday 4=Thursday 5=Friday 6=Saturday 7=Sunday			0=reserved	Daylight saving time off, day of week
DST offset	-720...720	min	1	60	Daylight saving time offset

3.6 Parameter setting groups

3.6.1 Function block

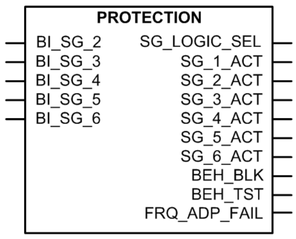


Figure 19: Function block

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 35: 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.

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 36: 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 37: 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 Test mode

3.7.1 Functionality

All of the relay's logical nodes can be set with *Test mode*. *Test mode* is selected through one common parameter via the HMI path **Tests/IED test**. By default, *Test mode* can only be set locally through LHMI. *Test mode* is also available via IEC 61850 communication (LD0.LLN0.Mod).

Table 38: Test mode

Test mode	Description
Normal mode	Normal operation
IED blocked	Protection working as in "Normal mode" but Control function commands blocked.
IED test	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters.
IED test and blocked	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters. Control function commands blocked.

The physical outputs from control commands to process are blocked with "IED blocked" and "IED test and blocked" modes. The physical outputs from the protection functions are not blocked.

3.7.2 Control mode

The mode of all logical nodes located under CTRL logical device can be set with *Control mode*. The *Control mode* parameter is available via the HMI or PCM600 path **Configuration/Control/General**. By default, *Control mode* can only be set locally through LHMI.*Control mode* inherits its value from *Test mode* but *Control mode* ”On”, "Blocked" and "Off" can also be set independently. *Control mode* is also available via IEC 61850 communication (CTRL.LLN0.Mod).

Table 39: Control mode

Control mode	Description
On	Normal operation
Blocked	Control function commands blocked
Off	Control functions disabled

The physical outputs from commands to process are blocked with "Blocked" mode.

3.7.3 Authorization

By default, *Test mode* and *Control mode* can only be changed from LHMI. It is possible to write test mode by remote client, if it is needed in configuration. This is done via LHMI only by setting the *Remote test mode* parameter via **Tests/IED test/ Test mode**. Remote operation is possible only when control position of the relay is in remote position. Local and remote control can be selected with R/L button or via Control function block in application configuration.

When using the Signal Monitoring tool to force online values, the following conditions need to be met.

- *Remote force* is set to “All levels”
- *Test mode* is enabled
- Control position of the relay is in remote position

Table 40: Remote test mode

Remote test mode	61850-8-1-MMS	WHMI/PCM600
Off	No access	No access
Maintenance	Command originator category maintenance	No access
All levels	All originator categories	Yes

3.7.4 LHMI indications

The yellow Start LED flashes when the relay is in “IED blocked” or “IED test and blocked” mode. The green Ready LED flashes to indicate that the “IED test and blocked” mode or "IED test" mode is activated.

3.8 Local/Remote control

Local/Remote control is realized through the R/L button on the front panel. Local/ Remote control supports control operations in substations according to the IEC 61850 standard.

By default, the relay supports station Authority level “L, R” and only local or remote control access is allowed. Control access selection is made with R/L button.

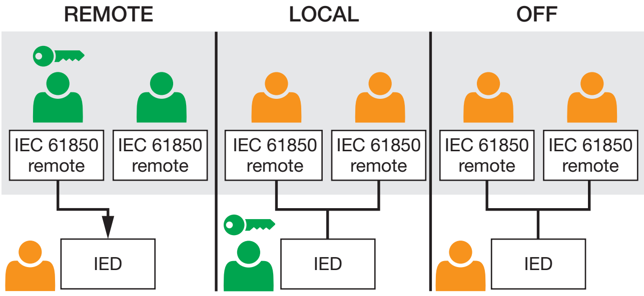


Figure 20: Station authority is “L,R”

The present control status can be monitored in the HMI or PCM600 via **MonitoringControl command** with the *LR state* parameter or from the IEC 61850 data object CTRL.LLN0. LocKeyHMI.

Table 41: Station authority level “L,R” using R/L button

L/R control		L/R control status		Control access	
R/L button	CTRL.LLN0.LocSta	CTRL.LLN0.MltLev	L/R state CTRL.LLN0.LocKeyHMI	Local user	IEC 61850 client 1)
Local	N/A	FALSE	1	x	
Remote	N/A	FALSE	2		x
Off	N/A	FALSE	0		

1) Client IEC 61850 command originator category check is not performed.

3.9 Fault recorder FLTRFRC

3.9.1 Function block

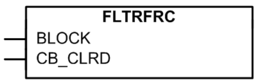


Figure 21: Function block

3.9.2 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 (FLTRFRC) 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 start event of any protection function and ends if any protection function trips or the start is restored before the operate event. If a start is restored without an operate event, the start duration shows the protection function that has started first.

Start duration that has the value of 100% indicates that a protection function has operated during the fault. If the protection functions has not operated, though another function might have operated during this period, Start duration always shows values less than 100%.

The Fault recorded data Protection and Start duration is from the same protection function. The Fault recorded data operate time shows the time of the actual fault period. This value is the time difference between the activation of the internal start and operate signals. The actual operate time also includes the starting time and the delay of the output relay. The Fault recorded data *Breaker clear time* is the time difference between internal operate signal and activation of `CB_CLRD` input.

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

3.9.3 Settings

Table 42: FLTRFRC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Trig mode	0=From all faults 1=From operate 2=From only start			0=From all faults	Triggering mode

Table 43: FLTRFRC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
A measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode phase currents and residual current

3.9.4 Monitored data

Table 44: FLTRFRC 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 65=LSHDPFRQ1 66=LSHDPFRQ2 67=LSHDPFRQ3 68=LSHDPFRQ4 69=LSHDPFRQ5		Protection function

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		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 -93=SPHLPTOC2 -92=SPHLPTOC1 -89=SPHHPTOC2 -88=SPHHPTOC1 -87=SPHPTUV4 -86=SPHPTUV3 -85=SPHPTUV2 -84=SPHPTUV1 -83=SPHPTOV4 -82=SPHPTOV3 -81=SPHPTOV2 -80=SPHPTOV1 -25=OEPVPH4 -24=OEPVPH3 -23=OEPVPH2 -22=OEPVPH1 -19=PSPTOV2 -18=PSPTOV1 -15=PREVPTOC1		

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		-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 -13=PHPTUC3 3=PHLPTOC3 10=PHHPTOC5 11=PHHPTOC6 28=EFHPTOC7 29=EFHPTOC8 107=PHPTOV4 111=PHPTUV4 114=NSPTOV3 115=NSPTOV4 -30=PHDSTPDIS1 -29=TR3PTDF1 -28=HICPDIF1 -27=HIBPDIF1 -26=HIAPDIF1 -32=LSHDPFRQ8 -31=LSHDPFRQ7 70=LSHDPFRQ6 80=MAPGAPC4 81=MAPGAPC5 82=MAPGAPC6 83=MAPGAPC7 -102=MAPGAPC12 -101=MAPGAPC11 -100=MAPGAPC10 -99=MAPGAPC9 -98=RESCPSCH1 -57=FDEFLPDEF2 -56=FDEFLPDEF1 -54=FEFLPTOC1 -53=FDPHLPDOC2 -52=FDPHLPDOC1 -50=FPHLPTOC1		

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		-47=MAP12GAPC8 -46=MAP12GAPC7 -45=MAP12GAPC6 -44=MAP12GAPC5 -43=MAP12GAPC4 -42=MAP12GAPC3 -41=MAP12GAPC2 -40=MAP12GAPC1 -37=HAEFPTOC1 -35=WPWDE3 -34=WPWDE2 -33=WPWDE1 52=DEFLPDEF3 84=MAPGAPC8 93=LREFPNDF2 97=HREFPDIF2 -117=XDEFLPDEF2 -116=XDEFLPDEF1 -115=SDPHLPDOC2 -114=SDPHLPDOC1 -113=XNSPTOC2 -112=XNSPTOC1 -111=XEFIPTOC2 -110=XEFHPTOC4 -109=XEFHPTOC3 -108=XEFLPTOC3 -107=XEFLPTOC2 -66=DQPTUV1 -65=VVSPPAM1 -64=PHPVOC1 -63=H3EFPSEF1 -60=HCUBPTOC1 -59=CUBPTOC1 -72=DOPPDPR1 -69=DUPPDPR1 -61=COLPTOC1		

Table continues on next page

Name	Type	Values (Range)	Unit	Description
		-106=MAPGAPC16 -105=MAPGAPC15 -104=MAPGAPC14 -103=MAPGAPC13 -76=MAPGAPC18 -75=MAPGAPC17 -62=SRCPTOC1 -74=DOPPDPR3 -73=DOPPDPR2 -70=DUPPDPR2 -58=UZPDIS1 -36=UEXPDIS1 14=MFADPSDE1 -10=LVRTPTUV1 -8=LVRTPTUV2 -6=LVRTPTUV3 -122=DPH3LPDOC1 -121=DPH3HPDOC2 -120=DPH3HPDOC1 -119=PH3LPTOC2 -118=PH3LPTOC1 -79=PH3HPTOC2 -78=PH3HPTOC1 -77=PH3IPTOC1 -127=PHAPTUV1 -124=PHAPTOV1 -123=DPH3LPDOC2 -68=PHPVOC2 -67=DQPTUV2 -39=UEXPDIS2 98=MHZPDIF1 -4=MREFPTOC1		
Start duration	FLOAT32	0.00...100.00	%	Maximum start duration of all stages during the fault
Operate time	FLOAT32	0.000...999999.999	s	Operate time
Breaker clear time	FLOAT32	0.000...3.000	s	Breaker clear time
Fault distance	FLOAT32	0.00...3000.00	pu	Distance to fault measured in pu
Fault resistance	FLOAT32	0.00...1000000.00	ohm	Fault resistance

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Fault loop Ris	FLOAT32	-1000.00...1000.00	ohm	Resistance of fault loop, PHDSTPDIS1
Fault loop React	FLOAT32	-1000.00...1000.00	ohm	Reactance of fault loop, PHDSTPDIS1
Active group	INT32	1...6		Active setting group
Shot pointer	INT32	1...7		Autoreclosing shot pointer value
Max diff current IL1	FLOAT32	0.000...80.000	pu	Maximum phase A differential current
Max diff current IL2	FLOAT32	0.000...80.000	pu	Maximum phase B differential current
Max diff current IL3	FLOAT32	0.000...80.000	pu	Maximum phase C differential current
Diff current IL1	FLOAT32	0.000...80.000	pu	Differential current phase A
Diff current IL2	FLOAT32	0.000...80.000	pu	Differential current phase B
Diff current IL3	FLOAT32	0.000...80.000	pu	Differential current phase C
Max bias current IL1	FLOAT32	0.000...50.000	pu	Maximum phase A bias current
Max bias current IL2	FLOAT32	0.000...50.000	pu	Maximum phase B bias current
Max bias current IL3	FLOAT32	0.000...50.000	pu	Maximum phase C bias current
Bias current IL1	FLOAT32	0.000...50.000	pu	Bias current phase A
Bias current IL2	FLOAT32	0.000...50.000	pu	Bias current phase B
Bias current IL3	FLOAT32	0.000...50.000	pu	Bias current phase C
Diff current Io	FLOAT32	0.000...80.000	pu	Differential current residual
Bias current Io	FLOAT32	0.000...50.000	pu	Bias current residual
Max current IL1	FLOAT32	0.000...50.000	xIn	Maximum phase A current
Max current IL2	FLOAT32	0.000...50.000	xIn	Maximum phase B current
Max current IL3	FLOAT32	0.000...50.000	xIn	Maximum phase C current
Max current Io	FLOAT32	0.000...50.000	xIn	Maximum residual current
Current IL1	FLOAT32	0.000...50.000	xIn	Phase A current
Current IL2	FLOAT32	0.000...50.000	xIn	Phase B current
Current IL3	FLOAT32	0.000...50.000	xIn	Phase C current
Current Io	FLOAT32	0.000...50.000	xIn	Residual current
Current Io-Calc	FLOAT32	0.000...50.000	xIn	Calculated residual current
Current Ps-Seq	FLOAT32	0.000...50.000	xIn	Positive sequence current

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Current Ng-Seq	FLOAT32	0.000...50.000	xIn	Negative sequence current
Max current IL1B	FLOAT32	0.000...50.000	xIn	Maximum phase A current (b)
Max current IL2B	FLOAT32	0.000...50.000	xIn	Maximum phase B current (b)
Max current IL3B	FLOAT32	0.000...50.000	xIn	Maximum phase C current (b)
Max current IoB	FLOAT32	0.000...50.000	xIn	Maximum residual current (b)
Current IL1B	FLOAT32	0.000...50.000	xIn	Phase A current (b)
Current IL2B	FLOAT32	0.000...50.000	xIn	Phase B current (b)
Current IL3B	FLOAT32	0.000...50.000	xIn	Phase C current (b)
Current IoB	FLOAT32	0.000...50.000	xIn	Residual current (b)
Current Io-CalcB	FLOAT32	0.000...50.000	xIn	Calculated residual current (b)
Current Ps-SeqB	FLOAT32	0.000...50.000	xIn	Positive sequence current (b)
Current Ng-SeqB	FLOAT32	0.000...50.000	xIn	Negative sequence current (b)
Max current IL1C	FLOAT32	0.000...50.000	xIn	Maximum phase A current (c)
Max current IL2C	FLOAT32	0.000...50.000	xIn	Maximum phase B current (c)
Max current IL3C	FLOAT32	0.000...50.000	xIn	Maximum phase C current (c)
Max current IoC	FLOAT32	0.000...50.000	xIn	Maximum residual current (c)
Current IL1C	FLOAT32	0.000...50.000	xIn	Phase A current (c)
Current IL2C	FLOAT32	0.000...50.000	xIn	Phase B current (c)
Current IL3C	FLOAT32	0.000...50.000	xIn	Phase C current (c)
Current IoC	FLOAT32	0.000...50.000	xIn	Residual current (c)
Current Io-CalcC	FLOAT32	0.000...50.000	xIn	Calculated residual current (c)
Current Ps-SeqC	FLOAT32	0.000...50.000	xIn	Positive sequence current (c)
Current Ng-SeqC	FLOAT32	0.000...50.000	xIn	Negative sequence current (c)
Voltage UL1	FLOAT32	0.000...4.000	xUn	Phase A voltage
Voltage UL2	FLOAT32	0.000...4.000	xUn	Phase B voltage
Voltage UL3	FLOAT32	0.000...4.000	xUn	Phase C voltage
Voltage U12	FLOAT32	0.000...4.000	xUn	Phase A to phase B voltage
Voltage U23	FLOAT32	0.000...4.000	xUn	Phase B to phase C voltage

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Voltage U31	FLOAT32	0.000...4.000	xUn	Phase C to phase A voltage
Voltage Uo	FLOAT32	0.000...4.000	xUn	Residual voltage
Voltage Zro-Seq	FLOAT32	0.000...4.000	xUn	Zero sequence voltage
Voltage Ps-Seq	FLOAT32	0.000...4.000	xUn	Positive sequence voltage
Voltage Ng-Seq	FLOAT32	0.000...4.000	xUn	Negative sequence voltage
Voltage UL1B	FLOAT32	0.000...4.000	xUn	Phase A voltage (b)
Voltage UL2B	FLOAT32	0.000...4.000	xUn	Phase B voltage (b)
Voltage UL3B	FLOAT32	0.000...4.000	xUn	Phase B voltage (b)
Voltage U12B	FLOAT32	0.000...4.000	xUn	Phase A to phase B voltage (b)
Voltage U23B	FLOAT32	0.000...4.000	xUn	Phase B to phase C voltage (b)
Voltage U31B	FLOAT32	0.000...4.000	xUn	Phase C to phase A voltage (b)
Voltage UoB	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)
PTTR thermal level	FLOAT32	0.00...99.99		PTTR calculated temperature of the protected object relative to the operate level
PDNSPTOC1 rat. I2/I1	FLOAT32	0.00...999.99	%	PDNSPTOC1 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 Uo - Io	FLOAT32	-180.00...180.00	deg	Angle residual voltage - residual current
Angle U23 - IL1	FLOAT32	-180.00...180.00	deg	Angle phase B to phase C voltage - phase A current
Angle U31 - IL2	FLOAT32	-180.00...180.00	deg	Angle phase C to phase A voltage - phase B current
Angle U12 - IL3	FLOAT32	-180.00...180.00	deg	Angle phase A to phase B voltage - phase C current
Angle UoB - IoB	FLOAT32	-180.00...180.00	deg	Angle residual voltage - residual current (b)

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Angle U23B - IL1B	FLOAT32	-180.00...180.00	deg	Angle phase B to phase C voltage - phase A current (b)
Angle U31B - IL2B	FLOAT32	-180.00...180.00	deg	Angle phase C to phase A voltage - phase B current (b)
Angle U12B - IL3B	FLOAT32	-180.00...180.00	deg	Angle phase A to phase B voltage - phase C current (b)

3.10 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, WHMI and Event viewer tool in PCM600.
- Recorded data
    - Fault records (up to 128)
    - Maximum demands
- Circuit breaker condition monitoring
- Latched alarm and trip LEDs' statuses
- Trip circuit lockout
- Counter values

3.11 Binary input

3.11.1 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.

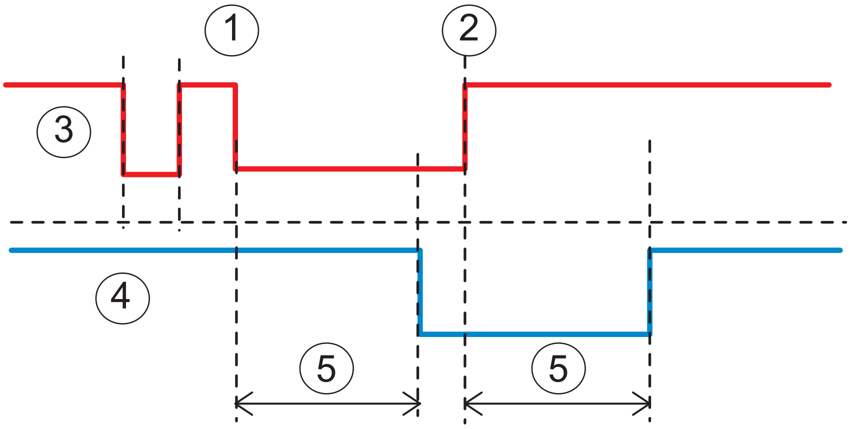


Figure 22: Binary input filtering

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 45: Input filter parameter values

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

3.11.2 Binary input inversion

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

Table 46: 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.

3.11.3 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 47: 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

3.12 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.

Power output contacts are used when the current rating requirements of the contacts are high, for example, for controlling a breaker, such as energizing the breaker trip and closing coils.

The contacts used for external signalling, recording and indicating, the signal outputs, need to adjust to smaller currents, but they can require a minimum current (burden) to ensure a guaranteed operation.

The protection relay provides both power output and signal output contacts. To guarantee proper operation, the type of the contacts used are chosen based on the operating and reset time, continuous current rating, make and carry for short time, breaking rate and minimum connected burden. A combination of series or parallel contacts can also be used for special applications. When appropriate, a signal output can also be used to energize an external trip relay, which in turn can be confiugred to energize the breaker trip or close coils.

Using an external trip relay can require an external trip circuit supervision relay. It can also require wiring a separate trip relay contact back to the protection relay for breaker failure protection function.

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

3.12.1 Power output contacts

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

3.12.1.1 Dual single-pole power outputs PO1 and PO2

Dual (series-connected) single-pole (normally open/form A) power output contacts PO1 and PO2 are rated for continuous current of 8 A. The contacts are normally used for closing circuit breakers and energizing high burden trip relays. They can be arranged to trip the circuit breakers when the trip circuit supervision is not available or when external trip circuit supervision relay is provided.

The power outputs are included in slot X100 of the power supply module.

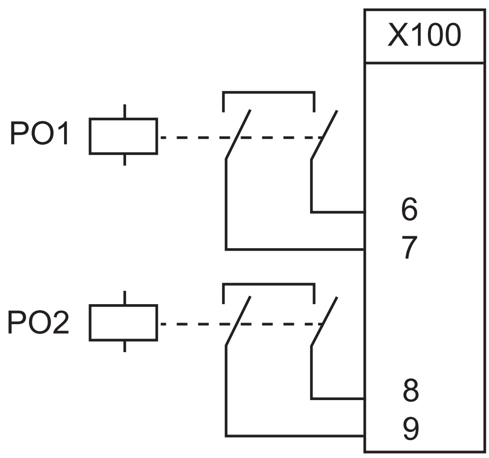


Figure 23: Dual single-pole power output contacts PO1 and PO2

3.12.1.2 Double-pole power outputs PO3 and PO4 with trip circuit supervision

The power outputs PO3 and PO4 are double-pole normally open/form A power outputs with trip circuit supervision.

When the two poles of the contacts are connected in series, they have the same technical specification as PO1 for breaking duty. The trip circuit supervision hardware and associated functionality which can supervise the breaker coil both during closing and opening condition are also provided. Contacts PO3 and PO4 are almost always used for energizing the breaker trip coils.

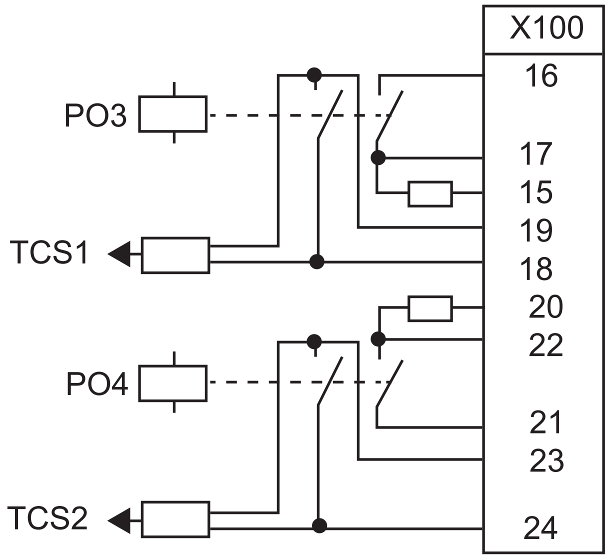


Figure 24: Double-pole power outputs PO3 and PO4 with trip circuit supervision

Power outputs PO3 and PO4 are included in the power supply module located in slot X100 of the protection relay.

3.12.2 Signal output contacts

Signal output contacts are single-pole, single (normally open/form A or change-over/ form C) signal output contacts (SO1, SO2,...) or parallel connected dual contacts.

The signal output contacts are used for energizing, for example, external low burden trip relays, auxiliary relays, annunciators and LEDs.

A single signal contact is rated for a continuous current of 5 A. It has a make and carry for 0.5 seconds at 15 A.

When two contacts are connected in parallel, the relay is of a different design. It has the make and carry rating of 30 A for 0.5 seconds. This can be applied for energizing breaker close coil and tripping coil. Due to the limited breaking capacity, a breaker auxiliary contact can be required to break the circuit.

3.12.2.1 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.

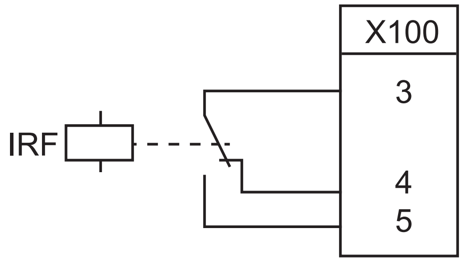


Figure 25: Internal fault signal output IRF

3.12.2.2 Signal outputs SO1 and SO2 in power supply module

Signal outputs (normally open/form A or change-over/form C) SO1 (dual parallel form C) and SO2 (single contact/form A) are part of the power supply module of the protection relay.

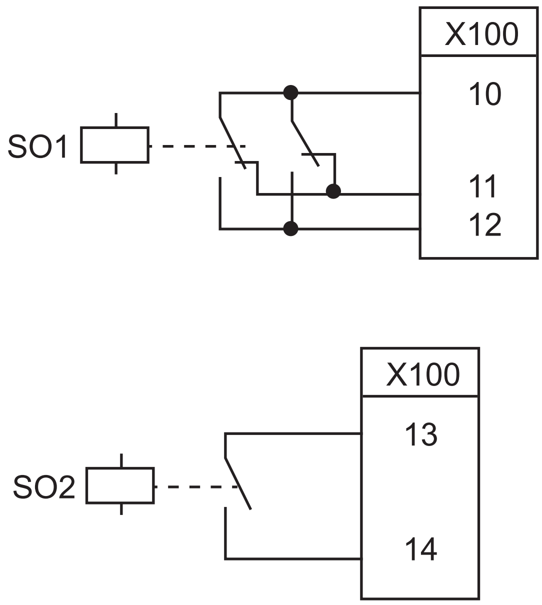


Figure 26: Signal outputs SO1 and SO2 in power supply module

3.12.2.3 Signal outputs SO1, SO2 and SO3 in BIO0006

The optional card BIO0006 provides the signal outputs SO1, SO2 and SO3. Signal outputs SO1 and SO2 are dual, parallel form C contacts; SO3 is a single form C contact.

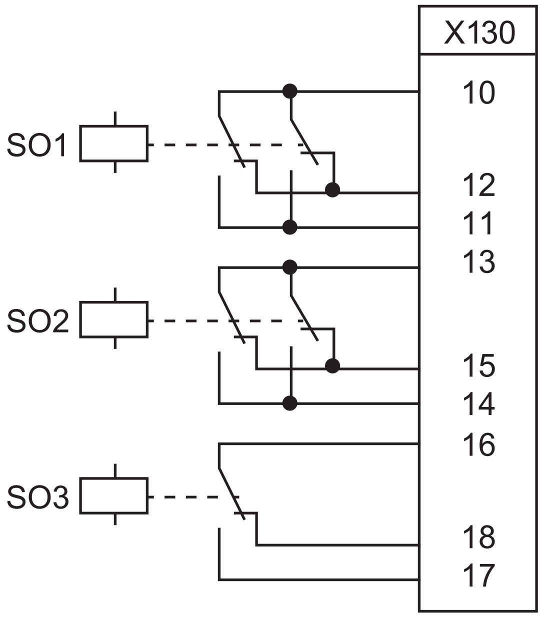


Figure 27: Signal output in BIO0006

3.13 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.

3.13.1 GOOSERCV_BIN function block

3.13.1.1 Function block

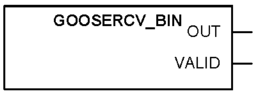


Figure 28: Function block

3.13.1.2 Functionality

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

3.13.1.3 Signals

Table 48: GOOSERCV_BIN Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
VALID	BOOLEAN	Output signal

3.13.2 GOOSERCV_MV function block

3.13.2.1 Function block

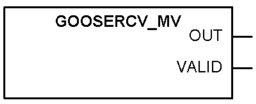


Figure 29: Function block

3.13.2.2 Functionality

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

3.13.2.3 Signals

Table 49: GOOSERCV_MV Output signals

Name	Type	Description
OUT	FLOAT32	Output signal
VALID	BOOLEAN	Output signal

3.14 Configurable logic blocks

3.14.1 Minimum pulse timer

3.14.1.1 Minimum pulse timer TPGAPC

Function block

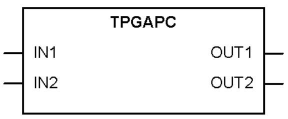


Figure 30: Function block

Functionality

The Minimum pulse timer function TPGAPC contains two independent timers. 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 output is set for a specific duration using the *Pulse time* setting. Both timers use the same setting parameter.

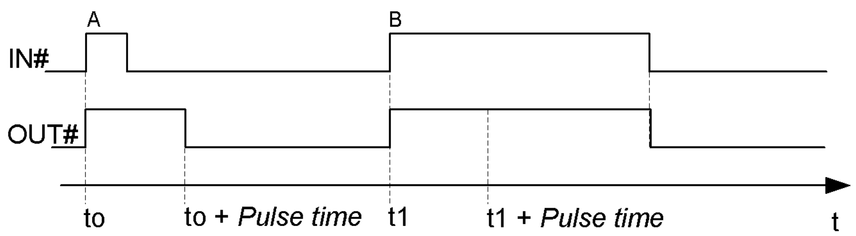


Figure 31: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

Signals

Table 50: TPGAPC Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

Settings

Table 51: TPGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...60000	ms	1	150	Minimum pulse time

Technical revision history

Table 52: TPGAPC Technical revision history

Technical revision	Change
B	Outputs now visible in menu
C	Internal improvement

3.14.1.2 Minimum pulse timer TPSGAPC

Function block

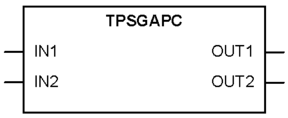


Figure 32: Function block

Functionality

The Minimum second pulse timer function TPSGAPC 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 output is set for a specific duration using the *Pulse time* setting. Both timers use the same setting parameter.

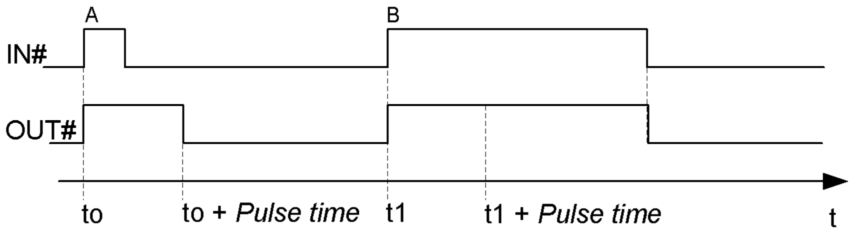


Figure 33: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

Signals

Table 53: TPSGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2

Table 54: TPSGAPC Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

Settings

Table 55: TPSGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	s	1	0	Minimum pulse time

Technical revision history

Table 56: TPSGAPC Technical revision history

Technical revision	Change
B	Outputs now visible in menu
C	Internal improvement

3.14.2 Move (8 pcs) MVGAPC

3.14.2.1 Function block

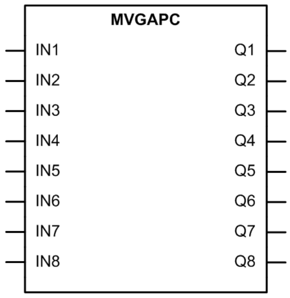


Figure 34: Function block

3.14.2.2 Functionality

The move (8 pcs) function MVGAPC is used for user logic bits. Each input state is directly copied to the output state. This allows the creating of events from advanced logic combinations.

3.14.2.3 Signals

Table 57: MVGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	IN1 status
IN2	BOOLEAN	0=False	IN2 status
IN3	BOOLEAN	0=False	IN3 status
IN4	BOOLEAN	0=False	IN4 status
IN5	BOOLEAN	0=False	IN5 status
IN6	BOOLEAN	0=False	IN6 status
IN7	BOOLEAN	0=False	IN7 status
IN8	BOOLEAN	0=False	IN8 status

Table 58: MVGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Q1 status
Q2	BOOLEAN	Q2 status
Q3	BOOLEAN	Q3 status
Q4	BOOLEAN	Q4 status
Q5	BOOLEAN	Q5 status
Table continues on next page		

Name	Type	Description
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

3.14.2.4 Settings

Table 59: MVGAPC Non group settings (Basic)

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

3.15 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.

3.16 ETHERNET channel supervision function blocks

3.16.1 Redundant Ethernet channel supervision RCHLCCH

3.16.1.1 Function block

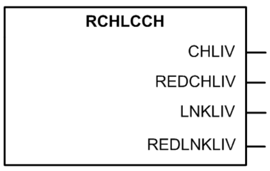


Figure 35: Function block

3.16.1.2 Functionality

Redundant Ethernet channel supervision RCHLCCH represents LAN A and LAN B redundant Ethernet channels.

3.16.1.3 Signals

Table 60: RCHLCCH output signals

Parameter	Values (Range)	Unit	Step	Default	Description
CHLIV	True False				Status of redundant Ethernet channel LAN A. When *Redundant mode* is set to "HSR" or "PRP", value is "True" if the protection relay is receiving redundancy supervision frames. Otherwise value is "False".
REDCHLIV	True False				Status of redundant Ethernet channel LAN B. When *Redundant mode* is set to "HSR" or "PRP", value is "True" if the protection relay is receiving redundancy supervision frames. Otherwise value is "False".
LNKLIV	Up Down				Link status of redundant port LAN A. Valid only when *Redundant mode* is set to "HSR" or "PRP".
REDLNKLIV	Up Down				Link status of redundant port LAN B. Valid only when *Redundant mode* is set to "HSR" or "PRP".

3.16.1.4 Settings

Table 61: Redundancy settings

Parameter	Values (Range)	Unit	Step	Default	Description
Redundant mode	None PRP HSR			None	Mode selection for Ethernet switch on redundant communication modules. The "None" mode is used with normal and Self-healing Ethernet topologies.

3.16.1.5 Monitored data

Monitored data is available in four locations.

- **Monitoring/Communication/Ethernet/Activity/CHLIV_A**
- **Monitoring/Communication/Ethernet/Activity/REDCHLIV_B**
- **Monitoring/Communication/Ethernet/Link statuses/LNKLIV_A**
- **Monitoring/Communication/Ethernet/Link statuses/REDLNKLIV_B**

3.16.2 Ethernet channel supervision SCHLCCH

3.16.2.1 Function block

Figure 36: Function block

3.16.2.2 Functionality

Ethernet channel supervision SCHLCCH represents X1/LAN, X2/LAN and X3/LAN Ethernet channels.

An unused Ethernet port can be set "Off" with the setting **Configuration/ Communication/Ethernet/Rear port(s)/Port x Mode**. This setting closes the port from software, disabling the Ethernet communication in that port. Closing an unused Ethernet port enhances the cyber security of the relay.

3.16.2.3 Signals

Table 62: SCHLCCH1 output signals

Parameter	Values (Range)	Unit	Step	Default	Description
CH1LIV	True False				Status of Ethernet channel X1/LAN. Value is "True" if the port is receiving Ethernet frames. Valid only when *Redundant mode* is set to "None" or port is not one of the redundant ports (LAN A or LAN B).
LNK1LIV	Up Down				Link status of Ethernet port X1/LAN.

Table 63: SCHLCCH2 output signals

Parameter	Values (Range)	Unit	Step	Default	Description
CH2LIV	True False				Status of Ethernet channel X2/LAN. Value is "True" if the port is receiving Ethernet frames. Valid only when *Redundant mode* is set to "None" or port is not one of the redundant ports (LAN A or LAN B).
LNK2LIV	Up Down				Link status of Ethernet port X2/LAN.

Table 64: SCHLCCH3 output signals

Parameter	Values (Range)	Unit	Step	Default	Description
CH3LIV	True False				Status of Ethernet channel X3/LAN. Value is "True" if the port is receiving Ethernet frames. Valid only when *Redundant mode* is set to "None" or port is not one of the redundant ports (LAN A or LAN B).
LNK3LIV	Up Down				Link status of Ethernet port X3/LAN.

3.16.2.4 Settings

Table 65: Port mode settings

Parameter	Values (Range)	Unit	Step	Default	Description
Port 1 Mode	Off On			On	Mode selection for rear port(s). If port is not used, it can be set to “Off”. Port cannot be set to “Off” when *Redundant mode* is “HSR” or “PRP” and port is one of the redundant ports (LAN A or LAN B) .
Port 2 Mode	Off On			On	Mode selection for rear port(s). If port is not used, it can be set to “Off”. Port cannot be set to “Off” when *Redundant mode* is “HSR” or “PRP” and port is one of the redundant ports (LAN A or LAN B).
Port 3 Mode	Off On			On	Mode selection for rear port(s). If port is not used, it can be set to “Off”. Port cannot be set to “Off” when *Redundant mode* is “HSR” or “PRP” and port is one of the redundant ports (LAN A or LAN B).

3.16.2.5 Monitored data

Monitored data is available in six locations.

- **Monitoring/Communication/Ethernet/Activity/CH1LIV**
- **Monitoring/Communication/Ethernet/Activity/CH2LIV**
- **Monitoring/Communication/Ethernet/Activity/CH3LIV**
- **Monitoring/Communication/Ethernet/Link statuses/LNK1LIV**
- **Monitoring/Communication/Ethernet/Link statuses/LNK2LIV**
- **Monitoring/Communication/Ethernet/Link statuses/LNK3LIV**

Section 4 Protection functions

4.1 Three-phase current protection

4.1.1 Three-phase non-directional overcurrent protection PHxPTOC

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-1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	3I>>	51P-2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	3I>>>	50P/51P

4.1.1.2 Function block

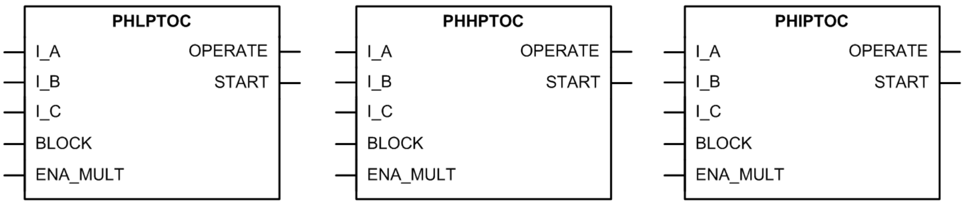


Figure 37: Function block

4.1.1.3 Functionality

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

The function starts when the current exceeds the set limit. The operate time characteristics for low stage PHLPTOC and high stage PHHPTOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage PHIPTOC always operates with the DT characteristic.

In the DT mode, the function operates after a predefined operate 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 "On" and "Off".

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

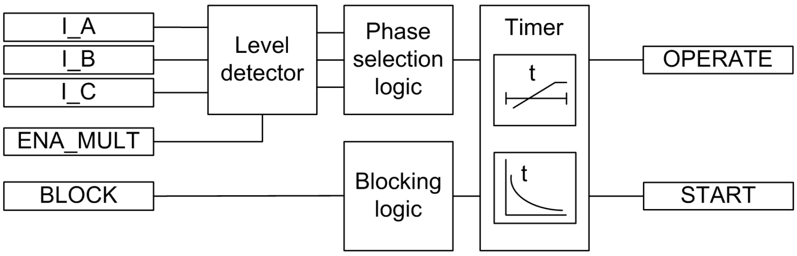


Figure 38: Functional module diagram

Level detector

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

The protection relay does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

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

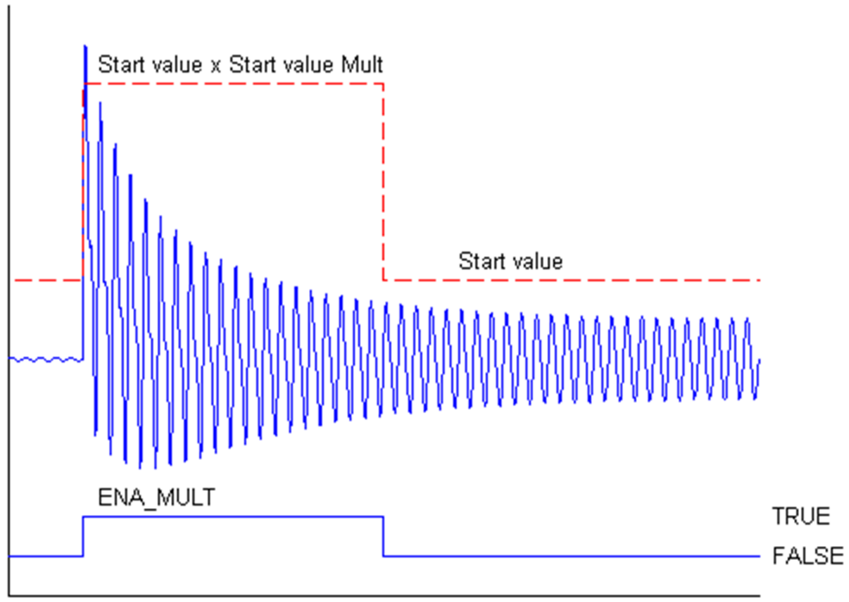


Figure 39: Start value behavior with `ENA_MULT` *input activated*

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 start phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the `START` 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 *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` 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 operate 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. The START output is deactivated when the reset timer has elapsed.

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 operate and reset times.

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE 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 66: *Measurement modes supported by PHxPTOC stages*

Measurement mode	PHLPTOC	PHHPTOC	PHIPTOC
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

PHxPTOC 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 *Operate 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 67: *Timer characteristics supported by different stages*

Operating curve type	PHLPTOC	PHHPTOC
(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
Table continues on next page		

Operating curve type	PHLPTOC	PHHPTOC
(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	

PHIPTOC supports only definite time characteristic.

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

Table 68: Reset time characteristics supported by different stages

Reset curve type	PHLPTOC	PHHPTOC	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

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

4.1.1.7 Application

PHxPTOC 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

PHxPTOC 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 start level for the function to operate. When the number of start-phase settings is set to "1 out of 3", the operation of PHxPTOC 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 start levels and time delays. PHxPTOC consists of three protection stages.

- Low PHLPTOC
- High PHHPTOC
- Instantaneous PHIPTOC

PHLPTOC is used for overcurrent protection. The function contains several types of time-delay characteristics. PHHPTOC and PHIPTOC 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 40. The low-set stage PHLPTOC operates time-selectively both in transformer and LV-side busbar faults. The high-set stage PHHPTOC 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 start value setting in each particular protection relay where the inrush current can occur. The overcurrent and contact based circuit breaker failure protection CCBRBRF is used to confirm the protection scheme in case of circuit breaker malfunction.

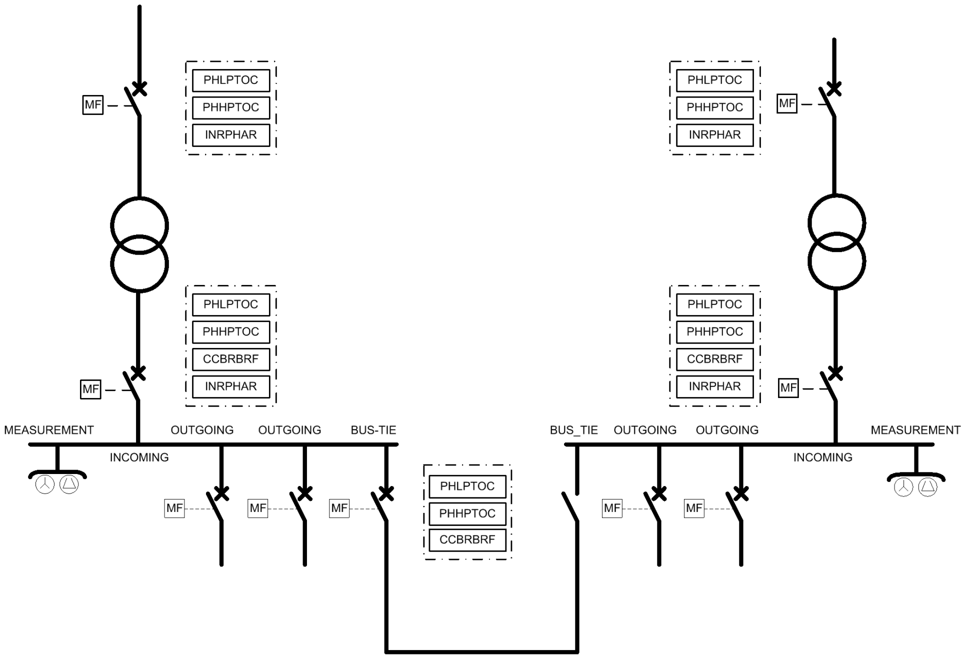


Figure 40: Example of traditional time selective transformer overcurrent protection

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 41 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 degree 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 41 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 69: 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/3I>	DT/IDMT	time selective	low	very high
HV/3I>>	DT	blockable/time selective	high/low	high
HV/3I>>>	DT	current selective	very high	low
LV/3I>	DT/IDMT	time selective	low	very high
LV/3I>>	DT	time selective	low	high
LV/3I>>>	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.

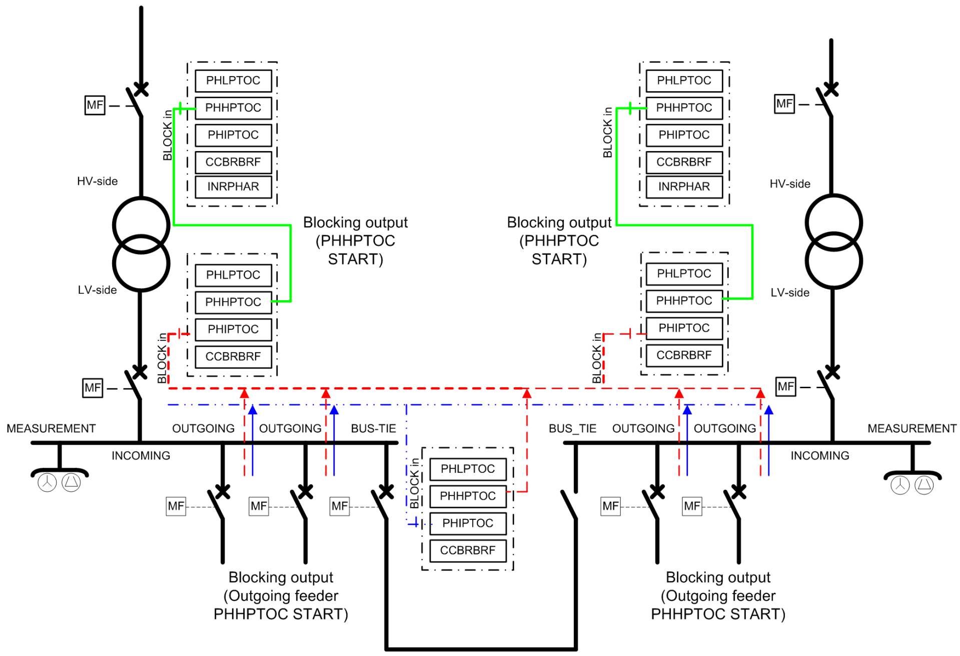


Figure 41: Numerical overcurrent protection functionality for a typical sub-transmission/distribution substation (feeder protection not shown).Blocking output = digital output signal from the start of a protection stage, Blocking in = digital input signal to block the operation of a protection stage

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 start 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 42 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 PHLPTOC operates in IDMT-mode and the two higher stages PHHPTOC and PHIPTOC 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 start value multiplying input of the instantaneous stage. In this way the start value is multiplied with a predefined setting during the inrush situation and nuisance tripping can be avoided.

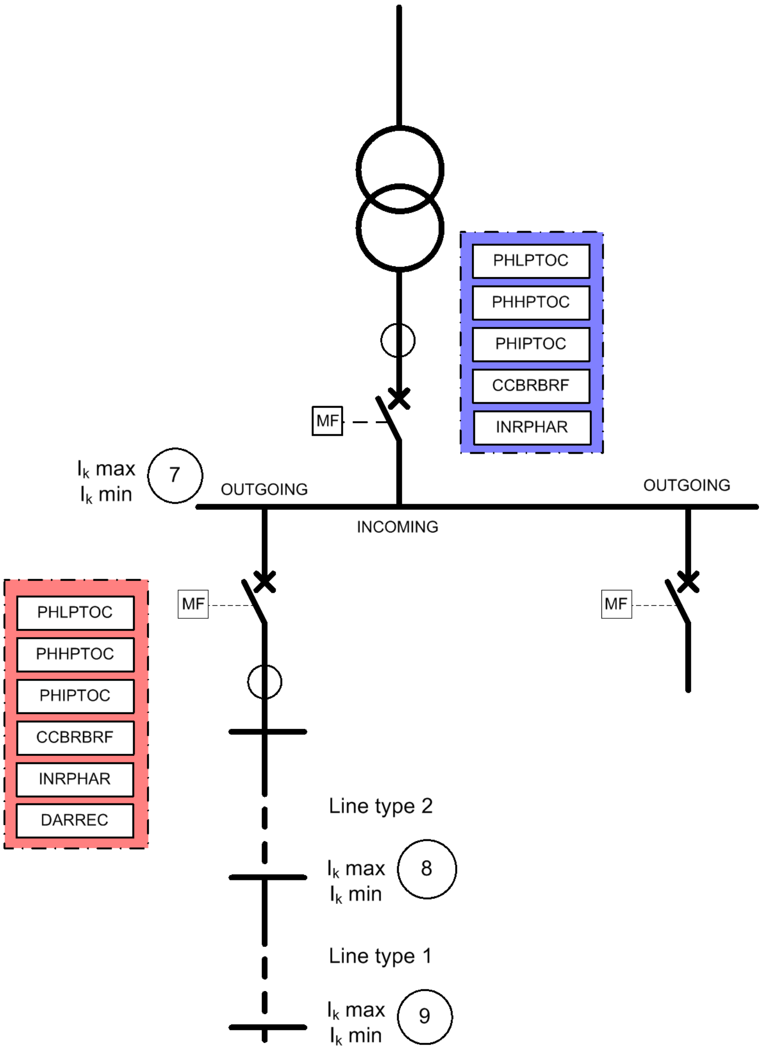


Figure 42: Functionality of numerical multiple-stage overcurrent protection

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 43, the coordination plan shows an example of operation characteristics in the LV-side incoming feeder and radial outgoing feeder.

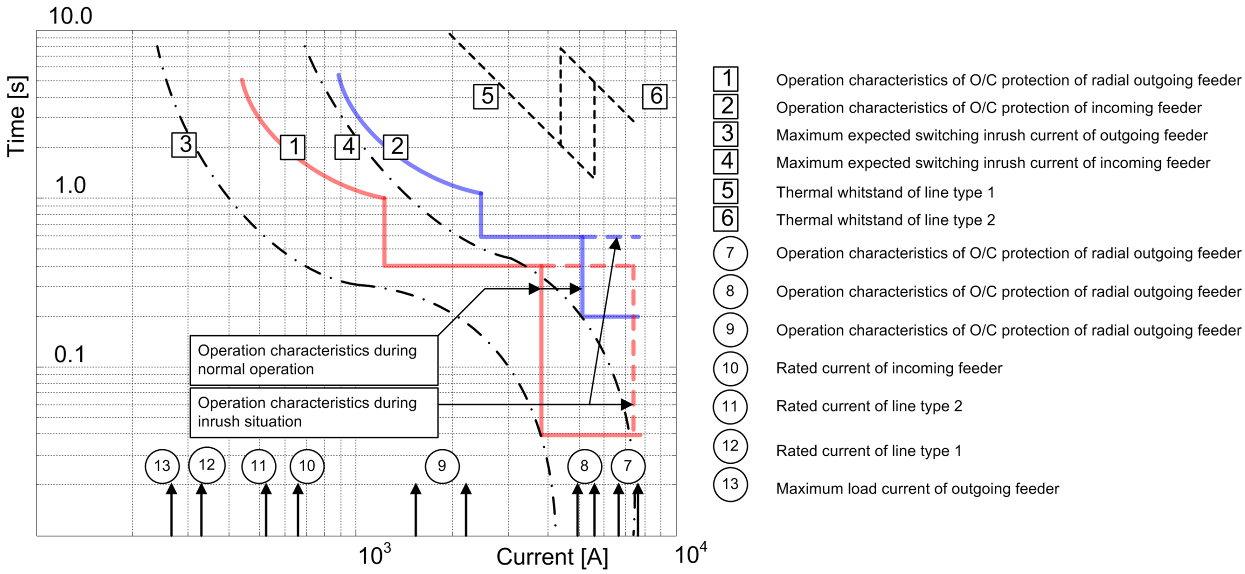


Figure 43: Example coordination of numerical multiple-stage overcurrent protection

4.1.1.8 Signals

Table 70: PHLPTOC 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 71: PHHPTOC 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: PHIPTOC 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: PHLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 74: PHHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 75: PHIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.1.9 Settings

Table 76: PHLPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...5.00	xIn	0.01	0.05	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type

Table 77: PHLPTOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 78: PHLPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 79: PHLPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate 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 5=Wide P-to-P			2=DFT	Selects used measurement mode

Table 80: PHHPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type

Table 81: PHHPTOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 82: PHHPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 83: PHHPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate 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 84: PHIPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	1.00...40.00	xIn	0.01	1.00	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Operate delay time	20...200000	ms	10	20	Operate delay time

Table 85: PHIPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation

Table 86: PHIPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.1.10 Monitored data

Table 87: PHLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHLPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 88: PHHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHHPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 89: PHIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHIPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.1.11 Technical data

Table 90: PHxPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
	PHLPTOC	±1.5% of the set value or ±0.002 × I_n		
	PHHPTOC and PHIPTOC	±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)		
Start time [1)2)]		Minimum	Typical	Maximum
	PHIPTOC: I_{Fault} = 2 × set *Start value* I_{Fault} = 10 × set *Start value*	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	PHHPTOC and PHLPTOC: I_{Fault} = 2 × set *Start value*	22 ms	24 ms	25 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<30 ms		

Table continues on next page

Characteristic	Value
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 ±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 = 50 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 *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.1.1.12 Technical revision history

Table 91: PHIPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting
C	Minimum and default values changed to 20 ms for the *Operate delay time* setting Minimum value changed to 1.00 x I_n for the *Start value* setting
D	Internal improvement
E	Internal improvement

Table 92: PHHPTOC Technical revision history

Technical revision	Change
C	*Measurement mode* "P-to-P + backup" replaced with "Peak-to-Peak"
D	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting
E	Internal improvement
F	Internal improvement

Table 93: PHLPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting
C	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting
D	Internal improvement
E	Internal improvement

4.1.2 Three-phase directional overcurrent protection DPHxPDOC

4.1.2.1 Identification

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

4.1.2.2 Function block

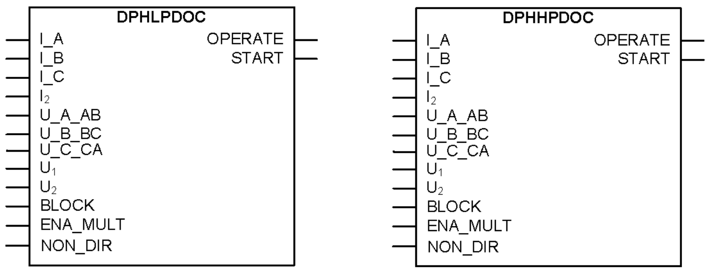


Figure 44: Function block

4.1.2.3 Functionality

In the DT mode, the function operates after a predefined operate 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.

4.1.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

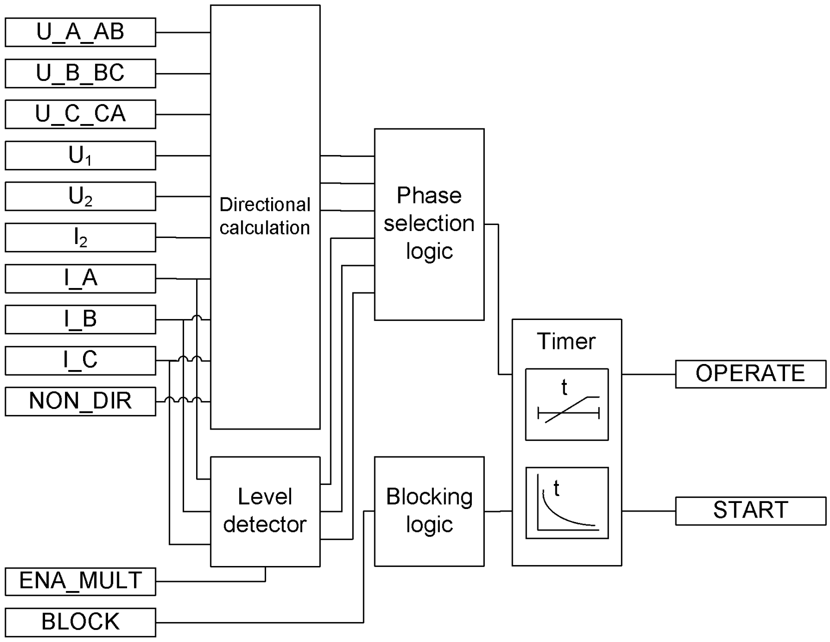


Figure 45: Functional module diagram

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 94: 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 operate current* setting. The minimum amplitude level for the polarizing quantity (voltage) is set with the *Min operate 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 operate 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.

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 operate 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 operate 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 operate 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 operate voltage* and hysteresis. The fictive voltage is also discarded if the measured voltage stays below *Min operate 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 operate 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.

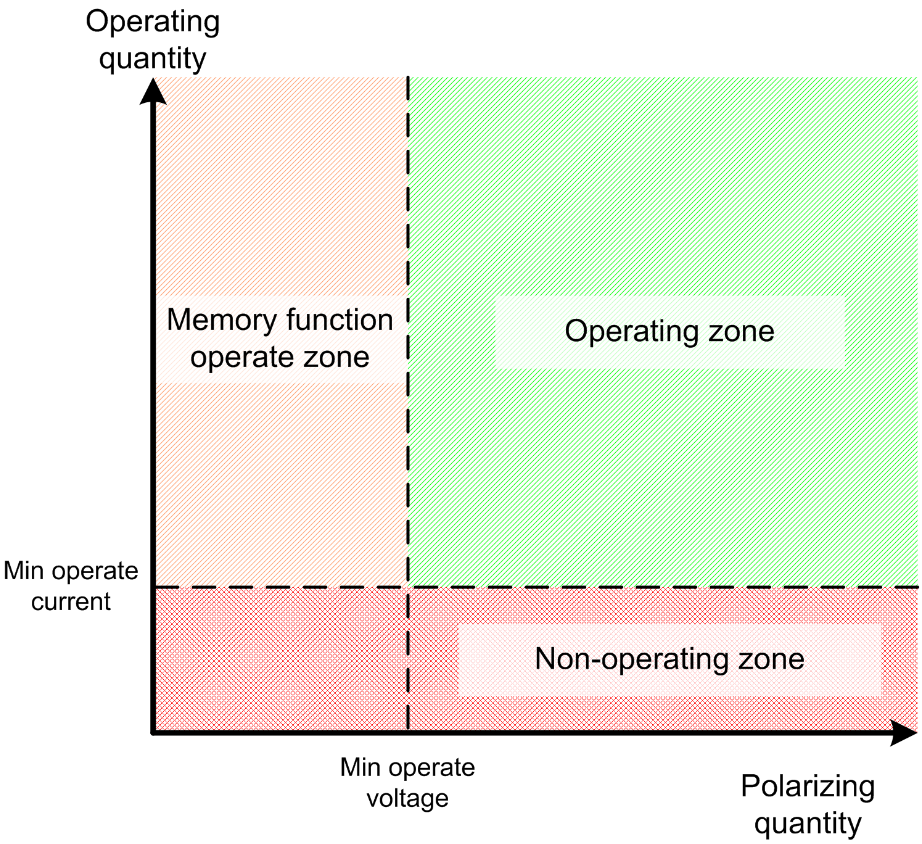


Figure 46: Operating zones at minimum magnitude levels

Level detector

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

The protection relay does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

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

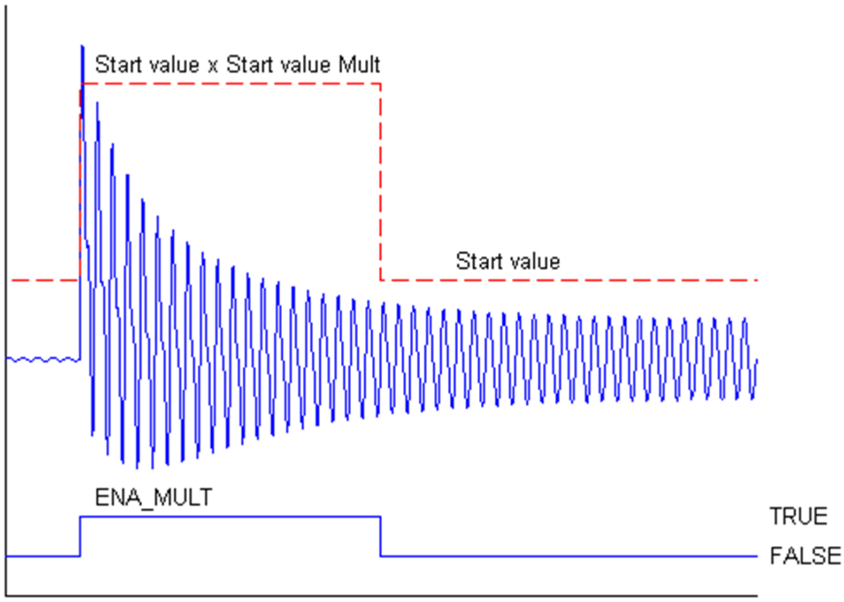


Figure 47: Start value behavior with `ENA_MULT` *input activated*

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 start phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the `START` 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 *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` 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 operate 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. The START output is deactivated when the reset timer has elapsed.

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 operate and reset times.

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.1.2.5 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 95: Measurement modes supported by DPHxPDOC stages

Measurement mode	DPHLPDOC	DPHHPDOC
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

4.1.2.6 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.

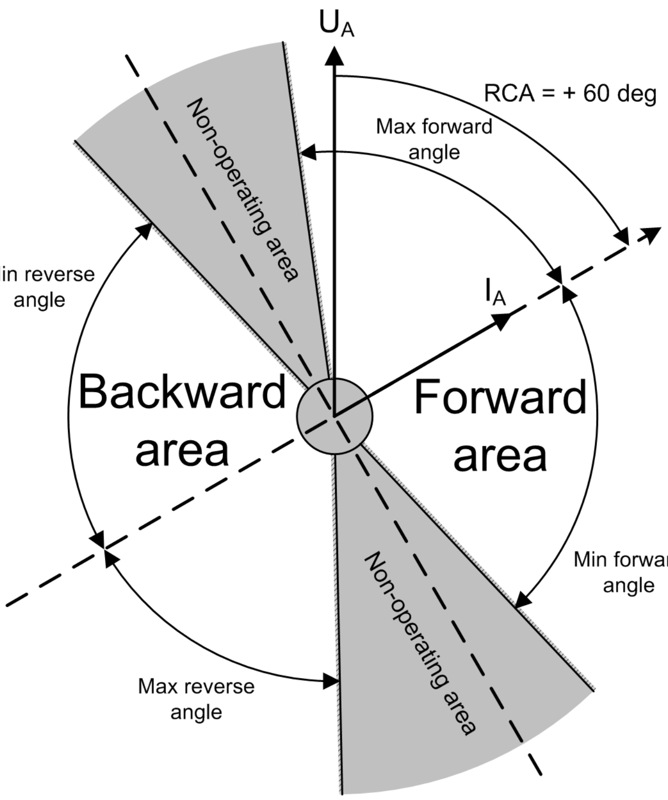


Figure 48: Configurable operating sectors

Table 96: 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 97: 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 START output is active.

Self-polarizing as polarizing method

Table 98: Equations for calculating angle difference for self-polarizing method

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

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

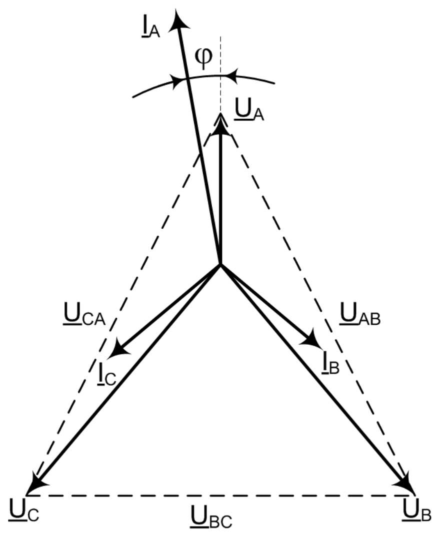


Figure 49: Single-phase earth fault, phase A

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 U_{BC} and operating quantity $\underline{I}_B$ - $\underline{I}_C$ in the self-polarizing method.

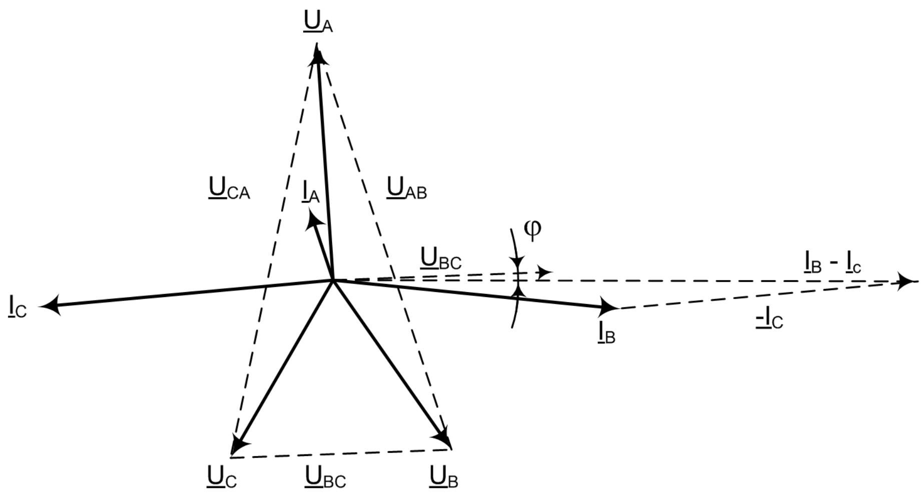


Figure 50: Two-phase short circuit, short circuit is between phases B and C

Cross-polarizing as polarizing quantity

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

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

The angle difference between the polarizing quantity U_{BC} and operating quantity I_A is marked as φ in an example of the phasors in a single-phase earth fault where the faulted phase is phase A. The polarizing quantity is rotated with 90 degrees. The characteristic angle is assumed to be ~ 0 degrees.

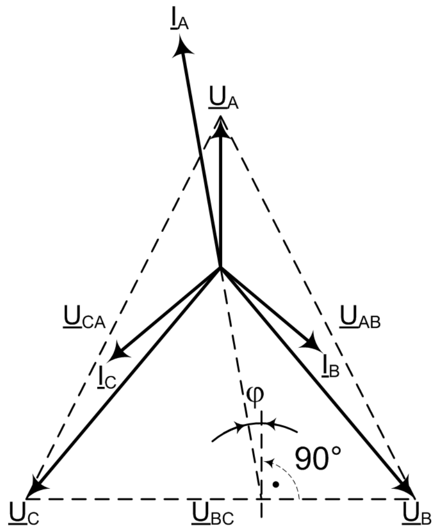


Figure 51: Single-phase earth fault, phase A

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 $\underline{U}_{AB}$ and operating quantity $\underline{I}_B$ - $\underline{I}_C$ marked as φ.

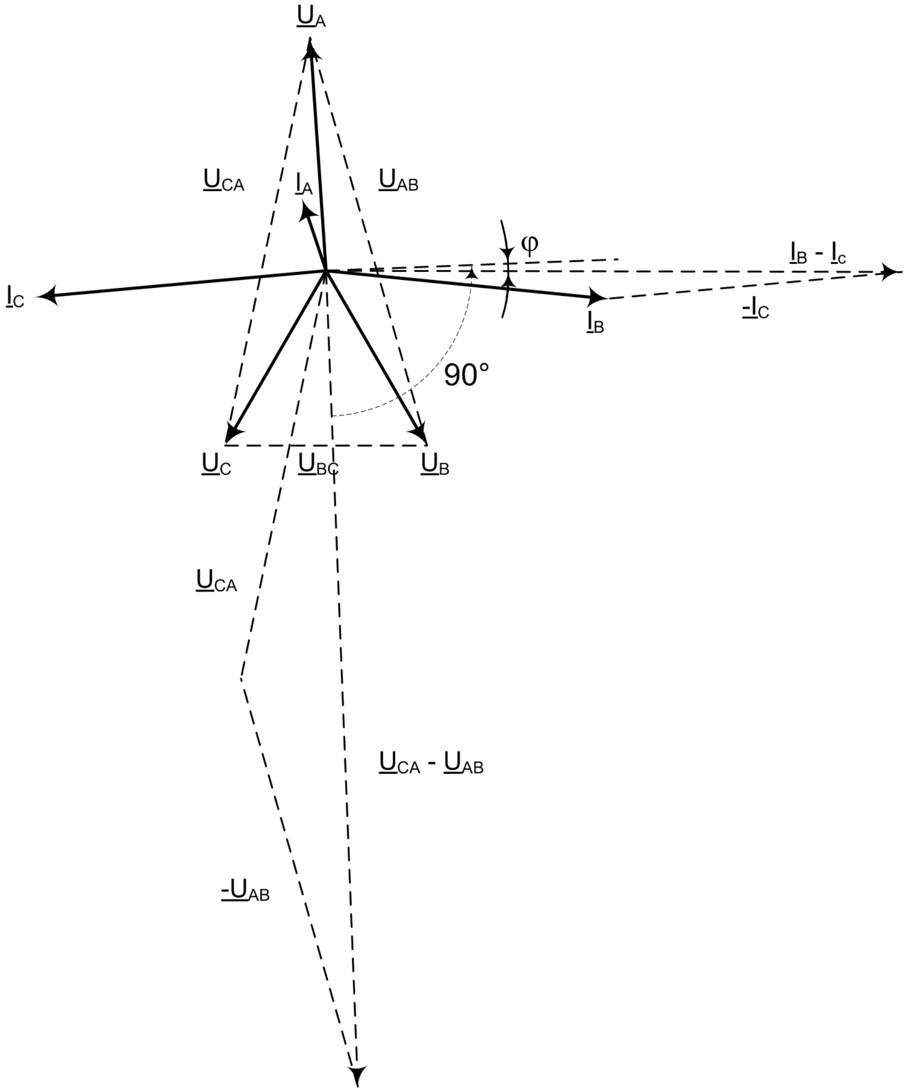


Figure 52: Two-phase short circuit, short circuit is between phases B and C

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:

$$ANGLE\_X = \varphi(-\underline{U}_2) - \varphi(\underline{I}_2) - \varphi_{RCA}$$

(Equation 1)

This means that the actuating polarizing quantity is -$\underline{U}_2$.

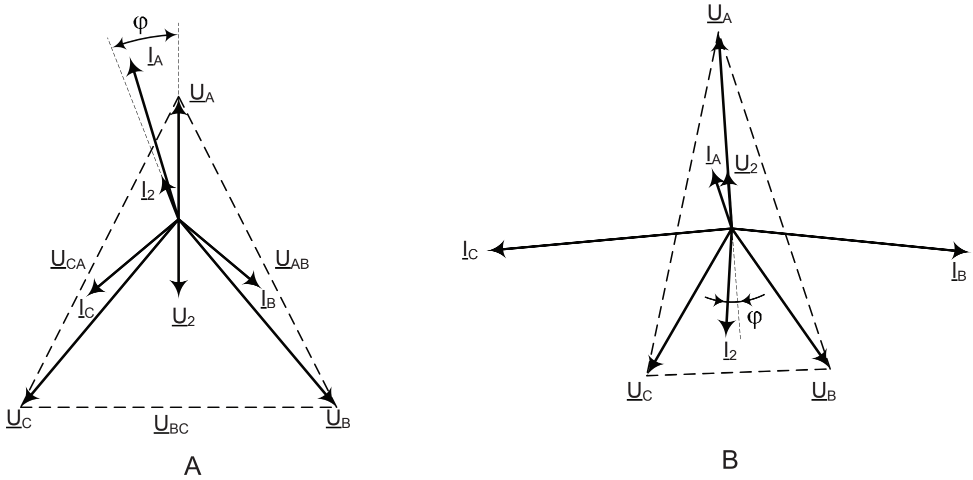


Figure 53: Phasors in a single-phase earth fault, phases A-N, and two-phase short circuit, phases B and C, when the actuating polarizing quantity is the negative-sequence voltage -U2

Positive sequence voltage as polarizing quantity

Table 100: Equations for calculating angle difference for positive-sequence quantity polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{U}_1$	$ANGLE\_A = \varphi(\underline{U}_1) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	$\underline{I}_B$	$\underline{U}_1$	$ANGLE\_B = \varphi(\underline{U}_1) - \varphi(\underline{I}_B) - \varphi_{RCA} - 120^\circ$
C	$\underline{I}_C$	$\underline{U}_1$	$ANGLE\_C = \varphi(\underline{U}_1) - \varphi(\underline{I}_C) - \varphi_{RCA} + 120^\circ$
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{U}_1$	$ANGLE\_A = \varphi(\underline{U}_1) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 30^\circ$
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{U}_1$	$ANGLE\_B = \varphi(\underline{U}_1) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} - 90^\circ$
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{U}_1$	$ANGLE\_C = \varphi(\underline{U}_1) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 150^\circ$

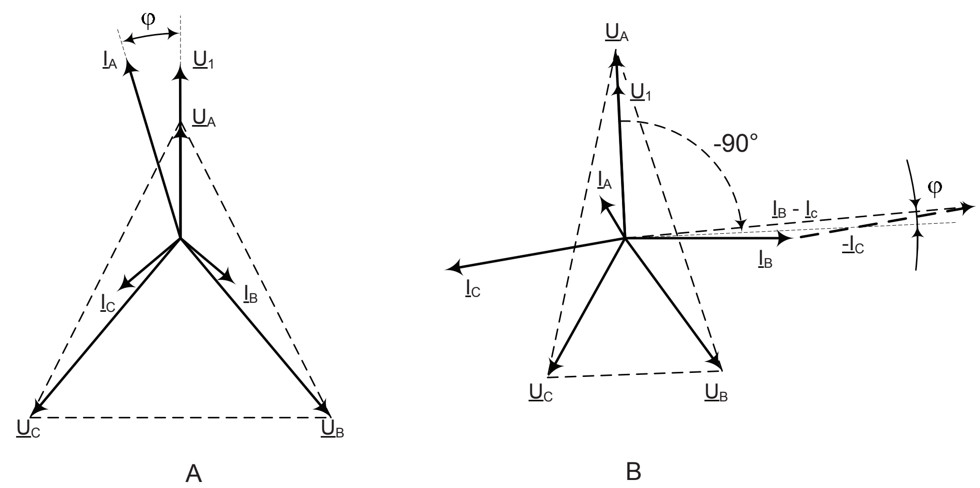


Figure 54: Phasors in a single-phase earth fault, phase A to ground, and a two-phase short circuit, phases B-C, are short-circuited when the polarizing quantity is the positive-sequence voltage U_1

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".

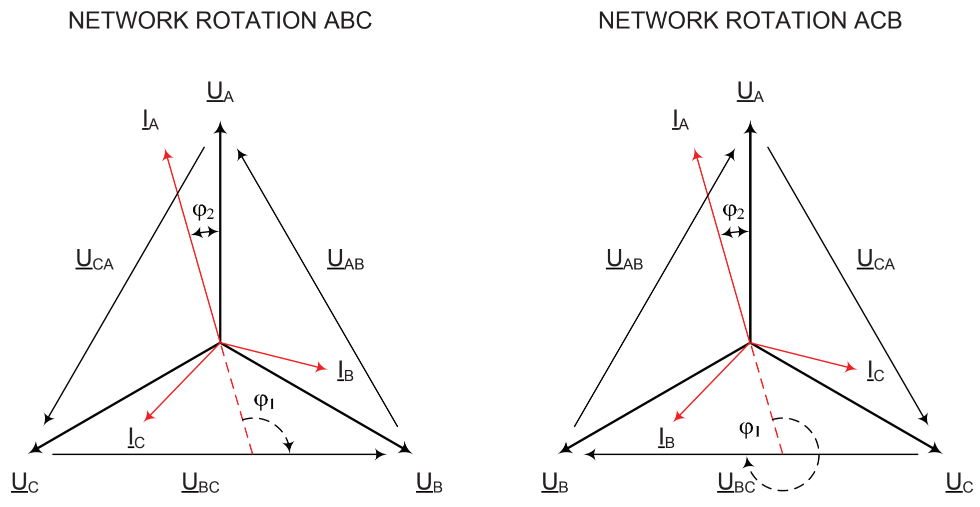


Figure 55: Examples of network rotating direction

4.1.2.7 Application

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.

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.

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 DPHxPDOC 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.

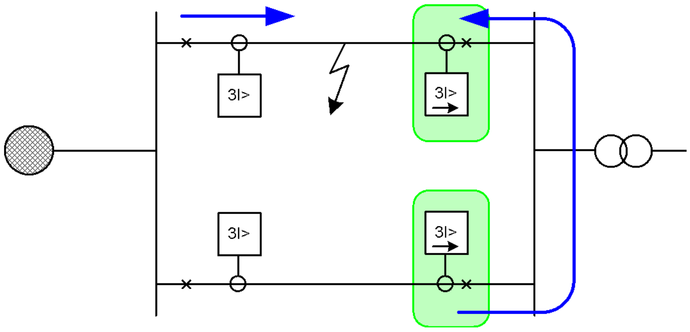


Figure 56: Overcurrent protection of parallel lines using directional protection relays

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.

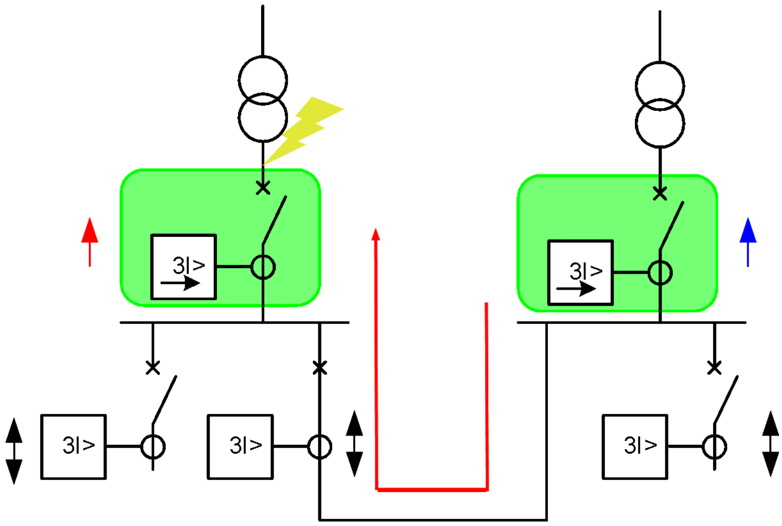


Figure 57: Overcurrent protection of parallel operating transformers

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.

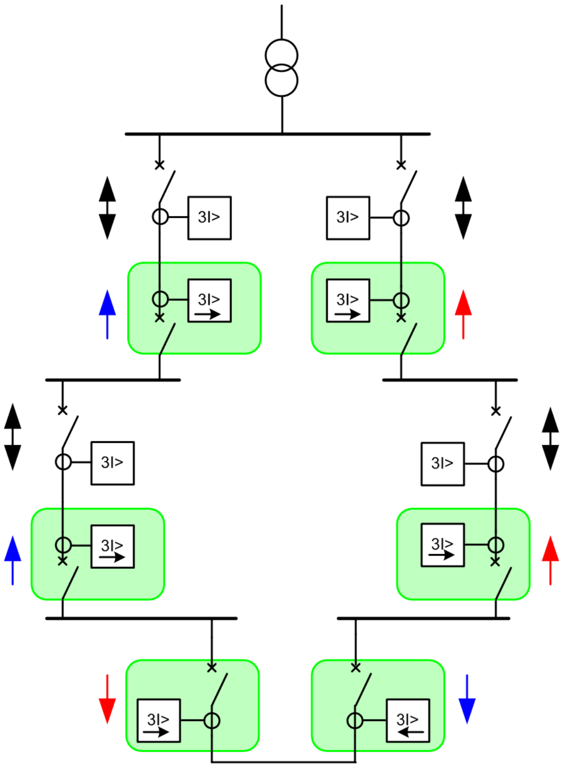


Figure 58: Closed ring network topology where feeding lines are protected with directional overcurrent protection relays

4.1.2.8 Signals

Table 101: DPHLPDOC 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
U_A_AB	SIGNAL	0	Phase-to-earth voltage A or phase-to-phase voltage AB
U_B_BC	SIGNAL	0	Phase-to-earth voltage B or phase-to-phase voltage BC
U_C_CA	SIGNAL	0	Phase-to-earth voltage C or phase-to-phase voltage CA
U_1	SIGNAL	0	Positive phase sequence voltage
U_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 102: DPHHPDOC 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
U_A_AB	SIGNAL	0	Phase-to-earth voltage A or phase-to-phase voltage AB
U_B_BC	SIGNAL	0	Phase-to-earth voltage B or phase-to-phase voltage BC
U_C_CA	SIGNAL	0	Phase-to-earth voltage C or phase-to-phase voltage CA
U_1	SIGNAL	0	Positive phase sequence voltage
U_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: DPHLPDOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 104: DPHHPDOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.2.9 Settings

Table 105: DPHLPDOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...5.00	xIn	0.01	0.05	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate 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 Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
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

Table 106: DPHLPDOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Pol quantity	1=Self pol 4=Neg. seq. volt. 5=Cross pol 7=Pos. seq. volt.			5=Cross pol	Reference quantity used to determine fault direction

Table 107: DPHLPDOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 108: DPHLPDOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate 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
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Min operate current	0.01...1.00	xIn	0.01	0.01	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage

Table 109: DPHHPDOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start 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 Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Operate delay time	40...200000	ms	10	40	Operate 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
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction

Table 110: DPHHPDOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Pol quantity	1=Self pol 4=Neg. seq. volt. 5=Cross pol 7=Pos. seq. volt.			5=Cross pol	Reference quantity used to determine fault direction

Table 111: DPHHPDOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve
Num of start 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 operate activation

Table 112: DPHHPDOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	20...60000	ms	1	20	Minimum operate 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 operate current	0.01...1.00	xIn	0.01	0.01	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage

4.1.2.10 Monitored data

Table 113: DPHLPDOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate 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 -1=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward -1=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
VMEM_USED	BOOLEAN	0=False 1=True		Voltage memory in use status
DPHLPDOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 114: DPHHPDOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate 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 -1=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward -1=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
VMEM_USED	BOOLEAN	0=False 1=True		Voltage memory in use status
DPHHPDOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.2.11 Technical data

Table 115: DPHxPDOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current/voltage measured: f_n ±2 Hz		
	DPHLPDOC	Current: ±1.5% of the set value or ±0.002 × I_n Voltage: ±1.5% of the set value or ±0.002 × U_n Phase angle: ±2°		
	DPHHPDOC	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 × U_n Phase angle: ±2°		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Start value*	39 ms	43 ms	47 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Table continues on next page				

Characteristic	Value
Retardation time	<35 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 ±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 × U_n, f_n = 50 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 *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.1.2.12 Technical revision history

Table 116: DPHHPDOC Technical revision history

Technical revision	Change
B	Added a new input `NON_DIR`
C	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
D	Monitored data VMEM_USED indicating voltage memory use.
E	Internal improvement.

Table 117: DPHLPDOC Technical revision history

Technical revision	Change
B	Added a new input `NON_DIR`
C	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
D	Monitored data VMEM_USED indicating voltage memory use.
E	Internal improvement.

4.1.3 Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR

4.1.3.1 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

4.1.3.2 Function block

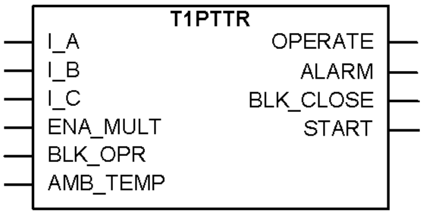


Figure 59: Function block

4.1.3.3 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 three-phase thermal protection for feeders, cables and distribution transformers function T1PTTR 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 the thermal overload operation can be inhibited during the time the cooling of the line is in progress. The cooling of the line is estimated by the thermal model.

4.1.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of T1PTTR can be described using a module diagram. All the modules in the diagram are explained in the next sections.

The function uses ambient temperature which can be measured locally or remotely. Local measurement is done by the protection relay. Remote measurement uses analog GOOSE to connect `AMB_TEMP` input.

If the quality of remotely measured temperature is invalid or communication channel fails the function uses ambient temperature set in *Env temperature Set*.

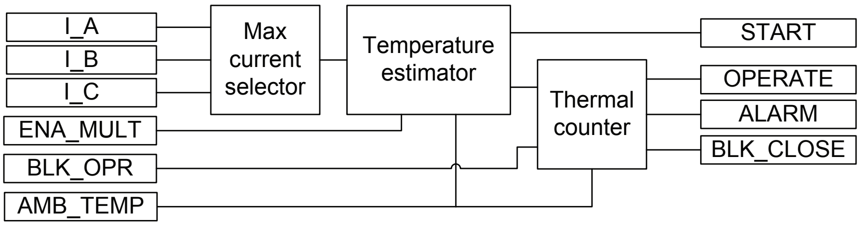


Figure 60: Functional module diagram

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 2)

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 `START` output is activated.

Current reference and *Temperature rise* 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 3)

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 `OPERATE` output is activated. The `OPERATE` 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 performed if the final temperature is calculated to be above the operation temperature:

$$t_{operate} = -\tau \cdot \ln\left(\frac{\Theta_{final} - \Theta_{operate}}{\Theta_{final} - \Theta_n}\right)$$

(Equation 4)

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 `OPERATE` output is activated and is not reset until the device temperature has cooled down below the set value of the *Reclose temperature* setting. 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 5)

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 ambient temperature can be measured with the RTD measurement. The measured temperature value is then connected, for example, from the `AI_VAL3` output of the X130 (RTD) function to the `AMB_TEMP` input of T1PTTR.

The *Env temperature Set* setting is used to define the ambient temperature if the ambient temperature measurement value is not connected to the `AMB_TEMP` input. The *Env temperature Set* setting is also used when the ambient temperature measurement connected to T1PTTR is set to “Not in use” in the X130 (RTD) function.

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 turned "Off" and back "On" 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.

T1PTTR thermal model complies with the IEC 60255-149 standard.

4.1.3.5 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-earth 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.

4.1.3.6 Signals

Table 118: T1PTTR 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
ENA_MULT	BOOLEAN	0=False	Enable Current multiplier
BLK_OPR	BOOLEAN	0=False	Block signal for operate outputs
AMB_TEMP	FLOAT32	0	The ambient temperature used in the calculation

Table 119: T1PTTR Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
ALARM	BOOLEAN	Thermal Alarm
BLK_CLOSE	BOOLEAN	Thermal overload indicator. To inhibite reclose.
START	BOOLEAN	Start

4.1.3.7 Settings

Table 120: T1PTTR Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Env temperature Set	-50...100	°C	1	40	Ambient temperature used when no external temperature measurement available
Current reference	0.05...4.00	xIn	0.01	1.00	The load current leading to Temperature raise temperature
Temperature rise	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.
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Maximum temperature	20.0...200.0	°C	0.1	90.0	Temperature level for operate
Alarm value	20.0...150.0	°C	0.1	80.0	Temperature level for start (alarm)
Reclose temperature	20.0...150.0	°C	0.1	70.0	Temperature for reset of block reclose after operate

Table 121: T1PTTR Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Current multiplier	1...5		1	1	Current multiplier when function is used for parallel lines

Table 122: T1PTTR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 123: T1PTTR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Initial temperature	-50.0...100.0	°C	0.1	0.0	Temperature raise above ambient temperature at startup

4.1.3.8 Monitored data

Table 124: T1PTTR 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 operate level
T_OPERATE	INT32	0...60000	s	Estimated time to operate
T_ENA_CLOSE	INT32	0...60000	s	Estimated time to deactivate BLK_CLOSE
TEMP_AMB	FLOAT32	-99...999	°C	The ambient temperature used in the calculation
T1PTTR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.3.9 Technical data

Table 125: T1PTTR 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)
Operate time accuracy[1)]	±2.0% of the theoretical value or ±0.50 s

1) Overload current > 1.2 × Operate level temperature

4.1.3.10 Technical revision history

Table 126: T1PTTR Technical revision history

Technical revision	Change
C	Removed the *Sensor available* setting parameter
D	Added the `AMB_TEMP` input
E	Internal improvement.
F	Internal improvement.

4.1.4 Motor load jam protection JAMPTOC

4.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor load jam protection	JAMPTOC	Ist>	51LR

4.1.4.2 Function block

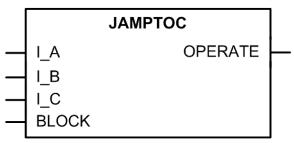


Figure 61: Function block

4.1.4.3 Functionality

The motor load jam protection function JAMPTOC is used for protecting the motor in stall or mechanical jam situations during the running state.

When the motor is started, a separate function is used for the startup protection, and JAMPTOC is normally blocked during the startup period. When the motor has passed the starting phase, JAMPTOC monitors the magnitude of phase currents. The function starts when the measured current exceeds the breakdown torque level, that is, above the set limit. The operation characteristic is definite time.

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

4.1.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

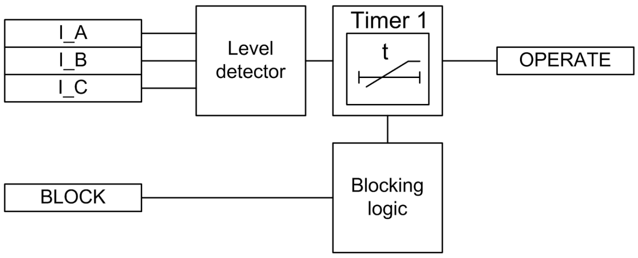


Figure 62: Functional module diagram

Level detector

The measured phase currents are compared to the set *Start value*. The TRMS values of the phase currents are considered for the level detection. The timer module is enabled if at least two of the measured phase currents exceed the set *Start value*.

Timer

Once activated, the internal `START` signal is activated. The value is available only through the Monitored data view. The time characteristic is according to DT. When the operation timer has reached the *Operate delay time* value, the `OPERATE` output is activated.

When the timer has elapsed but the motor stall condition still exists, the `OPERATE` output remains active until the phase currents values drop below the *Start value*, that is, until the stall condition persists. If the drop-off situation occurs while the operating time is still counting, the reset timer is activated. If the drop-off time exceeds the set *Reset delay time*, the operating timer is reset.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 **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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.1.4.5 Application

The motor protection during stall is primarily needed to protect the motor from excessive temperature rise, as the motor draws large currents during the stall phase. This condition causes a temperature rise in the stator windings. Due to reduced speed, the temperature also rises in the rotor. The rotor temperature rise is more critical when the motor stops.

The physical and dielectric insulations of the system deteriorate with age and the deterioration is accelerated by the temperature increase. Insulation life is related to the time interval during which the insulation is maintained at a given temperature.

An induction motor stalls when the load torque value exceeds the breakdown torque value, causing the speed to decrease to zero or to some stable operating point well below the rated speed. This occurs, for example, when the applied shaft load is suddenly increased and is greater than the producing motor torque due to the bearing failures. This condition develops a motor current almost equal to the value of the locked-rotor current.

JAMPTOC is designed to protect the motor in stall or mechanical jam situations during the running state. To provide a good and reliable protection for motors in a stall situation, the temperature effects on the motor have to be kept within the allowed limits.

4.1.4.6 Signals

Table 127: JAMPTOC 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 128: JAMPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate

4.1.4.7 Settings

Table 129: JAMPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Start value	0.10...10.00	xIn	0.01	2.50	Start value
Operate delay time	100...120000	ms	10	2000	Operate delay time

Table 130: JAMPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	100	Reset delay time

4.1.4.8 Monitored data

Table 131: JAMPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START	BOOLEAN	0=False 1=True		Start
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
JAMPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.4.9 Technical data

Table 132: JAMPTOC 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
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Retardation time	<35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

4.1.4.10 Technical revision history

Table 133: JAMPTOC Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

4.1.5 Loss of load supervision LOFLPTUC

4.1.5.1 Identification

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

4.1.5.2 Function block

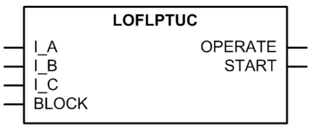


Figure 63: Function block

4.1.5.3 Functionality

The loss of load supervision function LOFLPTUC is used to detect a sudden load loss which is considered as a fault condition.

LOFLPTUC starts when the current is less than the set limit. It operates with the definite time (DT) characteristics, which means that the function operates after a predefined operate time and resets when the fault current disappears.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer 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 "On" and "Off".

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

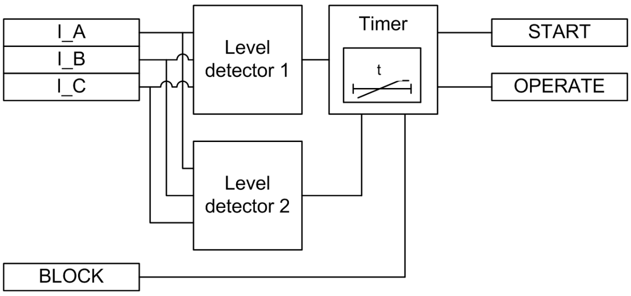


Figure 64: Functional module diagram

Level detector 1

This module compares the phase currents (RMS value) to the set *Start value high* setting. If all the phase current values are less than the set *Start value high* value, the loss of load condition is detected and an enable signal is sent to the timer. This signal is disabled after one or several phase currents have exceeded the set *Start value high* value of the element.

Level detector 2

This is a low-current detection module, which monitors the de-energized condition of the motor. It compares the phase currents (RMS value) to the set *Start value low* setting. If any of the phase current values is less than the set *Start value low*, a signal is sent to block the operation of the timer.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating time. The value is available in the monitored data view.

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

4.1.5.5 Application

When a motor runs with a load connected, it draws a current equal to a value between the no-load value and the rated current of the motor. The minimum load current can be determined by studying the characteristics of the connected load. When the current drawn by the motor is less than the minimum load current drawn, it can be inferred that the motor is either disconnected from the load or the coupling mechanism is faulty. If the motor is allowed to run in this condition, it may aggravate the fault in the coupling mechanism or harm the personnel handling the machine. Therefore, the motor has to be disconnected from the power supply as soon as the above condition is detected.

LOFLPTUC detects the condition by monitoring the current values and helps disconnect the motor from the power supply instantaneously or after a delay according to the requirement.

When the motor is at standstill, the current will be zero and it is not recommended to activate the trip during this time. The minimum current drawn by the motor when it is connected to the power supply is the no load current, that is, the higher start value current. If the current drawn is below the lower start value current, the motor is disconnected from the power supply. LOFLPTUC detects this condition and interprets that the motor is de-energized and disables the function to prevent unnecessary trip events.

4.1.5.6 Signals

Table 134: LOFLPTUC 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 all binary outputs by resetting timers

Table 135: LOFLPTUC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.5.7 Settings

Table 136: LOFLPTUC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value low	0.01...0.50	xIn	0.01	0.10	Current setting/Start value low
Start value high	0.01...1.00	xIn	0.01	0.50	Current setting/Start value high
Operate delay time	400...600000	ms	10	2000	Operate delay time

Table 137: LOFLPTUC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 138: LOFLPTUC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.5.8 Monitored data

Table 139: LOFLPTUC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
LOFLPTUC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.5.9 Technical data

Table 140: LOFLPTUC 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
Start time	Typically 300 ms
Reset time	Typically 40 ms
Reset ratio	Typically 1.04
Retardation time	<35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

4.1.5.10 Technical revision history

Table 141: LOFLPTUC Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

4.1.6 Thermal overload protection for motors MPTTR

4.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Thermal overload protection for motors	MPTTR	3Ith>M	49M

4.1.6.2 Function block

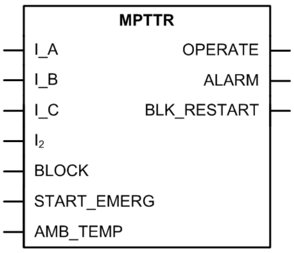


Figure 65: Function block

4.1.6.3 Functionality

The thermal overload protection for motors function MPTTR protects the electric motors from overheating. MPTTR models the thermal behavior of motor on the basis of the measured load current and disconnects the motor when the thermal content reaches 100 percent.

Thermal overload conditions are the most often encountered abnormal conditions in industrial motor applications. The thermal overload conditions are typically the result of an abnormal rise in the motor running current, which produces an increase in the thermal dissipation of the motor and temperature or reduces cooling. MPTTR prevents an electric motor from drawing excessive current and overheating, which causes the premature insulation failures of the windings and, in worst cases, burning out of the motors.

4.1.6.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

The function uses ambient temperature which can be measured locally or remotely. Local measurement is done by the protection relay. Remote measurement uses analog GOOSE to connect `AMB_TEMP` input.

If the quality of remotely measured temperature is invalid or communication channel fails the function uses ambient temperature set in *Env temperature Set*.

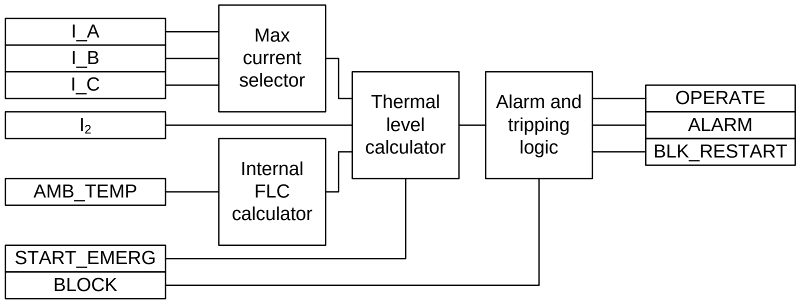


Figure 66: Functional module diagram

Max current selector

Max current selector selects the highest measured TRMS phase current and reports it to Thermal level calculator.

Internal FLC calculator

Full load current (FLC) of the motor is defined by the manufacturer at an ambient temperature of 40°C. Special considerations are required with an application where the ambient temperature of a motor exceeds or remains below 40°C. A motor operating at a higher temperature, even if at or below rated load, can subject the motor windings to excessive temperature similar to that resulting from overload operation at normal ambient temperature. The motor rating has to be appropriately reduced for operation in such high ambient temperatures. Similarly, when the ambient temperature is considerably lower than the nominal 40°C, the motor can be slightly overloaded. For calculating thermal level it is better that the FLC values are scaled for different temperatures. The scaled currents are known as internal FLC. An internal FLC is calculated based on the ambient temperature shown in the table. The *Env temperature mode* setting defines whether the thermal level calculations are based on FLC or internal FLC.

When the value of the *Env temperature mode* setting is set to the "FLC Only" mode, no internal FLC is calculated. Instead, the FLC given in the data sheet of the manufacturer is used. When the value of the *Env temperature mode* setting is set to "Set Amb Temp" mode, the internal FLC is calculated based on the ambient temperature taken as an input through the *Env temperature Set* setting. When the *Env temperature mode* setting is on "Use input" mode, the internal FLC is calculated from temperature data available through resistance temperature detectors (RTDs) using the `AMB_TEMP` input.

Table 142: *Modification of internal FLC*

Ambient Temperature T_{amb}	Internal FLC
<20°C	FLC x 1.09
20 to <40°C	FLC x (1.18 - T_{amb} x 0.09/20)
40°C	FLC
>40 to 65°C	FLC x (1 –[(T_{amb} -40)/100])
>65°C	FLC x 0.75

The ambient temperature is used for calculating thermal level and it is available in the monitored data view from the `TEMP_AMB` output. The activation of the `BLOCK` input does not affect the `TEMP_AMB` output.

The *Env temperature Set* setting is used:

- If the ambient temperature measurement value is not connected to the AMB_TEMP input in ACT.
- When the ambient temperature measurement connected to 49M is set to "Not in use" in the RTD function.
- In case of any errors or malfunctioning in the RTD output.

Thermal level calculator

The module calculates the thermal load considering the TRMS and negative-sequence currents. The heating up of the motor is determined by the square value of the load current.

However, in case of unbalanced phase currents, the negative-sequence current also causes additional heating. By deploying a protection based on both current components, abnormal heating of the motor is avoided.

The thermal load is calculated based on different situations or operations and it also depends on the phase current level. The equations used for the heating calculations are:

$$\theta_B = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times \left(1 - e^{-t/\tau}\right) \times p\%$$

(Equation 6)

$$\theta_A = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times \left(1 - e^{-t/\tau}\right) \times 100\%$$

(Equation 7)

I TRMS value of the measured max of phase currents

I_r set *Current reference*, FLC or internal FLC

I_2 measured negative sequence current

k set value of *Overload factor*

K_2 set value of *Negative Seq factor*

p set value of *Weighting factor*

τ time constant

The equation θ_B is used when the values of all the phase currents are below the overload limit, that is, k x I_r. The equation θ_A is used when the value of any one of the phase currents exceeds the overload limit.

During overload condition, the thermal level calculator calculates the value of θ_B in background, and when the overload ends the thermal level is brought linearly from θ_A to θ_B with a speed of 1.66 percent per second. For the motor at standstill, that is, when the current is below the value of 0.12 x I_r, the cooling is expressed as:

$$\theta = \theta_{02} \times e^{\frac{-t}{\tau}}$$

(Equation 8)

θ_{02} initial thermal level when cooling begins

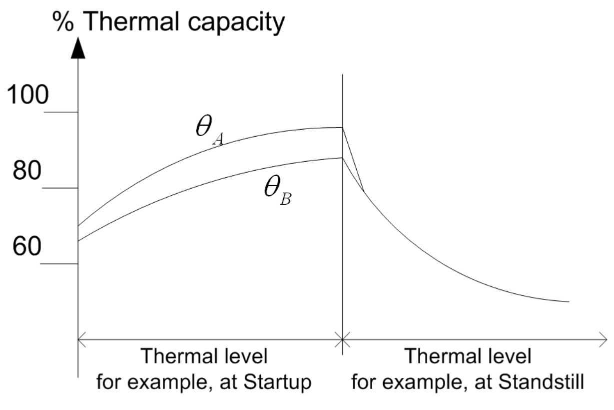


Figure 67: Thermal behavior

The required overload factor and negative sequence current heating effect factor are set by the values of the *Overload factor* and *Negative Seq factor* settings.

In order to accurately calculate the motor thermal condition, different time constants are used in the above equations. These time constants are employed based on different motor running conditions, for example starting, normal or stop, and are set through the

Time constant start, *Time constant normal* and *Time constant stop* settings. Only one time constant is valid at a time.

Table 143: Time constant and the respective phase current values

Time constant (tau) in use	Phase current
Time constant start	Any current whose value is over 2.5 x I_r
Time constant normal	Any current whose value is over 0.12 x I_r and all currents are below 2.5 x I_r
Time constant stop	All the currents whose values are below 0.12 x I_r

The *Weighting factor p* setting determines the ratio of the thermal increase of the two curves θ_A and θ_B.

The thermal level at the power-up of the protection relay is defined by the *Initial thermal Val* setting.

The temperature calculation is initiated from the value defined in the *Initial thermal Val* setting. This is done if the protection relay is powered up or the function is turned off and back on or reset through the Clear menu.

The calculated temperature of the protected object relative to the operate level, the `TEMP_RL` output, is available through the monitored data view. The activation of the `BLOCK` input does not affect the calculated temperature.

The thermal level at the beginning of the start-up condition of a motor and at the end of the start-up condition is available in the monitored data view at the `THERMLEV_ST` and `THERMLEV_END` outputs respectively. The activation of the `BLOCK` input does not have any effect on these outputs.

Alarm and tripping logic

The module generates alarm, restart inhibit and tripping signals.

When the thermal level exceeds the set value of the *Alarm thermal value* setting, the `ALARM` output is activated. Sometimes a condition arises when it becomes necessary to inhibit the restarting of a motor, for example in case of some extreme starting condition like long starting time. If the thermal content exceeds the set value of the *Restart thermal val* setting, the `BLK_RESTART` output is activated. The time for the next possible motor start-up is available through the monitored data view from the `T_ENARESTART` output. The `T_ENARESTART` output estimates the time for the `BLK_RESTART` deactivation considering as if the motor is stopped.

When the emergency start signal `START_EMERG` is set high, the thermal level is set to a value below the thermal restart inhibit level. This allows at least one motor start-up, even though the thermal level has exceeded the restart inhibit level.

When the thermal content reaches 100 percent, the OPERATE output is activated. The OPERATE output is deactivated when the value of the measured current falls below 12 percent of *Current reference* or the thermal content drops below 100 percent.

The activation of the BLOCK input blocks the ALARM, BLK_RESTART and OPERATE outputs.

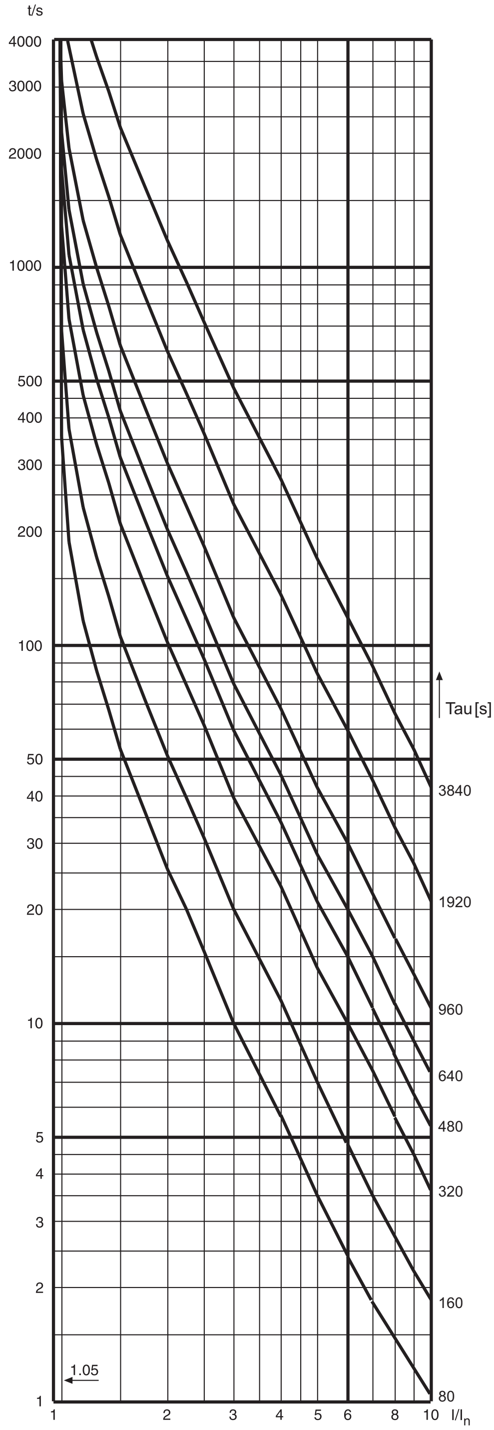


Figure 68: Trip curves when no prior load and p=20...100 %. Overload factor = 1.05.

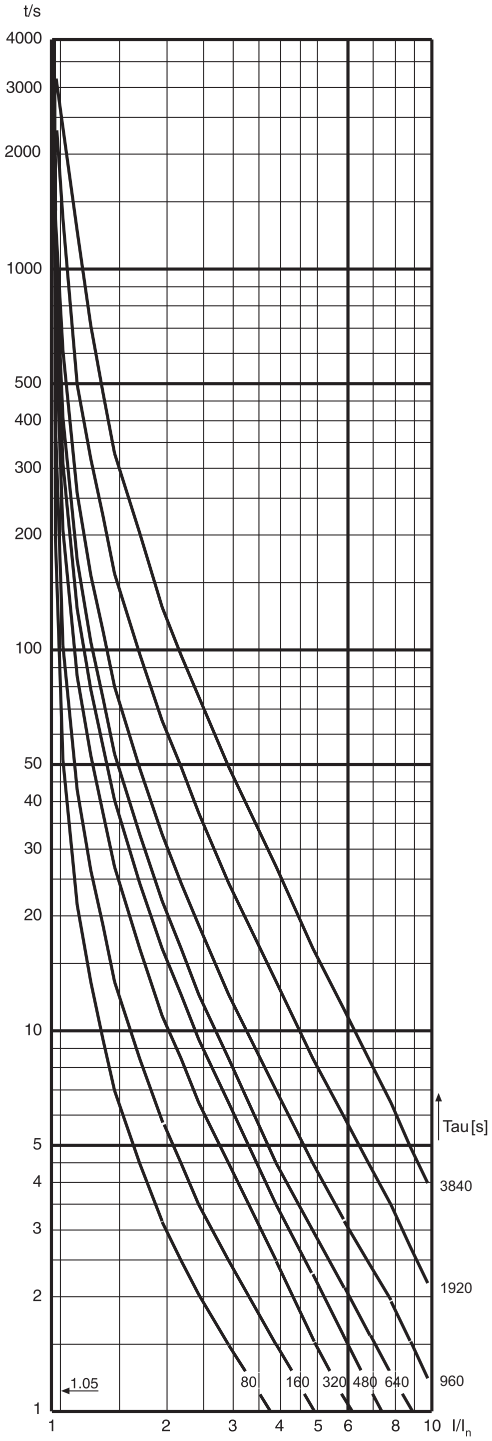


Figure 69: Trip curves at prior load 1 x FLC and p=100 %, Overload factor = 1.05.

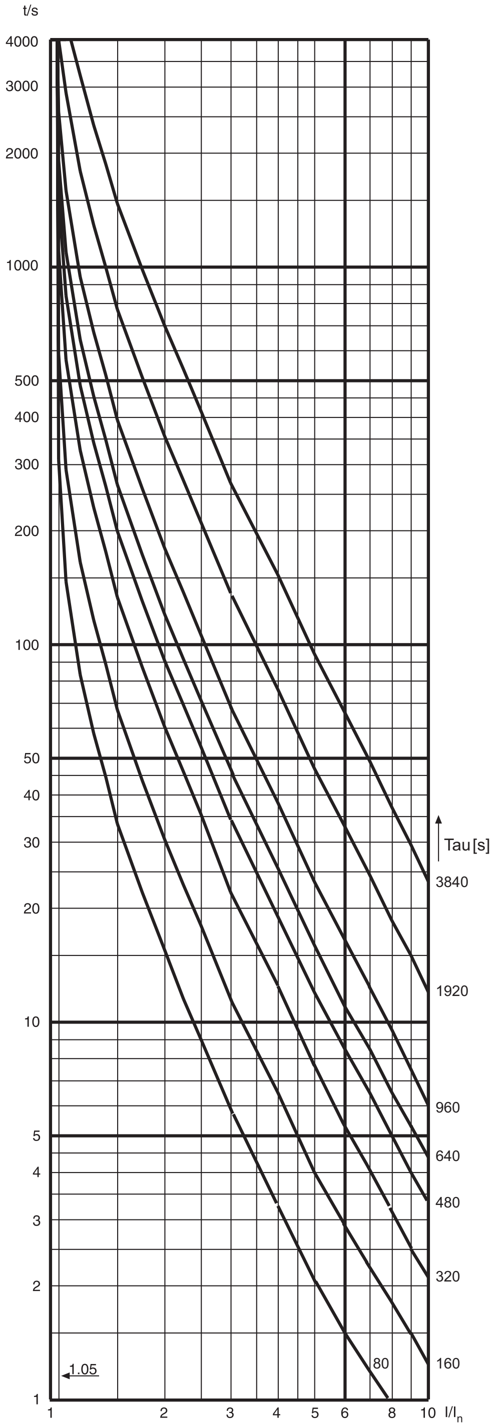


Figure 70: Trip curves at prior load 1 x FLC and p=50 %. Overload factor = 1.05.

4.1.6.5 Application

MPTTR is intended to limit the motor thermal level to predetermined values during the abnormal motor operating conditions. This prevents a premature motor insulation failure.

The abnormal conditions result in overheating and include overload, stalling, failure to start, high ambient temperature, restricted motor ventilation, reduced speed operation, frequent starting or jogging, high or low line voltage or frequency, mechanical failure of the driven load, improper installation and unbalanced line voltage or single phasing. The protection of insulation failure by the implementation of current sensing cannot detect some of these conditions, such as restricted ventilation. Similarly, the protection by sensing temperature alone can be inadequate in cases like frequent starting or jogging. The thermal overload protection addresses these deficiencies to a larger extent by deploying a motor thermal model based on load current.

The thermal load is calculated using the true RMS phase value and negative sequence value of the current. The heating up of the motor is determined by the square value of the load current. However, while calculating the thermal level, the rated current should be re-rated or de-rated depending on the value of the ambient temperature. Apart from current, the rate at which motor heats up or cools is governed by the time constant of the motor.

Setting the weighting factor

There are two thermal curves: one which characterizes the short-time loads and long-time overloads and which is also used for tripping and another which is used for monitoring the thermal condition of the motor. The value of the *Weighting factor p* setting determines the ratio of the thermal increase of the two curves.

When the *Weighting factor p* setting is 100 percent, a pure single time constant thermal unit is produced which is used for application with the cables. As presented in Figure 71, the hot curve with the value of *Weighting factor p* being 100 percent only allows an operate time which is about 10 percent of that with no prior load. For example, when the set time constant is 640 seconds, the operate time with the prior load 1 x FLC (full Load Current) and overload factor 1.05 is only 2 seconds, even if the motor could withstand at least 5 to 6 seconds. To allow the use of the full capacity of the motor, a lower value of *Weighting factor p* should be used.

Normally, an approximate value of half of the thermal capacity is used when the motor is running at full load. Thus by setting *Weighting factor p* to 50 percent, the protection relay notifies a 45 to 50 percent thermal capacity use at full load.

For direct-on-line started motors with hot spot tendencies, the value of *Weighting factor p* is typically set to 50 percent, which will properly distinguish between short-time thermal stress and long-time thermal history. After a short period of thermal stress, for example a motor start-up, the thermal level starts to decrease quite sharply, simulating the leveling out of the hot spots. Consequently, the probability of successive allowed start-ups increases.

When protecting the objects without hot spot tendencies, for example motors started with soft starters, and cables, the value of *Weighting factor p* is set to 100 percent. With the value of *Weighting factor p* set to 100 percent, the thermal level decreases slowly after a heavy load condition. This makes the protection suitable for applications where no hot spots are expected. Only in special cases where the thermal overload protection is required to follow the characteristics of the object to be protected more closely and the thermal capacity of the object is very well known, a value between 50 and 100 percent is required.

For motor applications where, for example, two hot starts are allowed instead of three cold starts, the value of the setting *Weighting factor p* being 40 percent has proven to be useful. Setting the value of *Weighting factor p* significantly below 50 percent should be handled carefully as there is a possibility to overload the protected object as a thermal unit might allow too many hot starts or the thermal history of the motor has not been taken into account sufficiently.

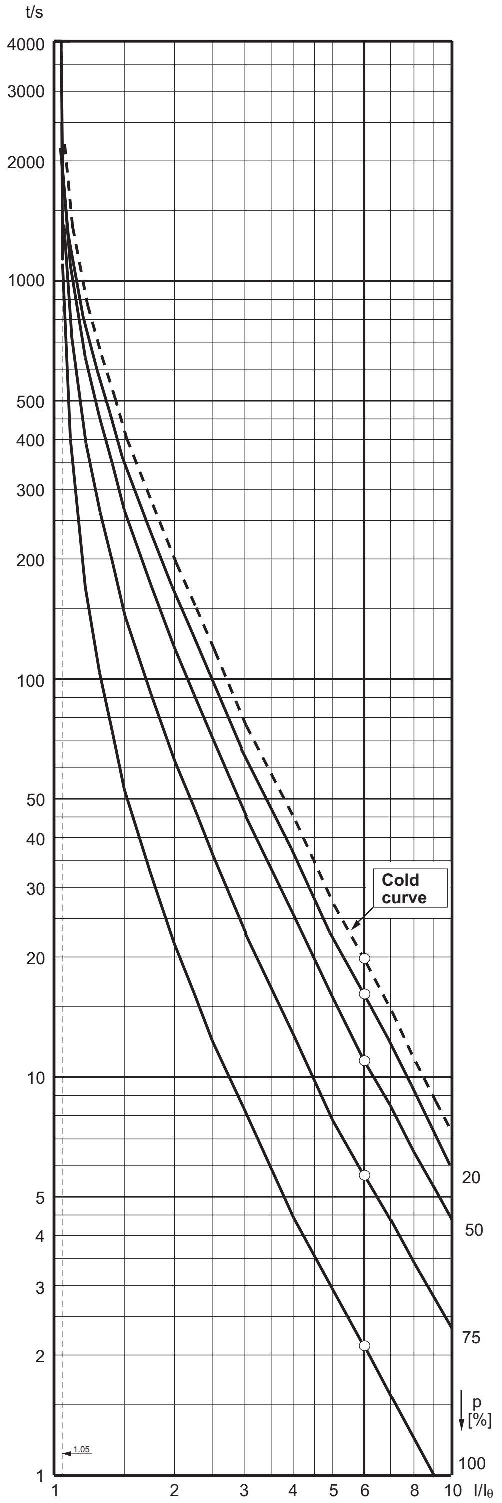


Figure 71: The influence of Weighting factor p at prior load 1xFLC, timeconstant = 640 s, and Overload factor = 1.05

Setting the overload factor

The value of *Overload factor* defines the highest permissible continuous load. The recommended value is 1.05.

Setting the negative sequence factor

During the unbalance condition, the symmetry of the stator currents is disturbed and a counter-rotating negative sequence component current is set up. An increased stator current causes additional heating in the stator and the negative sequence component current excessive heating in the rotor. Also mechanical problems like rotor vibration can occur.

The most common cause of unbalance for three-phase motors is the loss of phase resulting in an open fuse, connector or conductor. Often mechanical problems can be more severe than the heating effects and therefore a separate unbalance protection is used.

Unbalances in other connected loads in the same busbar can also affect the motor. A voltage unbalance typically produces 5 to 7 times higher current unbalance. Because the thermal overload protection is based on the highest TRMS value of the phase current, the additional heating in stator winding is automatically taken into account. For more accurate thermal modeling, the *Negative Seq factor* setting is used for taking account of the rotor heating effect.

$$Negative\,Seq\ factor = \frac{R_{R2}}{R_{R1}}$$

(Equation 9)

R_{R2} Rotor negative sequence resistance

R_{R1} Rotor positive sequence resistance

A conservative estimate for the setting can be calculated:

$$Negative\,Seq\ factor = \frac{175}{I_{LR}^{2}}$$

(Equation 10)

I_{LR} Locked rotor current (multiple of set *Rated current*). The same as the start-up current at the beginning of the motor start-up.

For example, if the rated current of a motor is 230 A, start-up current is 5.7 x I_r,

$$Negative\,Seq\ factor = \frac{175}{5.7^{2}} = 5.4$$

(Equation 11)

Setting the thermal restart level

The restart disable level can be calculated as follows:

$$\theta_i = 100\% - \left(\frac{\textit{startup time of the motor}}{\textit{operate time when no prior load}} \times 100\% + \textit{margin} \right)$$

(Equation 12)

For example, the motor start-up time is 11 seconds, start-up current 6 x rated and *Time constant start* is set for 800 seconds. Using the trip curve with no prior load, the operation time at 6 x rated current is 25 seconds, one motor start-up uses 11/25 ≈ 45 percent of the thermal capacity of the motor. Therefore, the restart disable level must be set to below 100 percent - 45 percent = 55 percent, for example to 50 percent (100 percent - (45 percent + margin), where margin is 5 percent).

Setting the thermal alarm level

Tripping due to high overload is avoided by reducing the load of the motor on a prior alarm.

The value of *Alarm thermal value* is set to a level which allows the use of the full thermal capacity of the motor without causing a trip due to a long overload time. Generally, the prior alarm level is set to a value of 80 to 90 percent of the trip level.

4.1.6.6 Signals

Table 144: MPTTR 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
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
START_EMERG	BOOLEAN	0=False	Signal for indicating the need for emergency start
AMB_TEMP	FLOAT32	0	The ambient temperature used in the calculation

Table 145: MPTTR Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
ALARM	BOOLEAN	Thermal Alarm
BLK_RESTART	BOOLEAN	Thermal overload indicator, to inhibit restart

4.1.6.7 Settings

Table 146: MPTTR Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Overload factor	1.00...1.20		0.01	1.05	Overload factor (k)
Alarm thermal value	50.0...100.0	%	0.1	95.0	Thermal level above which function gives an alarm
Restart thermal Val	20.0...80.0	%	0.1	40.0	Thermal level above which function inhibits motor restarting
Negative Seq factor	0.0...10.0		0.1	0.0	Heating effect factor for negative sequence current
Weighting factor p	20.0...100.0	%	0.1	50.0	Weighting factor (p)
Time constant normal	80...4000	s	1	320	Motor time constant during the normal operation of motor
Time constant start	80...4000	s	1	320	Motor time constant during the start of motor
Time constant stop	80...60000	s	1	500	Motor time constant during the standstill condition of motor
Env temperature mode	1=FLC Only 2=Use input 3=Set Amb Temp			1=FLC Only	Mode of measuring ambient temperature
Env temperature Set	-20.0...70.0	°C	0.1	40.0	Ambient temperature used when no external temperature measurement available

Table 147: MPTTR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 148: MPTTR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Current reference	0.30...2.00	xIn	0.01	1.00	The load current leading to Temperature raise temperature
Initial thermal Val	0.0...100.0	%	0.1	74.0	Initial thermal level of the motor

4.1.6.8 Monitored data

Table 149: MPTTR Monitored data

Name	Type	Values (Range)	Unit	Description
TEMP_RL	FLOAT32	0.00...9.99		The calculated temperature of the protected object relative to the operate level
TEMP_AMB	FLOAT32	-99...999	°C	The ambient temperature used in the calculation
THERMLEV_ST	FLOAT32	0.00...9.99		Thermal level at beginning of motor startup
THERMLEV_END	FLOAT32	0.00...9.99		Thermal level at the end of motor startup situation
T_ENARESTART	INT32	0...99999	s	Estimated time to reset of block restart
MPTTR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status
Therm-Lev	FLOAT32	0.00...9.99		Thermal level of protected object (1.00 is the operate level)

4.1.6.9 Technical data

Table 150: MPTTR 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)
Operate time accuracy[1)]	±2.0% of the theoretical value or ±0.50 s

1) Overload current > 1.2 × Operate level temperature

4.1.6.10 Technical revision history

Table 151: MPTTR Technical revision history

Technical revision	Change
B	Added a new input `AMB_TEMP`. Added a new selection for the *Env temperature mode* setting "Use input".
C	Internal improvement.
D	Time constant stop range maximum value changed from 8000 s to 60000 s.
E	Internal improvement.

4.2 Earth-fault protection

4.2.1 Non-directional earth-fault protection EFxPTOC

4.2.1.1 Identification

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

4.2.1.2 Function block

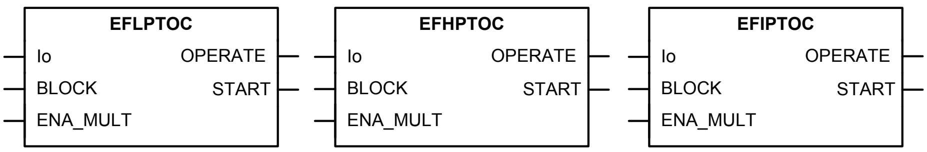


Figure 72: Function block

4.2.1.3 Functionality

The non-directional earth-fault protection function EFxPTOC is used as non-directional earth-fault protection for feeders.

The function starts and operates when the residual current exceeds the set limit. The operate time characteristic for low stage EFLPTOC and high stage EFHPTOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage EFIPTOC always operates with the DT characteristic.

In the DT mode, the function operates after a predefined operate 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.

4.2.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

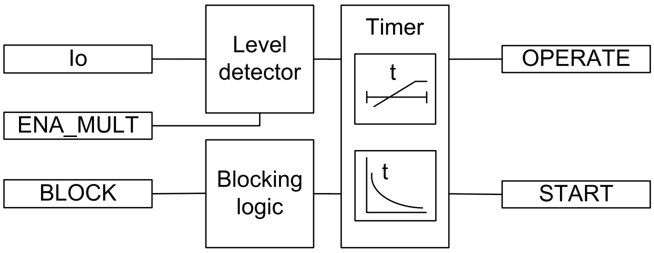


Figure 73: Functional module diagram

Level detector

The operating quantity can be selected with the setting *Io signal Sel*. The selectable options are "Measured Io" and "Calculated Io". The operating quantity is compared to the set *Start value*. If the measured value exceeds the set *Start value*, the level detector sends an enable-signal to the timer module. If the ENA_MULT input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The protection relay does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

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

Timer

Once activated, the timer activates the START 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 *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the OPERATE 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 operate 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. The START output is deactivated when the reset timer has elapsed.

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 operate and reset times.

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.2.1.5 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 152: Measurement modes supported by EFxPTOC stages

Measurement mode	EFLPTOC	EFHPTOC	EFIPTOC
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.

4.2.1.6 Timer characteristics

EFxPTOC 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 *Operate 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 153: Timer characteristics supported by different stages

Operating curve type	EFLPTOC	EFHPTOC
(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	
Table continues on next page		

Operating curve type	EFLPTOC	EFHPTOC
(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	

EFIPTOC supports only definite time characteristics.

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

Table 154: Reset time characteristics supported by different stages

Reset curve type	EFLPTOC	EFHPTOC	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

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

4.2.1.7 Application

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

Many applications require several steps using different current start levels and time delays. EFxPTOC consists of three different protection stages.

- Low EFLPTOC
- High EFHPTOC
- Instantaneous EFIPTOC

EFLPTOC contains several types of time-delay characteristics. EFHPTOC and EFIPTOC are used for fast clearance of serious earth faults.

4.2.1.8 Signals

Table 155: EFLPTOC Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 156: EFHPTOC Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 157: EFIPTOC Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 158: EFLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 159: EFHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 160: EFIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.1.9 Settings

Table 161: EFLPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...5.000	xIn	0.005	0.010	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type

Table 162: EFLPTOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 163: EFLPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 164: EFLPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate 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
Io signal Sel	1=Measured Io 2=Calculated Io			1=Measured Io	Selection for used Io signal

Table 165: EFHPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type

Table 166: EFHPTOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 167: EFHPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 168: EFHPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate 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
Io signal Sel	1=Measured Io 2=Calculated Io			1=Measured Io	Selection for used Io signal

Table 169: EFIPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	1.00...40.00	xIn	0.01	1.00	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Operate delay time	20...200000	ms	10	20	Operate delay time

Table 170: EFIPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 171: EFIPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Io signal Sel	1=Measured Io 2=Calculated Io			1=Measured Io	Selection for used Io signal

4.2.1.10 Monitored data

Table 172: EFLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFLPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 173: EFHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFHPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 174: EFIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFIPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.1.11 Technical data

Table 175: EFxPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
	EFLPTOC	±1.5% of the set value or ±0.002 × I_n		
	EFHPTOC and EFIPTOC	±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)		
Start time [1)2)]		Minimum	Typical	Maximum
	EFIPTOC: I_{Fault} = 2 × set *Start value* I_{Fault} = 10 × set *Start value*	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	EFHPTOC and EFLPTOC: I_{Fault} = 2 × set *Start value*	23 ms	26 ms	29 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<30 ms		
Table continues on next page				

Characteristic	Value
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 ±20 ms [3)]
Suppression of harmonics	RMS: No suppression DFT: -50 dB at $f = n \times f_n$, 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 = 50 Hz, earth-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 *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.2.1.12 Technical revision history

Table 176: EFIPTOC Technical revision history

Technical revision	Change
B	The minimum and default values changed to 40 ms for the *Operate delay time* setting
C	Minimum and default values changed to 20 ms for the *Operate delay time* setting Minimum value changed to 1.00 x I_n for the *Start value* setting
D	Added a setting parameter for the "Measured Io" or "Calculated Io" selection
E	Internal improvement
F	Internal improvement

Table 177: EFHPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting
C	Added a setting parameter for the "Measured Io" or "Calculated Io" selection
D	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting
E	Internal improvement
F	Internal improvement

Table 178: EFLPTOC Technical revision history

Technical revision	Change
B	The minimum and default values changed to 40 ms for the *Operate delay time* setting
C	*Start value* step changed to 0.005
D	Added a setting parameter for the "Measured Io" or "Calculated Io" selection
Table continues on next page	

Technical revision	Change
E	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting
F	Internal improvement
G	Internal improvement

4.2.2 Directional earth-fault protection DEFxPDEF

4.2.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional earth-fault protection, low stage	DEFLPDEF	Io> ->	67N-1
Directional earth-fault protection, high stage	DEFHPDEF	Io>> ->	67N-2

4.2.2.2 Function block

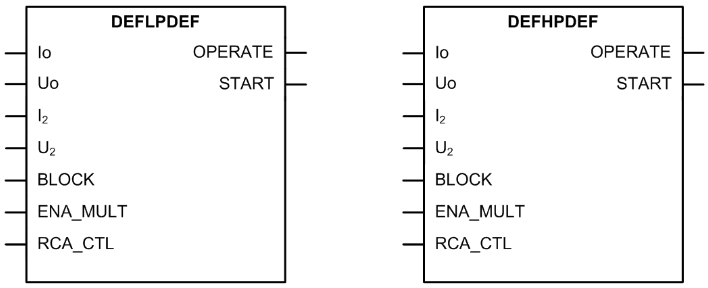


Figure 74: Function block

4.2.2.3 Functionality

The directional earth-fault protection function DEFxPDEF is used as directional earth-fault protection for feeders.

The function starts and operates when the operating quantity (current) and polarizing quantity (voltage) exceed the set limits and the angle between them is inside the set operating sector. The operate time characteristic for low stage (DEFLPDEF) and high stage (DEFHPDEF) can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

In the DT mode, the function operates after a predefined operate 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.

4.2.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

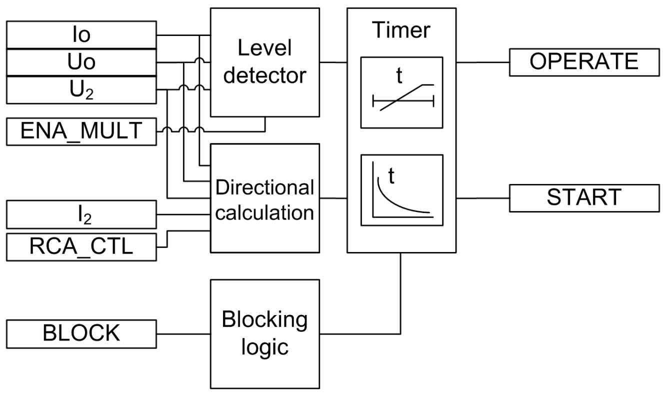


Figure 75: Functional module diagram

Level detector

The magnitude of the operating quantity is compared to the set *Start value* and the magnitude of the polarizing quantity is compared to the set *Voltage start value*. If both the limits are exceeded, the level detector sends an enabling signal to the timer module. When the *Enable voltage limit* setting is set to "False", *Voltage start value* has no effect and the level detection is purely based on the operating quantity. If the `ENA_MULT` input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The operating quantity (residual current) can be selected with the setting *Io signal Sel*. The options are "Measured Io" and "Calculated Io". If "Measured Io" is selected, the current ratio for Io-channel is given in **Configuration/Analog inputs/Current (Io,CT)**. If "Calculated Io" is selected, the current ratio is obtained from the phase-current channels given in **Configuration/Analog inputs/Current (3I,CT)**.

The operating quantity (residual voltage) can be selected with the setting *Uo signal Sel.* The options are "Measured Uo" and "Calculated Uo". If "Measured Uo" is selected, the voltage ratio for Uo-channel is given in **Configuration/Analog inputs/Voltage (Uo,VT)**. If "Calculated Uo" is selected, the voltage ratio is obtained from the phase-voltage channels given in **Configuration/Analog inputs/Voltage (3U,VT)**.

Example 1: Io is measured with cable core CT (100/1 A) and Uo is measured from open-delta connected VTs (20/sqrt(3) kV : 100/sqrt(3) V : 100/3 V). In this case, "Measured Io" and "Measured Uo" are selected. The nominal values for residual current and residual voltage are obtained from CT and VT ratios entered in Residual current Io: **Configuration/Analog inputs/Current (Io,CT)**: 100 A : 1 A. The Residual voltage Uo: **Configuration/Analog inputs/Voltage (Uo,VT)**: 11.547 kV : 100 V. The *Start value* of 1.0 × In corresponds to 1.0 * 100 A = 100 A in the primary. The *Voltage start value* of 1.0 × Un corresponds to 1.0 * 11.547 kV = 11.547 kV in the primary.

Example 2: Both Io and Uo are calculated from the phase quantities. Phase CT-ratio is 100 : 1 A and phase VT-ratio is 20/sqrt(3) kV : 100/sqrt(3) V. In this case, "Calculated Io" and "Calculated Uo" are selected. The nominal values for residual current and residual voltage are obtained from CT and VT ratios entered in Residual current Io: **Configuration/Analog inputs/Current (3I,CT)**: 100 A : 1 A. The residual voltage Uo: **Configuration/Analog inputs/Voltage (3U,VT)**: 20.000 kV : 100 V. The *Start value* of 1.0 × In corresponds to 1.0 * 100 A = 100 A in the primary. The *Voltage start value* of 1.0 × Un corresponds to 1.0 * 20.000 kV = 20.000 kV in the primary.

If "Calculated Uo" is selected, the residual voltage nominal value is always phase-to-phase voltage. Thus, the valid maximum setting for residual Voltage start value is 0.577 x Un. The calculated Uo requires that all the three phase-to-earth voltages are connected to the protection relay. Uo cannot be calculated from the phase-to-phase voltages.

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 *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

Typically, the `ENA_MULT` input is connected to the inrush detection function INRHPAR. In case of inrush, INRPHAR activates the `ENA_MULT` input, which multiplies *Start value* by the *Start value Mult* setting.

Directional calculation

The directional calculation module monitors the angle between the polarizing quantity and operating quantity. Depending on the *Pol quantity* setting, the polarizing quantity can be the residual voltage (measured or calculated) or the negative sequence voltage. When the angle is in the operation sector, the module sends the enabling signal to the timer module.

The minimum signal level which allows the directional operation can be set with the *Min operate current* and *Min operate voltage* settings.

If *Pol quantity* is set to "Zero. seq. volt", the residual current and residual voltage are used for directional calculation.

If *Pol quantity* is set to "Neg. seq. volt", the negative sequence current and negative sequence voltage are used for directional calculation.

In the phasor diagrams representing the operation of DEFxPDEF, the polarity of the polarizing quantity (Uo or U2) is reversed, that is, the polarizing quantity in the phasor diagrams is either -Uo or -U2. Reversing is done by switching the polarity of the residual current measuring channel (see the connection diagram in the application manual). Similarly the polarity of the calculated Io and I_2 is also switched.

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

Table 179: 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 |Io| x sin (ANGLE) has a positive value and "reverse" when the value is negative. ANGLE is the angle difference between -Uo and Io.
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.

Polarizing quantity selection "Neg. seq. volt." is available only in the "Phase angle" operation 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, that is, when the magnitude of the polarizing quantity is less than the value of the *Min operate voltage* setting.

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".

If the *Enable voltage limit* setting is set to "True", the magnitude of the polarizing quantity is checked even if *Directional mode* is set to "Non-directional" or *Allow Non Dir* to "True".

The *Characteristic angle* setting is used in the "Phase angle" mode to adjust the operation according to the method of neutral point earthing 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`. `RCA_CTL` affects 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.

The polarity of the polarizing quantity can be reversed by setting the *Pol reversal* to "True", which turns the polarizing quantity by 180 degrees.

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

For definitions of different directional earth-fault characteristics, refer to general function block features information.

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

Table 180: Monitored data values

Monitored data values	Description
FAULT_DIR	The detected direction of fault during fault situations, that is, when `START` output is active.
DIRECTION	The momentary operating direction indication output.
ANGLE	Also called operating angle, shows the angle difference between the polarizing quantity (Uo, U_2) and operating quantity (Io, I_2).
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 = Io x sin(ANGLE). If the *Operation mode* setting is "IoCos", I_OPER is calculated as follows I_OPER = Io x cos(ANGLE).

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

Timer

Once activated, the timer activates the `START` 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 *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` 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 operate 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. The `START` output is deactivated when the reset timer has elapsed.

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 operate and reset times.

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 `OPERATE` 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.2.2.5 Directional earth-fault principles

In many cases it is difficult to achieve selective earth-fault protection based on the magnitude of residual current only. To obtain a selective earth-fault protection scheme, it is necessary to take the phase angle of Io into account. This is done by comparing the phase angle of the operating and polarizing quantity.

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

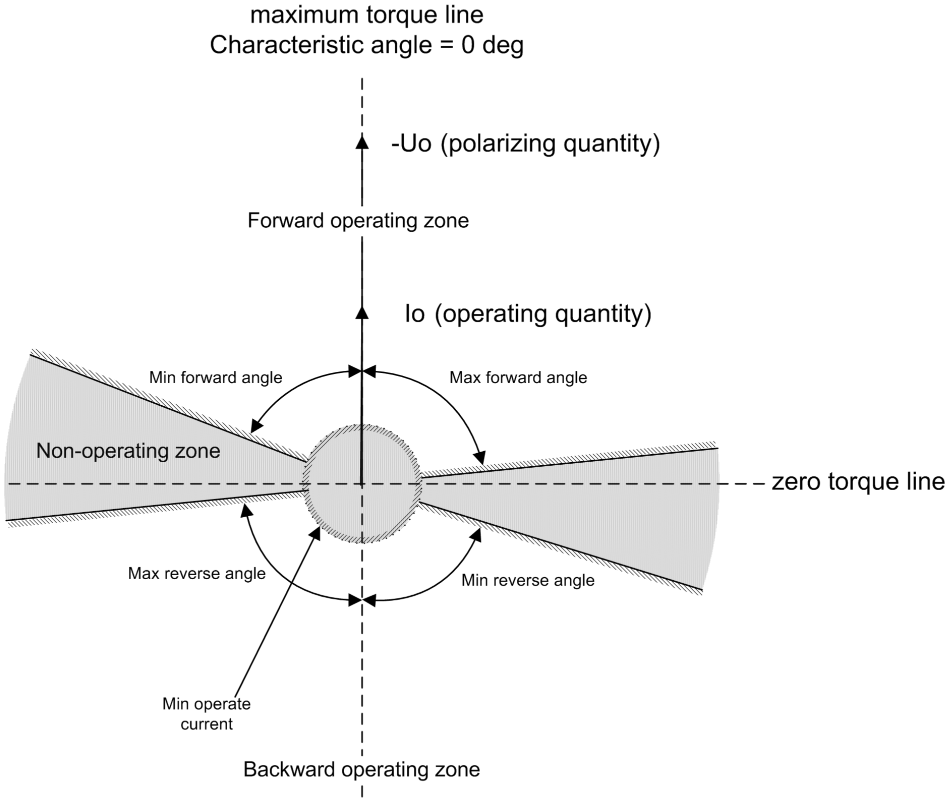


Figure 76: Definition of the relay characteristic angle, RCA=0 degrees in a compensated network

Example 2

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

=> *Characteristic angle* = +60 deg

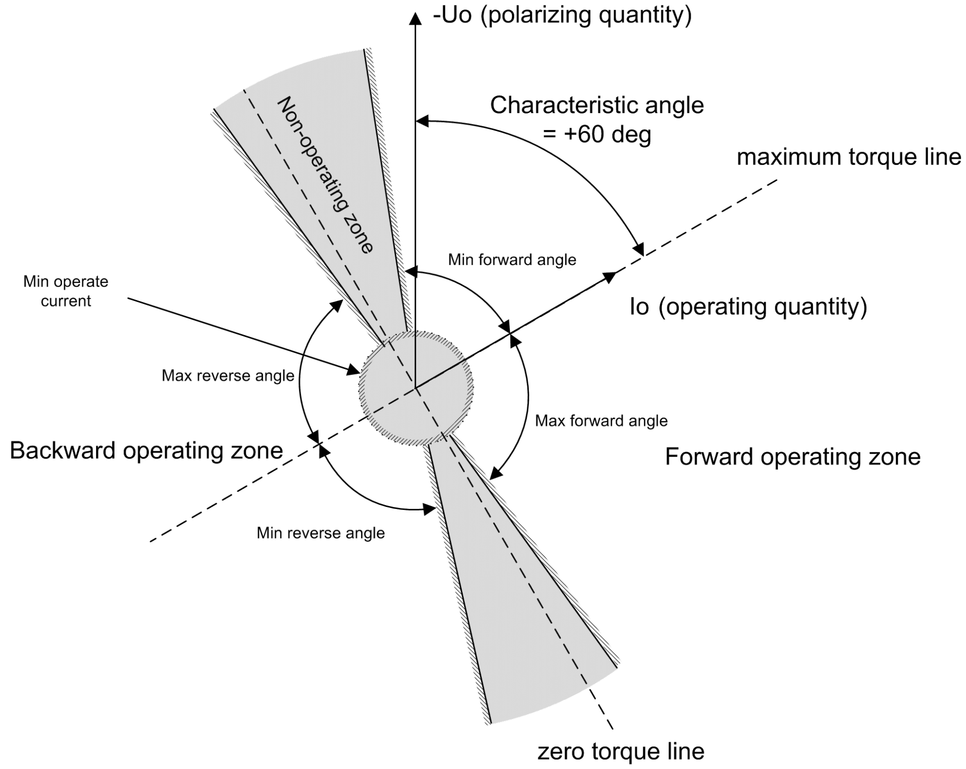


Figure 77: Definition of the relay characteristic angle, RCA=+60 degrees in a solidly earthed network

Example 3

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

=> *Characteristic angle* = -90 deg

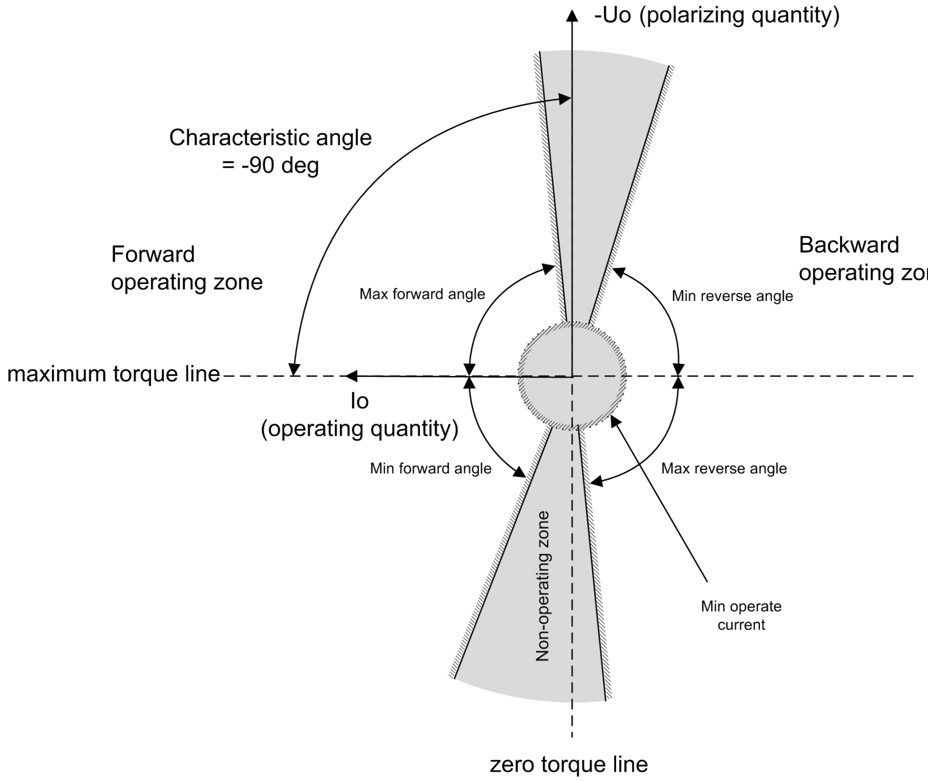


Figure 78: Definition of the relay characteristic angle, RCA=–90 degrees in an isolated network

Directional earth-fault protection in an isolated neutral network

In isolated networks, there is no intentional connection between the system neutral point and earth. The only connection is through the phase-to-earth capacitances (C_0) of phases and leakage resistances (R_0). This means that the residual current is mainly capacitive and has a phase shift of -90 degrees compared to the polarizing voltage. 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 79 illustrates a simplified equivalent circuit for an unearthed network with an earth fault in phase C.

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

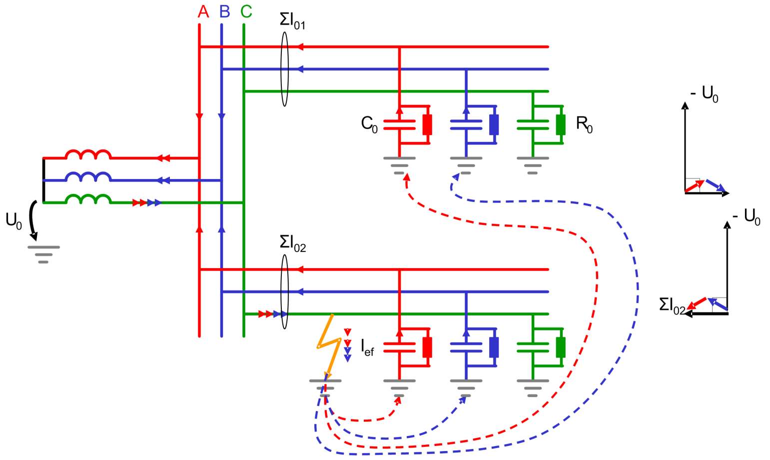


Figure 79: Earth-fault situation in an isolated network

Directional earth-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 residual current, the relay characteristic angle (RCA) should be set to 0 degrees and the operation criteria to "IoCos" or "Phase angle". Figure 80 illustrates a simplified equivalent circuit for a compensated network with an earth fault in phase C.

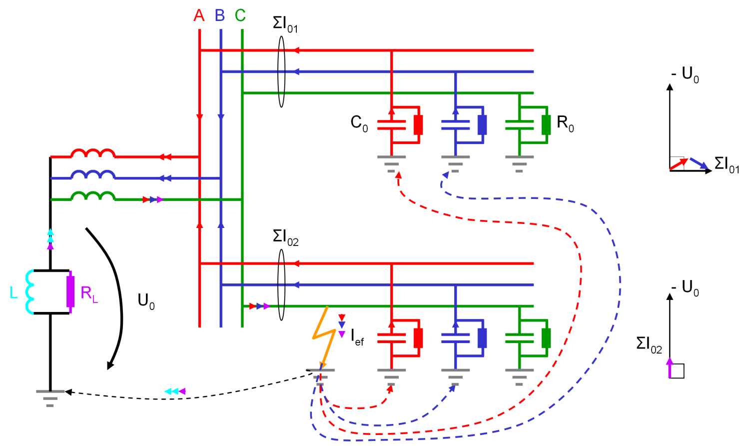


Figure 80: Earth-fault situation in a compensated network

The Petersen coil or the earthing resistor may be temporarily out of operation. To keep the protection scheme selective, it is necessary to update the *Characteristic angle* setting accordingly. This can be 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. As a result the characteristic angle is set automatically to suit the earthing method used. The RCA_CTL input can be used to change the operation criteria as described in Table 181 and Table 182.

Table 181: *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 182: *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

The traditional method of adapting the directional earth-fault protection function to the prevailing neutral earthing conditions is done with the *Characteristic angle* setting. In an unearthed network, *Characteristic angle* is set to -90 degrees and in a compensated network *Characteristic angle* is set to 0 degrees. In case the earthing method of the network is temporarily changed from compensated to unearthed due to the disconnection of the arc suppression coil, the *Characteristic angle* setting should be modified correspondingly. This can be done using the setting groups or the `RCA_CTL` input. Alternatively, the operating sector of the directional earth-fault protection function can be extended to cover the operating sectors of both neutral earthing principles. Such characteristic is valid for both unearthed and compensated network and does not require any modification in case the neutral earthing changes temporarily from the unearthed to compensated network or vice versa.

The extended phase angle characteristic is created by entering a value of over 90 degrees for the *Min forward angle* setting; a typical value is 170 degrees (*Min reverse angle* in case *Directional mode* is set to "Reverse"). The *Max forward angle* setting should be set to cover the possible measurement inaccuracies of current and voltage transformers; a typical value is 80 degrees (*Max reverse angle* in case *Directional mode* is set to "Reverse").

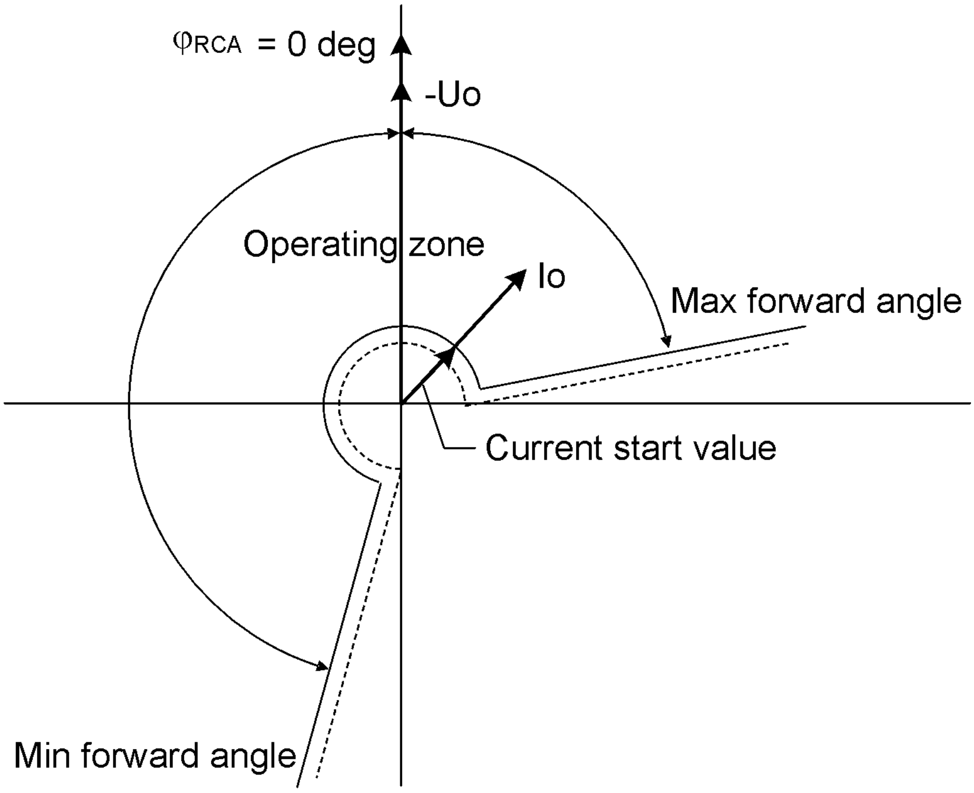


Figure 81: Extended operation area in directional earth-fault protection

4.2.2.6 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 183: Measurement modes supported by DEFxPDEF stages

Measurement mode	DEFLPDEF	DEFHPDEF
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.

4.2.2.7 Timer characteristics

DEFxPDEF 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 184: Timer characteristics supported by different stages

Operating curve type	DEFLPDEF	DEFHPDEF
(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 185: Reset time characteristics supported by different stages

Reset curve type	DEFLPDEF	DEFHPDEF	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

4.2.2.8 Directional earth-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.

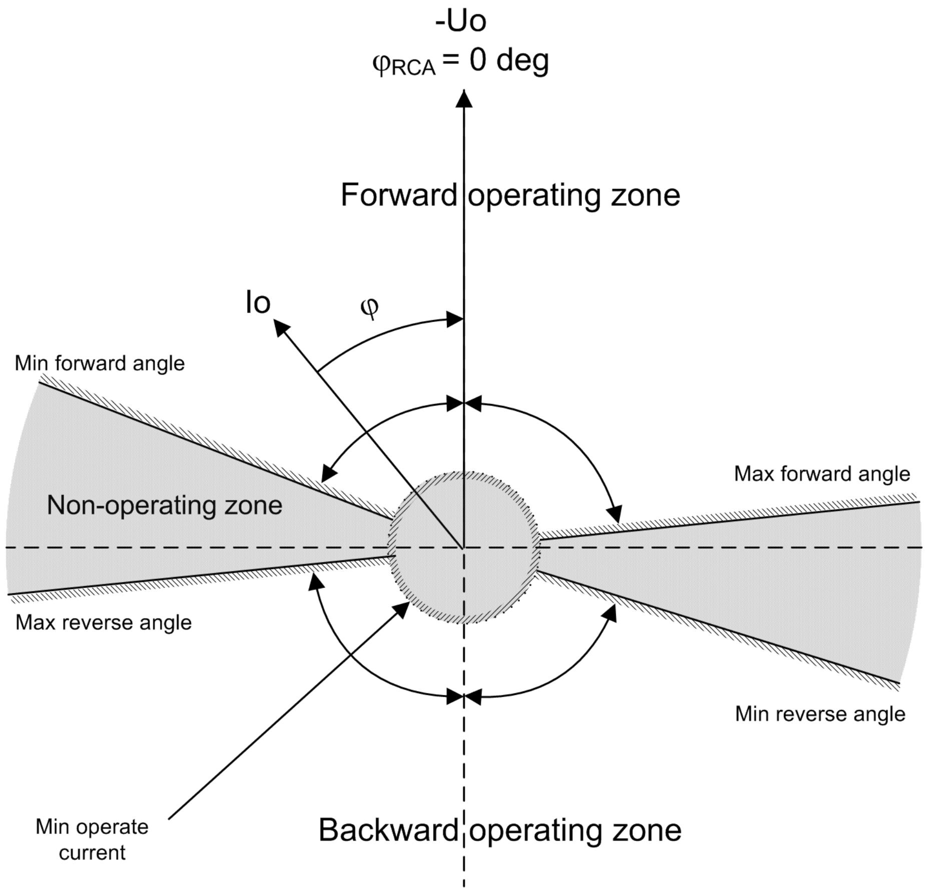


Figure 82: Configurable operating sectors in phase angle characteristic

Table 186: 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

If the *Allow Non Dir* setting is "False", the directional operation (forward, reverse) is not allowed when the measured polarizing or operating quantities are invalid, that is, their magnitude is below the set minimum values. The minimum values can be defined with the settings *Min operate current* and *Min operate 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.

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 earthing principle of the network. The Iosin(φ) characteristics is used in an isolated network, measuring the reactive component of the fault current caused by the earth capacitance. The Iocos(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.

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 Io characteristic:

Table 187: 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 operate current* and *Min operate 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 start and operate 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

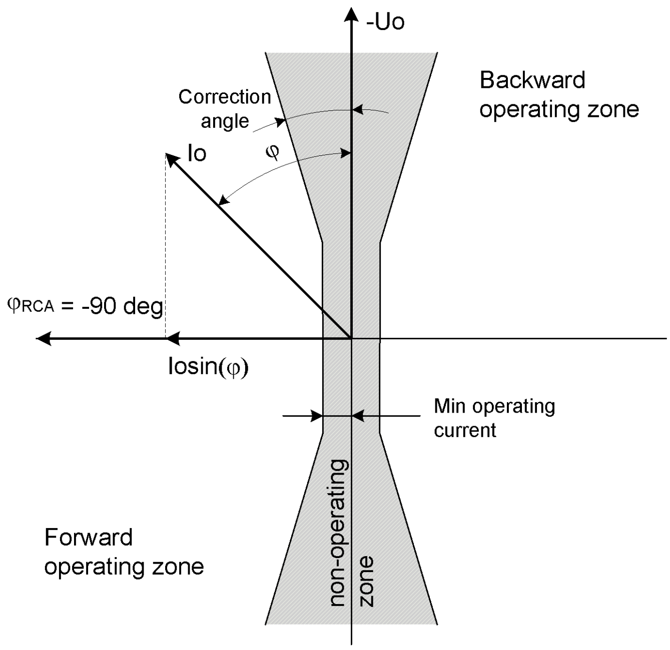


Figure 83: Operating characteristic Iosin(φ) in forward fault

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

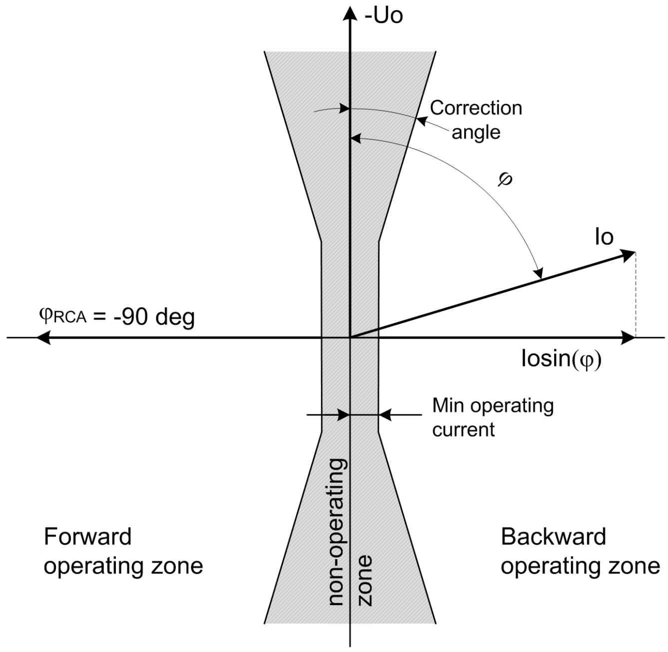


Figure 84: Operating characteristic Iosin(φ) in reverse fault

Example 3.

Iocos(φ) criterion selected, forward-type fault

=> FAULT_DIR = 1

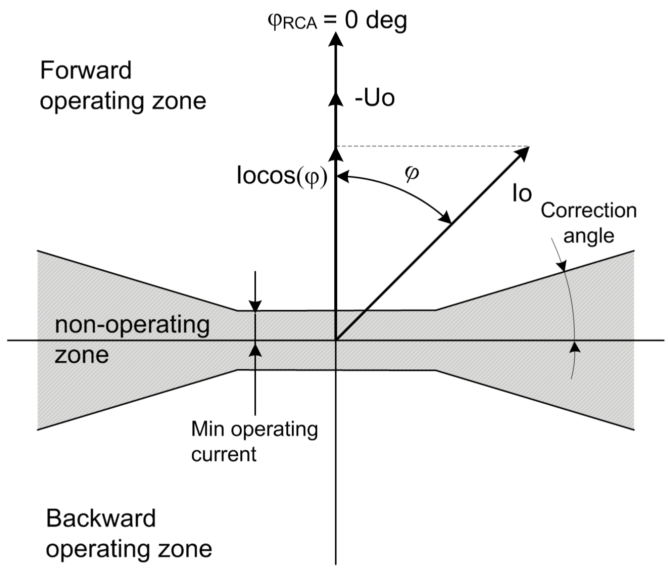


Figure 85: Operating characteristic Iocos(φ) in forward fault

Example 4.

Iocos(φ) criterion selected, reverse-type fault

```
=> FAULT_DIR = 2
```

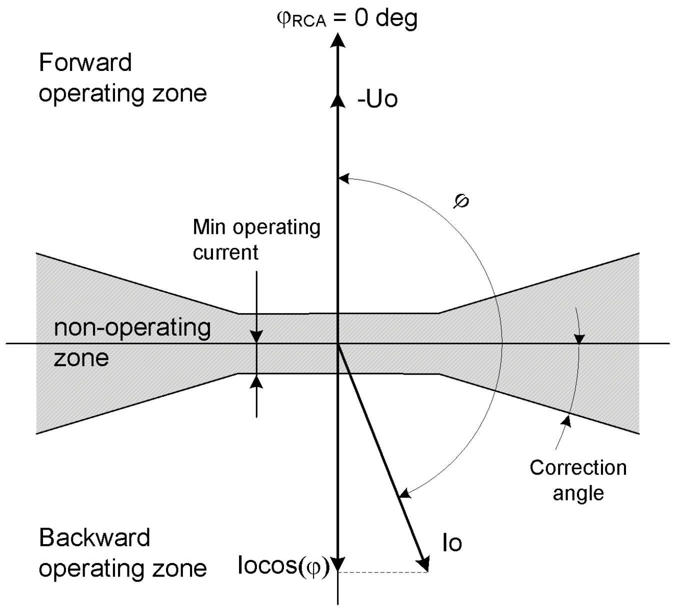


Figure 86: Operating characteristic Iocos(φ) in reverse fault

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.

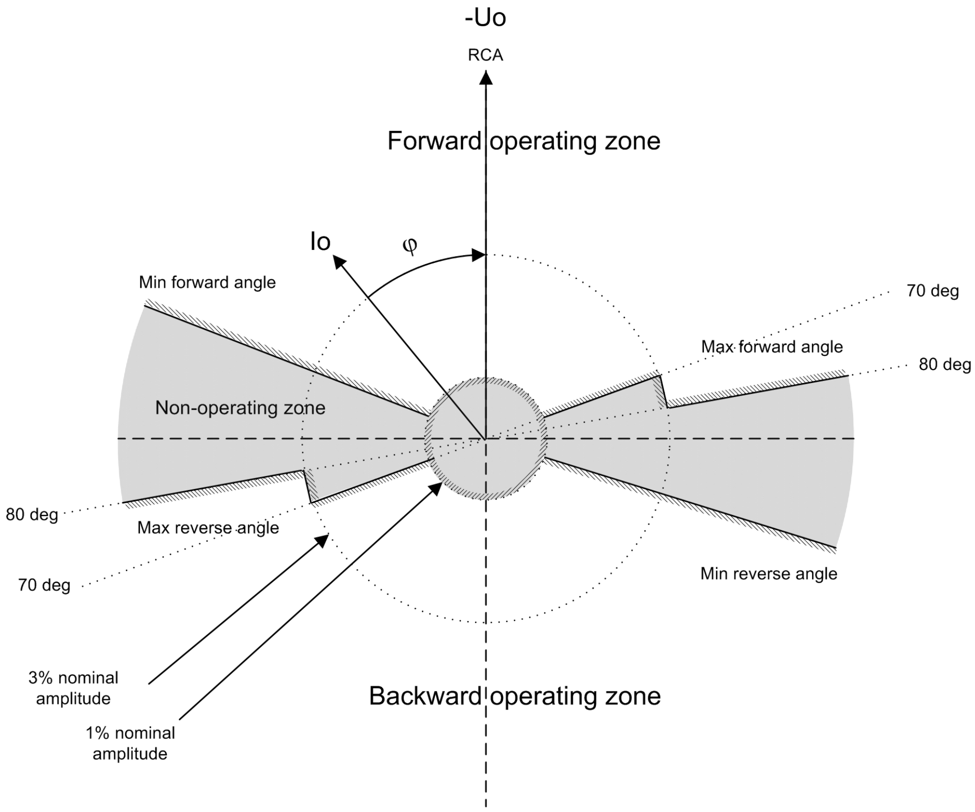


Figure 87: Operating characteristic for phase angle 80

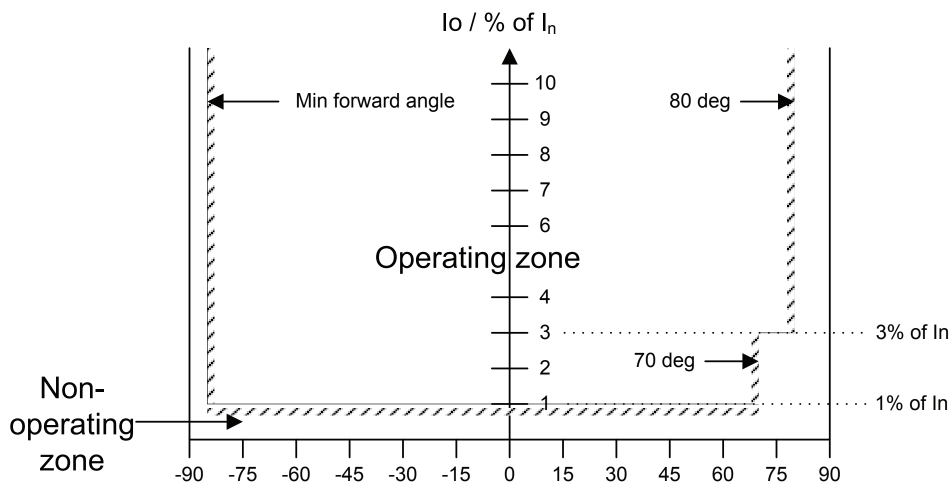


Figure 88: Phase angle 80 amplitude (Directional mode = Forward)

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.

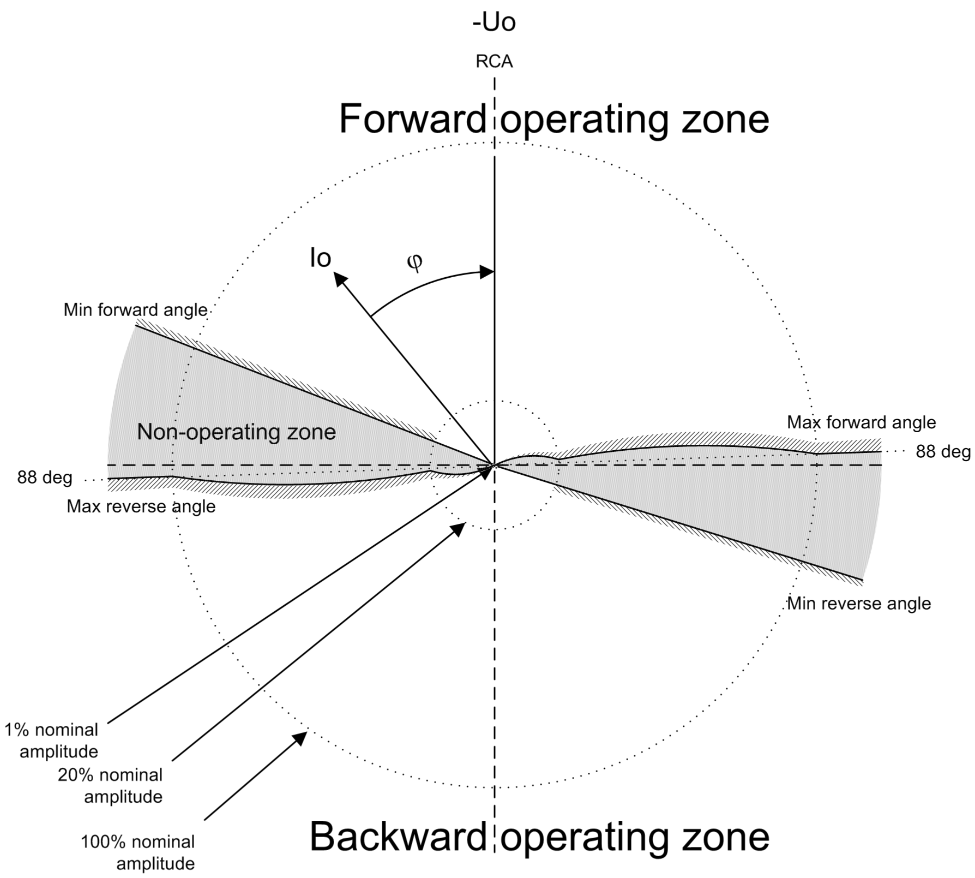


Figure 89: Operating characteristic for phase angle 88

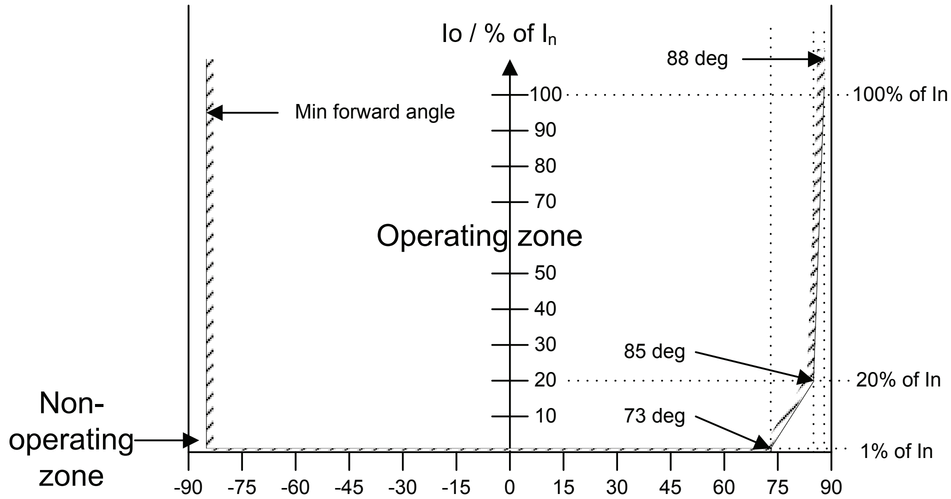


Figure 90: Phase angle 88 amplitude (Directional mode = Forward)

4.2.2.9 Application

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

Many applications require several steps using different current start levels and time delays. DEFxPDEF consists of two different stages.

- Low DEFLPDEF
- High DEFHPDEF

DEFLPDEF contains several types of time delay characteristics. DEFHPDEF is used for fast clearance of serious earth 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 Iosin(φ) or the active part Iocos(φ) of the residual current. In isolated networks or in networks with high impedance earthing, the phase-to-earth 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 residual current components Iocos(φ) or Iosin(φ) according to the earthing method, where φ is the angle between the residual current and the reference residual voltage (-Uo). 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 earth.

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

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

In resonance-earthed 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 residual current is mainly resistive and has zero phase shift compared to the residual voltage (-Uo) 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 earthed through low resistance, the characteristic angle is also 0 degrees (for phase angle). Alternatively, Iocos(φ) operation can be used.

In solidly earthed 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 residual voltage measurement wires. Although the Iosin(φ) operation can be used in solidly earthed networks, the phase angle is recommended.

Connection of measuring transformers in directional earth fault applications

The residual current Io 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 earthed with high impedance, a core balance current transformer is recommended to be used in earth-fault protection. To ensure sufficient accuracy of residual 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 DEFxPDEF is able to detect the fault current direction without failure. As directional earth fault uses residual current and residual voltage (-Uo), the poles of the measuring transformers must match each other and also the fault current direction. Also the earthing of the cable sheath must be taken into notice when using core balance current transformers. The following figure describes how measuring transformers can be connected to the protection relay.

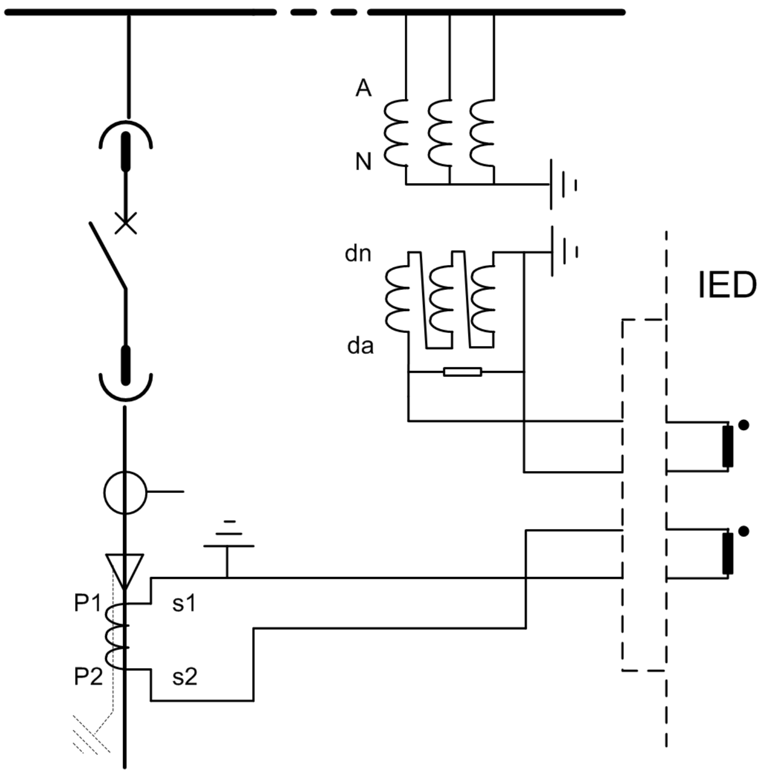


Figure 91: Connection of measuring transformers

4.2.2.10 Signals

Table 188: DEFLPDEF Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
Uo	SIGNAL	0	Residual 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 189: DEFHPDEF Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
Uo	SIGNAL	0	Residual 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 190: DEFLPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 191: DEFHPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.2.11 Settings

Table 192: DEFLPDEF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...5.000	xIn	0.005	0.010	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start 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. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Operate delay time	50...200000	ms	10	50	Operate delay time
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 start value	0.010...1.000	xUn	0.001	0.010	Voltage start value

Table 193: DEFLPDEF Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 194: DEFLPDEF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 195: DEFLPDEF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	50...60000	ms	1	50	Minimum operate 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 operate current	0.005...1.000	xIn	0.001	0.005	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating 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
Io signal Sel	1=Measured Io 2=Calculated Io			1=Measured Io	Selection for used Io signal
Uo signal Sel	1=Measured Uo 2=Calculated Uo			1=Measured Uo	Selection for used Uo signal
Pol quantity	3=Zero seq. volt. 4=Neg. seq. volt.			3=Zero seq. volt.	Reference quantity used to determine fault direction

Table 196: DEFHPDEF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start 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 Def. Time 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Operate delay time	40...200000	ms	10	40	Operate delay time
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 start value	0.010...1.000	xUn	0.001	0.010	Voltage start value

Table 197: DEFHPDEF Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 198: DEFHPDEF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	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		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 199: DEFHPDEF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	40...60000	ms	1	40	Minimum operate 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 operate current	0.005...1.000	xIn	0.001	0.005	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating 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
Io signal Sel	1=Measured Io 2=Calculated Io			1=Measured Io	Selection for used Io signal
Uo signal Sel	1=Measured Uo 2=Calculated Uo			1=Measured Uo	Selection for used Uo signal
Pol quantity	3=Zero seq. volt. 4=Neg. seq. volt.			3=Zero seq. volt.	Reference quantity used to determine fault direction

4.2.2.12 Monitored data

Table 200: DEFLPDEF Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle

Table continues on next page

Name	Type	Values (Range)	Unit	Description
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
I_OPER	FLOAT32	0.00...40.00	xIn	Calculated operating current
DEFLPDEF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 201: DEFHPDEF Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
I_OPER	FLOAT32	0.00...40.00	xIn	Calculated operating current
DEFHPDEF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.2.13 Technical data

Table 202: DEFxPDEF 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">DEFLPDEF</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 × U_n
Phase angle:
±2°</td></tr>
<tr><td>DEFHPDEF</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 × U_n
Phase angle:
±2°</td></tr>
<tr><td rowspan="3">Start time 1)2)</td><td rowspan="2">DEFHPDEF
I_{Fault} = 2 × set Start value</td><td>Minimum</td><td>Typical</td><td>Maximum</td></tr>
<tr><td>42 ms</td><td>46 ms</td><td>49 ms</td></tr>
<tr><td>DEFLPDEF
I_{Fault} = 2 × set Start value</td><td>58 ms</td><td>62 ms</td><td>66 ms</td></tr>
<tr><td colspan="2">Reset time</td><td colspan="3">Typically 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">Operate 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">Operate 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 = 50 Hz, earth-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 *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.2.2.14 Technical revision history

Table 203: DEFHPDEF Technical revision history

Technical revision	Change
B	Maximum value changed to 180 deg for the *Max forward angle* setting
C	Added a setting parameter for the "Measured Io" or "Calculated Io" selection and setting parameter for the "Measured Uo", "Calculated Uo" or "Neg. seq. volt." selection for polarization. *Operate delay time* and *Minimum operate time* changed from 60 ms to 40 ms. The sector default setting values are changed from 88 degrees to 80 degrees.
D	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
E	Unit added to calculated operating current output (I_OPER).
F	Added setting *Pol quantity*.

Table 204: DEFLPDEF Technical revision history

Technical revision	Change
B	Maximum value changed to 180 deg for the *Max forward angle* setting. *Start value* step changed to 0.005
C	Added a setting parameter for the "Measured Io" or "Calculated Io" selection and setting parameter for the "Measured Uo", "Calculated Uo" or "Neg. seq. volt." selection for polarization. The sector default setting values are changed from 88 degrees to 80 degrees.
D	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
E	Unit added to calculated operating current output (I_OPER).
F	Added setting *Pol quantity*. Minimum value for *Operate delay time* and *Minimum operate time* changed from “60 ms” to “50 ms”. Default value for *Operate delay time* and *Minimum operate time* changed from “60 ms” to “50 ms”.

4.2.3 Transient/intermittent earth-fault protection INTRPTEF

4.2.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Transient/intermittent earth-fault protection	INTRPTEF	Io> -> IEF	67NIEF

4.2.3.2 Function block

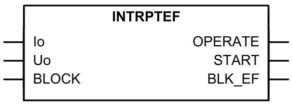


Figure 92: Function block

4.2.3.3 Functionality

The transient/intermittent earth-fault protection function INTRPTEF is a function designed for the protection and clearance of permanent and intermittent earth faults in distribution and sub-transmission networks. Fault detection is done from the residual current and residual voltage signals by monitoring the transients.

The operating time characteristics are according to definite time (DT).

The function contains a blocking functionality. It is possible to block function outputs, timers 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 "On" and "Off".

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

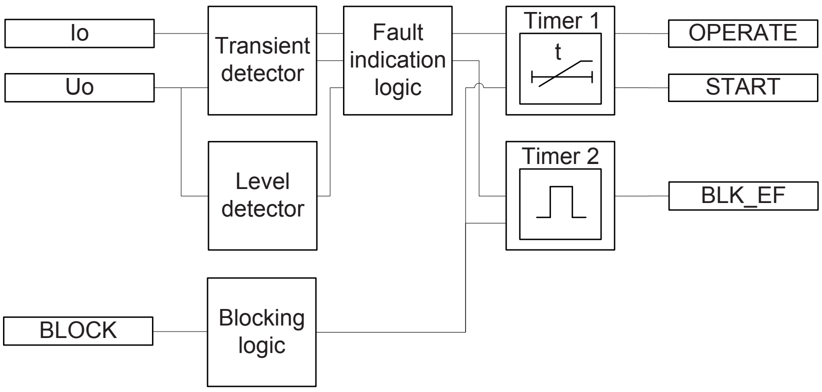


Figure 93: Functional module diagram

Level detector

The residual voltage can be selected from the *Uo signal Sel* setting. The options are "Measured Uo" and "Calculated Uo". If "Measured Uo" is selected, the voltage ratio for Uo-channel is given in the global setting **Configuration/Analog inputs/Voltage (Uo,VT)**. If "Calculated Uo" is selected, the voltage ratio is obtained from phase-voltage channels given in the global setting **Configuration/Analog inputs/Voltage (3U,VT)**.

Example 1: Uo is measured from open-delta connected VTs (20/sqrt(3) kV : 100/sqrt(3) V : 100/3 V). In this case, "Measured Uo" is selected. The nominal values for residual voltage is obtained from VT ratios entered in Residual voltage Uo: **Configuration/Analog inputs/Voltage (Uo,VT)**: 11.547 kV :100 V. The residual voltage start value of 1.0 × Un corresponds to 1.0 × 11.547 kV = 11.547 kV in the primary.

Example 2: Uo is calculated from phase quantities. The phase VT-ratio is 20/sqrt(3) kV : 100/sqrt(3) V. In this case, "Calculated Uo" is selected. The nominal values for residual current and residual voltage are obtained from VT ratios entered in Residual voltage Uo: **Configuration/Analog inputs/Voltage (3U,VT)**: 20.000 kV : 100 V. The residual voltage start value of 1.0 × Un corresponds to 1.0 × 20.000 kV = 20.000 kV in the primary.

If "Calculated Uo" is selected, the residual voltage nominal value is always phase-to-phase voltage. Thus, the valid maximum setting for residual voltage start value is 0.577 × Un. Calculated Uo requires that all three phase-to-earth voltages are connected to the protection relay. Uo cannot be calculated from the phase-to-phase voltages.

Transient detector

The Transient detector module is used for detecting transients in the residual current and residual voltage signals.

The transient detection is supervised with a settable current threshold. With a special filtering technique, the setting *Min operate current* is based on the fundamental frequency current. This setting should be set based on the value of the parallel resistor of the coil, with security margin. For example, if the resistive current of the parallel resistor is 10 A, then a value of 0.7×10 A = 7 A could be used. The same setting is also applicable in case the coil is disconnected and the network becomes unearthed. Generally, a smaller value should be used and it must never exceed the value of the parallel resistor in order to allow operation of the faulted feeder.

Fault indication logic

Depending on the set *Operation mode*, INTRPTEF has two independent modes for detecting earth faults. The "Transient EF" mode is intended to detect all kinds of earth faults. The "Intermittent EF" mode is dedicated for detecting intermittent earth faults in cable networks.

To satisfy the sensitivity requirements, basic earth-fault protection (based on fundamental frequency phasors) should always be used in parallel with the INTRPTEF function.

The Fault indication logic module determines the direction of the fault. The fault direction determination is secured by multi-frequency neutral admittance measurement and special filtering techniques. This enables fault direction determination which is not sensitive to disturbances in measured Io and Uo signals, for example, switching transients.

When *Directional mode* setting "Forward" is used, the protection operates when the fault is in the protected feeder. When *Directional mode* setting "Reverse" is used, the protection operates when the fault is outside the protected feeder (in the background network). If the direction has no importance, the value "Non-directional" can be selected. The detected fault direction (FAULT_DIR) is available in the monitored data view.

In the "Transient EF" mode, when the start transient of the fault is detected and the Uo level exceeds the set "Voltage start value", Timer 1 is activated. Timer 1 is kept activated until the Uo level exceeds the set value or in case of a drop-off, the drop-off duration is shorter than the set *Reset delay time*.

In the "Intermittent EF" mode, when the start transient of the fault is detected and the Uo level exceeds the set *Voltage start value*, the Timer 1 is activated. When a required number of intermittent earth-fault transients set with the *Peak counter limit* setting are detected without the function being reset (depends on the drop-off time set with the *Reset delay time* setting), the `START` output is activated. The Timer 1 is kept activated as long as transients are occurring during the drop-off time defined by setting *Reset delay time*.

Timer 1

The time characteristic is according to DT.

In the "Transient EF" mode, the `OPERATE` output is activated after *Operate delay time* if the residual voltage exceeds the set "Voltage start value". The *Reset delay time* starts to elapse when residual voltage falls below *Voltage start value*. If there is no `OPERATE` activation, for example, the fault disappears momentarily, `START` stays activated until the the *Reset delay time* elapses. After `OPERATE` activation, `START` and `OPERATE` signals are reset as soon as Uo falls below *Voltage start value*.

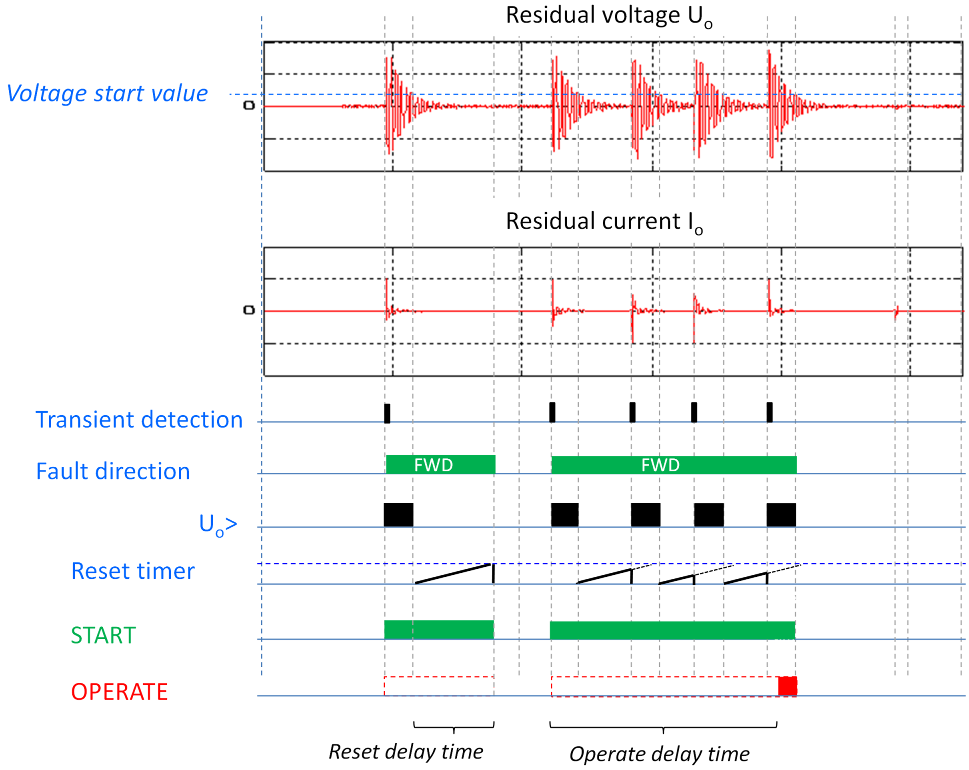


Figure 94: Example of INTRPTEF operation in "Transient EF" mode in the faulty feeder

In the "Intermittent EF" mode the OPERATE output is activated when the following conditions are fulfilled:

- the number of transients that have been detected exceeds the *Peak counter limit* setting
- the timer has reached the time set with the *Operate delay time*
- and one additional transient is detected during the drop-off cycle

The *Reset delay time* starts to elapse from each detected transient (peak). In case there is no OPERATE activation, for example, the fault disappears momentarily START stays activated until the *Reset delay time* elapses, that is, reset takes place if time between transients is more than *Reset delay time*. After OPERATE activation, a fixed pulse length of 100 ms for OPERATE is given, whereas START is reset after *Reset delay time* elapses

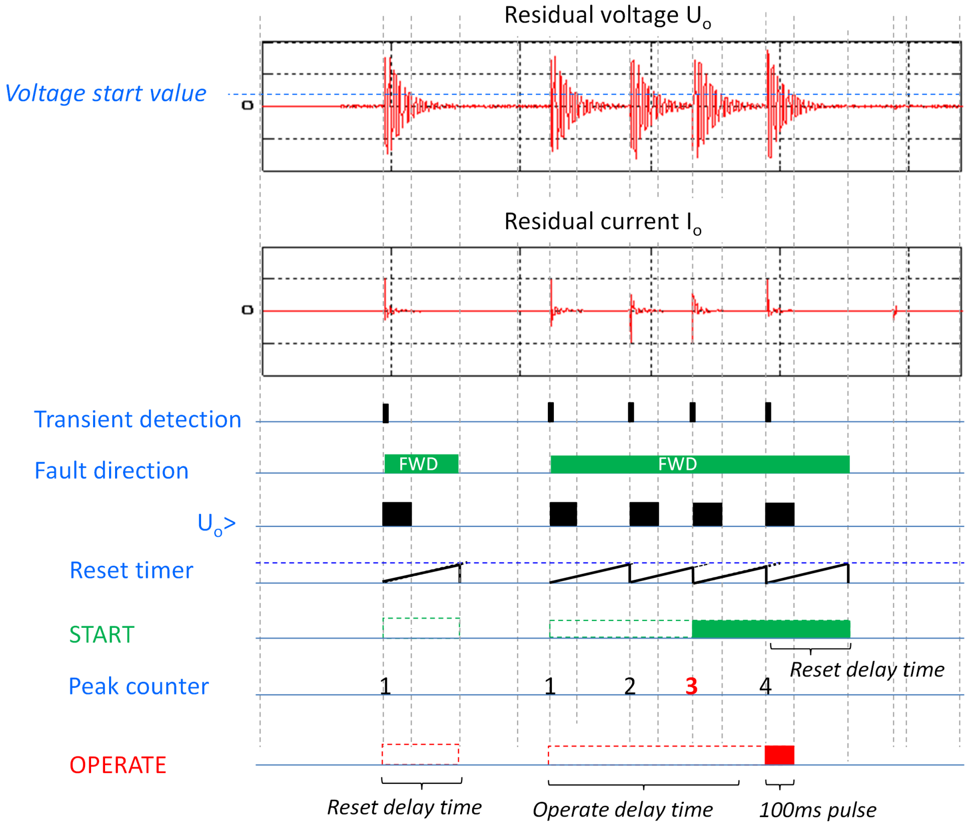


Figure 95: Example of INTRPTEF operation in "Intermittent EF" mode in the faulty feeder, Peak counter limit=3

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operating time. The value is available in the monitored data view.

Timer 2

If the function is used in the directional mode and an opposite direction transient is detected, the `BLK_EF` output is activated for the fixed delay time of 25 ms. If the `START` output is activated when the `BLK_EF` output is active, the `BLK_EF` output is deactivated.

Blocking logic

There are three operation modes in the blocking function. 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.2.3.5 Application

INTRPTEF is an earth-fault function dedicated to operate in intermittent and permanent earth faults occurring in distribution and sub-transmission networks. Fault detection is done from the residual current and residual voltage signals by monitoring the transients with predefined criteria. As the function has a dedicated purpose for the fault types, fast detection and clearance of the faults can be achieved.

Intermittent earth fault

Intermittent earth fault is a special type of fault that is encountered especially in compensated networks with underground cables. A typical reason for this type of fault is the deterioration of cable insulation either due to mechanical stress or due to insulation material aging process where water or moisture gradually penetrates the cable insulation. This eventually reduces the voltage withstand of the insulation, leading to a series of cable insulation breakdowns. The fault is initiated as the phase-to-earth voltage exceeds the reduced insulation level of the fault point and mostly extinguishes itself as the fault current drops to zero for the first time, as shown in Figure 96. As a result, very short transients, that is, rapid changes in the form of spikes in residual current (Io) and in residual voltage (Uo), can be repeatedly measured. Typically, the fault resistance in case of an intermittent earth fault is only a few ohms.

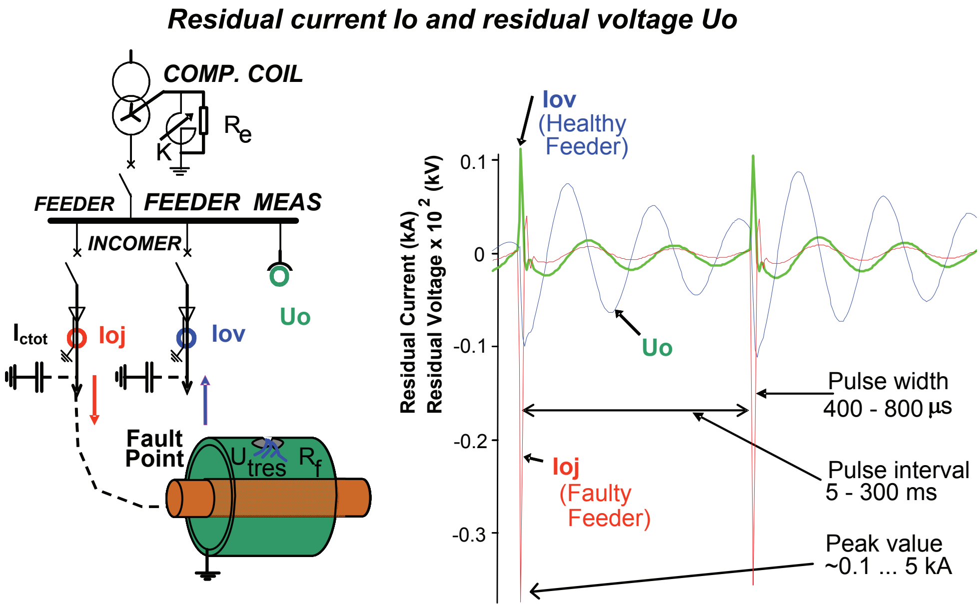


Figure 96: Typical intermittent earth-fault characteristics

Earth-fault transients

In general, earth faults generate transients in currents and voltages. There are several factors that affect the magnitude and frequency of these transients, such as the fault moment on the voltage wave, fault location, fault resistance and the parameters of the feeders and the supplying transformers. In the fault initiation, the voltage of the faulty phase decreases and the corresponding capacitance is discharged to earth (→ discharge transients). At the same time, the voltages of the healthy phases increase and the related capacitances are charged (→ charge transient).

If the fault is permanent (non-transient) in nature, only the initial fault transient in current and voltage can be measured, whereas the intermittent fault creates repetitive transients.

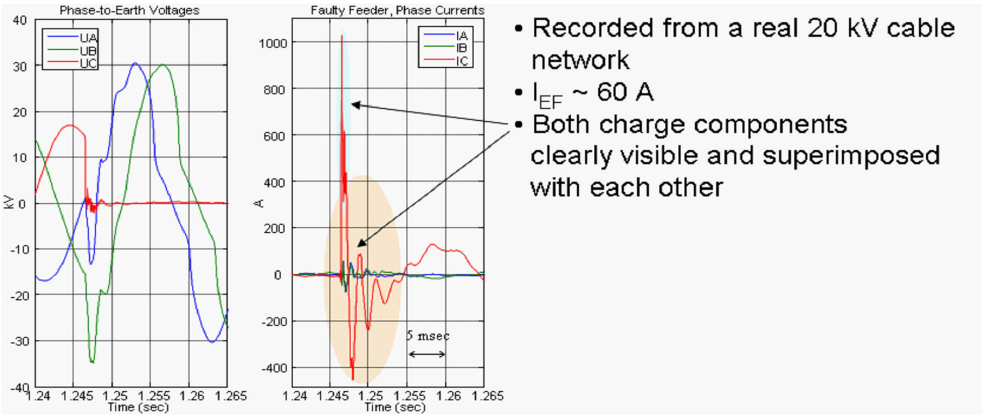


Figure 97: Example of earth-fault transients, including discharge and charge transient components, when a permanent fault occurs in a 20 kV network in phase C

4.2.3.6 Signals

Table 205: INTRPTEF Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
Uo	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 206: INTRPTEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start
BLK_EF	BOOLEAN	Block signal for EF to indicate opposite direction peaks

4.2.3.7 Settings

Table 207: INTRPTEF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Operate delay time	40...1200000	ms	10	500	Operate delay time
Voltage start value	0.05...0.50	xUn	0.01	0.20	Voltage start value

Table 208: INTRPTEF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operation mode	1=Intermittent EF 2=Transient EF			1=Intermittent EF	Operation criteria
Uo signal Sel	1=Measured Uo 2=Calculated Uo			1=Measured Uo	Selection for used Uo signal

Table 209: INTRPTEF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	40...60000	ms	1	500	Reset delay time
Peak counter limit	2...20		1	2	Min requirement for peak counter before start in IEF mode
Min operate current	0.01...1.00	xIn	0.01	0.01	Minimum operating current for transient detector

4.2.3.8 Monitored data

Table 210: INTRPTEF Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
INTRPTEF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.3.9 Technical data

Table 211: INTRPTEF Technical data

Characteristic	Value
Operation accuracy (Uo criteria with transient protection)	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × Uo
Operate time accuracy	±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

4.2.3.10 Technical revision history

Table 212: INTRPTEF Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting
C	The *Minimum operate current* setting is added. Correction in IEC 61850 mapping: DO BlkEF renamed to InhEF. Minimum value changed from 0.01 to 0.10 (default changed from 0.01 to 0.20) for the *Voltage start value* setting. Minimum value changed from 0 ms to 40 ms for the *Reset delay time* setting.
D	Voltage start value description changed from "Voltage start value for transient EF" to "Voltage start value" since the start value is effective in both operation modes. Added support for calculated Uo. Uo source (measured/calculated) can be selected with "Uo signal Sel". *Voltage start value* setting minimum changed from 0.10 to 0.05.
E	*Min operate current* setting scaling corrected to RMS level from peak level.

4.3 Differential protection

4.3.1 High-impedance differential protection HIxPDIF

4.3.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
High-impedance differential protection for phase A	HIAPDIF	dHi>	87
High-impedance differential protection for phase B	HIBPDIF	dHi>	87
High-impedance differential protection for phase C	HICPDIF	dHi>	87

4.3.1.2 Function block

Figure 98: Function block

4.3.1.3 Functionality

The high-impedance differential protection function HIxPDIF is a general differential protection. It provides a phase-segregated short circuit protection for the busbar. However, the function can also be used for providing generator, motor, transformer and reactor protection.

The function starts and operates when the differential current exceeds the set limit. The operate time characteristics are according to definite time (DT).

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

4.3.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

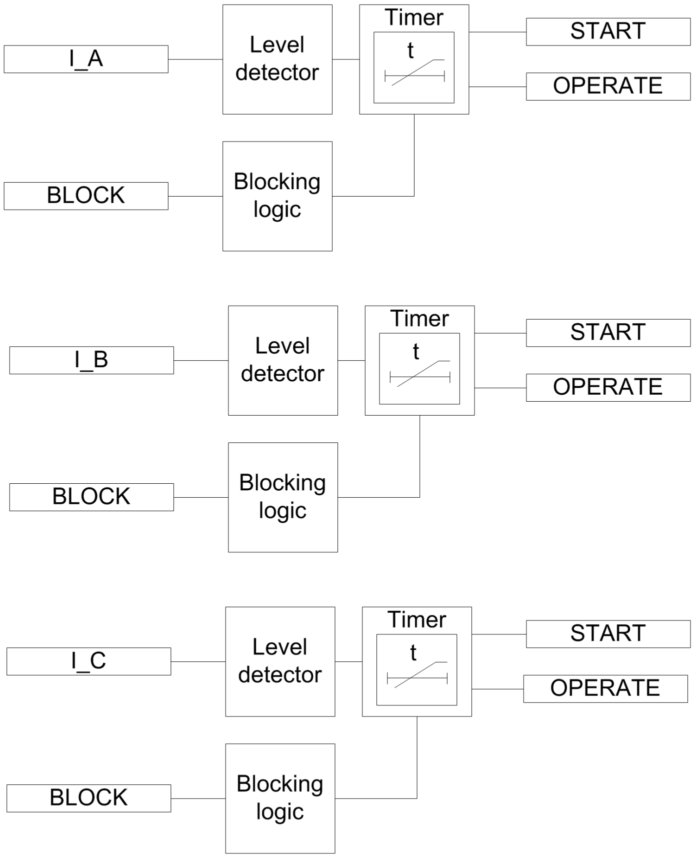


Figure 99: Functional module diagram

The module diagram illustrates all the phases of the function. Functionality for phases A, B and C is identical.

All three phases have independent settings.

Level detector

The module compares differential currents `I_A` calculated by the peak-to-peak measurement mode to the set *Operate value*. The Timer module is activated if the differential current exceeds the value of the *Operate value* setting.

Timer

Once activated, Timer activates the `START` output. The time characteristic is according to DT. When the operation timer reaches the value set by *Minimum operate time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operation timer resets and the `START` output is deactivated.

Timer calculates the start duration START_DUR value, which indicates the percentage ratio of the start situation and the set operating time. The value is available in the Monitored data view.

The activation of the BLOCK input resets Timer and deactivates the START and OPERATE outputs.

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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.3.1.5 Application

HIxPDIF provides a secure and dependable protection scheme against all types of faults. The high-impedance principle is used for differential protection due to its capability to manage the through-faults also with the heavy current transformer (CT) saturation.

For current transformer recommendations, see the Requirements for measurement transformers section in this manual.

High-impedance principle

The phase currents are measured from both the incoming and the outgoing feeder sides of the busbar. The secondary of the current transformer in each phase is connected in parallel with a protection relay measuring branch. Hence, the relay measures only the difference of the currents. In an ideal situation, there is a differential current to operate the relay only if there is a fault between the CTs, that is, inside the protected zone.

If there is a fault outside the zone, a high current, known as the through-fault current, can go through the protected object. This can cause partial saturation in the CTs. The relay operation is avoided with a stabilizing resistor (R_s) in the protection relay measuring branch. R_s increases the impedance of the protection relay; hence the name high-impedance differential scheme.

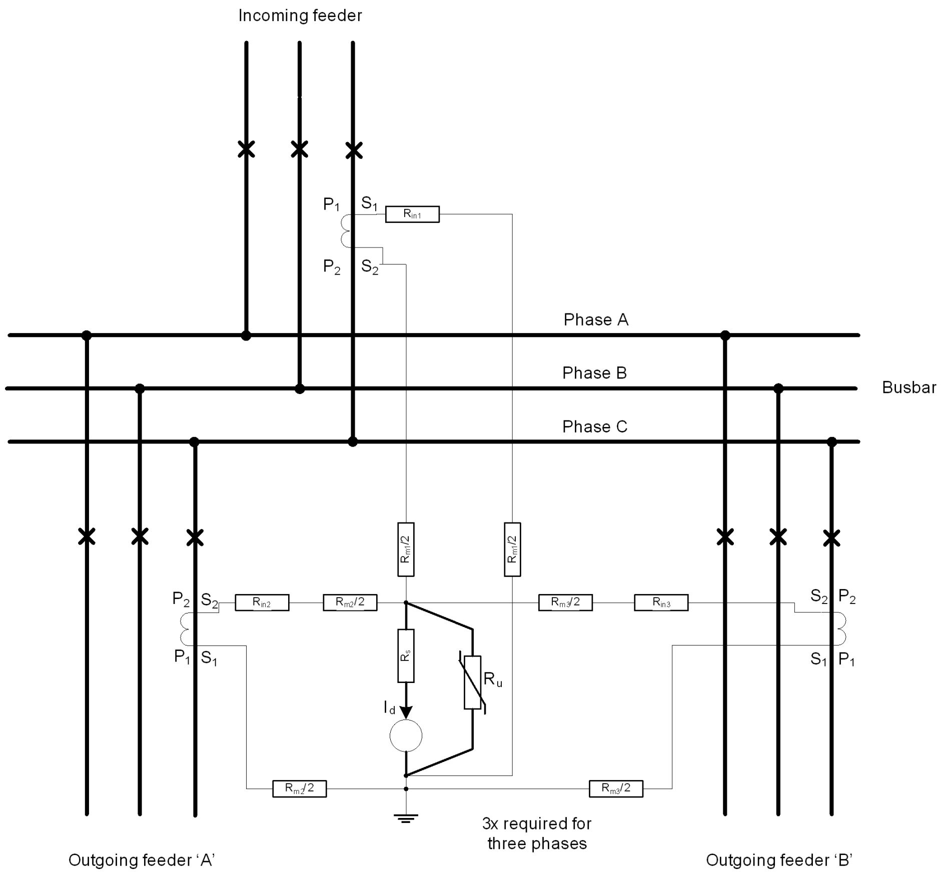


Figure 100: Phase-segregated bus differential protection based on high-impedance principle

CT secondary winding resistances (R_{in}) and connection wire resistances ($R_m/2$) are also shown in Figure 101.

Figure 101 demonstrates a simplified circuit consisting only of one incoming and outgoing feeder. To keep it simple, the voltage-dependent resistor (R_u) is not included. The wiring resistances are presented as total wiring resistances R_{m1} and R_{m2}.

R_{m1} is the maximum wiring resistance concerning all incoming feeder sets, whereas R_{m2} is the maximum wiring resistance concerning all outgoing feeder sets.

The lower part of Figure 101 shows the voltage balance when there is no fault in the system and no CT saturation.

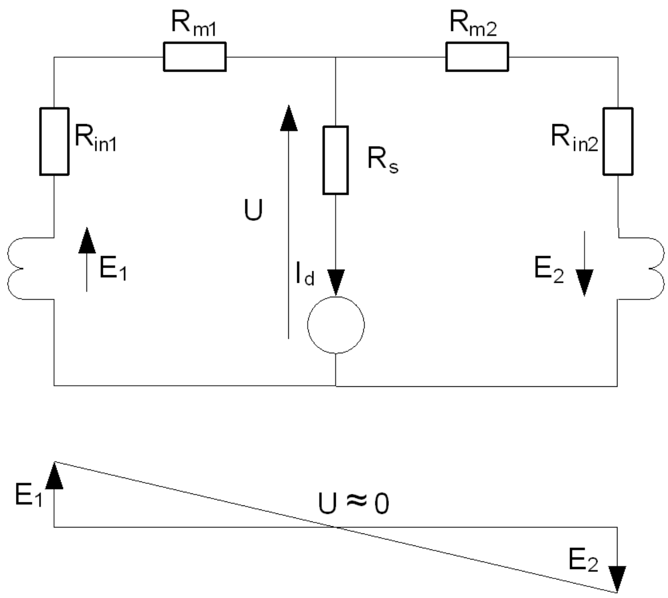


Figure 101: Equivalent circuit when there is no fault or CT saturation

When there is no fault, the CT secondary currents and their emf voltages, E_1 and E_2, are opposite and the protection relay measuring branch has no voltage or current. If an in-zone fault occurs, the secondary currents have the same direction. The relay measures the sum of the currents as a differential and trips the circuit breaker. If the fault current goes through only one CT, its secondary emf magnetizes the opposite CT, that is, $E_1 \approx E_2$.

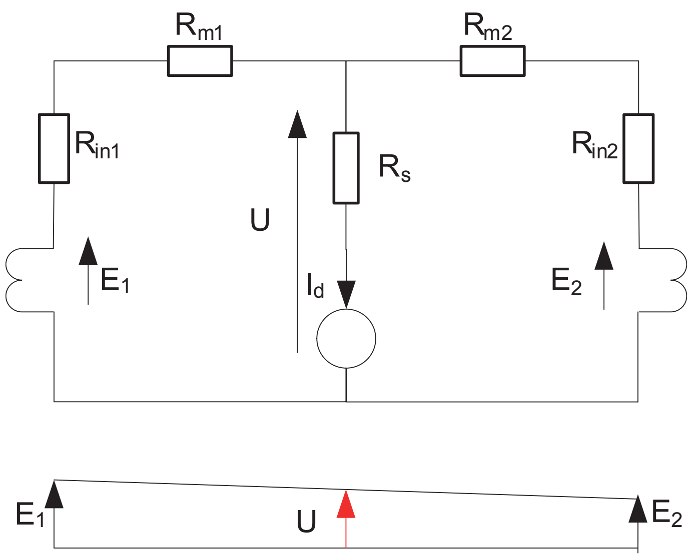


Figure 102: Equivalent circuit in case of in-zone fault

Figure 103 shows CT saturation at a through-fault, that is, out-of-zone, situation. The magnetization impedance of a saturated CT is almost zero. The saturated CT winding can be presented as a short circuit. When one CT is saturated, the current of the non-saturated CT follows two paths, one through the protection relay measuring branch (R_s + relay) and the other through the saturated CT ($R_m + R_{in2}$).

The protection relay must not operate during the saturation. This is achieved by increasing the relay impedance by using the stabilizing resistor (R_s) which forces the majority of the differential current to flow through the saturated CT. As a result, the relay operation is avoided, that is, the relay operation is stabilized against the CT saturation at through-fault current. The stabilizing voltage U_s is the basis of all calculations.

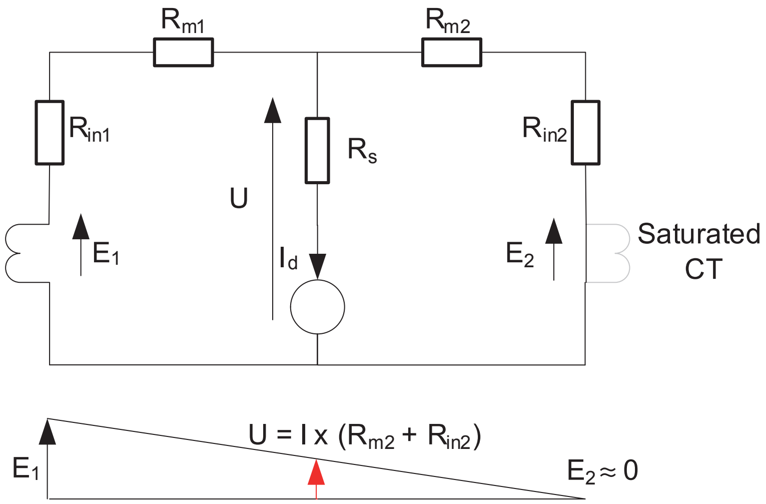


Figure 103: Equivalent circuit in case of the CT saturation at through-fault

The CT saturation happens most likely in the case of an in-zone fault. This is not a problem, because although the operation remains stable (non-operative) during the saturated parts of the CT secondary current waveform, the non-saturated part of the current waveform causes the protection to operate.

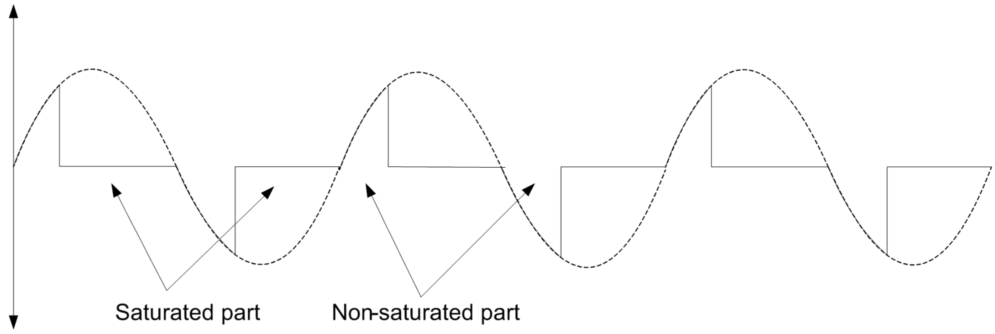


Figure 104: Secondary waveform of a saturated CT

The secondary circuit voltage can easily exceed the isolation voltage of the CTs, connection wires and the protection relay because of the stabilizing resistance and CT saturation. A voltage dependent resistor (VDR, R_u) is used to limit the voltage as shown in Figure 100.

Busbar protection scheme

The basic concept for any bus differential protection relay is a direct use of Kirchoff's first law that the sum of all currents connected to one differential protection zone is zero. If the sum is not zero, an internal fault has occurred. In other words, as seen by the busbar differential protection, the sum of all currents that flow into the protection zone, that is, currents with positive value, must be equal to currents that flow out of the protection zone, that is, currents with negative value, at any instant of time.

Figure 105 shows an example of a phase segregated single busbar protection employing high-impedance differential protection. The example system consists of a single incoming busbar feeder and two outgoing busbar feeders. The CTs from both the outgoing busbar feeders and the incoming busbar feeders are connected in parallel with the polarity. During normal load conditions, the total instantaneous incoming current is equal to the total instantaneous outgoing current and the difference current is negligible. A fault in the busbar results in an imbalance between the incoming and the outgoing current. The difference current flows through the protection relay, which generates a trip signal.

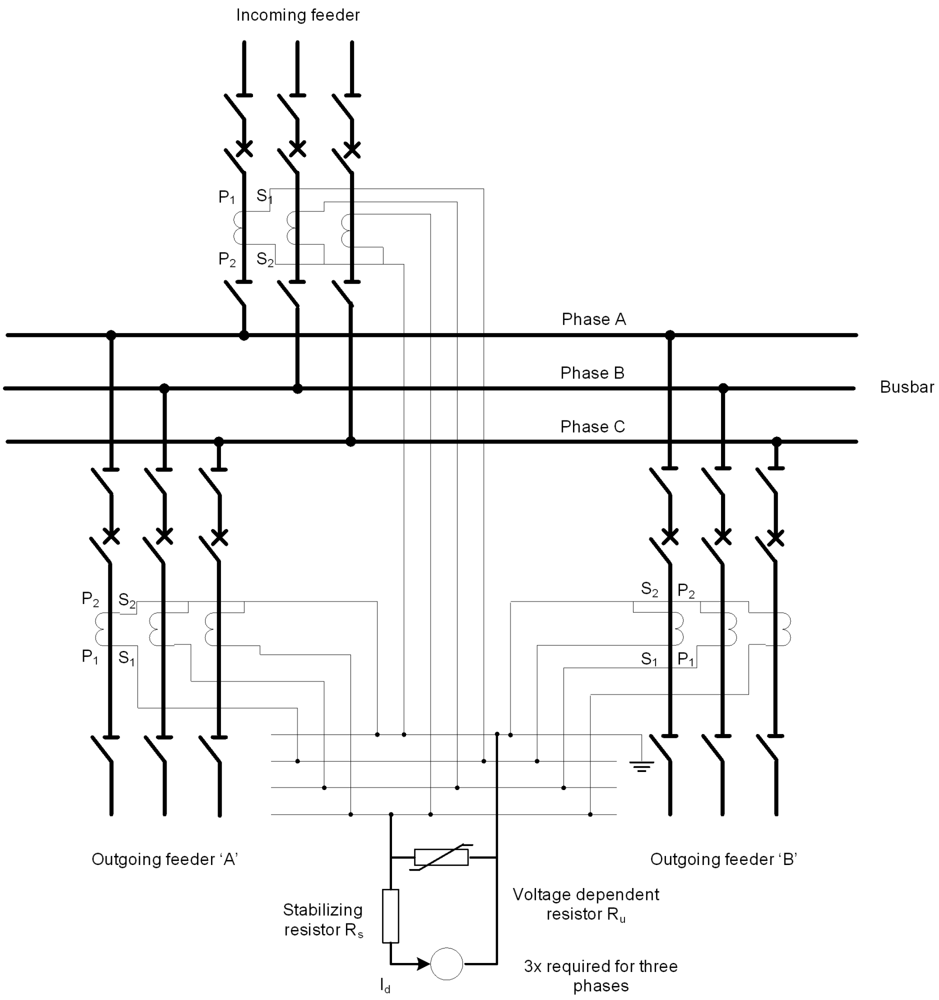


Figure 105: Phase-segregated single busbar protection employing high-impedance differential protection

Figure 106 shows an example for a system consisting of two busbar section coupled with a bus coupler. Each busbar section consists of two feeders and both sections are provided with a separate differential protection to form different zones. The formed zones overlap at the bus coupler.

When the bus coupler is in the open position, each section of the busbar handles the current flow independently, that is, the instantaneous incoming current is equal to the total instantaneous outgoing current and the difference current is negligible. The difference current is no longer zero with a fault in the busbar and the protection operates.

With the bus coupler in the closed position, the current also flows from one busbar section to another busbar section. Thus, the current flowing through the bus coupler needs to be considered in calculating differential current. During normal condition, the summation of the current on each bus section is zero. However, if there is a fault in any busbar section, the difference current is no longer zero and the protection operates.

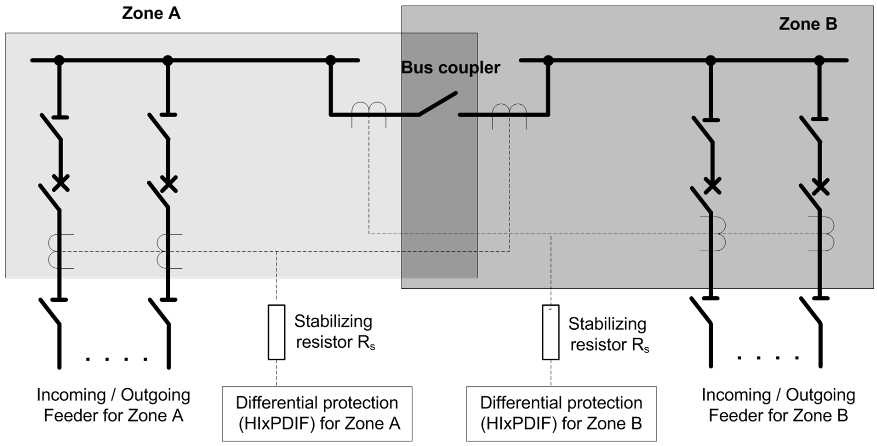


Figure 106: Differential protection on busbar with bus coupler (Single-phase representation)

4.3.1.6 Example calculations for busbar high-impedance differential protection

The protected object in the example for busbar differential protection is a single-bus system with two zones of protection.

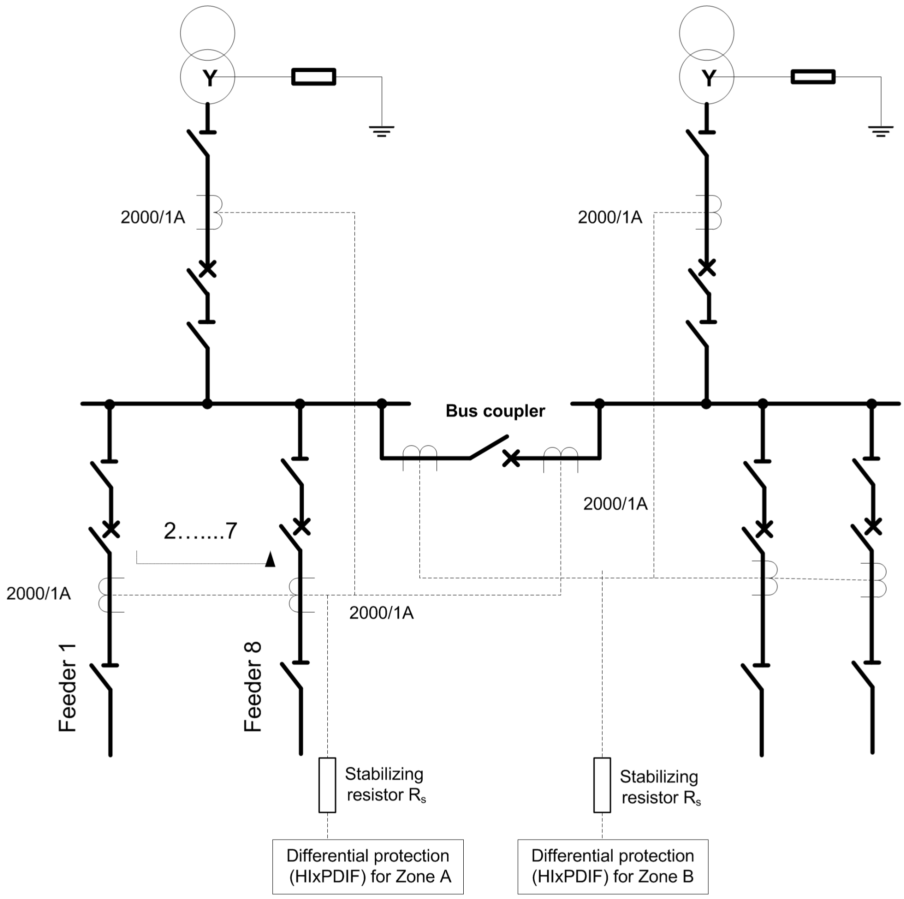


Figure 107: Example for busbar differential protection

Bus data:

U_n	20 kV
I_n	2000 A
I_{kmax}	25 kA

10 feeders per protected zone including bus coupler and incomer.

CT data is assumed to be:

CT	2000/1 A
R_{in}	15.75 Ω
U_{kn}	436 V
I_e	<7 mA (at U_{kn})
R_m	1Ω

The stabilizing voltage is calculated using the formula:

$$U_s = \frac{25000A}{2000}\left(15.75\Omega + 1.\Omega\right) \approx 209.37\ V$$

(Equation 13)

In this case, the requirement for the current transformer knee point voltage is fulfilled because $U_{kn} > 2U_s$.

The magnetizing curve of the CT is assumed to be linear. The magnetizing current at the stabilizing voltage can be estimated as:

$$I_m = \frac{U_s}{U_{kn}} \cdot I_e$$

(Equation 14)

$$I_m = \frac{209.37V}{436V} \cdot 7mA \approx 3.4mA$$

(Equation 15)

To obtain adequate protection stability, the setting current I_{rs} must be at the minimum of the sum of magnetizing currents of all connected CTs.

$$I_{rs} = 10 \cdot 3.4mA \approx 34\,mA$$

(Equation 16)

The resistance of the stabilizing resistor is calculated based on Equation 17.

$$R_S = \frac{209.37\ V}{0.034A} \approx 6160\,\Omega$$

(Equation 17)

The calculated value is the maximum value for the stabilizing resistor. If the value is not available, the next available value below should be selected and the protection relay setting current is tuned according to the selected resistor. For example, in this case, the resistance value 5900 **Ω** is used.

$$I_{rs} = \frac{209.37V}{5900\,\Omega} \approx 35\,mA$$

(Equation 18)

The sensitivity of the protection is obtained as per Equation 19, assuming $I_u = 0$.

$$I_{prim} = 2000 \cdot (0.035\,A + 10 \cdot 0.0034\,A + 0\,A) \approx 140A$$

(Equation 19)

The power of the stabilizing resistor is calculated:

$$P \geq \frac{(436V)^2}{5900\Omega} \approx 32W$$

(Equation 20)

Based on Equation 21 and Equation 22, the need for voltage-dependent resistor is checked.

$$U_{max} = \frac{25000A}{2000}(5900\Omega + 15.75\Omega + 1.00\Omega) \approx 74.0kV$$

(Equation 21)

$$\breve{u} = 2 \cdot \sqrt{2 \cdot 436V \cdot (74000V - 436V)} \approx 16.0kV$$

(Equation 22)

The voltage-dependent resistor (one for each phase) is needed in this case as the voltage during the fault is higher than 2 kV.

The leakage current through the VDR at the stabilizing voltage can be available from the VDR manual, assuming that to be approximately 2 mA at stabilizing voltage

$$Iu \approx 0.002\,A$$

(Equation 23)

The sensitivity of the protection can be recalculated taking into account the leakage current through the VDR as per Equation 24.

$$I_{prim} = 2000 \cdot (0.035\,A + 10 \cdot 0.0034\,A + 0.002\,A) \approx 142\,A$$

(Equation 24)

4.3.1.7 Signals

Table 213: HIAPDIF Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 214: HIBPDIF Input signals

Name	Type	Default	Description
I_B	SIGNAL	0	Phase B current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 215: HICPDIF Input signals

Name	Type	Default	Description
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 216: HIAPDIF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 217: HIBPDIF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 218: HICPDIF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.1.8 Settings

Table 219: HIAPDIF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operate value	1.0...200.0	%In	1.0	5.0	Operate value, percentage of the nominal current
Minimum operate time	20...300000	ms	10	20	Minimum operate time

Table 220: HIAPDIF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 221: HIAPDIF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time

Table 222: HIBPDIF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operate value	1.0...200.0	%In	1.0	5.0	Operate value, percentage of the nominal current
Minimum operate time	20...300000	ms	10	20	Minimum operate time

Table 223: HIBPDIF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 224: HIBPDIF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time

Table 225: HICPDIF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operate value	1.0...200.0	%In	1.0	5.0	Operate value, percentage of the nominal current
Minimum operate time	20...300000	ms	10	20	Minimum operate time

Table 226: HICPDIF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 227: HICPDIF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time

4.3.1.9 Monitored data

Table 228: HIAPDIF Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
HIAPDIF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 229: HIBPDIF Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
HIBPDIF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 230: HICPDIF Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
HICPDIF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.1.10 Technical data

Table 231: HIxPDIF 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		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Start value*	12 ms	16 ms	24 ms
	I_{Fault} = 10 × set *Start value*	10 ms	12 ms	14 ms
Reset time		<40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 × I_n, f_n = 50 Hz, 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

4.3.1.11 Technical revision history

Table 232: HIxPDIF Technical revision history

Technical revision	Change
B	Function name changed from HIPDIF to HIAPDIF, HIBPDIF, HICPDIF

4.4 Unbalance protection

4.4.1 Negative-sequence overcurrent protection NSPTOC

4.4.1.1 Identification

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

4.4.1.2 Function block

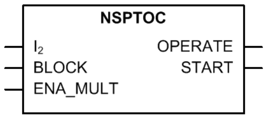


Figure 108: Function block

4.4.1.3 Functionality

The negative-sequence overcurrent protection function NSPTOC 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.

NSPTOC 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 starts when the negative sequence current exceeds the set limit. The operate time characteristics can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). In the DT mode, the function operates after a predefined operate 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.

4.4.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

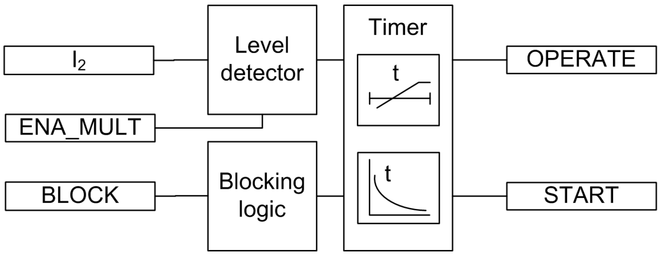


Figure 109: Functional module diagram

Level detector

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

The protection relay does not accept the *Start value* or *Start value Mult* setting if the product of the settings exceeds the *Start value* setting range.

Timer

Once activated, the timer activates the START 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 *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the OPERATE 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 operate 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. The START output is deactivated when the reset timer has elapsed.

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 operate and reset times.

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operating 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.4.1.5 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 earth-fault protection in solid and low resistance earthed networks.

The negative sequence overcurrent protection provides the back-up earth-fault protection on the high voltage side of a delta-wye connected power transformer for earth faults taking place on the wye-connected low voltage side. If an earth 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.

The most common application for the negative sequence overcurrent protection is probably 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 damages 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.

4.4.1.6 Signals

Table 233: NSPTOC 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 234: NSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.1.7 Settings

Table 235: NSPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.01...5.00	xIn	0.01	0.30	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type

Table 236: NSPTOC Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 237: NSPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		1	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		1	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		1	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		1	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		1	1.0	Parameter E for customer programmable curve

Table 238: NSPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time

4.4.1.8 Monitored data

Table 239: NSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
NSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.1.9 Technical data

Table 240: NSPTOC 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		
Start time [1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2 × set *Start value*	23 ms	26 ms	28 ms
	I_{Fault} = 10 × set *Start value*	15 ms	18 ms	20 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 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 ±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 = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.4.1.10 Technical revision history

Table 241: NSPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting
C	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting
D	Internal improvement
E	Internal Improvements

4.4.2 Phase discontinuity protection PDNSPTOC

4.4.2.1 Identification

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

4.4.2.2 Function block

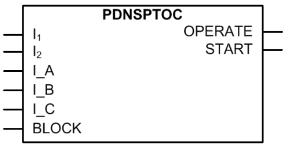


Figure 110: Function block

4.4.2.3 Functionality

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

The function starts and operates 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. PDNSPTOC operates with DT characteristic.

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

4.4.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

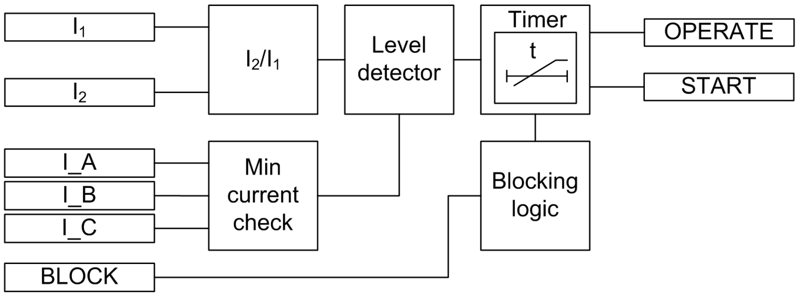


Figure 111: Functional module diagram

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 *Start value*. If the calculated value exceeds the set *Start 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 `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.4.2.5 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.

PDNSPTOC 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 PDNSPTOC is based on the ratio of the positive-sequence and negative-sequence currents. This gives a 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 25)

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

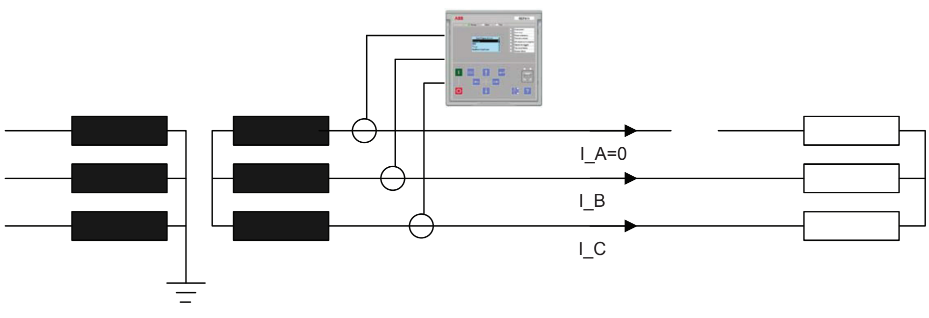


Figure 112: Broken conductor fault situation in phase A in a distribution or subtransmission feeder

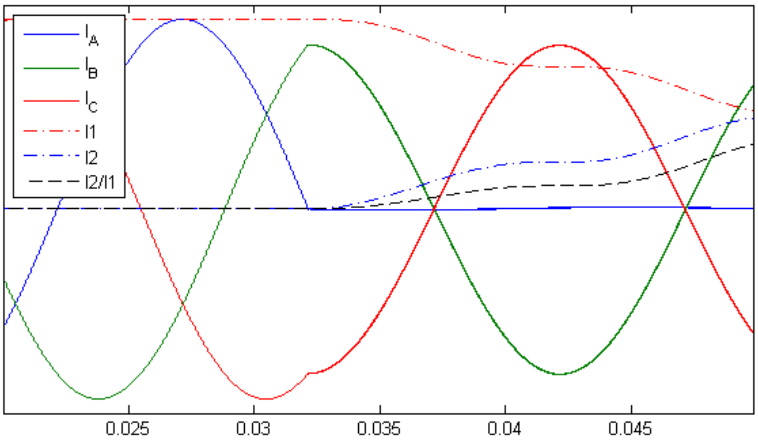


Figure 113: Three-phase current quantities during the broken conductor fault in phase A with the ratio of negative-sequence and positive-sequence currents

4.4.2.6 Signals

Table 242: PDNSPTOC 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 243: PDNSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.2.7 Settings

Table 244: PDNSPTOC Group settings (Basic)

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

Table 245: PDNSPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 246: PDNSPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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

4.4.2.8 Monitored data

Table 247: PDNSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
RATIO_I2_I1	FLOAT32	0.00...999.99	%	Measured current ratio I2 / I1
PDNSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.2.9 Technical data

Table 248: PDNSPTOC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±2% of the set value
Start time	<70 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Retardation time	<35 ms
Operate 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,…

4.4.2.10 Technical revision history

Table 249: PDNSPTOC Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement
D	Internal improvement

4.4.3 Phase reversal protection PREVPTOC

4.4.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase reversal protection	PREVPTOC	I2>>	46R

4.4.3.2 Function block

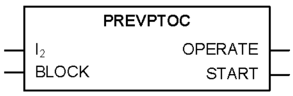


Figure 114: Function block

4.4.3.3 Functionality

The phase reversal protection function PREVPTOC is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase sequence current I_2 of the motor.

PREVPTOC starts and operates when I_2 exceeds the set limit. PREVPTOC operates on definite time (DT) characteristics. PREVPTOC is based on the calculated I_2, and the function detects too high I_2 values during the motor start-up. The excessive I_2 values are caused by incorrectly connected phases, which in turn makes the motor rotate in the opposite direction.

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

4.4.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

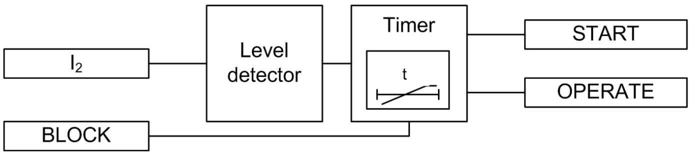


Figure 115: Functional module diagram

Level detector

The level detector compares the negative-sequence current to the set *Start value*. If the I_2 value exceeds the set *Start value*, the level detector sends an enabling signal to the timer module.

Timer

Once activated, the timer activates the `START` output. When the operation timer has reached the set *Operate delay time* value, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value of 200 ms, the operation timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation time. The value is available in the monitored data view.

4.4.3.5 Application

The rotation of a motor in the reverse direction is not a desirable operating condition. When the motor drives fans and pumps, for example, and the rotation direction is reversed due to a wrong phase sequence, the driven process can be disturbed and the flow of the cooling air of the motor can become reversed too. With a motor designed only for a particular rotation direction, the reversed rotation direction can lead to an inefficient cooling of the motor due to the fan design.

In a motor, the value of the negative-sequence component of the phase currents is very negligible when compared to the positive-sequence component of the current during a healthy operating condition of the motor. But when the motor is started with the phase connections in the reverse order, the magnitude of I_2 is very high. So whenever the value of I_2 exceeds the start value, the function detects the reverse rotation direction and provides an operating signal that disconnects the motor from the supply.

4.4.3.6 Signals

Table 250: PREVPTOC Input signals

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

Table 251: PREVPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.3.7 Settings

Table 252: PREVPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.00	xIn	0.01	0.75	Start value
Operate delay time	100...60000	ms	10	100	Operate delay time

Table 253: PREVPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

4.4.3.8 Monitored data

Table 254: PREVPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PREVPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.3.9 Technical data

Table 255: PREVPTOC 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		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Start value*	23 ms	25 ms	28 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate 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 current before = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.4.3.10 Technical revision history

Table 256: PREVPTOC Technical revision history

Technical revision	Change
B	Internal improvement

4.4.4 Negative-sequence overcurrent protection for machines MNSPTOC

4.4.4.1 Identification

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

4.4.4.2 Function block

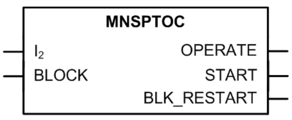


Figure 116: Function block

4.4.4.3 Functionality

The negative-sequence overcurrent protection for machines function MNSPTOC protects electric motors from phase unbalance. A small voltage unbalance can produce a large negative-sequence current flow in the motor. For example, a 5 percent voltage unbalance produces a stator negative-sequence current of 30 percent of the full load current, which can severely heat the motor. MNSPTOC detects the large negative-sequence current and disconnects the motor.

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

4.4.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

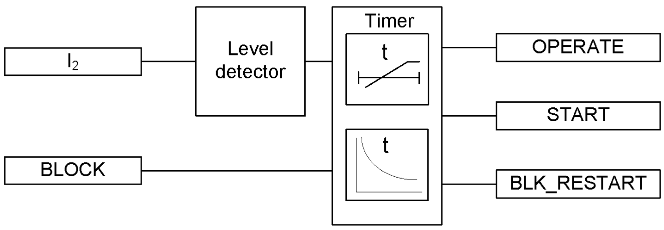


Figure 117: Functional module diagram

Level detector

The calculated negative-sequence current is compared to the *Start value* setting. If the measured value exceeds the *Start value* setting, the function activates the timer module.

Timer

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

In a drop-off situation, that is, when the value of the negative-sequence current drops below the *Start value* setting, the reset timer is activated and the `START` output resets after the time delay of *Reset delay time* for the DT characteristics. For IDMT, the reset time depends on the curve type selected.

For the IDMT curves, it is possible to define minimum and maximum operate times with the *Minimum operate time* and *Maximum operate time* settings. The *Machine time Mult* setting parameter corresponds to the machine constant, equal to the $I_2{}^2t$ constant of the machine, as stated by the machine manufacturer. In case there is a mismatch between the used CT and the protected motor's nominal current values, it is possible to fit the IDMT curves for the protected motor using the *Current reference* setting.

The activation of the `OPERATE` output activates the `BLK_RESTART` output. The deactivation of the `OPERATE` output activates the cooling timer. The timer is set to the value entered in the *Cooling time* setting. The `BLK_RESTART` output is kept active until the cooling timer is exceeded. If the negative-sequence current increases above the set value during this period, the `OPERATE` output is activated immediately.

The `T_ENARESTART` output indicates the duration for which the `BLK_RESTART` output remains active, that is, it indicates the remaining time of the cooling timer. The value is available in the monitored data view.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation time. The value is available in the monitored data view.

4.4.4.5 Timer characteristics

MNSPTOC supports both DT and IDMT characteristics. The DT timer characteristics can be selected with "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 *Operate delay time* and *Reset delay time* settings.

The protection relay provides two user-programmable IDMT characteristics curves, "Inv. curve A" and "Inv. curve B".

Current-based inverse definite minimum time curve (IDMT)

In inverse-time modes, the operate time depends on the momentary value of the current: the higher the current, the shorter the operate time. The operate time calculation or integration starts immediately when the current exceeds the set *Start value* and the `START` output is activated.

The `OPERATE` 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 *Minimum operate time* and *Maximum operate time* settings define the minimum operate time and maximum operate time possible for the IDMT mode. For setting these parameters, a careful study of the particular IDMT curves is recommended.

Inv. curve A

The inverse time equation for curve type A is:

$$t[s] = \frac{k}{\left(\frac{I_2}{I_r}\right)^2}$$

(Equation 26)

t[s]	Operate time in seconds
k	Set *Machine time Mult*
I_2	Negative-sequence current
I_r	Set *Rated current*

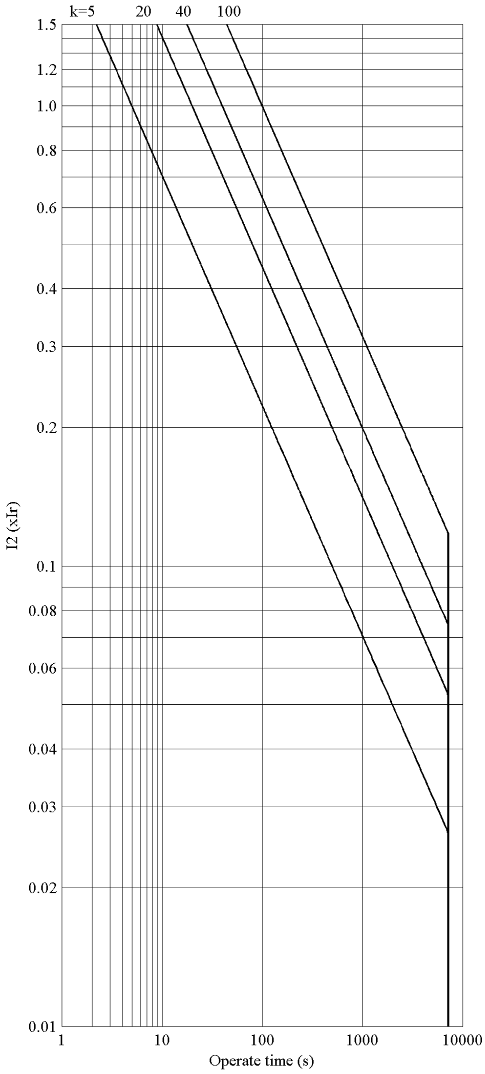


Figure 118: MNSPTOC Inverse Curve A

If the negative sequence current drops below the *Start value* setting, the reset time is defined as:

$$t[s] = a \times \left(\frac{b}{100}\right)$$

(Equation 27)

t[s] Reset time in seconds

a set *Cooling time*

b percentage of start time elapse (`START_DUR`)

When the reset period is initiated, the time for which START has been active is saved. If the fault reoccurs, that is, the negative-sequence current rises above the set value during the reset period, the operate calculations are continued using the saved values. If the reset period elapses without a fault being detected, the operate timer is reset and the saved values of start time and integration are cleared.

Inv. curve B

The inverse time equation for curve type B is:

$$t[s] = \frac{k}{\left(\frac{I_2}{I_r}\right)^2 - \left(\frac{I_S}{I_r}\right)^2}$$

(Equation 28)

t[s]	Operate time in seconds
k	*Machine time Mult*
I_2	Negative-sequence current
I_S	Set *Start value*
I_r	Set *Rated current*

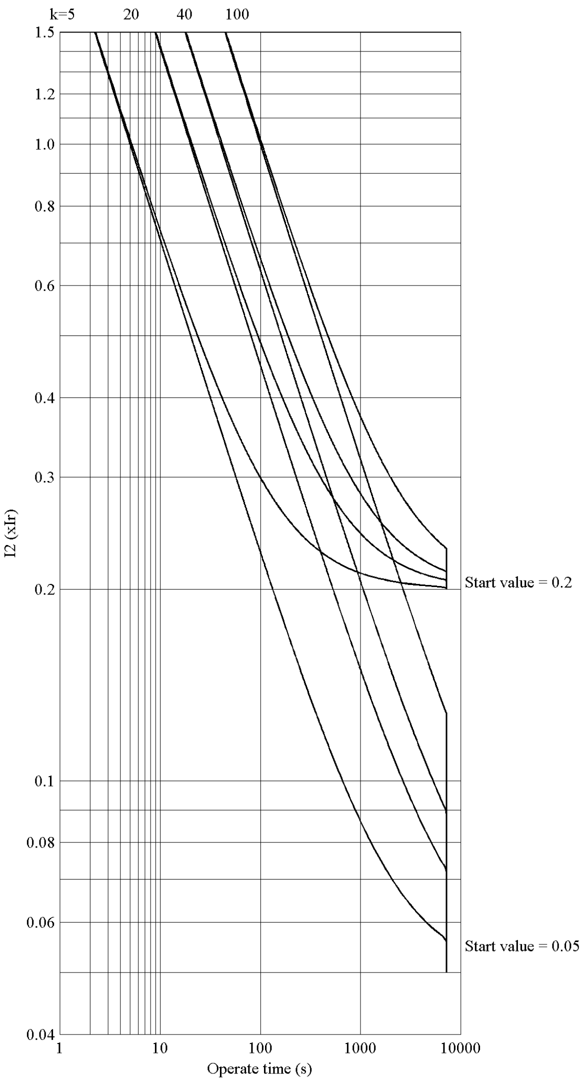


Figure 119: MNSPTOC Inverse Curve B

If the fault disappears, the negative-sequence current drops below the *Start value* setting and the START output is deactivated. The function does not reset instantaneously. Resetting depends on the equation or the *Cooling time* setting.

The timer is reset in two ways:

- When the negative sequence current drops below start value the subtraction in the denominator becomes negative and the cumulative sum starts to decrease. The decrease in the sum indicates the cooling of the machine and the cooling speed

depends on the value of the negative-sequence current. If the sum reaches zero without a fault being detected, the accumulation stops and the timer is reset.
- If the reset time set through the *Cooling time* setting elapses without a fault being detected, the timer is reset.

The reset period thus continues for a time equal to the *Cooling time* setting or until the operate time decreases to zero, whichever is less.

4.4.4.6 Application

In a three-phase motor, the conditions that can lead to unbalance are single phasing, voltage unbalance from the supply and single-phase fault. The negative sequence current damages the motor during the unbalanced voltage condition, and therefore the negative sequence current is monitored to check the unbalance condition.

When the voltages supplied to an operating motor become unbalanced, the positive-sequence current remains substantially unchanged, but the negative-sequence current flows due to the unbalance. For example, if the unbalance is caused by an open circuit in any phase, a negative-sequence current flows and it is equal and opposite to the previous load current in a healthy phase. The combination of positive and negative-sequence currents produces phase currents approximately 1.7 times the previous load in each healthy phase and zero current in the open phase.

The negative-sequence currents flow through the stator windings inducing negative-sequence voltage in the rotor windings. This can result in a high rotor current that damages the rotor winding. The frequency of the induced current is approximately twice the supply frequency. Due to skin effect, the induced current with a frequency double the supply frequency encounters high rotor resistance which leads to excessive heating even with phase currents with value less than the rated current of the motor.

The negative-sequence impedance of induction or a synchronous motor is approximately equal to the locked rotor impedance, which is approximately one-sixth of the normal motor impedance, considering that the motor has a locked-rotor current of six times the rated current. Therefore, even a three percent voltage unbalance can lead to 18 percent stator negative sequence current in windings. The severity of this is indicated by a 30-40 percent increase in the motor temperature due to the extra current.

4.4.4.7 Signals

Table 257: MNSPTOC Input signals

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

Table 258: MNSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start
BLK_RESTART	BOOLEAN	Overheated machine reconnection blocking

4.4.4.8 Settings

Table 259: MNSPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.01...0.50	xIn	0.01	0.20	Start value
Operating curve type	5=ANSI Def. Time 15=IEC Def. Time 17=Inv. Curve A 18=Inv. Curve B			15=IEC Def. Time	Selection of time delay curve type
Machine time Mult	5.0...100.0		0.1	5.0	Machine related time constant
Operate delay time	100...120000	ms	10	1000	Operate delay time

Table 260: MNSPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Maximum operate time	500000...7200000	ms	1000	1000000	Max operate time regardless of the inverse characteristic
Minimum operate time	100...120000	ms	1	100	Minimum operate time for IDMT curves
Cooling time	5...7200	s	1	50	Time required to cool the machine

Table 261: MNSPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Current reference	0.30...2.00	xIn	0.01	1.00	Rated current (Ir) of the machine (used only in the IDMT)
Reset delay time	0...60000	ms	1	20	Reset delay time

4.4.4.9 Monitored data

Table 262: MNSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
T_ENARESTART	INT32	0...10000	s	Estimated time to reset of block restart
MNSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.4.10 Technical data

Table 263: MNSPTOC 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		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Start value*	23	25 ms	28 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 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 ±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 = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) *Start value* multiples in range of 1.10...5.00

4.4.4.11 Technical revision history

Table 264: MNSPTOC Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

4.5 Voltage protection

4.5.1 Three-phase overvoltage protection PHPTOV

4.5.1.1 Identification

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

4.5.1.2 Function block

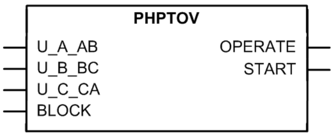


Figure 120: Function block

4.5.1.3 Functionality

The three-phase overvoltage protection function PHPTOV 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.

PHPTOV 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.

4.5.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

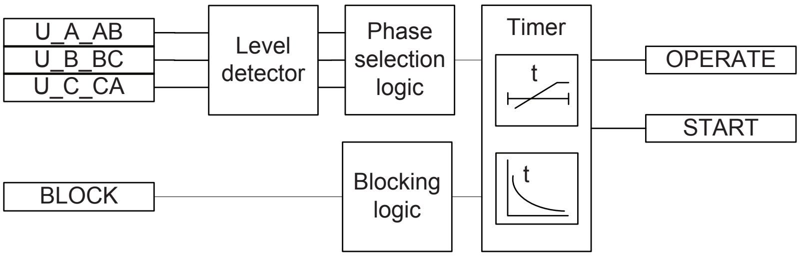


Figure 121: Functional module diagram

Level detector

The fundamental frequency component of the measured three-phase voltages are compared phase-wise to the set value of the *Start value* setting. If the measured value is higher than the set value of the *Start 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 *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

The *Voltage selection* setting is used for selecting phase-to-earth 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 start phases*, the phase selection logic activates the Timer.

Timer

Once activated, the Timer activates the `START` 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 *Operate delay time* in the DT mode or the maximum value defined by the IDMT, the `OPERATE` output is activated.

When the user-programmable IDMT curve is selected, the operate 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 operate delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected operate 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 `START` 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*, *Type of time reset* and *Reset delay time* settings.

Table 265: Reset time functionality when IDMT operation time curve selected

Reset functionality		Setting Type of reset curve	Setting Type of time reset	Setting Reset delay time
Instantaneous reset	Operation timer is “Reset instantaneously” when drop-off occurs	“Immediate”	Setting has no effect	Setting has no effect
Frozen timer	Operation timer is frozen during drop-off	“Def time reset”	“Freeze Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed
Linear decrease	Operation timer value linearly decreases during the drop-off situation	“Def time reset”	“Decrease Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed

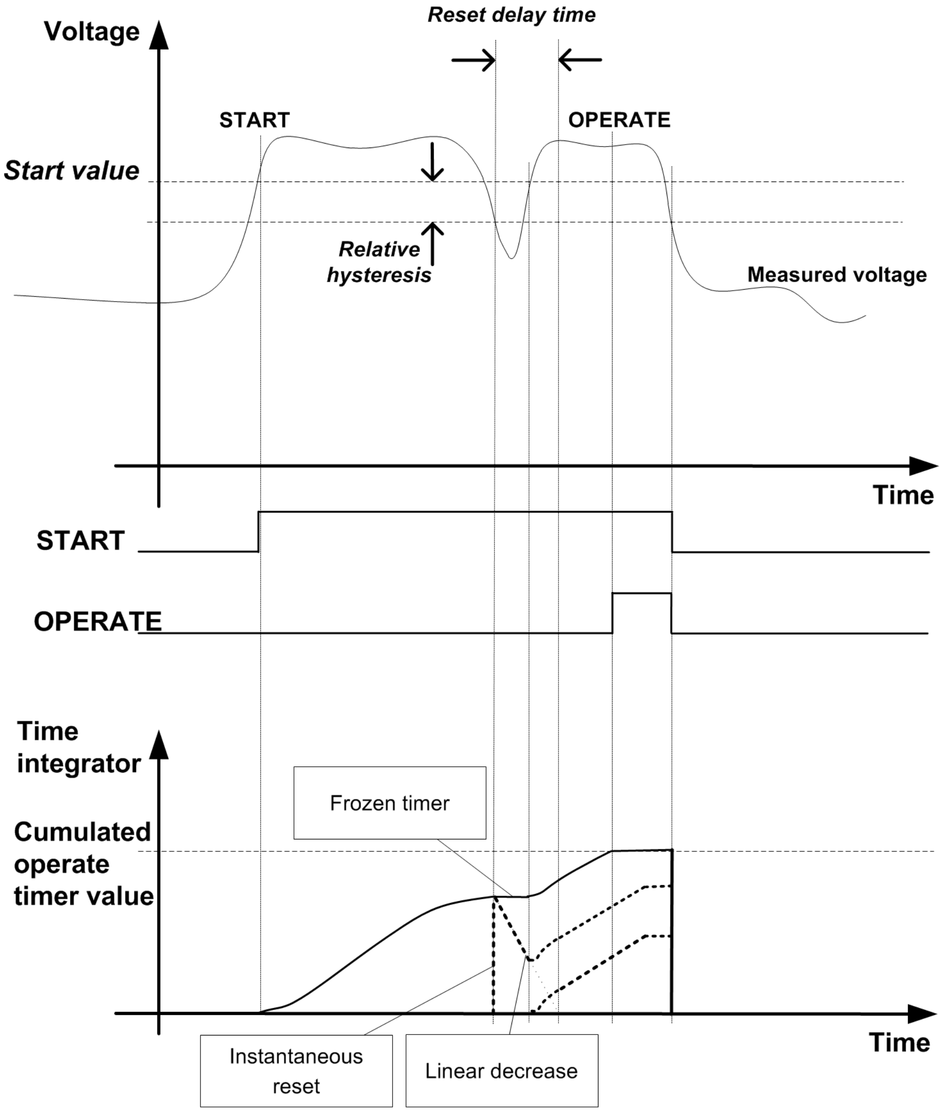


Figure 122: Behavior of different IDMT reset modes. Operate signal is based on settings Type of reset curve = "Def time reset" and Type of time reset= "Freeze Op timer". The effect of other reset modes is also presented

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

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overvoltage protection section in this manual.

The Timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 `OPERATE` 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

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

4.5.1.5 Timer characteristics

The operating curve types supported by PHPTOV are:

Table 266: 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

4.5.1.6 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.

4.5.1.7 Signals

Table 267: PHPTOV Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 268: PHPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.1.8 Settings

Table 269: PHPTOV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.60	xUn	0.01	1.10	Start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...300000	ms	10	40	Operate delay time
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			15=IEC Def. Time	Selection of time delay curve type

Table 270: PHPTOV Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset			1=Immediate	Selection of reset curve type
Type of time reset	1=Freeze Op timer 2=Decrease Op timer			1=Freeze Op timer	Selection of time reset

Table 271: PHPTOV Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation
Curve parameter A	0.005...200.000		1	1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00		1	1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0		1	0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000		1	0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000		1	1.000	Parameter E for customer programmable curve
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages

Table 272: PHPTOV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	40...60000	ms	1	40	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve Sat Relative	0.0...10.0		0.1	0.0	Tuning parameter to avoid curve discontinuities
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.5.1.9 Monitored data

Table 273: PHPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.1.10 Technical data

Table 274: PHPTOV 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 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 × set *Start value*	23 ms	27 ms	31 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 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 ±20 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 × U_n, Voltage before fault = 0.9 × U_n, f_n = 50 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 *Start value* = 1.20 × U_n, *Start value* multiples in range of 1.10...2.00

4.5.1.11 Technical revision history

Table 275: PHPTOV Technical revision history

Technical revision	Change
B	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
C	Curve Sat relative max range widened from 3.0 to 10.0 % and default value changed from 2.0 to 0.0 %.
D	Added setting *Type of time reset*.

4.5.2 Three-phase undervoltage protection PHPTUV

4.5.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase undervoltage protection	PHPTUV	3U<	27

4.5.2.2 Function block

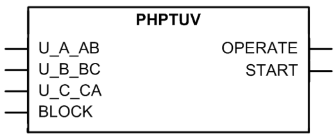


Figure 123: Function block

4.5.2.3 Functionality

The three-phase undervoltage protection function PHPTUV is used to disconnect from the network devices, for example electric motors, which are damaged when subjected to service under low voltage conditions. PHPTUV 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.

4.5.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

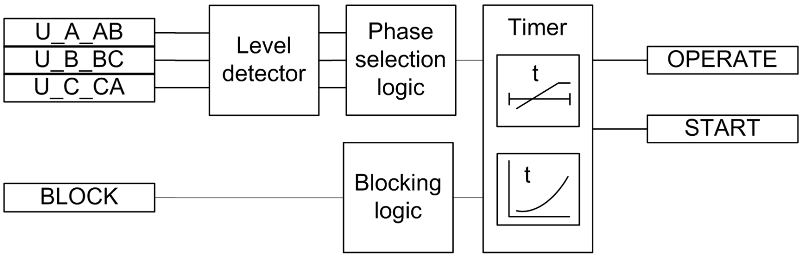


Figure 124: Functional module diagram

Level detector

The fundamental frequency component of the measured three phase voltages are compared phase-wise to the set *Start value*. If the measured value is lower than the set value of the *Start 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 *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return back to the hysteresis area.

The *Voltage selection* setting is used for selecting the phase-to-earth 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 starts and operates 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 start phases*, the phase selection logic activates the Timer.

Timer

Once activated, the Timer activates the START 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 *Operate delay time* in the DT mode or the maximum value defined by the IDMT, the OPERATE output is activated.

When the user-programmable IDMT curve is selected, the operate 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 operate delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected operate 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 START 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*, *Type of time reset* and *Reset delay time* settings.

Table 276: Reset time functionality when IDMT operation time curve selected

Reset functionality		Setting Type of reset curve	Setting Type of time reset	Setting Reset delay time
Instantaneous reset	Operation timer is “Reset instantaneously” when drop-off occurs	“Immediate”	Setting has no effect	Setting has no effect
Frozen timer	Operation timer is frozen during drop-off	“Def time reset”	“Freeze Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed
Linear decrease	Operation timer value linearly decreases during the drop-off situation	“Def time reset”	“Decrease Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed

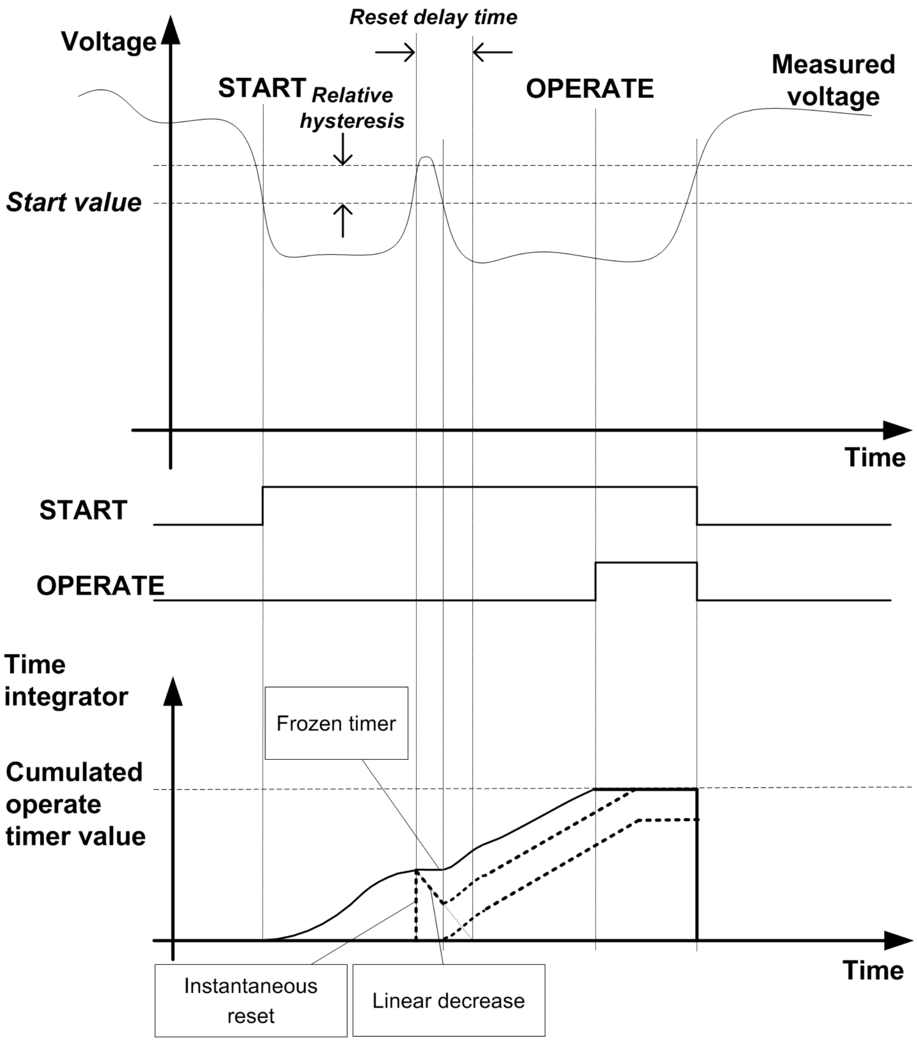


Figure 125: Behavior of different IDMT reset modes. Operate signal is based on settings Type of reset curve = "Def time reset" and Type of time reset= "Freeze Op timer". The effect of other reset modes is also presented

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

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

The *Minimum operate 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 operate time* setting. For more information, see the IDMT curves for overcurrent protection section in this manual.

The Timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

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

4.5.2.5 Timer characteristics

The operating curve types supported by PHPTUV are:

Table 277: 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

4.5.2.6 Application

PHPTUV 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. PHPTUV 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. PHPTUV 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.

PHPTUV can be used to disconnect from the network devices, such as electric motors, which are damaged when subjected to service under low voltage conditions. PHPTUV 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-earth faults (unsymmetrical voltage increase).

PHPTUV prevents sensitive equipment from running under conditions that could cause overheating and thus shorten their life time expectancy. In many cases, PHPTUV is a useful function in circuits for local or remote automation processes in the power system.

4.5.2.7 Signals

Table 278: PHPTUV Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 279: PHPTUV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.2.8 Settings

Table 280: PHPTUV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.20	xUn	0.01	0.90	Start value
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	60...300000	ms	10	60	Operate delay time
Operating curve type	5=ANSI Def. Time 15=IEC Def. Time 21=Inv. Curve A 22=Inv. Curve B 23=Programmable			15=IEC Def. Time	Selection of time delay curve type

Table 281: PHPTUV Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset			1=Immediate	Selection of reset curve type
Type of time reset	1=Freeze Op timer 2=Decrease Op timer			1=Freeze Op timer	Selection of time reset

Table 282: PHPTUV Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start 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 operate activation
Curve parameter A	0.005...200.000		1	1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00		1	1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0		1	0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000		1	0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000		1	1.000	Parameter E for customer programmable curve
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages

Table 283: PHPTUV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Minimum operate time	60...60000	ms	1	60	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve Sat Relative	0.0...10.0		0.1	0.0	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
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.5.2.9 Monitored data

Table 284: PHPTUV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTUV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.2.10 Technical data

Table 285: PHPTUV 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 × U_n		
Start time 1)2)		Minimum	Typical	Maximum
	U_{Fault} = 0.9 × set *Start value*	62 ms	66 ms	70 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 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 ±20 ms 3)		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 × U_n, Voltage before fault = 1.1 × U_n, f_n = 50 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 *Start value* = 0.50, *Start value* multiples in range of 0.90...0.20

4.5.2.11 Technical revision history

Table 286: PHPTUV Technical revision history

Technical revision	Change
B	Step value changed from 0.05 to 0.01 for the *Time multiplier* setting.
C	Curve Sat relative max range widened from 3.0 to 10.0 % and default value changed from 2.0 to 0.0 %.
D	Added setting *Type of time reset*.

4.5.3 Residual overvoltage protection ROVPTOV

4.5.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual overvoltage protection	ROVPTOV	Uo>	59G

4.5.3.2 Function block

Figure 126: Function block

4.5.3.3 Functionality

The residual overvoltage protection function ROVPTOV is used in distribution networks where the residual overvoltage can reach non-acceptable levels in, for example, high impedance earthing.

The function starts when the residual voltage exceeds the set limit. ROVPTOV 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.

4.5.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

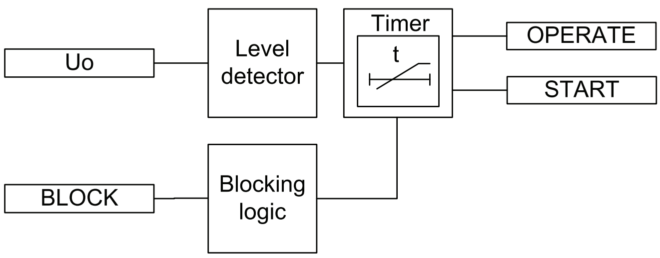


Figure 127: Functional module diagram

Level detector

The residual voltage is compared to the set *Start value*. If the value exceeds the set *Start value*, the level detector sends an enable signal to the timer. The residual voltage can be selected with the *Uo signal Sel* setting. The options are "Measured Uo" and "Calculated Uo". If "Measured Uo" is selected, the voltage ratio for Uo-channel is given in the global setting **Configuration/Analog inputs/Voltage (Uo,VT)**. If "Calculated Uo" is selected, the voltage ratio is obtained from phase-voltage channels given in the global setting **Configuration/Analog inputs/Voltage (3U,VT)**.

Example 1: Uo is measured from the open-delta connected VTs (20/sqrt(3) kV : 100/sqrt(3) V : 100/3 V). In this case, "Measured Uo" is selected. The nominal values for residual voltage is obtained from the VT ratios entered in Residual voltage Uo: **Configuration/Analog inputs/Voltage (Uo,VT)**: 11.547 kV:100 V. The residual voltage start value of 1.0 × Un corresponds to 1.0 × 11.547 kV = 11.547 kV in the primary.

Example 2: Uo is calculated from the phase quantities. The phase VT-ratio is 20/sqrt(3) kV : 100/sqrt(3) V. In this case, "Calculated Uo" is selected. The nominal value for residual voltage is obtained from the VT ratios entered in Residual voltage Uo: **Configuration/Analog inputs/Voltage (3U,VT)**: 20.000kV : 100V. The residual voltage start value of 1.0 × Un corresponds to 1.0 × 20.000 kV = 20.000 kV in the primary.

If "Calculated Uo" is selected, the nominal value of residual voltage is always phase-to-phase voltage. Thus, the valid maximum setting for residual voltage *Start value* is 0.577 × Un. The calculated Uo requires that all three phase-to-earth voltages are connected to the protection relay. Uo cannot be calculated from the phase-to-phase voltages.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 OPERATE 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 OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.5.3.5 Application

ROVPTOV is designed to be used for earth-fault protection in isolated neutral, resistance earthed or reactance earthed systems. In compensated networks, starting 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 residual voltage, increases in case of any fault connected to earth. Depending on the type of the fault and the fault resistance, the residual voltage reaches different values. The highest residual voltage, equal to the phase-to-earth voltage, is achieved for a single-phase earth fault. The residual 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 backup protection or as a release signal for the feeder earth-fault protection.

The protection can also be used for the earth-fault protection of generators and motors and for the unbalance protection of capacitor banks.

The residual 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 earth, or by using an open-delta connection of three single-phase voltage transformers.

4.5.3.6 Signals

Table 287: ROVPTOV Input signals

Name	Type	Default	Description
Uo	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 288: ROVPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.3.7 Settings

Table 289: ROVPTOV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.000	xUn	0.001	0.030	Residual overvoltage start value
Operate delay time	40...300000	ms	1	40	Operate delay time

Table 290: ROVPTOV Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Uo signal Sel	1=Measured Uo 2=Calculated Uo			1=Measured Uo	Selection for used Uo signal

Table 291: ROVPTOV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.5.3.8 Monitored data

Table 292: ROVPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
ROVPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.3.9 Technical data

Table 293: ROVPTOV Technical data

<table>
<tr><th colspan="2">Characteristic</th><th colspan="3">Value</th></tr>
<tr><td colspan="2" rowspan="2">Operation accuracy</td><td colspan="3">Depending on the frequency of the measured voltage: f_n ±2 Hz</td></tr>
<tr><td colspan="3">±1.5% of the set value or ±0.002 × U_n</td></tr>
<tr><td rowspan="2">Start time1)2)</td><td rowspan="2">U_{Fault} = 2 × set *Start value*</td><td>Minimum</td><td>Typical</td><td>Maximum</td></tr>
<tr><td>48 ms</td><td>51 ms</td><td>54 ms</td></tr>
<tr><td colspan="2">Reset time</td><td colspan="3">Typically 40 ms</td></tr>
<tr><td colspan="2">Reset ratio</td><td colspan="3">Typically 0.96</td></tr>
<tr><td colspan="5">Table continues on next page</td></tr>
</table>

Characteristic	Value
Retardation time	<35 ms
Operate 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,…

1) Residual voltage before fault = 0.0 × U_n, f_n = 50 Hz, residual 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

4.5.3.10 Technical revision history

Table 294: ROVPTOV Technical revision history

Technical revision	Change
B	Added a setting parameter for the "Measured Uo" or "Calculated Uo" selection
C	Internal improvement
D	Internal improvement

4.5.4 Negative-sequence overvoltage protection NSPTOV

4.5.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative-sequence overvoltage protection	NSPTOV	U2>	47O-

4.5.4.2 Function block

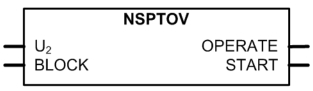


Figure 128: Function block

4.5.4.3 Functionality

The negative-sequence overvoltage protection function NSPTOV is used to detect negative sequence overvoltage conditions. NSPTOV is used for the protection of machines.

The function starts when the negative sequence voltage exceeds the set limit. NSPTOV 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.

4.5.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

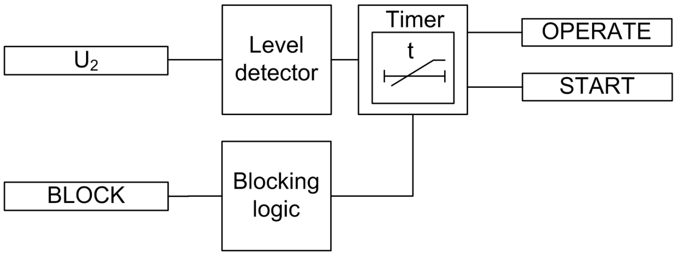


Figure 129: Functional module diagram

Level detector

The calculated negative-sequence voltage is compared to the set *Start value* setting. If the value exceeds the set *Start value*, the level detector enables the timer.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated if the overvoltage condition persists. If the negative-sequence voltage normalizes before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 `OPERATE` 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.5.4.5 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 U_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 U_2. When U_2 is P% of U_n, I_2 is typically about 5 x P% x I_n.

The negative-sequence overcurrent NSPTOC 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 NSPTOV function, monitoring the voltage unbalance of the busbar.

If the machines have an unbalance protection of their own, the NSPTOV 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 NSPTOV operation has started. 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 start value* is approximately 3 percent of U_n. A suitable value for the setting parameter *Operate delay time* depends on the application. If the NSPTOV operation is used as backup protection, the operate time should be set in accordance with the operate time of NSPTOC used as main protection. If the NSPTOV operation is used as main protection, the operate time should be approximately one second.

4.5.4.6 Signals

Table 295: NSPTOV Input signals

Name	Type	Default	Description
U_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 296: NSPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.4.7 Settings

Table 297: NSPTOV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.000	xUn	0.001	0.030	Start value
Operate delay time	40...120000	ms	1	40	Operate delay time

Table 298: NSPTOV Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 299: NSPTOV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.5.4.8 Monitored data

Table 300: NSPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
NSPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.4.9 Technical data

Table 301: NSPTOV 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 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 × set *Start value* U_{Fault} = 2.0 × set *Start value*	33 ms 24 ms	35 ms 26 ms	37 ms 28 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate 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 × U_n, f_n = 50 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

4.5.4.10 Technical revision history

Table 302: NSPTOV Technical revision history

Technical revision	Change
B	Internal change
C	Internal improvement.
D	Internal improvement.

4.5.5 Positive-sequence undervoltage protection PSPTUV

4.5.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Positive-sequence undervoltage protection	PSPTUV	U1<	47U+

4.5.5.2 Function block

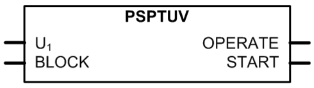


Figure 130: Function block

4.5.5.3 Functionality

The positive-sequence undervoltage protection function PSPTUV is used to detect positive-sequence undervoltage conditions. PSPTUV is used for the protection of small power generation plants. The function helps in isolating an embedded plant from a fault line when the fault current fed by the plant is too low to start an overcurrent function but high enough to maintain the arc. Fast isolation of all the fault current sources is necessary for a successful autoreclosure from the network-end circuit breaker.

The function starts when the positive-sequence voltage drops below the set limit. PSPTUV 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.

4.5.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

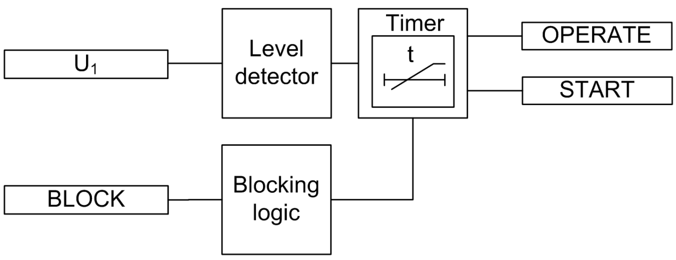


Figure 131: Functional module diagram. U_1 is used for representing positive phase sequence voltage.

Level detector

The calculated positive-sequence voltage is compared to the set *Start value* setting. If the value drops below the set *Start value*, the level detector enables the timer. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly varies from the *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated if the undervoltage condition persists. If the positive-sequence voltage normalizes before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR, which indicates the percentage ratio of the start situation and the set operation 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 `OPERATE` 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.5.5.5 Application

PSPTUV can be applied for protecting a power station used for embedded generation when network faults like short circuits or phase-to-earth faults in a transmission or a distribution line cause a potentially dangerous situations for the power station. A network fault can be dangerous for the power station for various reasons. The operation of the protection can cause an islanding condition, also called a loss-of-mains condition, in which a part of the network, that is, an island fed by the power station, is isolated from the rest of the network. There is then a risk of an autoreclosure taking place when the voltages of different parts of the network do not synchronize, which is a straining incident for the power station. Another risk is that the generator can lose synchronism during the network fault. A sufficiently fast trip of the utility circuit breaker of the power station can avoid these risks.

The lower the three-phase symmetrical voltage of the network is, the higher is the probability that the generator loses the synchronism. The positive-sequence voltage is also available during asymmetrical faults. It is a more appropriate criterion for detecting the risk of loss of synchronism than, for example, the lowest phase-to-phase voltage.

Analyzing the loss of synchronism of a generator is rather complicated and requires a model of the generator with its prime mover and controllers. The generator can be able to operate synchronously even if the voltage drops by a few tens of percent for some hundreds of milliseconds. The setting of PSPTUV is thus determined by the need to protect the power station from the risks of the islanding conditions since that requires a higher setting value.

The loss of synchronism of a generator means that the generator is unable to operate as a generator with the network frequency but enters into an unstable condition in which it operates by turns as a generator and a motor. Such a condition stresses the generator thermally and mechanically. This kind of loss of synchronism should not be mixed with the one between an island and the utility network. In the islanding situation, the condition of the generator itself is normal but the phase angle and the frequency of the phase-to-phase voltage can be different from the corresponding voltage in the rest of the network. The island can have a frequency of its own relatively fast when fed by a small power station with a low inertia.

PSPTUV complements other loss-of-grid protection principles based on the frequency and voltage operation.

Motor stalling and failure to start can lead to a continuous undervoltage. The positive-sequence undervoltage is used as a backup protection against the motor stall condition.

4.5.5.6 Signals

Table 303: PSPTUV Input signals

Name	Type	Default	Description
U_1	SIGNAL	0	Positive phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 304: PSPTUV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.5.7 Settings

Table 305: PSPTUV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.200	xUn	0.001	0.500	Start value
Operate delay time	40...120000	ms	10	40	Operate delay time

Table 306: PSPTUV Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Voltage block value	0.01...1.00	xUn	0.01	0.20	Internal blocking level
Enable block value	0=False 1=True			1=True	Enable Internal Blocking

Table 307: PSPTUV Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 308: PSPTUV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.5.5.8 Monitored data

Table 309: PSPTUV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PSPTUV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.5.9 Technical data

Table 310: PSPTUV 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 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 0.99 × set *Start value* U_{Fault} = 0.9 × set *Start value*	52 ms 44 ms	55 ms 47 ms	58 ms 50 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		

Table continues on next page

Characteristic	Value
Retardation time	<35 ms
Operate 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) *Start value* = 1.0 × U_n, positive-sequence voltage before fault = 1.1 × U_n, f_n = 50 Hz, positive sequence undervoltage 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

4.5.5.10 Technical revision history

Table 311: PSPTUV Technical revision history

Technical revision	Change
B	-
C	Internal improvement
D	Internal improvement

4.6 Frequency protection FRPFRQ

4.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency protection	FRPFRQ	f>/f<,df/dt	81

4.6.2 Function block

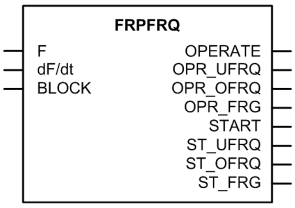


Figure 132: Function block

4.6.3 Functionality

The frequency protection function FRPFRQ 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.

4.6.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

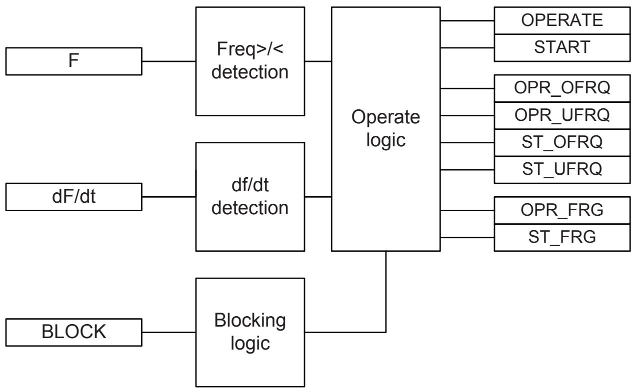


Figure 133: Functional module diagram

Freq>/< 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 *Start value Freq>*. If the measured value exceeds the set value of the *Start value Freq>* setting, the module reports the exceeding of the value to the operate logic module.

In the “Freq<” mode, the measured frequency is compared to the set *Start value Freq<*. If the measured value is lower than the set value of the *Start value Freq<* setting, the module reports the value to the operate 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 *Start 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 *Start value df/dt* value, the module reports the exceeding of the value to the operate logic module.

The protection relay does not accept the set value "0.00" for the *Start 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 312: Operation modes for operation logic

Operation mode	Description
Freq<	The function operates independently as the underfrequency ("Freq<") protection function. When the measured frequency is below the set value of the *Start value Freq<* setting, the module activates the `START` and `STR_UFRQ` outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Operate Tm Freq* setting, the `OPERATE` and `OPR_UFRQ` outputs are activated. If the frequency restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operate timer resets and the `START` and `STR_UFRQ` outputs are deactivated.
Freq>	The function operates independently as the overfrequency ("Freq>") protection function. When the measured frequency exceeds the set value of the *Start value Freq>* setting, the module activates the `START` and `STR_OFRQ` outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Operate Tm Freq* setting, the `OPERATE` and `OPR_OFRQ` outputs are activated. If the frequency restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operate timer resets and the `START` and `STR_OFRQ` outputs are deactivated.
df/dt	The function operates independently as the frequency gradient ("df/dt"), rate-of-change, protection function. When the frequency gradient exceeds the set value of the *Start value df/dt* setting, the module activates the `START` and `STR_FRG` outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Operate Tm df/dt* setting, the `OPERATE` and `OPR_FRG` outputs are activated. If the frequency gradient restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operate timer resets and the `START` and `STR_FRG` outputs are deactivated.

Table continues on next page

Operation mode	Description
Freq< + df/dt	A consecutive operation is enabled between the protection methods. When the measured frequency is below the set value of the *Start 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 *Start value df/dt* setting. When the frequency gradient exceeds the set value, the module activates the `START` and `STR_FRG` outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Operate Tm df/dt* setting, the `OPERATE` and `OPR_FRG` outputs are activated. If the frequency gradient restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operate timer resets and the `START` and `STR_FRG` outputs are deactivated. The `OPR_UFRQ` output is not active when this operation mode is used.
Freq> + df/dt	A consecutive operation is enabled between the protection methods. When the measured frequency exceeds the set value of the *Start 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 *Start value df/dt* setting. When the frequency gradient exceeds the set value, the module activates the `START` and `STR_FRG` outputs. The time characteristic is according to DT. When the operation timer has reached the value set by the *Operate Tm df/dt* setting, the `OPERATE` and `OPR_FRG` outputs are activated. If the frequency gradient restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operate timer resets and the `START` and `STR_FRG` outputs are deactivated. The `OPR_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 `START` 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 `STR_UFRQ` and `STR_FRG` outputs. The shortest operate delay time from the set *Operate Tm Freq* or *Operate Tm df/dt* is dominant regarding the `OPERATE` output. The time characteristic is according to DT. The characteristic that activates the `OPERATE` output can be seen from the `OPR_UFRQ` or `OPR_FRG` output. If the frequency gradient restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operate timer resets and the `STR_FRG` output is deactivated. If the frequency restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operate timer resets and the `STR_UFRQ` output is deactivated.
Freq> OR df/dt	A parallel operation between the protection methods is enabled. The `START` output is activated when either of the measured values of the protection module exceeds its set value. A detailed information from the active module is available at the `STR_OFRQ` and `STR_FRG` outputs. The shortest operate delay time from the set *Operate Tm Freq* or *Operate Tm df/dt* is dominant regarding the `OPERATE` output. The time characteristic is according to DT. The characteristic that activates the `OPERATE` output can be seen from the `OPR_OFRQ` or `OPR_FRG` output. If the frequency gradient restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm df/dt* setting, the operate timer resets and the `STR_FRG` output is deactivated. If the frequency restores before the module operates, the reset timer is activated. If the timer reaches the value set by the *Reset delay Tm Freq* setting, the operate timer resets and the `STR_UFRQ` output is deactivated.

The module calculates the start duration value which indicates the percentage ratio of the start situation and set operate time (DT). The start duration is available according to the selected value of the *Operation mode* setting.

Table 313: Start duration value

Operation mode in use	Available start duration value
Freq<	`ST_DUR_UFRQ`
Freq>	`ST_DUR_OFRQ`
df/dt	`ST_DUR_FRG`

The combined start duration `START_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 `OPERATE` 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 OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.6.5 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.

4.6.6 Signals

Table 314: FRPFRQ 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 315: FRPFRQ Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
OPR_UFRQ	BOOLEAN	Operate signal for underfrequency
OPR_OFRQ	BOOLEAN	Operate signal for overfrequency
OPR_FRG	BOOLEAN	Operate signal for frequency gradient
START	BOOLEAN	Start
ST_UFRQ	BOOLEAN	Start signal for underfrequency
ST_OFRQ	BOOLEAN	Start signal for overfrequency
ST_FRG	BOOLEAN	Start signal for frequency gradient

4.6.7 Settings

Table 316: FRPFRQ Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation 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 operation mode selection
Start value Freq>	0.9000...1.2000	xFn	0.0001	1.0500	Frequency start value overfrequency
Start value Freq<	0.8000...1.1000	xFn	0.0001	0.9500	Frequency start value underfrequency
Start value df/dt	-0.2000...0.2000	xFn /s	0.0025	0.0100	Frequency start value rate of change
Operate Tm Freq	80...200000	ms	10	200	Operate delay time for frequency
Operate Tm df/dt	120...200000	ms	10	400	Operate delay time for frequency rate of change

Table 317: FRPFRQ Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 318: FRPFRQ Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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

4.6.8 Monitored data

Table 319: FRPFRQ Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Start duration
ST_DUR_OFRQ	FLOAT32	0.00...100.00	%	Start duration
ST_DUR_UFRQ	FLOAT32	0.00...100.00	%	Start duration
ST_DUR_FRG	FLOAT32	0.00...100.00	%	Start duration
FRPFRQ	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.6.9 Technical data

Table 320: FRPFRQ Technical data

Characteristic		Value
Operation accuracy	f>/f<	±5 mHz
	df/dt	±50 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)
Start time	f>/f<	<80 ms
	df/dt	<120 ms
Reset time		<150 ms
Operate time accuracy		±1.0% of the set value or ±30 ms

4.6.10 Technical revision history

Table 321: FRPFRQ Technical revision history

Technical revision	Change
B	Step value changed from 0.001 to 0.0001 for the *Start value Freq>* and *Start value Freq<* settings.
C	df/dt setting step changed from 0.005 ×Fn /s to 0.0025 ×Fn /s.
D	Internal improvement.

4.7 Motor start-up supervision STTPMSU

4.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor start-up supervision	STTPMSU	Is2t n<	49,66,48,51LR

4.7.2 Function block

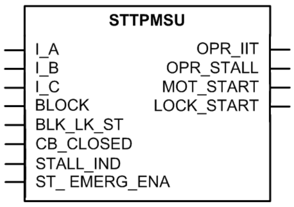


Figure 134: Function block

4.7.3 Functionality

The motor start-up supervision function STTPMSU is designed for protection against excessive starting time and locked rotor conditions of the motor during starting. For the good and reliable operation of the motor, the thermal stress during the motor starting is maintained within the allowed limits.

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

During the start-up period of the motor, STTPMSU calculates the integral of the I^2t value. If the calculated value exceeds the set value, the operate signal is activated.

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

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

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

4.7.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

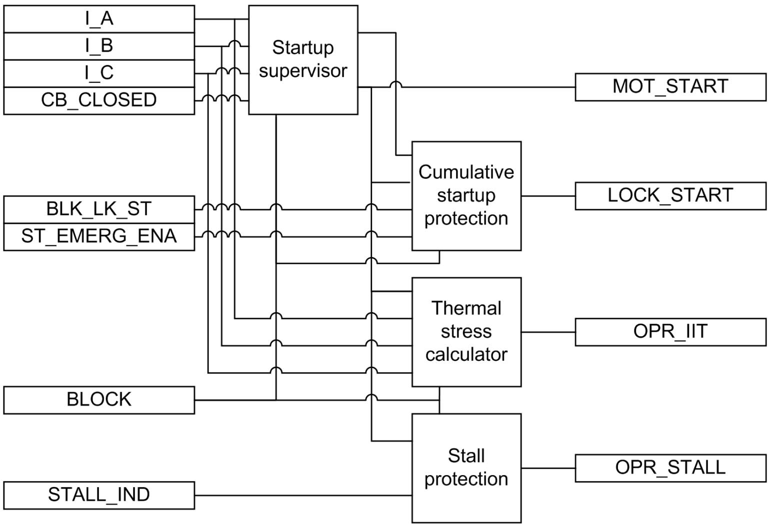


Figure 135: Functional module diagram

Startup supervisor

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

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

The *Operation mode* setting in the "IIt, CB" mode enables the function to calculate the value of the thermal stress when a start-up is monitored in addition to the `CB_CLOSED` input.

In the "IIt & stall" mode, the function calculates the thermal stress of the motor during the start-up condition. The start-up condition is detected by monitoring the TRMS currents.

In the "IIt & stall, CB" mode, the function calculates the thermal stress of the motor during the start-up condition but the start-up condition is detected by monitoring the TRMS current as well as the circuit breaker status.

In both the "IIt & stall" and "IIt & stall, CB" mode, the function also checks for motor stalling by monitoring the speed switch.

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

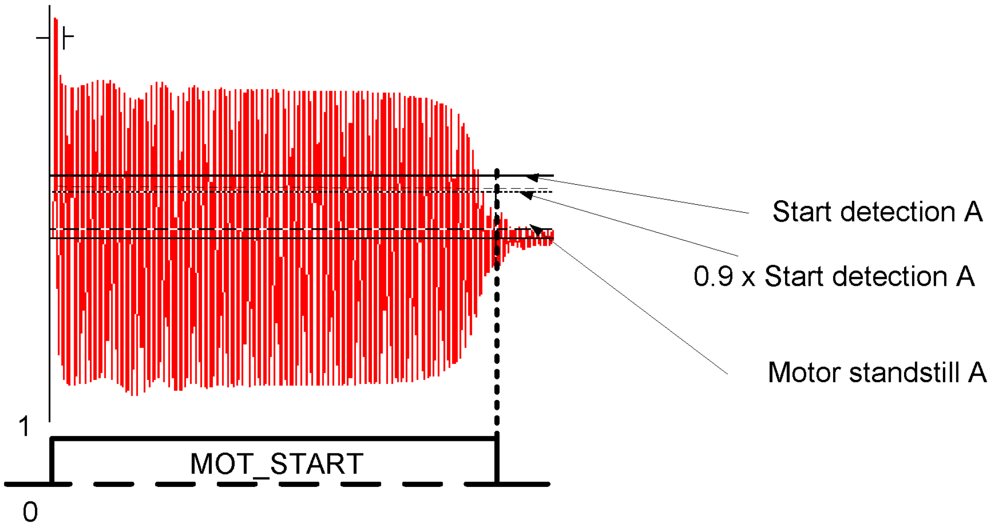


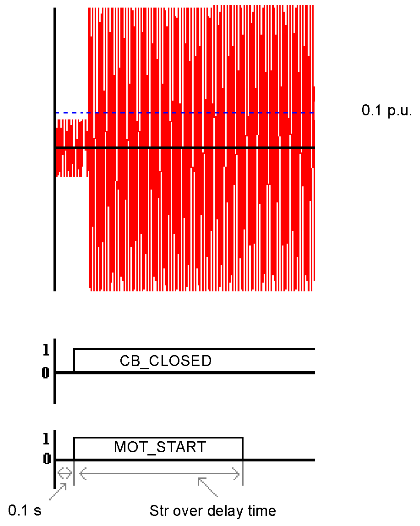
Figure 136: Functionality of start-up supervision in the "IIt and IIt&stall" mode

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

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

The motor start-up ends either within the value of the *Str over delay time* setting from the beginning of the start-up or the opening of CB or when the `CB_CLOSED` input is deactivated. The operation of the `MOT_START` output signal in this operation mode is as illustrated in Figure 137.

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



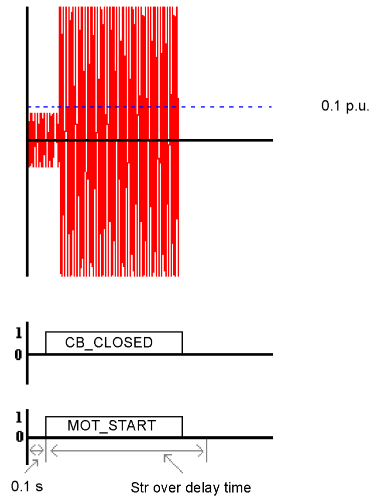


Figure 137: Functionality of start-up supervision in the "IIt, CB" mode and the "IIt and stall, CB" mode

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

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

delay setting can even be as high as within the range of seconds, for example around 30 seconds.

The activation of the BLOCK input signal deactivates the MOT_START output.

Thermal stress calculator

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

This module calculates the thermal stress developed in the motor during start-up. The heat developed during the starting can be calculated with the equation.

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

(Equation 29)

R_s combined rotor and stator resistance

i_s starting current of the motor

t starting time of the motor

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

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

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

The activation of the BLOCK input signal resets the thermal stress calculator and deactivates the OPR_IIT output.

Stall protection

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

The start-up current is specific to each motor and depends on the start-up method used, such as direct online, autotransformer and rotor resistance insertion. The start-up time is dependent on the load connected to the motor.

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

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

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

The activation of the `BLOCK` input signal resets the operation time and deactivates the `OPR_STALL` output.

Cumulative start-up protection

This module protects the motor from an excessive number of start-ups.

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

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

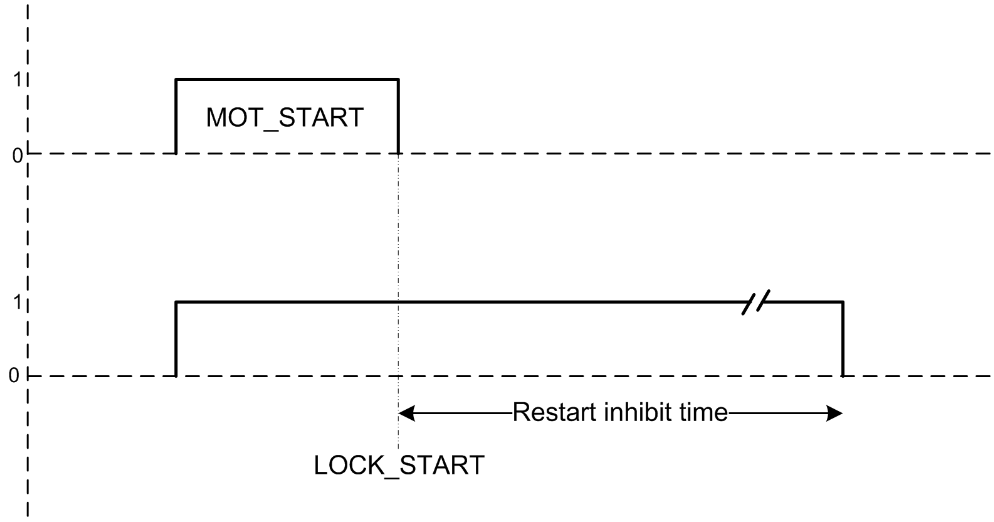


Figure 138: Time delay for cumulative start

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

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

This module also calculates the total number of start-ups occurred, START_CNT. The value can be reset from the Clear menu.

The old *Number of motor start-ups occurred* counter value (START_CNT) can be taken into use by writing the value to the *Ini start up counter* parameter and resetting the value via the Clear menu from WHMI or LHMI.

The calculated values of T_RST_ENA, T_ST_CNT and START_CNT are available in the Monitored data view.

The activation of the BLK_LK_ST input signal deactivates the LOCK_START output. The activation of the BLOCK input signal resets the cumulative start-up counter module.

4.7.5 Application

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

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

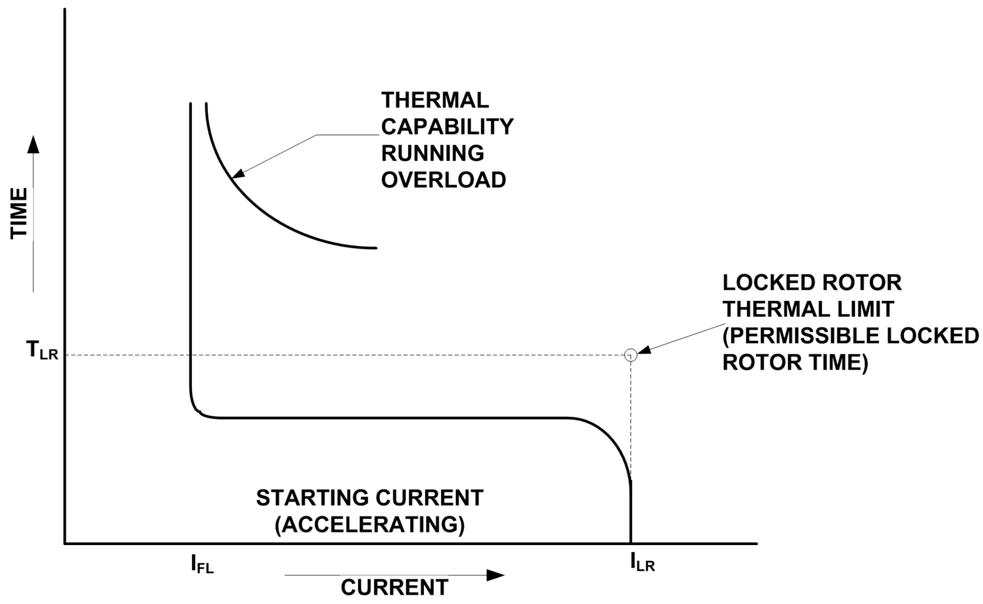


Figure 139: Typical motor starting and capability curves

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

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

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

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

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

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

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

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

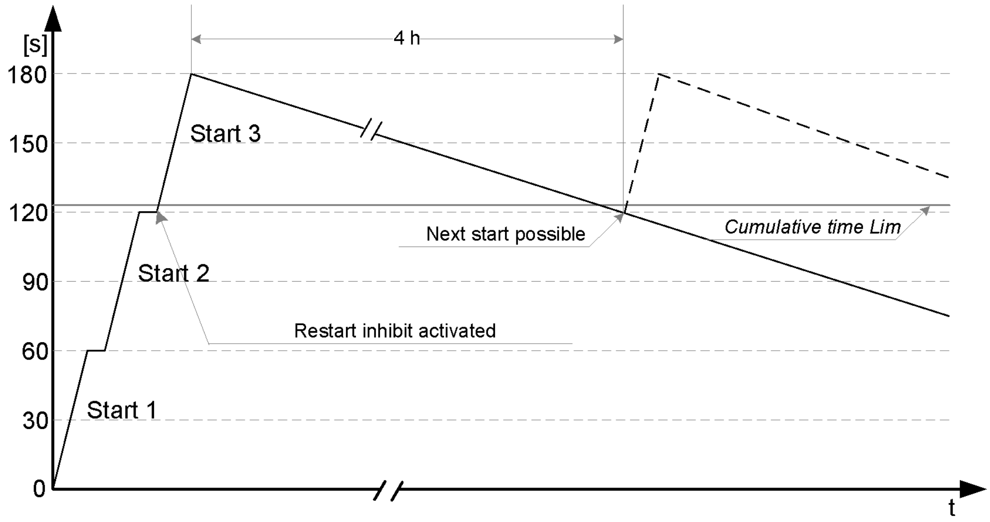


Figure 140: Typical motor-starting and capability curves

Setting of *Cumulative time Lim*

Cumulative time Lim is calculated by

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

(Equation 30)

n	specified maximum allowed number of motor start-ups
t	start-up time of the motor (in seconds)
margin	safety margin (~10...20 percent)

Setting of *Counter Red rate*

Counter Red rate is calculated by

$$\Delta \sum t_s = \frac{t}{t_{reset}}$$

(Equation 31)

t	specified start time of the motor in seconds
t_{reset}	duration during which the maximum number of motor start-ups stated by the manufacturer can be made; time in hours

4.7.6 Signals

Table 322: STTPMSU Input signals

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

Table 323: STTPMSU Output signals

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

4.7.7 Settings

Table 324: STTPMSU Group settings (Basic)

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

Table 325: STTPMSU Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Start detection A	0.1...10.0	xIn	0.1	1.5	Current value for detecting starting of motor.

Table 326: STTPMSU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operation mode	1=IIt 2=IIt, CB 3=IIt + stall 4=IIt + stall, CB			1=IIt	Motor start-up operation mode
Counter Red rate	2.0...250.0	s/h	0.1	60.0	Start time counter reduction rate
Cumulative time Lim	1...500	s	1	10	Cumulative time based restart inhibit limit
Emg start Red rate	0.00...100.00	%	0.01	20.00	Start time reduction factor when emergency start is On
Restart inhibit time	0...250	min	1	30	Time delay between consecutive startups
Ini start up counter	0...999999		1	0	Initial value for the START_CNT

Table 327: STTPMSU Non group settings (Advanced)

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

4.7.8 Monitored data

Table 328: STTPMSU Monitored data

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

4.7.9 Technical data

Table 329: STTPMSU 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		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 1.1 × set *Start detection A*	27 ms	30 ms	34 ms
Operate time accuracy		±1.0% of the set value or ±20 ms		
Reset ratio		Typically 0.90		

1) Current before = 0.0 × I_n, f_n = 50 Hz, overcurrent in one phase, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.7.10 Technical revision history

Table 330: STTPMSU Technical revision history

Technical revision	Change
B	Internal improvement
C	Added setting *Ini start up counter*.

Section 5 Protection related functions

5.1 Three-phase inrush detector INRPHAR

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase inrush detector	INRPHAR	3I2f>	68

5.1.2 Function block

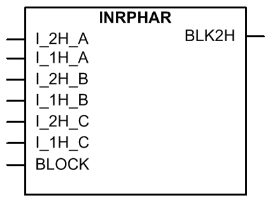


Figure 141: Function block

5.1.3 Functionality

The three-phase inrush detector function INRPHAR 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 operate 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 "On" and "Off".

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

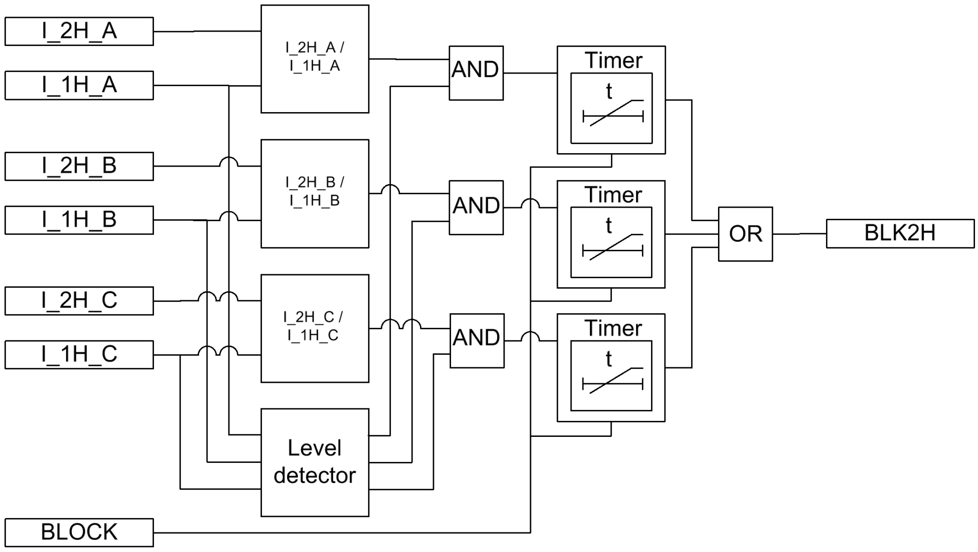


Figure 142: Functional module diagram

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 *Start value*. If the calculated value exceeds the set *Start 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 *Operate delay time* value. The time characteristic is according to DT. When the operation timer has reached the *Operate 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 operate time up counting, the reset timer is activated. If the drop-off time exceeds *Reset delay time*, the operate 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 TR2PTDF 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 start value of an overcurrent protection during inrush detection.

The inrush detection function can be used to selectively block overcurrent and earth-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.

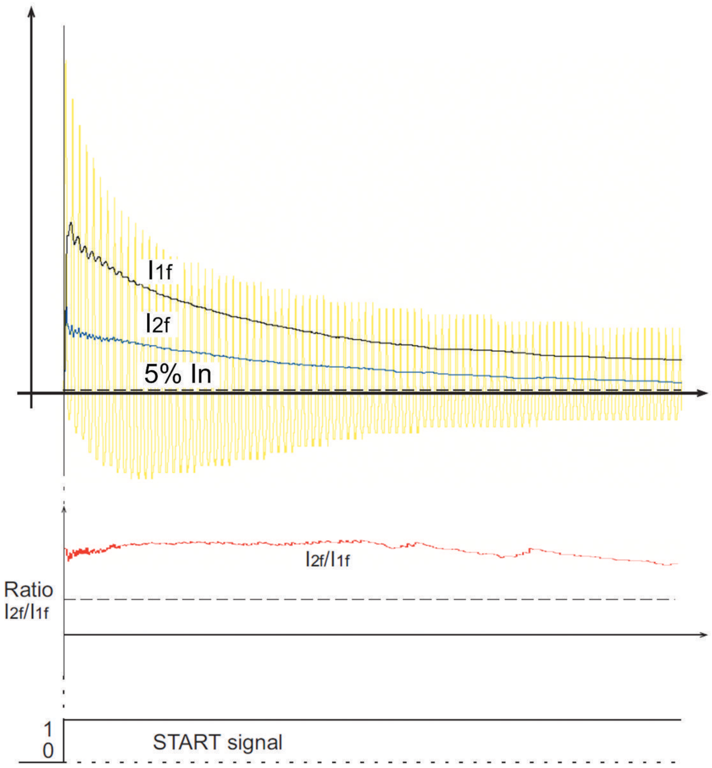


Figure 143: Inrush current in transformer

It is recommended to use the second harmonic and the waveform based inrush blocking from the transformer differential protection function TR2PTDF, if available.

5.1.6 Signals

Table 331: INRPHAR 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 332: INRPHAR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

5.1.7 Settings

Table 333: INRPHAR Group settings (Basic)

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

Table 334: INRPHAR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

Table 335: INRPHAR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

5.1.8 Monitored data

Table 336: INRPHAR Monitored data

Name	Type	Values (Range)	Unit	Description
INRPHAR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.1.9 Technical data

Table 337: INRPHAR 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
Operate time accuracy	+35 ms / -0 ms

5.1.10 Technical revision history

Table 338: INRPHAR Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

5.2 Circuit breaker failure protection CCBRBRF

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	51BF/51NBF

5.2.2 Function block

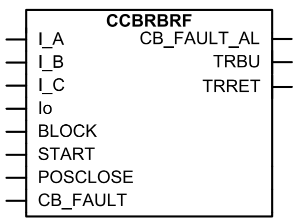


Figure 144: Function block

5.2.3 Functionality

The circuit breaker failure protection function CCBRBRF 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 start command is always a default for three-phase operation. CCBRBRF includes a three-phase conditional or unconditional retrip function, and also a three-phase conditional back-up trip function.

CCBRBRF 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 "On" and "Off".

The operation of CCBRBRF 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.

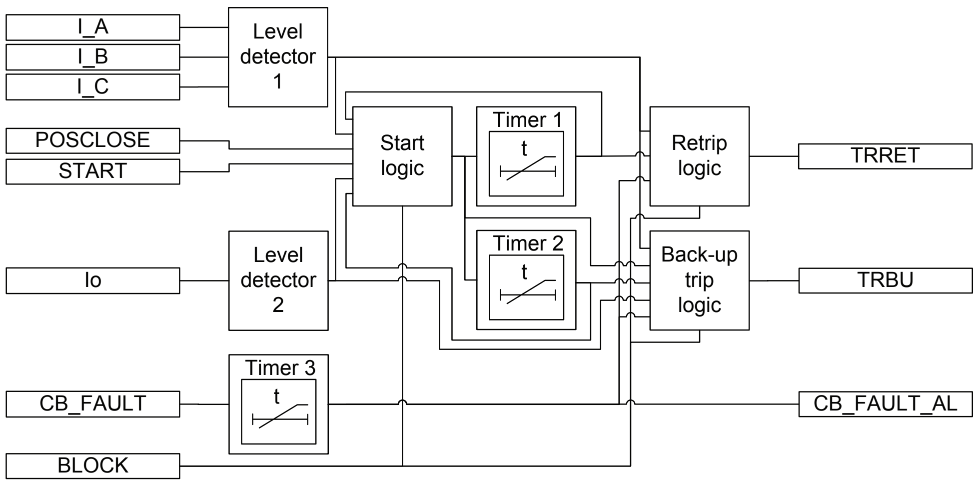


Figure 145: Functional module diagram

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 start and backup trip logics. In high-impedance earthed systems, the residual current at phase-to-earth faults is normally much smaller than the short circuit currents. To detect a breaker failure at single-phase earth faults in these systems, it is necessary to measure the residual current separately. In effectively earthed systems, also the setting of the earth-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 earth-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 `START` input, the enabling signal is send to the timer 1 and timer 2.

Function resetting is prevented during the next 150 ms. The 150 ms time elapse is provided to prevent malfunctioning due to oscillation in the starting signal.

In case the setting *Start latching mode* is set to "Level sensitive", the CCBRBRF is reset immediately after the `START` 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.

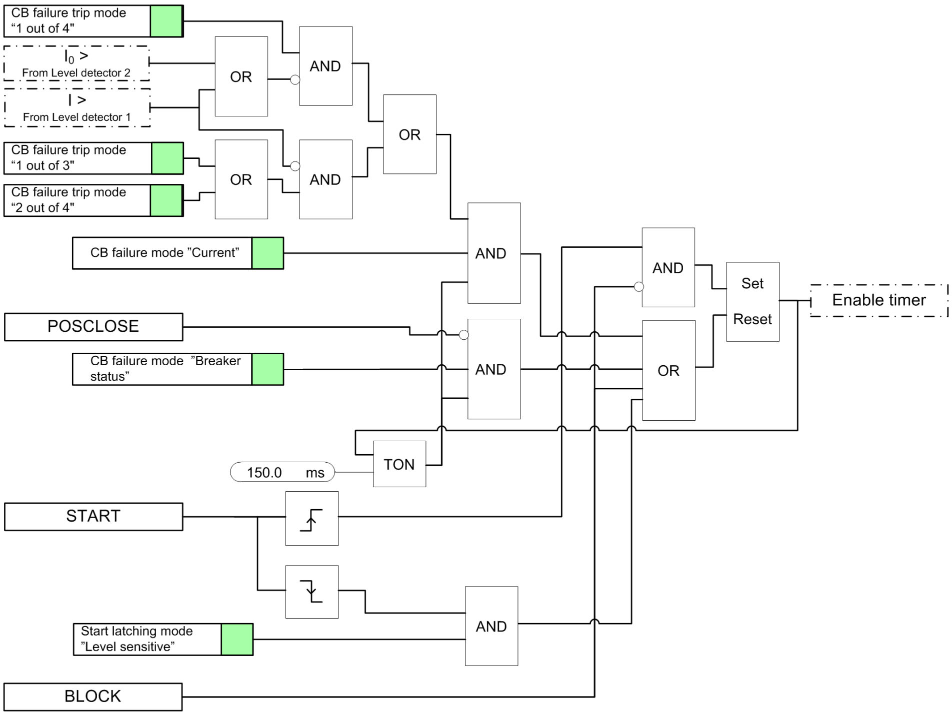


Figure 146: Start logic

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 32)

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.

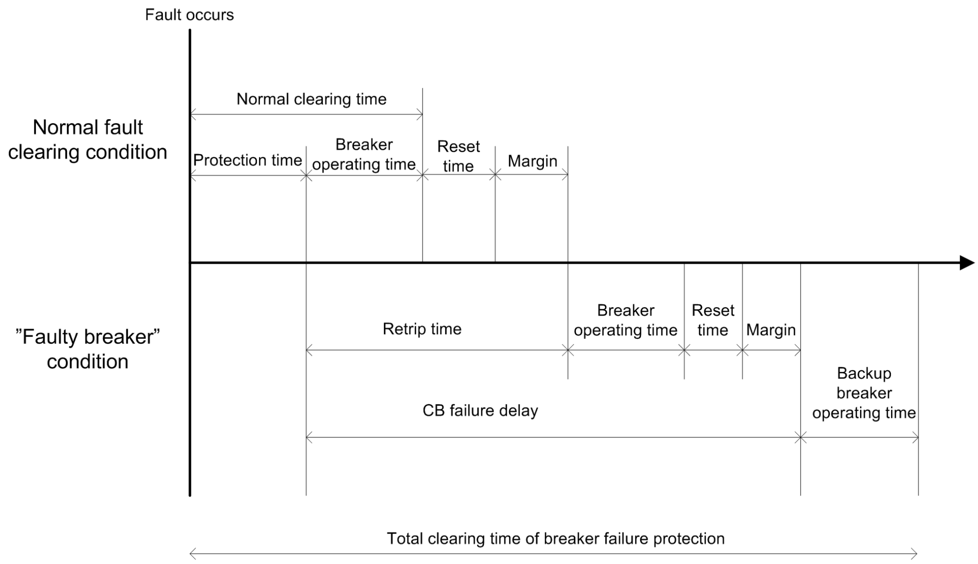


Figure 147: Timeline of the breaker failure protection

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 "Off".
- 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.

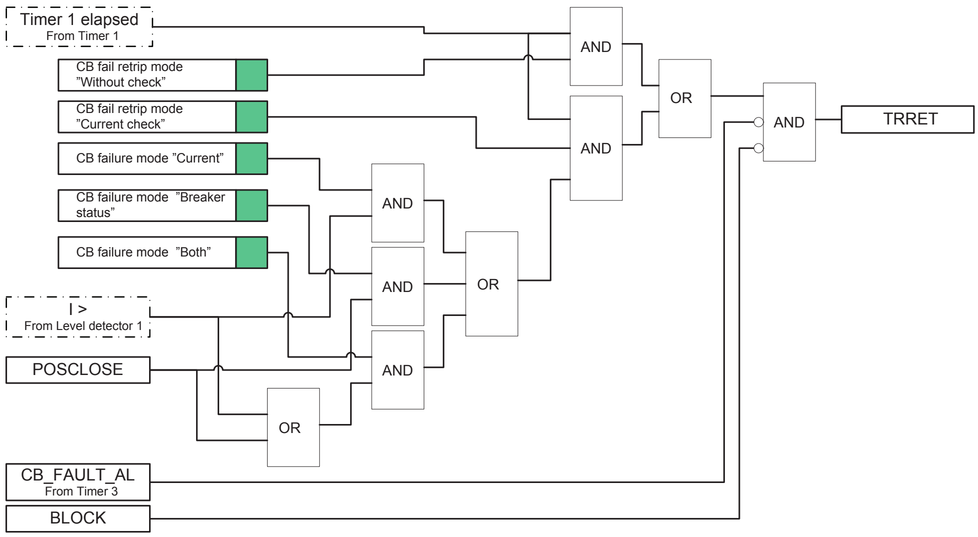


Figure 148: Retrip logic

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 START 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.

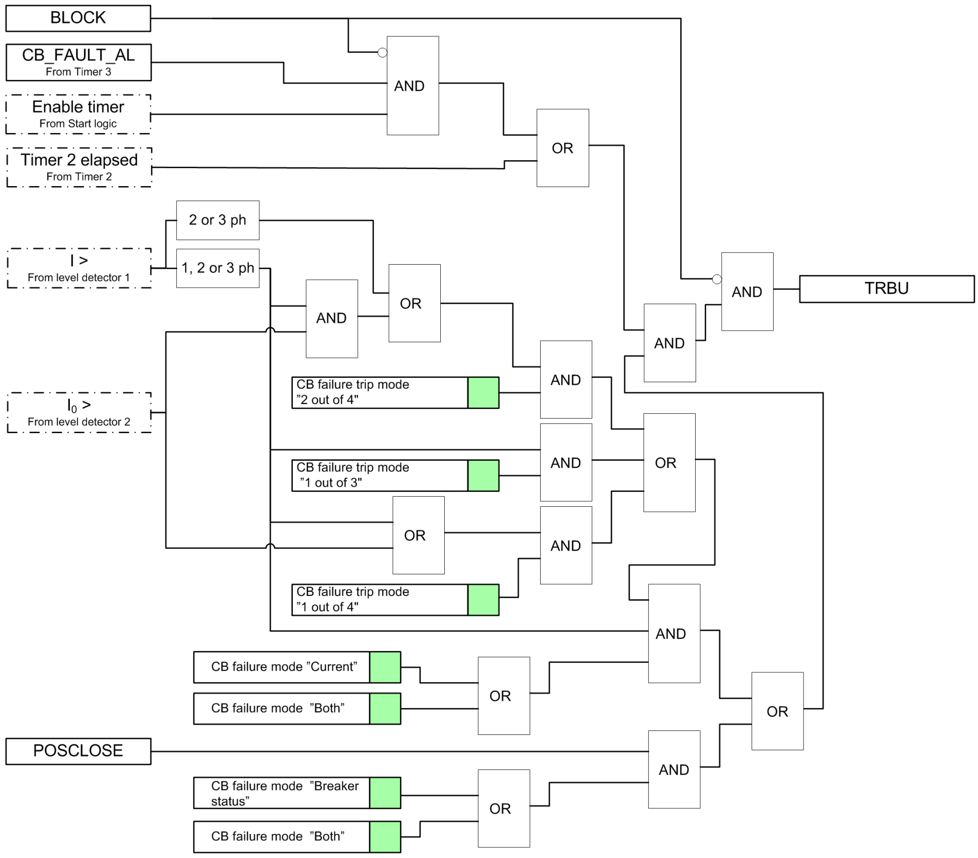


Figure 149: *Backup trip logic*

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).

CCBRBRF 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.

CCBRBRF 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.

CCBRBRF 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 start input is set to true. When the pre-defined time setting is exceeded, CCBRBRF 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 CCBRBRF 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.

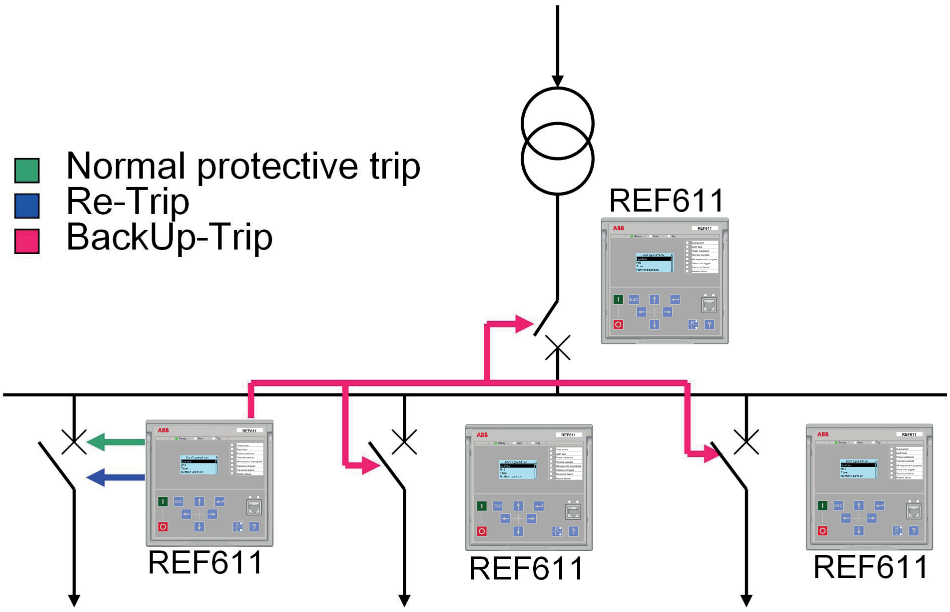


Figure 150: Typical breaker failure protection scheme in distribution substations

5.2.6 Signals

Table 339: CCBRBRF 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
Io	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block CBFP operation
START	BOOLEAN	0=False	CBFP start command
POSCLOSE	BOOLEAN	0=False	CB in closed position
CB_FAULT	BOOLEAN	0=False	CB faulty and unable to trip

Table 340: CCBRBRF 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 341: CCBRBRF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Current value	0.05...2.00	xIn	0.05	0.30	Operating phase current
Current value Res	0.05...2.00	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			2=1 out of 3	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=Off 2=Without Check 3=Current check			1=Off	Operating mode of retrip logic
Retrip time	0...60000	ms	10	120	Delay timer for retrip
CB failure delay	0...60000	ms	10	240	Delay timer for backup trip

Table 342: CCBRBRF Non group settings (Advanced)

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			3=Peak-to-Peak	Phase current measurement mode of function
Trip pulse time	0...60000	ms	10	200	Pulse length of retrip and backup trip outputs
Start latching mode	1=Rising edge 2=Level sensitive			1=Rising edge	Start reset delayed or immediately

5.2.8 Monitored data

Table 343: CCBRBRF Monitored data

Name	Type	Values (Range)	Unit	Description
CCBRBRF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.2.9 Technical data

Table 344: CCBRBRF 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
Operate time accuracy	±1.0% of the set value or ±20 ms
Reset time[1)]	Typically 40 ms
Retardation time	<20 ms

1) Trip pulse time defines the minimum pulse length

5.2.10 Technical revision history

Table 345: CCBRBRF Technical revision history

Technical revision	Change
B	Default trip pulse time changed to 150 ms
C	Added new setting parameter *Start latching mode*. Maximum value changed to 2.00 xIn for the *Current value* setting.
D	Internal improvement.
E	Maximum value for *Current value* and *Current value Res* changed from “1.00 x In” to “2.00 x In”.

5.3 Master trip TRPPTRC

5.3.1 Identification

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

5.3.2 Function block

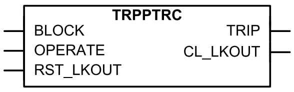


Figure 151: Function block

5.3.3 Functionality

The master trip function TRPPTRC is 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 "On" and "Off".

When the TRPPTRC function is disabled, all trip outputs intended to go through the function to the circuit breaker trip coil are blocked.

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

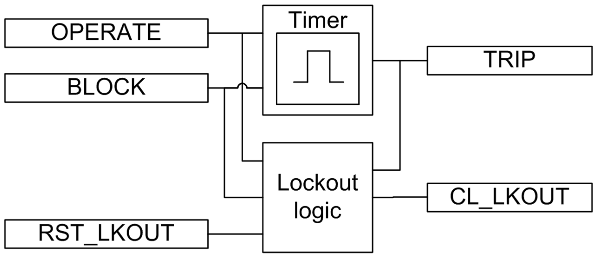


Figure 152: Functional module diagram

Timer

The duration of the `TRIP` output signal from TRPPTRC 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, TRPPTRC has a single input `OPERATE`, 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

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

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

The `CL_LKOUT` and `TRIP` outputs can be blocked with the `BLOCK` input.

Table 346: Operation modes for the TRPPTRC 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, TRPPTRC can block the CBXCBR closing.

TRPPTRC 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, TRPPTRC1 and TRPPTRC2, are different. Therefore, even if all references are made only to TRPPTRC1, they also apply to TRPPTRC2.

The inputs from the protection functions are connected to the `OPERATE` 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.

TRPPTRC is used for simple three-phase tripping applications.

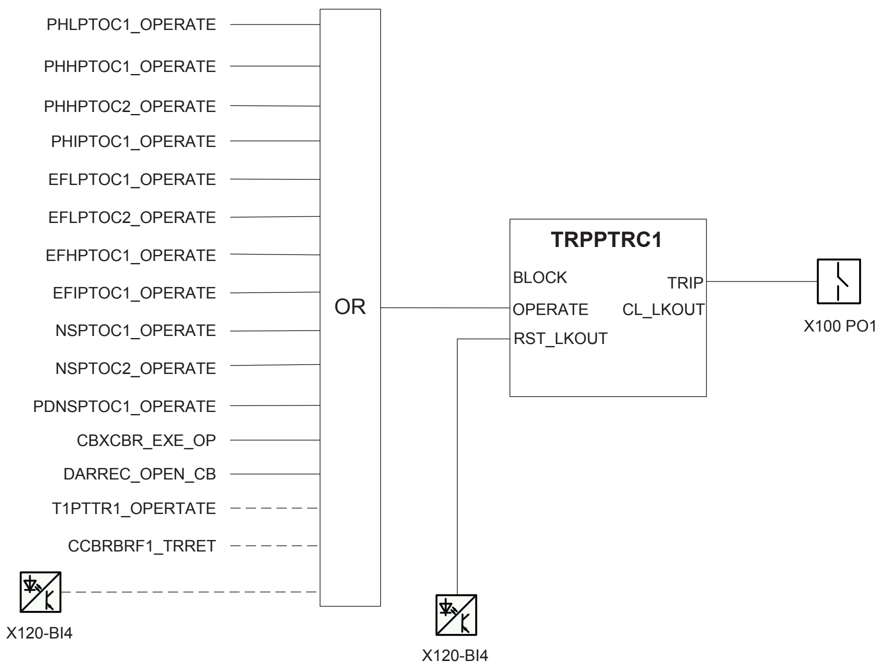


Figure 153: Typical TRPPTRC connection

5.3.6 Signals

Table 347: TRPPTRC Input signals

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

Table 348: TRPPTRC 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 349: TRPPTRC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Trip pulse time	20...60000	ms	1	250	Minimum duration of trip output signal
Trip output mode	1=Non-latched 2=Latched 3=Lockout			1=Non-latched	Select the operation mode for trip output

5.3.8 Monitored data

Table 350: TRPPTRC Monitored data

Name	Type	Values (Range)	Unit	Description
TRPPTRC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.3.9 Technical revision history

Table 351: TRPPTRC Technical revision history

Technical revision	Change
B	-
C	-
D	Internal improvement.
E	Setting *Trip output mode* default setting is changed to "Latched".
F	Internal improvement.

5.4 Emergency start-up ESMGAPC

5.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Emergency start-up	ESMGAPC	ESTART	ESTART

5.4.2 Function block

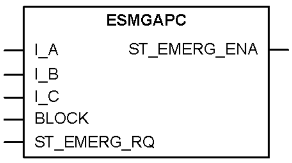


Figure 154: Function block

5.4.3 Functionality

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

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

5.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

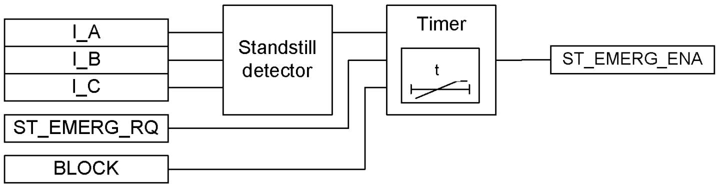


Figure 155: Functional module diagram

Standstill detector

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

Timer

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

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

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

5.4.5 Application

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

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

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

5.4.6 Signals

Table 352: ESMGAPC Input signals

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

Table 353: ESMGAPC Output signals

Name	Type	Description
ST_EMERG_ENA	BOOLEAN	Emergency start

5.4.7 Settings

Table 354: ESMGAPC Group settings (Advanced)

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

Table 355: ESMGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

5.4.8 Monitored data

Table 356: ESMGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
T_ST_EMERG	Timestamp			Emergency start activation timestamp
ESMGAPC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.4.9 Technical data

Table 357: ESMGAPC Technical data

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$
	±1.5% of the set value or ±0.002 × U_n

5.4.10 Technical revision history

Table 358: ESMGAPC Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

5.5 Switch onto fault CBPSOF

5.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Switch onto fault	CBPSOF	SOTF	SOTF

5.5.2 Function block

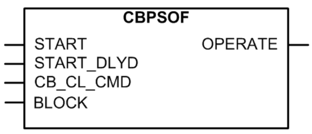


Figure 156: Function block

5.5.3 Functionality

The switch onto fault function CBPSOF provides an instantaneous trip or a time delayed trip when closing the breaker while a fault exists.

CBPSOF is activated when the `CB_CL_CMD` circuit breaker closing command is set high. The function has `START` and `START_DLYD` inputs for immediate or delayed start operation respectively.

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

5.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

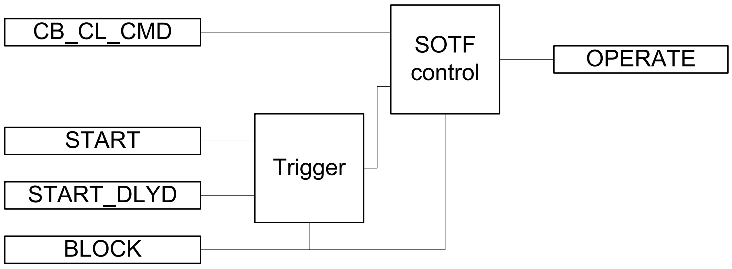


Figure 157: Functional module diagram

Trigger

This module is used for detecting possible fault immediately after closing the circuit breaker. An external protection function for example, PHxPTOC or EFxPTOC is used for fault indication. The `START` and `START_DLYD` inputs are available for feeding the detected fault.

- `START` input is used when it is required to enable SOTF control immediately after protection function indicates a fault.
- `START_DLYD` input is used when time delayed SOTF control enabling is needed. In this case, the delay can be set with a *Operate delay time* setting.

SOTF control

The SOTF control is activated when `CB_CL_CMD` circuit breaker closing command input is activated. The module is kept active until the set *SOTF reset time* is exceeded after the CB_CL_CMD is deactivated. The `OPERATE` output is activated when a fault indication signal is received from the Trigger module while the SOTF control is still active.

5.5.5 Application

The `CB_CL_CMD` input activates CBPSOF. In the standard configuration, the breaker close command should be connected to this input. The *SOTF reset time* setting parameter is used for keeping CBPSOF active for a certain time after the CB close command is executed.

The overcurrent high and instantaneous signals, for example, the PHIPTOC START signal is connected to the function START input. When the SOTF control module is active and the START input is activated, the function operates instantaneously without any delays.

The overcurrent low stage signals, for example, PHLPTOC START signal is connected to the function START_DLYD input. The setting parameter *Operate delay time* is used to delay the operation in case of inrush situation.

5.5.6 Signals

Table 359: CBPSOF Input signals

Name	Type	Default	Description
START	BOOLEAN	0=False	Start from function to be accelerated by SOTF
START_DLYD	BOOLEAN	0=False	Start from function to be accelerated with delay by SOTF
CB_CL_CMD	BOOLEAN	0=False	External enabling of SOTF by CB close command
BLOCK	BOOLEAN	0=False	Block of function

Table 360: CBPSOF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate

5.5.7 Settings

Table 361: CBPSOF Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operate delay time	0...60000	ms	1	0	Time delay for start input

Table 362: CBPSOF Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
SOTF reset time	0...60000	ms	1	1000	SOTF detection period after initialization

Table 363: CBPSOF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

5.5.8 Monitored data

Table 364: CBPSOF Monitored data

Name	Type	Values (Range)	Unit	Description
CBPSOF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.5.9 Technical data

Table 365: CBPSOF Technical data

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

Section 6 Supervision functions

6.1 Trip circuit supervision TCSSCBR

6.1.1 Identification

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

6.1.2 Function block

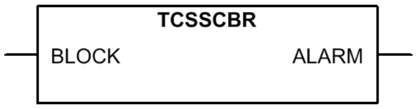


Figure 158: Function block

6.1.3 Functionality

The trip circuit supervision function TCSSCBR is designed to supervise the control circuit of the circuit breaker. The invalidity of a control circuit is detected by using a dedicated output contact that contains the supervision functionality. The failure of a circuit is reported to the corresponding function block in the relay configuration.

The function starts and operates when TCSSCBR detects a trip circuit failure. The operating time characteristic for the function is DT. The function operates after a predefined operating time and resets when the fault disappears.

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

6.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

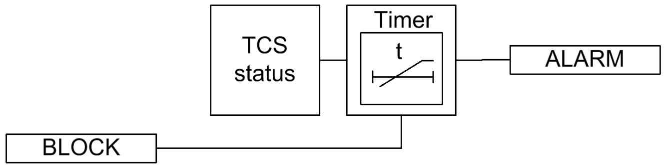


Figure 159: Functional module diagram

TCS status

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

Timer

Once activated, the timer runs until the set value of *Operate delay time* has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `ALARM` output is activated. If a drop-off situation occurs during the operate time up counting, the fixed 0.5 s reset timer is activated. After that 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 `ALARM` output to be activated.

6.1.5 Application

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

Figure 160 shows an application of the trip circuit supervision function use. The best solution is to connect an external R_{ext} shunt resistor in parallel with the circuit breaker internal contact. Although the circuit breaker internal contact is open, TCS can see the trip circuit through R_{ext}. The R_{ext} resistor should have such a resistance that the current through the resistance remains small, that is, it does not harm or overload the circuit breaker's trip coil.

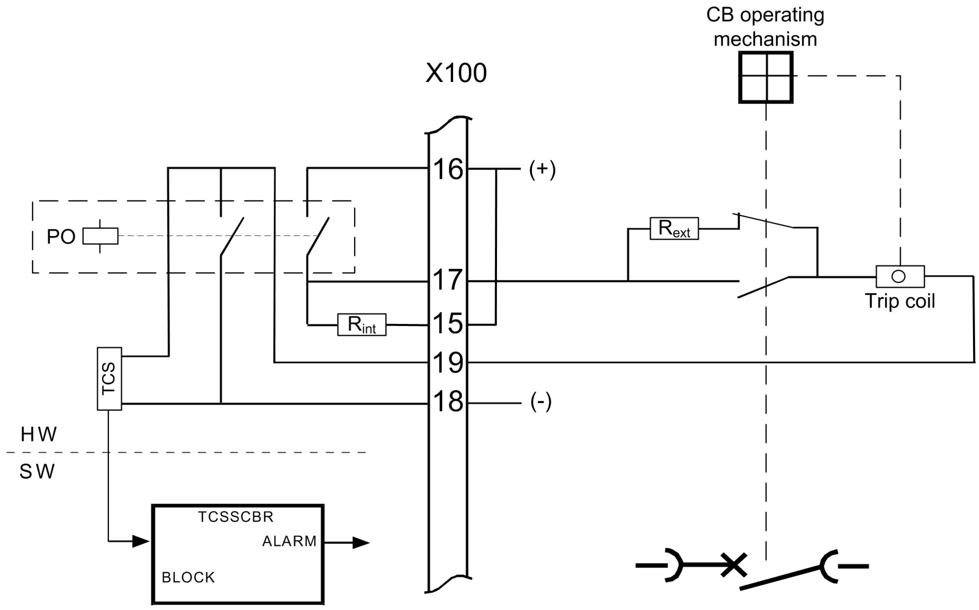


Figure 160: Operating principle of the trip-circuit supervision with an external resistor. The TCSSCBR blocking switch is not required since the external resistor is used.

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

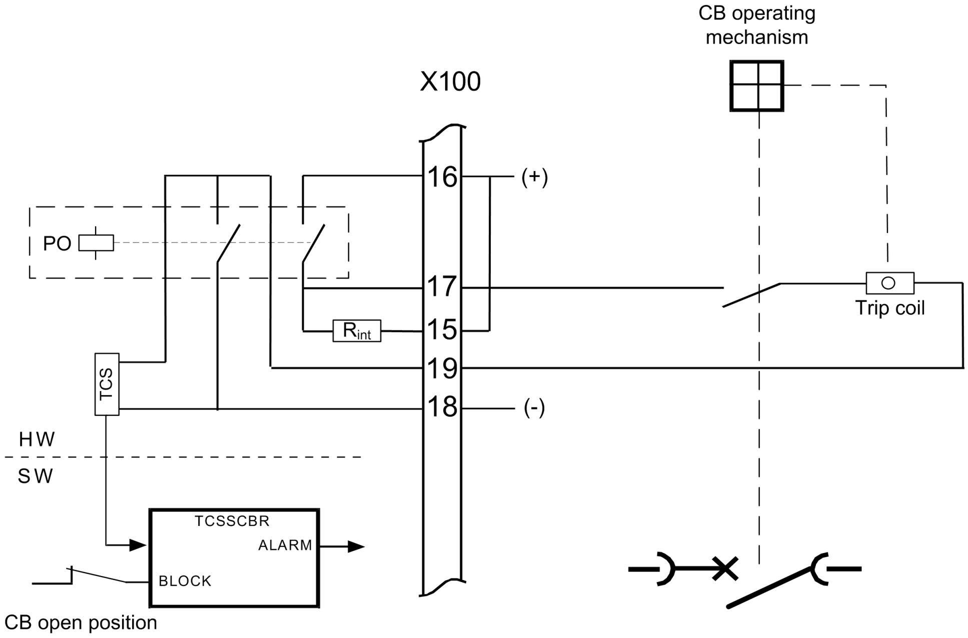


Figure 161: Operating principle of the trip-circuit supervision without an external resistor. The circuit breaker open indication is set to block TCSSCBR when the circuit breaker is open.

Trip circuit supervision and other trip contacts

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

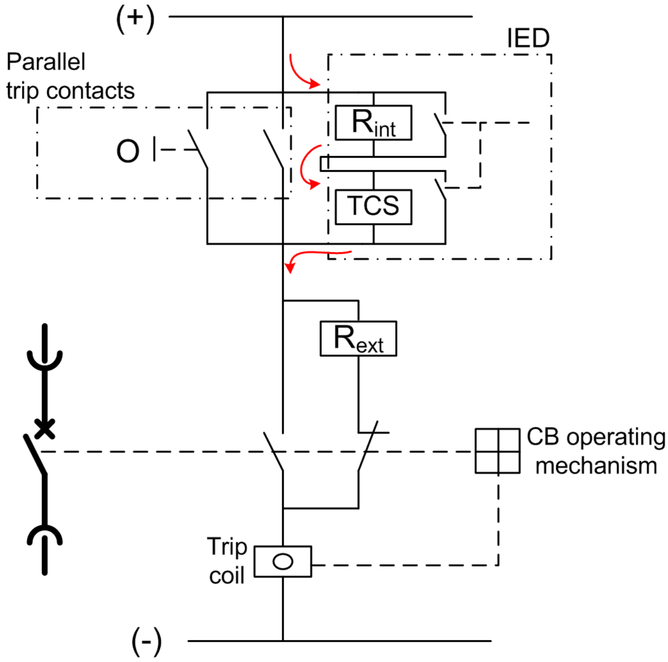


Figure 162: Constant test current flow in parallel trip contacts and trip circuit supervision

In case of parallel trip contacts, the recommended way to do the wiring is that the TCS test current flows through all wires and joints.

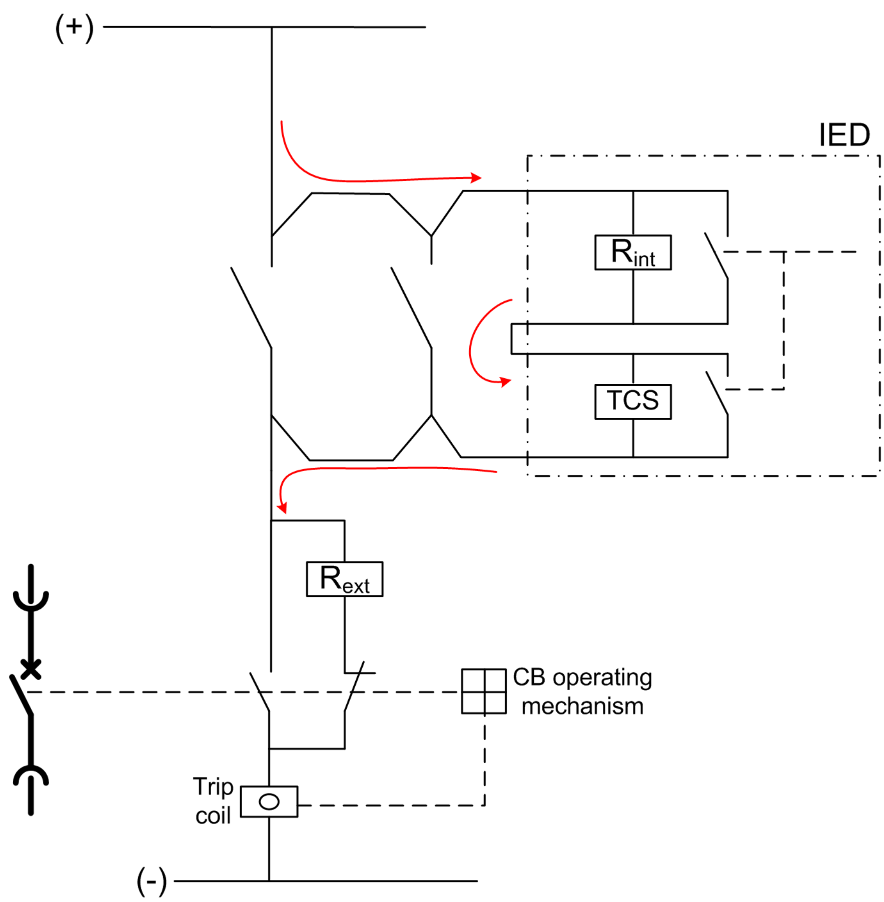


Figure 163: Improved connection for parallel trip contacts where the test current flows through all wires and joints

Several trip circuit supervision functions parallel in circuit

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

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

Trip circuit supervision with auxiliary relays

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

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

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

Dimensioning of the external resistor

Under normal operating conditions, the applied external voltage is divided between the relay's internal circuit and the external trip circuit so that at the minimum 20 V (15...20 V) remains over the relay's internal circuit. Should the external circuit's resistance be too high or the internal circuit's too low, for example due to welded relay contacts, a fault is detected.

Mathematically, the operation condition can be expressed as:

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

(Equation 33)

U_c	Operating voltage over the supervised trip circuit
I_c	Measuring current through the trip circuit, appr. 1.5 mA (0.99...1.72 mA)
R_{ext}	external shunt resistance
R_{int}	internal shunt resistance, 1 kΩ
R_s	trip coil resistance

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

Table 366: Values recommended for the external resistor R_{ext}

Operating voltage U_c	Shunt resistor R_{ext}
48 V AC/DC	1.2 kΩ, 5 W
60 V AC/DC	5.6 kΩ, 5 W
110 V AC/DC	22 kΩ, 5 W
220 V AC/DC	33 kΩ, 5 W

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

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

Using power output contacts without trip circuit supervision

If TCS is not used but the contact information of corresponding power outputs are required, the internal resistor can be by-passed. The output can then be utilized as a normal power output. When bypassing the internal resistor, the wiring between the terminals of the corresponding output X100:16-15(PO3) or X100:21-20(PO4) can be disconnected. The internal resistor is required if the complete TCS circuit is used.

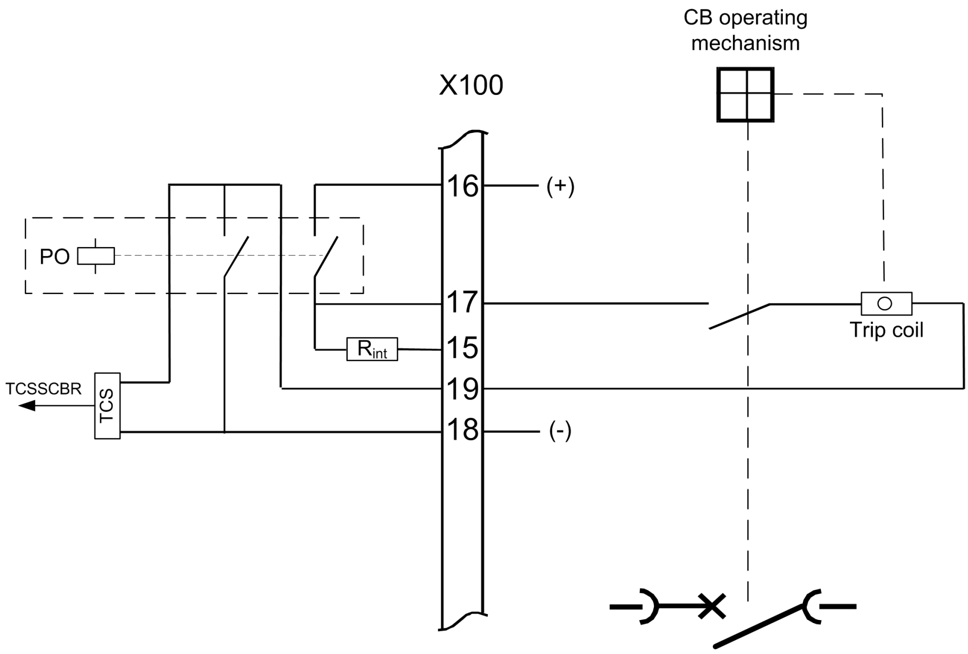


Figure 164: Connection of a power output in a case when TCS is not used and the internal resistor is disconnected

Incorrect connections and use of trip circuit supervision

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

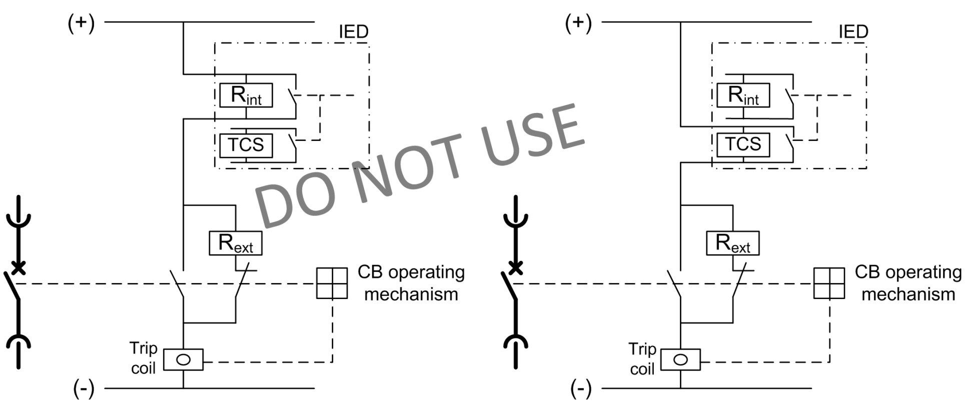


Figure 165: Incorrect connection of trip-circuit supervision

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

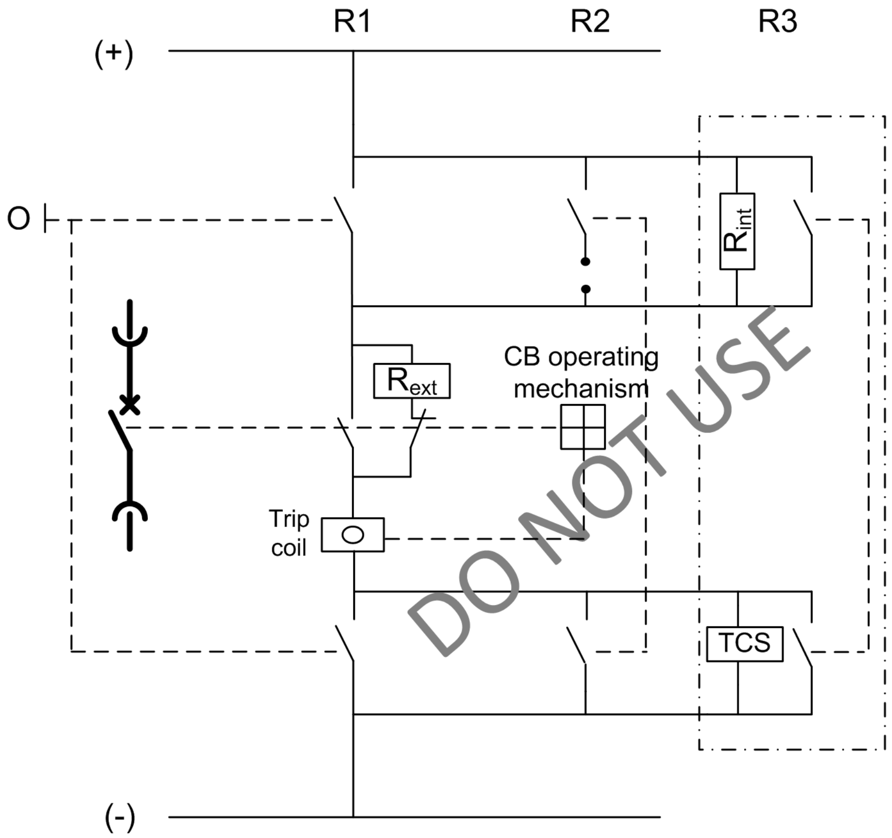


Figure 166: Incorrect testing of protection relays

6.1.6 Signals

Table 367: TCSSCBR Input signals

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

Table 368: TCSSCBR Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

6.1.7 Settings

Table 369: TCSSCBR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operate delay time	20...300000	ms	1	3000	Operate delay time

Table 370: TCSSCBR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	20...60000	ms	1	1000	Reset delay time

6.1.8 Monitored data

Table 371: TCSSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
TCSSCBR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.1.9 Technical revision history

Table 372: TCSSBR Technical revision history

Technical revision	Change
B	Internal improvement
C	Internal improvement

6.2 Phase segregated CT supervision function HZCCxSPVC

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase segregated CT supervision function for Phase A	HZCCASPVC	MCS 1I	MCS 1I
Phase segregated CT supervision function for Phase B	HZCCBSPVC	MCS 1I	MCS 1I
Phase segregated CT supervision function for Phase C	HZCCCSPVC	MCS 1I	MCS 1I

6.2.2 Function block

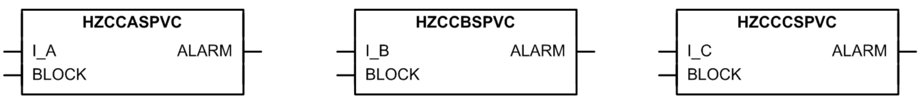


Figure 167: Function block

6.2.3 Functionality

Phase segregated CT supervision function HZCCxSPVC is a dedicated phase-segregated supervision function to be used along with the high-impedance differential protection for detecting the broken CT secondary wires. The differential current is taken as an input for the protection relay. During normal CT condition, the value of the differential current is zero. However, when the CT is broken, the secondary differential current starts flowing and it is used for generating alarms.

To avoid faulty operation, HZCCxSPVC should have a sensitive setting, compared to the high-impedance differential protection. The function is likely to start under through-fault conditions. However, by incorporating a high time delay (3 s or more), the downstream protection clears the fault before an alarm is generated.

HZCCxSPVC generates an alarm when the differential current exceeds the set limit. The function operates within the DT characteristic.

The function contains a blocking functionality. It is possible to block the function output, Timer or the whole function.

6.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

The module diagram illustrates all the phases of the function. However, the functionality is described only for phase A. The functionality for phase B and C is identical.

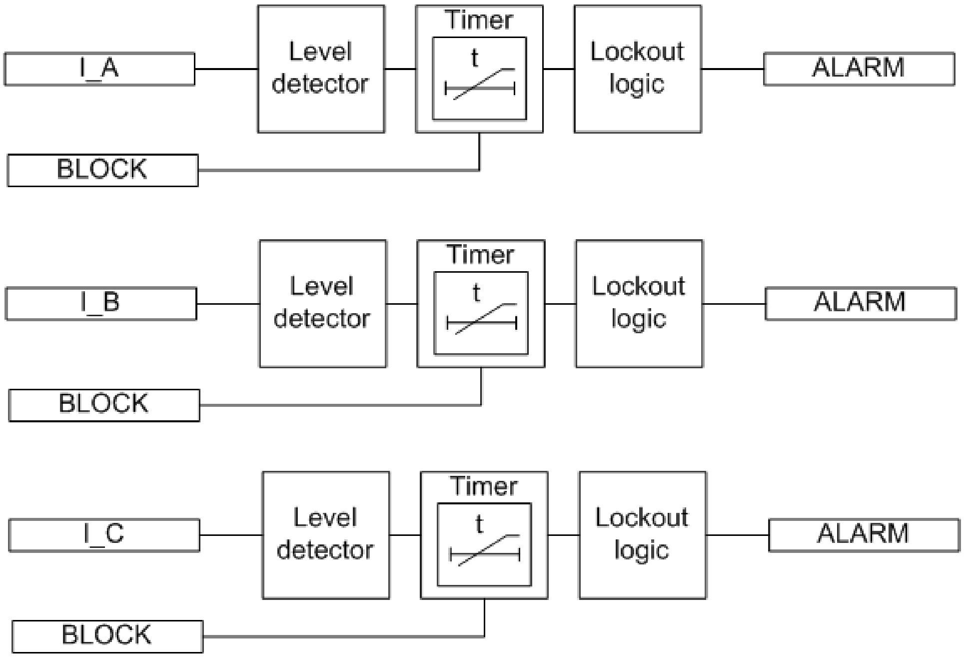


Figure 168: Functional module diagram

Level detector

This module compares the differential current I_A to the set *Start value*. The timer module is activated if the differential current exceeds the value set in the *Start value* setting.

Timer

The time characteristic is according to DT. When the alarm timer reaches the value set by *Alarm delay time*, the ALARM output is activated. If the fault disappears before the module generates an alarm signal, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the alarm timer resets. The activation of the BLOCK signal resets the Timer and deactivates the ALARM output.

Lockout logic

HZCCxSPVC is provided with the possibility to activate a lockout for the ALARM output depending on the *Alarm output mode* setting. In the "Lockout" mode, the ALARM must be reset manually from the LHMI Clear menu after checking the CT secondary circuit. In the "Non-latched" mode, the ALARM output functions normally, that is, it resets as soon as the fault is cleared.

6.2.5 Measuring modes

The function operates on two alternative measurement modes, DFT and Peak-to-Peak. The measurement mode is selected using the *Measurement mode* setting.

6.2.6 Application

HZCCxSPVC is a dedicated phase-segregated supervision function to be used along with the high-impedance differential protection for detecting the broken CT secondary wires. The operation principle of HZCCxSPVC is similar to the high-impedance differential protection function HIxPDIF. However, the current setting of HZCCxSPVC is set to be much more sensitive than HIxPDIF and it operates with a higher time delay. A typical example of the HZCCxSPVC *Start value* setting is 0.1 pu with an *Alarm delay time* of 3 s or more.

As the current setting of HZCCxSPVC is more sensitive than the actual differential stage, it can start internally under the through-fault conditions; however, a sufficient time delay prevents false alarm. If the bus wire is broken, differential current arises depending on the load of the feeder with the broken bus wire.

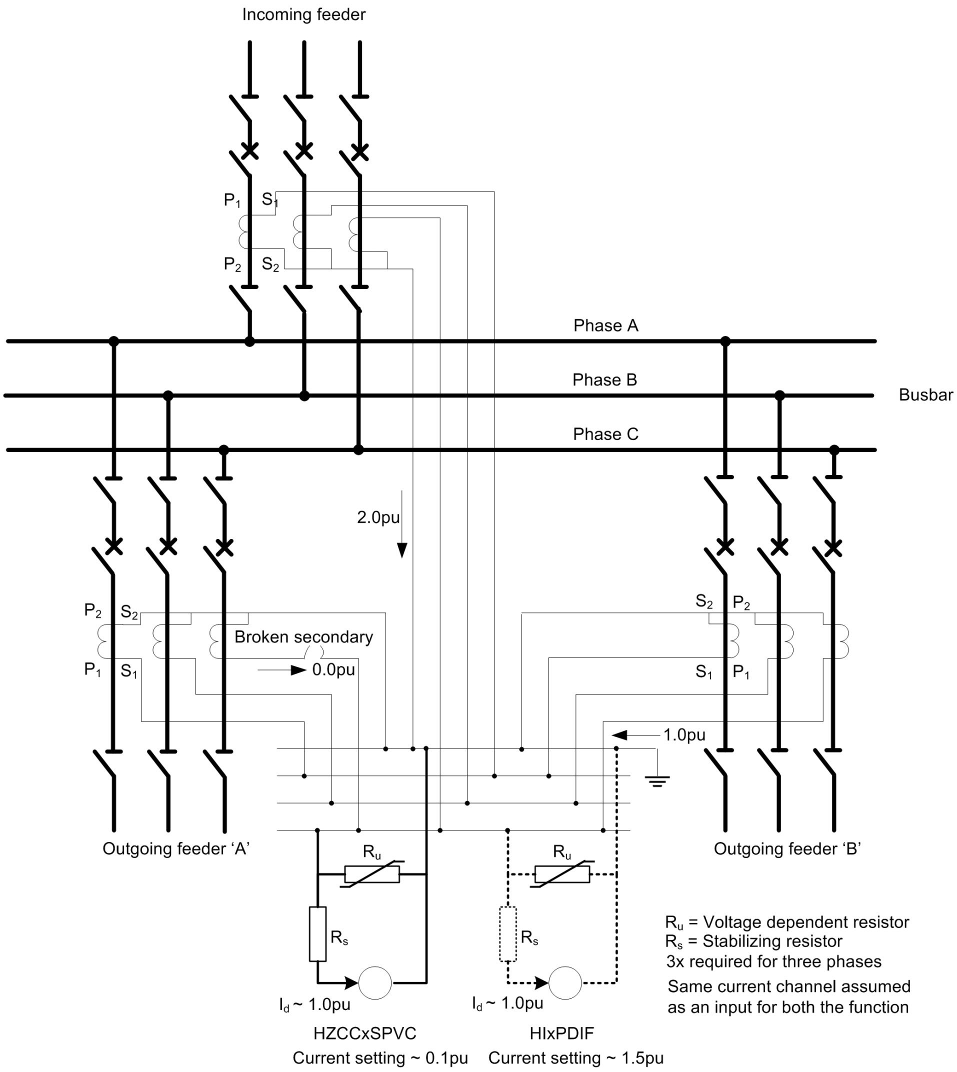


Figure 169: Broken secondary detection by HZCCxSPVC

In the example, the incoming feeder is carrying a load of 2.0 pu and both outgoing feeders carry an equal load of 1.0 pu However, both HIxPDIF and HZCCxSPVC consider the current as an increased differential or unbalance current because of the broken CT wire in phase C. Both HIxPDIF and HZCCxSPVC receive the differential current of approximately 1.0 pu The main differential protection HIxPDIF cannot operate because of the higher current setting.

All CTs must have the same ratio.

The ALARM output of the CT supervision function can be used to energize an auxiliary relay which can short-circuit the current CT wires, making the busbar differential protection inoperative. This arrangement does not prevent unwanted operation of HIxPDIF if the start setting is below the rated load. For example, if the start setting for HIxPDIF in the example is set as 0.8 pu HIxPDIF operates before HZCCxSPVC.

6.2.7 Signals

Table 373: HZCCASPVC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
BLOCK	BOOLEAN	0=False	Block signal for activating blocking mode

Table 374: HZCCBSPVC Input signals

Name	Type	Default	Description
I_B	SIGNAL	0	Phase B current
BLOCK	BOOLEAN	0=False	Block signal for activating blocking mode

Table 375: HZCCCSPVC Input signals

Name	Type	Default	Description
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating blocking mode

Table 376: HZCCASPVC Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

Table 377: HZCCBSPVC Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

Table 378: HZCCCSPVC Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

6.2.8 Settings

Table 379: HZCCASPVC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Start value	1.0...100.0	%In	0.1	10.0	Start value, percentage of the nominal current
Alarm delay time	100...300000	ms	10	3000	Alarm delay time
Alarm output mode	1=Non-latched 3=Lockout			3=Lockout	Select the operation mode for alarm output

Table 380: HZCCASPVC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

Table 381: HZCCBSPVC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Start value	1.0...100.0	%In	0.1	10.0	Start value, percentage of the nominal current
Alarm delay time	100...300000	ms	10	3000	Alarm delay time
Alarm output mode	1=Non-latched 3=Lockout			3=Lockout	Select the operation mode for alarm output

Table 382: HZCCBSPVC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

Table 383: HZCCCSPVC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Start value	1.0...100.0	%In	0.1	10.0	Start value, percentage of the nominal current
Alarm delay time	100...300000	ms	10	3000	Alarm delay time
Alarm output mode	1=Non-latched 3=Lockout			3=Lockout	Select the operation mode for alarm output

Table 384: HZCCCSPVC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	10	20	Reset delay time
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode

6.2.9 Monitored data

Table 385: HZCCASPVC Monitored data

Name	Type	Values (Range)	Unit	Description
HZCCASPVC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 386: HZCCBSPVC Monitored data

Name	Type	Values (Range)	Unit	Description
HZCCBSPVC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 387: HZCCCSPVC Monitored data

Name	Type	Values (Range)	Unit	Description
HZCCCSPVC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.2.10 Technical data

Table 388: HZCCxSPVC 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
Reset time	<40 ms
Reset ratio	Typically 0.96
Retardation time	<35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

6.2.11 Technical revision history

Table 389: HZCCxSPVC Technical revision history

Technical revision	Change
B	Function name changed from HZCCRDIF to HZCCASPVC, HZCCBSPVC, HZCCCSPVC.

6.3 Runtime counter for machines and devices MDSOPT

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Runtime counter for machines and devices	MDSOPT	OPTS	OPTM

6.3.2 Function block

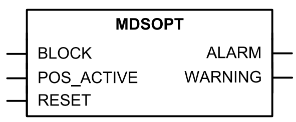


Figure 170: Function block

6.3.3 Functionality

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

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

6.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

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

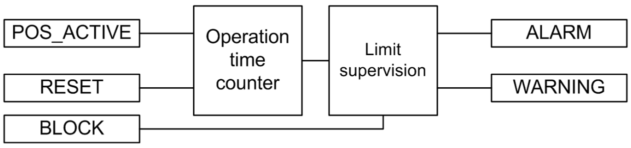


Figure 171: Functional module diagram

Operation time counter

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

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

Limit Supervision

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

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

Warn Alm”, the WARNING and ALARM outputs are activated at the time of day set using *Operating time hour*.

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

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

6.3.5 Application

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

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

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

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

6.3.6 Signals

Table 390: MDSOPT Input signals

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

Table 391: MDSOPT Output signals

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

6.3.7 Settings

Table 392: MDSOPT Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Warning value	0...299999	h	1	8000	Warning value for operation time supervision
Alarm value	0...299999	h	1	10000	Alarm value for operation time supervision

Table 393: MDSOPT Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Initial value	0...299999	h	1	0	Initial value for operation time supervision
Operating time hour	0...23	h	1	0	Time of day when alarm and warning will occur
Operating time mode	1=Immediate 2=Timed Warn 3=Timed Warn Alm			1=Immediate	Operating time mode for warning and alarm

6.3.8 Monitored data

Table 394: MDSOPT Monitored data

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

6.3.9 Technical data

Table 395: MDSOPT Technical data

Description	Value
Motor runtime measurement accuracy[1)]	±0.5%

1) Of the reading, for a stand-alone relay, without time synchronization

6.3.10 Technical revision history

Table 396: MDSOPT Technical revision history

Technical revision	Change
B	Internal improvement.
C	Internal improvement.
D	Internal improvement.

Section 7 Measurement functions

7.1 Basic measurements

7.1.1 Functions

The three-phase current measurement function CMMXU is used for monitoring and metering the phase currents of the power system.

The three-phase voltage measurement function VMMXU is used for monitoring and metering the phase-to-phase voltages of the power system. The phase-to-earth voltages are also available in VMMXU.

The residual current measurement function RESCMMXU is used for monitoring and metering the residual current of the power system.

The residual voltage measurement function RESVMMXU is used for monitoring and metering the residual voltage of the power system.

The sequence current measurement CSMSQI is used for monitoring and metering the phase sequence currents.

The sequence voltage measurement VSMSQI is used for monitoring and metering the phase sequence voltages.

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

The three-phase power and energy measurement PEMMXU is used for monitoring and metering active power (P), reactive power (Q), apparent power (S) and power factor (PF) and for calculating the accumulated energy separately as forward active, reversed active, forward reactive and reversed reactive. PEMMXU calculates these quantities using 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 or WHMI and remotely to a network control center with communication.

If the measured data in LHMI or WHMI 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 "On" and "Off".

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.

Reset of Recorded data initializes a present demand value to the minimum and maximum demand values.

Value reporting

The measurement functions are capable of reporting new values for network control center (SCADA system) based on various functions.

- Zero-point clamping
- Deadband supervision
- Limit value supervision

In the three-phase voltage measurement function VMMXU the supervision functions are based on the phase-to-phase voltages. However, the phase-to-earth voltage values are also reported with the phase-to-phase voltages.

GOOSE is an event based protocol service. Analog GOOSE uses the same event generation functions as vertical SCADA communication for updating the measurement values. Update interval of 500 ms is used for data that do not have zero-point clamping, deadband supervision or limit value supervision.

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 397: Zero-point clamping limits

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

When the frequency measurement function FMMXU 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.

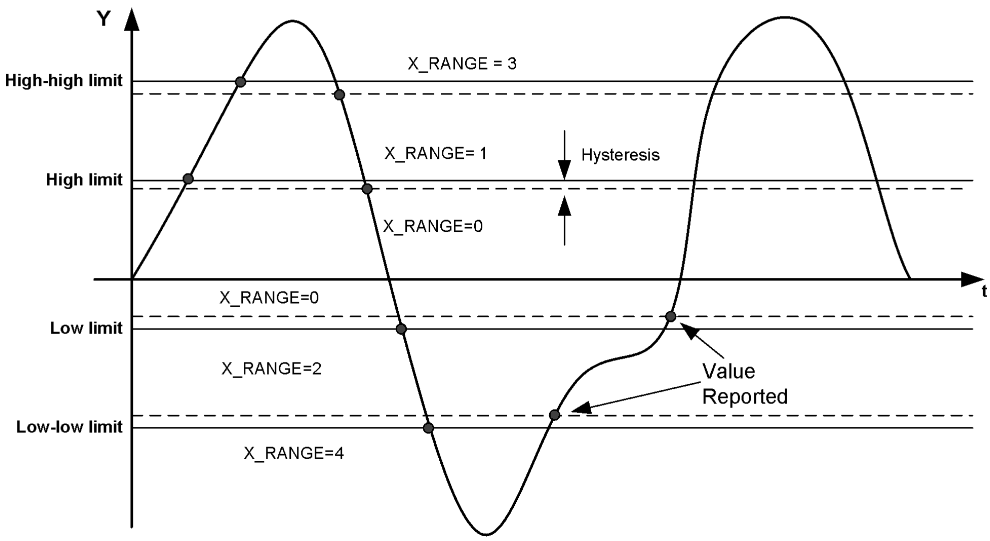


Figure 172: Presentation of operating limits

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 CMMXU and VMMXU. The limit supervision boolean alarm and warning outputs can be blocked.

Table 398: Settings for limit value supervision

Function	Settings for limit value supervision	
Three-phase current measurement (CMMXU)	High limit	*A high limit*
	Low limit	*A low limit*
	High-high limit	*A high high limit*
	Low-low limit	*A low low limit*
Table continues on next page		

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

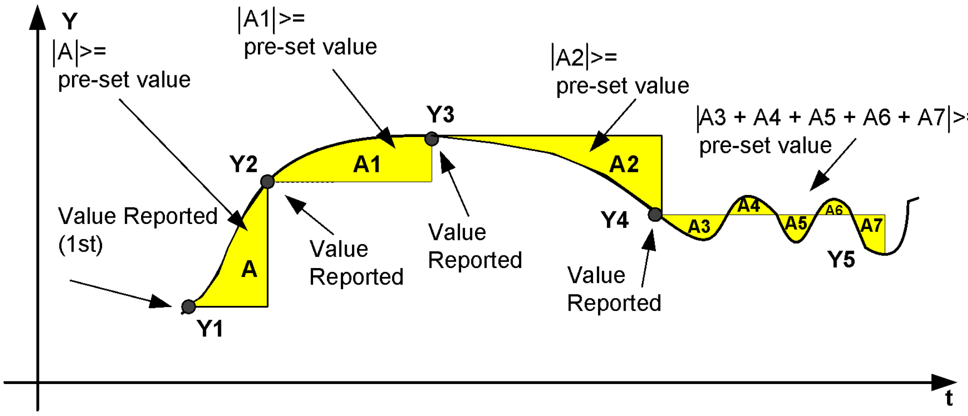


Figure 173: Integral deadband supervision

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 34)

Example for CMMXU:

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

I_INST_A = I_DB_A = 0.30

If I_INST_A changes to 0.40, the reporting delay is:

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

Table 399: Parameters for deadband calculation

Function	Settings	Maximum/minimum (=range)
Three-phase current measurement (CMMXU)	*A deadband*	*40/0 (=40xIn)*
Three-phase voltage measurement (VMMXU)	*V Deadband*	*4/0 (=4xUn)*
Residual current measurement (RESCMMXU)	*A deadband res*	*40/0 (=40xIn)*
Residual voltage measurement (RESVMMXU)	*V deadband res*	*4/0 (=4xUn)*

Table continues on next page

Function	Settings	Maximum/minimum (=range)
Frequency measurement (FMMXU)	*F deadband*	*75/35 (=40 Hz)*[1)]
Phase sequence current measurement (CSMSQI)	*Ps Seq A deadband, Ng Seq A deadband, Zro A deadband*	*40/0 (=40xIn)*
Phase sequence voltage measurement (VSMSQI)	*Ps Seq V deadband, Ng Seq V deadband, Zro V deadband*	*4/0 (=4xUn)*
Three-phase power and energy measurement (PEMMXU)	-	

1) The value provided is for 50 Hz network. The value for 60 Hz network is 90/36 (=54 Hz)

In the three-phase power and energy measurement function PEMMXU, 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 three-phase power is calculated from the phase-to-earth voltages and phase-to-earth currents. The power measurement function is capable of calculating a complex power based on the fundamental frequency component phasors (DFT).

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

(Equation 35)

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

$$P = \text{Re}(\overline{S})$$

(Equation 36)

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

(Equation 37)

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

(Equation 38)

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

(Equation 39)

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.

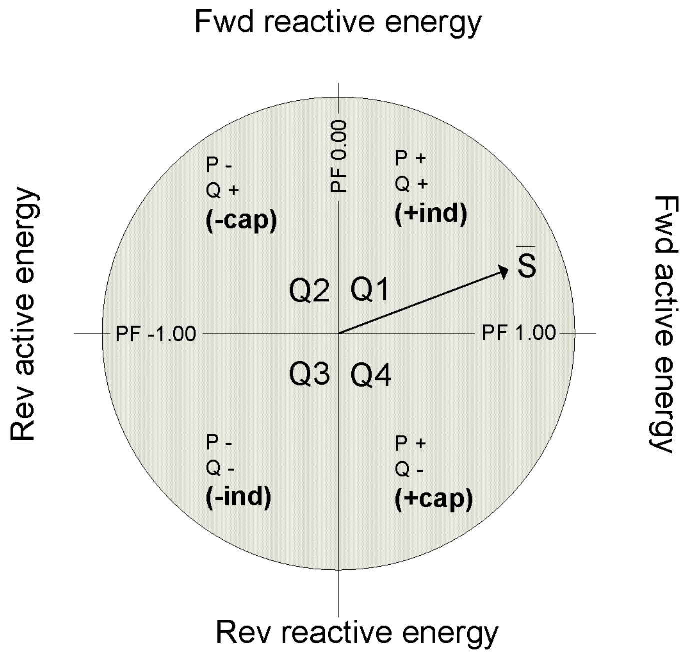


Figure 174: Complex power and power quadrants

Table 400: 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 VArh Initial* and ER_RV_ACM to *Reverse VArh 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 measurement CMMXU

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	3I

7.1.4.2 Function block

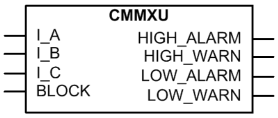


Figure 175: Function block

7.1.4.3 Signals

Table 401: CMMXU 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 402: CMMXU 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 403: CMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
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	1.40	High alarm current limit
A high limit	0.00...40.00	xIn	1	1.20	High warning current limit
A low limit	0.00...40.00	xIn	1	0.00	Low warning current limit
A low low limit	0.00...40.00	xIn	1	0.00	Low alarm current limit
A deadband	100...100000		1	2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table 404: CMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode

7.1.4.5 Monitored data

Table 405: CMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
IL1-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase A
IL2-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase B
IL3-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase C
Max demand IL1	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase A
Max demand IL2	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase B
Max demand IL3	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase C
Min demand IL1	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase A
Min demand IL2	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase B
Min demand IL3	FLOAT32	0.00...40.00	xIn	Minimum demand for Phase C
Time max demand IL1	Timestamp			Time of maximum demand phase A
Time max demand IL2	Timestamp			Time of maximum demand phase B
Time max demand IL3	Timestamp			Time of maximum demand phase C
Time min demand IL1	Timestamp			Time of minimum demand phase A
Time min demand IL2	Timestamp			Time of minimum demand phase B
Time min demand IL3	Timestamp			Time of minimum demand phase C
BLOCK	BOOLEAN	0=False 1=True		Block signal for all binary outputs
HIGH_ALARM	BOOLEAN	0=False 1=True		High alarm
HIGH_WARN	BOOLEAN	0=False 1=True		High warning
LOW_WARN	BOOLEAN	0=False 1=True		Low warning

Table continues on next page

Name	Type	Values (Range)	Unit	Description
LOW_ALARM	BOOLEAN	0=False 1=True		Low alarm
I_INST_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of instantaneous value
I_ANGL_A	FLOAT32	-180.00...180.00	deg	IL1 current angle
I_DB_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of reported value
I_DMD_A	FLOAT32	0.00...40.00	xIn	Demand value of IL1 current
I_RANGE_A	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL1 Amplitude range
I_INST_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of instantaneous value
I_ANGL_B	FLOAT32	-180.00...180.00	deg	IL2 current angle
I_DB_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of reported value
I_DMD_B	FLOAT32	0.00...40.00	xIn	Demand value of IL2 current
I_RANGE_B	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL2 Amplitude range
I_INST_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of instantaneous value
I_ANGL_C	FLOAT32	-180.00...180.00	deg	IL3 current angle
I_DB_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of reported value
I_DMD_C	FLOAT32	0.00...40.00	xIn	Demand value of IL3 current
I_RANGE_C	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL3 Amplitude range

7.1.4.6 Technical data

Table 406: CMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±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 × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.4.7 Technical revision history

Table 407: CMMXU Technical revision history

Technical revision	Change
B	Menu changes
C	Phase current angle values added to Monitored data view. Minimum demand value and time added to recorded data. Logarithmic demand calculation mode added and demand interval setting moved under Measurement menu as general setting to all demand calculations.
D	Internal improvement.
E	Internal improvement.

7.1.5 Three-phase voltage measurement VMMXU

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	3V

7.1.5.2 Function block

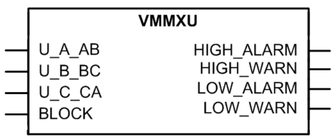


Figure 176: Function block

7.1.5.3 Signals

Table 408: VMMXU Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 409: VMMXU 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 410: VMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
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	1.40	High alarm voltage limit
V high limit	0.00...4.00	xUn	1	1.20	High warning voltage limit
V low limit	0.00...4.00	xUn	1	0.00	Low warning voltage limit
V low low limit	0.00...4.00	xUn	1	0.00	Low alarm voltage limit
V deadband	100...100000		1	10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table 411: VMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode

7.1.5.5 Monitored data

Table 412: VMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
U12-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase AB
U23-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase BC
U31-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase CA
BLOCK	BOOLEAN	0=False 1=True		Block signal for all binary outputs
HIGH_ALARM	BOOLEAN	0=False 1=True		High alarm
HIGH_WARN	BOOLEAN	0=False 1=True		High warning
LOW_WARN	BOOLEAN	0=False 1=True		Low warning
LOW_ALARM	BOOLEAN	0=False 1=True		Low alarm
U_INST_AB	FLOAT32	0.00...4.00	xUn	U12 Amplitude, magnitude of instantaneous value
U_ANGL_AB	FLOAT32	-180.00...180.00	deg	U12 angle
U_DB_AB	FLOAT32	0.00...4.00	xUn	U12 Amplitude, magnitude of reported value
U_DMD_AB	FLOAT32	0.00...4.00	xUn	Demand value of U12 voltage
U_RANGE_AB	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U12 Amplitude range
U_INST_BC	FLOAT32	0.00...4.00	xUn	U23 Amplitude, magnitude of instantaneous value
U_ANGL_BC	FLOAT32	-180.00...180.00	deg	U23 angle
U_DB_BC	FLOAT32	0.00...4.00	xUn	U23 Amplitude, magnitude of reported value
U_DMD_BC	FLOAT32	0.00...4.00	xUn	Demand value of U23 voltage
U_RANGE_BC	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U23 Amplitude range

Table continues on next page

Name	Type	Values (Range)	Unit	Description
U_INST_CA	FLOAT32	0.00...4.00	xUn	U31 Amplitude, magnitude of instantaneous value
U_ANGL_CA	FLOAT32	-180.00...180.00	deg	U31 angle
U_DB_CA	FLOAT32	0.00...4.00	xUn	U31 Amplitude, magnitude of reported value
U_DMD_CA	FLOAT32	0.00...4.00	xUn	Demand value of U31 voltage
U_RANGE_CA	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U31 Amplitude range
U_INST_A	FLOAT32	0.00...5.00	xUn	UL1 Amplitude, magnitude of instantaneous value
U_ANGL_A	FLOAT32	-180.00...180.00	deg	UL1 angle
U_DMD_A	FLOAT32	0.00...5.00	xUn	Demand value of UL1 voltage
U_INST_B	FLOAT32	0.00...5.00	xUn	UL2 Amplitude, magnitude of instantaneous value
U_ANGL_B	FLOAT32	-180.00...180.00	deg	UL2 angle
U_DMD_B	FLOAT32	0.00...5.00	xUn	Demand value of UL2 voltage
U_INST_C	FLOAT32	0.00...5.00	xUn	UL3 Amplitude, magnitude of instantaneous value
U_ANGL_C	FLOAT32	-180.00...180.00	deg	UL3 angle
U_DMD_C	FLOAT32	0.00...5.00	xUn	Demand value of UL3 voltage

7.1.5.6 Technical data

Table 413: VMMXU 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 × U_n
	±0.5% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.5.7 Technical revision history

Table 414: VMMXU Technical revision history

Technical revision	Change
B	Phase and phase-to-phase voltage angle values and demand values added to Monitored data view.
C	Internal improvement.
D	Internal improvement.

7.1.6 Residual current measurement RESCMMXU

7.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual current measurement	RESCMMXU	Io	In

7.1.6.2 Function block

Figure 177: Function block

7.1.6.3 Signals

Table 415: RESCMMXU Input signals

Name	Type	Default	Description
Io	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 416: RESCMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.6.4 Settings

Table 417: RESCMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
A Hi high limit res	0.00...40.00	xIn	1	0.20	High alarm current limit
A high limit res	0.00...40.00	xIn	1	0.05	High warning current limit
A deadband res	100...100000		1	2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table 418: RESCMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode

7.1.6.5 Monitored data

Table 419: RESCMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
Io-A	FLOAT32	0.00...40.00	xIn	Measured residual current
BLOCK	BOOLEAN	0=False 1=True		Block signal for all binary outputs
HIGH_ALARM	BOOLEAN	0=False 1=True		High alarm
HIGH_WARN	BOOLEAN	0=False 1=True		High warning
I_INST_RES	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of instantaneous value
I_ANGL_RES	FLOAT32	-180.00...180.00	deg	Residual current angle
I_DB_RES	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of reported value
I_DMD_RES	FLOAT32	0.00...40.00	xIn	Demand value of residual current
I_RANGE_RES	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual current Amplitude range
Max demand Io	FLOAT32	0.00...40.00	xIn	Maximum demand for residual current

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Min demand Io	FLOAT32	0.00...40.00	xIn	Minimum demand for residual current
Time max demand Io	Timestamp			Time of maximum demand residual current
Time min demand Io	Timestamp			Time of minimum demand residual current

7.1.6.6 Technical data

Table 420: RESCMMXU 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

7.1.6.7 Technical revision history

Table 421: RESCMMXU Technical revision history

Technical revision	Change
B	-
C	Residual current angle and demand value added to Monitored data view. Recorded data added for minimum and maximum values with timestamps.
D	Monitored data Min demand Io maximum value range (RESCMSTA2.MinAmps.maxVal.f) is corrected to 40.00.
E	Internal improvement

7.1.7 Residual voltage measurement RESVMMXU

7.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual voltage measurement	RESVMMXU	Uo	Vn

7.1.7.2 Function block

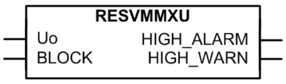


Figure 178: Function block

7.1.7.3 Signals

Table 422: RESVMMXU Input signals

Name	Type	Default	Description
Uo	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 423: RESVMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.7.4 Settings

Table 424: RESVMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
V Hi high limit res	0.00...4.00	xUn	1	0.20	High alarm voltage limit
V high limit res	0.00...4.00	xUn	1	0.05	High warning voltage limit
V deadband res	100...100000		1	10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table 425: RESVMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode

7.1.7.5 Monitored data

Table 426: RESVMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
Uo-kV	FLOAT32	0.00...4.00	xUn	Measured residual voltage
BLOCK	BOOLEAN	0=False 1=True		Block signal for all binary outputs
HIGH_ALARM	BOOLEAN	0=False 1=True		High alarm
HIGH_WARN	BOOLEAN	0=False 1=True		High warning
U_INST_RES	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of instantaneous value
U_ANGL_RES	FLOAT32	-180.00...180.00	deg	Residual voltage angle
U_DB_RES	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of reported value
U_DMD_RES	FLOAT32	0.00...4.00	xUn	Demand value of residual voltage
U_RANGE_RES	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual voltage Amplitude range

7.1.7.6 Technical data

Table 427: RESVMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: f/f_n = ±2 Hz
	±0.5% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.7.7 Technical revision history

Table 428: RESVMMXU Technical revision history

Technical revision	Change
B	-
C	Residual voltage angle and demand value added to Monitored data view
D	Internal improvement
E	Internal improvement

7.1.8 Frequency measurement FMMXU

7.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency measurement	FMMXU	f	f

7.1.8.2 Function block

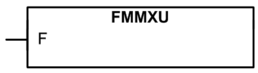


Figure 179: Function block

7.1.8.3 Functionality

The frequency measurement range is 35...75 Hz. The estimated frequencies outside the measurement range are considered to be out of range and the minimum and maximum values are then shown.

When the frequencies cannot be measured, for example, due to too low voltage amplitude, the default value for frequency measurement can be selected with the *Def frequency Sel* setting parameter. In the “Nominal” mode the frequency is set to 50 Hz (or 60 Hz) and in “Zero” mode the frequency is set to zero and shown in parentheses.

7.1.8.4 Signals

Table 429: FMMXU Input signals

Name	Type	Default	Description
F	SIGNAL	-	Measured system frequency

7.1.8.5 Settings

Table 430: FMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
F high high limit	35.00...75.00	Hz	1	60.00	High alarm frequency limit
F high limit	35.00...75.00	Hz	1	55.00	High warning frequency limit
F low limit	35.00...75.00	Hz	1	45.00	Low warning frequency limit
F low low limit	35.00...75.00	Hz	1	40.00	Low alarm frequency limit
F deadband	100...100000		1	1000	Deadband configuration value for integral calculation (percentage of difference between min and max as 0,001 % s)

Table 431: FMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Def frequency Sel	1=Nominal 2=Zero			1=Nominal	Default frequency selection

7.1.8.6 Monitored data

Table 432: FMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
f-Hz	FLOAT32	35.00...75.00	Hz	Measured frequency
F_INST	FLOAT32	35.00...75.00	Hz	Frequency, instantaneous value
F_DB	FLOAT32	35.00...75.00	Hz	Frequency, reported value
F_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Measured frequency range

7.1.8.7 Technical data

Table 433: FMMXU Technical data

Characteristic	Value
Operation accuracy	±10 mHz (in measurement range 35...75 Hz)

7.1.8.8 Technical revision history

Table 434: FMMXU Technical revision history

Technical revision	Change
B	Added new setting *Def frequency Sel*. Frequency measurement range lowered from 35 Hz to 10 Hz.

7.1.9 Sequence current measurement CSMSQI

7.1.9.1 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

7.1.9.2 Function block

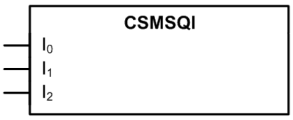


Figure 180: Function block

7.1.9.3 Signals

Table 435: CSMSQI 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

7.1.9.4 Settings

Table 436: CSMSQI Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Ps Seq A Hi high Lim	0.00...40.00	xIn	1	1.40	High alarm current limit for positive sequence current
Ps Seq A high limit	0.00...40.00	xIn	1	1.20	High warning current limit for positive sequence current
Ps Seq A low limit	0.00...40.00	xIn	1	0.00	Low warning current limit for positive sequence current
Ps Seq A low low Lim	0.00...40.00	xIn	1	0.00	Low alarm current limit for positive sequence current
Ps Seq A deadband	100...100000		1	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	1	0.20	High alarm current limit for negative sequence current
Ng Seq A High limit	0.00...40.00	xIn	1	0.05	High warning current limit for negative sequence current
Ng Seq A low limit	0.00...40.00	xIn	1	0.00	Low warning current limit for negative sequence current
Ng Seq A low low Lim	0.00...40.00	xIn	1	0.00	Low alarm current limit for negative sequence current

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Ng Seq A deadband	100...100000		1	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	1	0.20	High alarm current limit for zero sequence current
Zro A High limit	0.00...40.00	xIn	1	0.05	High warning current limit for zero sequence current
Zro A low limit	0.00...40.00	xIn	1	0.00	Low warning current limit for zero sequence current
Zro A low low Lim	0.00...40.00	xIn	1	0.00	Low alarm current limit for zero sequence current
Zro A deadband	100...100000		1	2500	Deadband configuration value for zero sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)

7.1.9.5 Monitored data

Table 437: CSMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
NgSeq-A	FLOAT32	0.00...40.00	xIn	Measured negative sequence current
PsSeq-A	FLOAT32	0.00...40.00	xIn	Measured positive sequence current
ZroSeq-A	FLOAT32	0.00...40.00	xIn	Measured zero sequence current
I2_INST	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, instantaneous value
I2_ANGL	FLOAT32	-180.00...180.00	deg	Negative sequence current angle
I2_DB	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, reported value
I2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence current amplitude range
I1_INST	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, instantaneous value
I1_ANGL	FLOAT32	-180.00...180.00	deg	Positive sequence current angle
I1_DB	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, reported value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
I1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence current amplitude range
I0_INST	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, instantaneous value
I0_ANGL	FLOAT32	-180.00...180.00	deg	Zero sequence current angle
I0_DB	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, reported value
I0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence current amplitude range

7.1.9.6 Technical data

Table 438: CSMSQI Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f/f_n = \pm 2$ Hz
	±1.0% or $\pm 0.002 \times I_n$ at currents in the range of $0.01...4.00 \times I_n$
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…

7.1.9.7 Technical revision history

Table 439: CSMSQI Technical revision history

Technical revision	Change
A	-
B	Sequence current angle values added to the Monitored data view.
C	Internal improvement.

7.1.10 Sequence voltage measurement VSMSQI

7.1.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sequence voltage measurement	VSMSQI	U1, U2, U0	U1, U2, U0

7.1.10.2 Function block

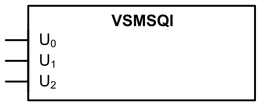


Figure 181: Function block

7.1.10.3 Signals

Table 440: VSMSQI Input signals

Name	Type	Default	Description
U_0	SIGNAL	0	Zero sequence voltage
U_1	SIGNAL	0	Positive phase sequence voltage
U_2	SIGNAL	0	Negative phase sequence voltage

7.1.10.4 Settings

Table 441: VSMSQI Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Ps Seq V Hi high Lim	0.00...4.00	xUn	1	1.40	High alarm voltage limit for positive sequence voltage
Ps Seq V high limit	0.00...4.00	xUn	1	1.20	High warning voltage limit for positive sequence voltage
Ps Seq V low limit	0.00...4.00	xUn	1	0.00	Low warning voltage limit for positive sequence voltage
Ps Seq V low low Lim	0.00...4.00	xUn	1	0.00	Low alarm voltage limit for positive sequence voltage
Ps Seq V deadband	100...100000		1	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	1	0.20	High alarm voltage limit for negative sequence voltage
Ng Seq V High limit	0.00...4.00	xUn	1	0.05	High warning voltage limit for negative sequence voltage
Ng Seq V low limit	0.00...4.00	xUn	1	0.00	Low warning voltage limit for negative sequence voltage
Ng Seq V low low Lim	0.00...4.00	xUn	1	0.00	Low alarm voltage limit for negative sequence voltage
Ng Seq V deadband	100...100000		1	10000	Deadband configuration value for negative sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Zro V Hi high Lim	0.00...4.00	xUn	1	0.20	High alarm voltage limit for zero sequence voltage
Zro V High limit	0.00...4.00	xUn	1	0.05	High warning voltage limit for zero sequence voltage
Zro V low limit	0.00...4.00	xUn	1	0.00	Low warning voltage limit for zero sequence voltage
Zro V low low Lim	0.00...4.00	xUn	1	0.00	Low alarm voltage limit for zero sequence voltage
Zro V deadband	100...100000		1	10000	Deadband configuration value for zero sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)

7.1.10.5 Monitored data

Table 442: VSMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
NgSeq-kV	FLOAT32	0.00...4.00	xUn	Measured negative sequence voltage
PsSeq-kV	FLOAT32	0.00...4.00	xUn	Measured positive sequence voltage
ZroSeq-kV	FLOAT32	0.00...4.00	xUn	Measured zero sequence voltage
U2_INST	FLOAT32	0.00...4.00	xUn	Negative sequence voltage amplitude, instantaneous value
U2_ANGL	FLOAT32	-180.00...180.00	deg	Negative sequence voltage angle
U2_DB	FLOAT32	0.00...4.00	xUn	Negative sequence voltage amplitude, reported value
U2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence voltage amplitude range
U1_INST	FLOAT32	0.00...4.00	xUn	Positive sequence voltage amplitude, instantaneous value
U1_ANGL	FLOAT32	-180.00...180.00	deg	Positive sequence voltage angle
U1_DB	FLOAT32	0.00...4.00	xUn	Positive sequence voltage amplitude, reported value
U1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence voltage amplitude range

Table continues on next page

Name	Type	Values (Range)	Unit	Description
U0_INST	FLOAT32	0.00...4.00	xUn	Zero sequence voltage amplitude, instantaneous value
U0_ANGL	FLOAT32	-180.00...180.00	deg	Zero sequence voltage angle
U0_DB	FLOAT32	0.00...4.00	xUn	Zero sequence voltage amplitude, reported value
U0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence voltage amplitude range

7.1.10.6 Technical data

Table 443: VSMSQI 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 × U_n
	±1.0% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

7.1.11 Three-phase power and energy measurement PEMMXU

7.1.11.1 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

7.1.11.2 Function block

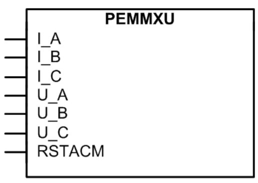


Figure 182: Function block

7.1.11.3 Signals

Table 444: PEMMXU 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
U_A	SIGNAL	0	Phase A voltage
U_B	SIGNAL	0	Phase B voltage
U_C	SIGNAL	0	Phase C voltage
RSTACM	BOOLEAN	0=False	Reset of accumulated energy reading

7.1.11.4 Settings

Table 445: PEMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Power unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the power related values
Energy unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the energy related values
Active power Dir	1=Forward 2=Reverse			1=Forward	Direction of active power flow: Forward, Reverse
Reactive power Dir	1=Forward 2=Reverse			1=Forward	Direction of reactive power flow: Forward, Reverse

Table 446: PEMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 447: PEMMXU 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
RSTACM	BOOLEAN	0=False 1=True		Reset of accumulated energy reading
S_INST	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value
S_DB	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value
S_DMD	FLOAT32	-999999.9...999999.9	kVA	Demand value of apparent power
P_INST	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value
P_DB	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value
P_DMD	FLOAT32	-999999.9...999999.9	kW	Demand value of active power
Q_INST	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value
Q_DB	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value
Q_DMD	FLOAT32	-999999.9...999999.9	kVAr	Demand value of reactive power
PF_INST	FLOAT32	-1.00...1.00		Power factor, magnitude of instantaneous value
PF_DB	FLOAT32	-1.00...1.00		Power factor, magnitude of reported value
PF_DMD	FLOAT32	-1.00...1.00		Demand value of power factor
EA_RV_ACM	INT64	0...999999999	kWh	Accumulated reverse active energy value
ER_RV_ACM	INT64	0...999999999	kVArh	Accumulated reverse reactive energy value
EA_FWD_ACM	INT64	0...999999999	kWh	Accumulated forward active energy value
ER_FWD_ACM	INT64	0...999999999	kVArh	Accumulated forward reactive energy value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
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
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

7.1.11.6 Technical data

Table 448: PEMMXU 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 × U_n At the frequency f_n ±1 Hz
	±1.5% for apparent power S ±1.5% for active power P and active energy[1)] ±1.5% for reactive power Q and reactive energy[2)] ±0.015 for power factor
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

1) |PF| >0.5 which equals |cosφ| >0.5
2) |PF| <0.86 which equals |sinφ| >0.5

7.1.11.7 Technical revision history

Table 449: PEMMXU Technical revision history

Technical revision	Change
B	Demand values added to Monitored data. Recorded data added to store minimum and maximum demand values with timestamps.
C	Internal improvement.
D	Internal improvement.

7.2 Disturbance recorder RDRE

7.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Disturbance recorder	RDRE	DR	DFR

7.2.2 Functionality

The relay is provided with a disturbance recorder featuring preconfigured analog and binary 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 start or trip signals of the relay stages, or external blocking or control signals. Binary relay signals, such as protection start and trip signals, 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.

7.2.2.1 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 "on" or "off".

All analog channels of the disturbance recorder that are enabled and have a valid signal type mapped are included in the recording.

7.2.2.2 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.

7.2.2.3 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.

7.2.2.4 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 450: Sampling frequencies of the disturbance 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

7.2.2.5 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.

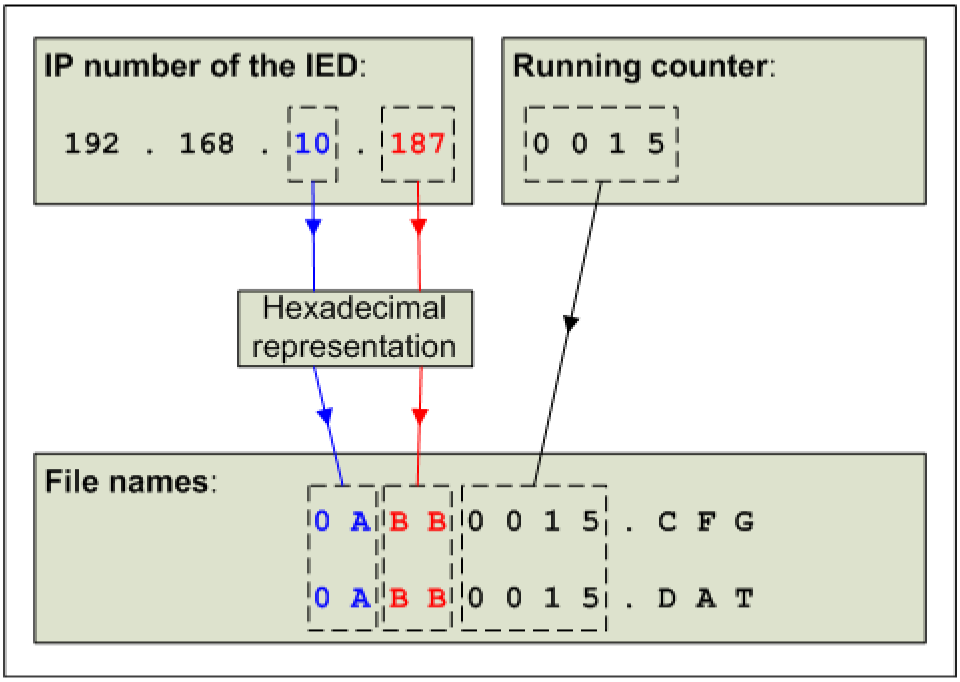


Figure 183: Disturbance recorder file naming

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.

7.2.2.6 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/Disturbance records** menu. Deleting all disturbance recordings at once also clears the pre-trigger recording in progress.

7.2.2.7 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 value is recorded for each enabled analog channel, once per fundamental cycle. The recorded values are RMS values, which are scaled to peak level. 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*.

7.2.2.8 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.

7.2.2.9 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.

7.2.2.10 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.

7.2.3 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/Disturbance recorder/General** menu.

One analog signal type of the protection relay can be mapped to each of the analog channels of the disturbance recorder. The mapping is done with the *Channel selection* parameter of the corresponding analog channel. The name of the analog channel is user-configurable. It can be modified 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 start and trip signals from protection function blocks or the external binary inputs of the protection relay. 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 an analog or a binary channel of the disturbance recorder, the *Operation* parameter of the corresponding analog or binary channel is set to "on" or "off".

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.

7.2.4 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.

7.2.5 Settings

Table 451: RDRE Non-group general settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Disturbance recorder on/off
Record length	10...500	fundamental cycles	1	50	Size of the recording in fundamental cycles
Pre-trg length	0...100	%	1	50	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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
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 452: RDRE Non-group channel settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Analog channel is enabled or disabled
Channel selection	0=Disabled 1=Io 2=IL1 3=IL2 4=IL3 10=U1 11=U2 12=U3 14=U1B 17=CIo 18=SI1 1) 19=SI2 1) 20=SU0 21=SU1 1) 22=SU2 1) 26=SUoB 27=SU1B 1) 28=SU2B 1)		0	0=Disabled	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.

Table 453: RDRE Non-group binary channel settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	5=off	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 454: RDRE Control data

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

7.2.6 Monitored data

Table 455: RDRE 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

7.2.7 Technical revision history

Table 456: RDRE Technical revision history

Technical revision	Change
B	ChNum changed to EChNum (RADR's) RADR9...12 added (Analog channels 9...12) RBDR33...64 added (Binary channels 33...64)
C	New channels added to parameter *Channel selection* Selection names for *Trig Recording* and *Clear Recordings updated*
D	Symbols in the *Channel selection* setting are updated
E	New channels IL1C, IL2C and IL3C added to *Channel selection* parameter
F	Internal improvement
G	Internal improvement

Section 8 Control functions

8.1 Circuit-breaker control CBXCBR

8.1.1 Identification

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

8.1.2 Function block

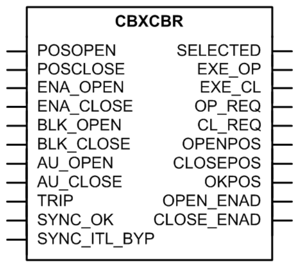


Figure 184: Function block

8.1.3 Functionality

The circuit breaker control function CBXCBR 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 which counts the number of circuit breaker openings. The counter value can be read and written remotely from the place of operation or via the LHMI.

8.1.4 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 according to Table 457. 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 457: Status indication

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

Enabling and blocking

CBXCBR has an enabling and blocking functionality for interlocking and synchrocheck purposes.

Circuit breaker control CBXCBR

Normally, the CB closing is enabled (that is, CLOSE_ENAD signal is TRUE) by activating both ENA_CLOSE and SYNC_OK inputs. Typically, the ENA_CLOSE comes from the interlocking, and SYNC_OK comes from the synchronism and energizing check. The input SYNC_ITL_BYP can be used for bypassing this control. The SYNC_ITL_BYP input can be used to activate CLOSE_ENAD discarding the ENA_CLOSE and SYNC_OK input states. However, the BLK_CLOSE input always blocks the CLOSE_ENAD output.

The CB opening (OPEN_ENAD) logic is the same as CB closing logic, except that SYNC_OK is used only in closing. The SYNC_ITL_BYP input is used in both CLOSE_ENAD and OPEN_ENAD logics.

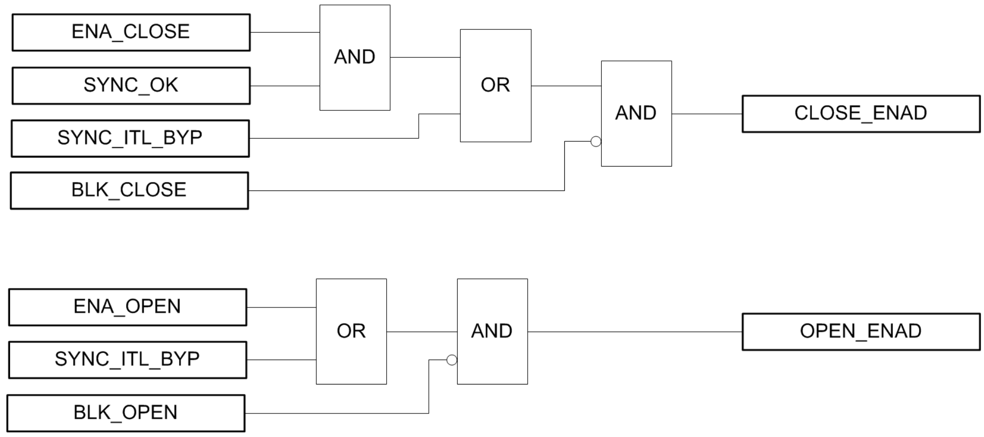


Figure 185: Enabling and blocking logic for CLOSE_ENAD and OPEN_ENAD signals

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, CBXCBR generates an error message.

When close command is given from communication, via LHMI or activating the `AU_CLOSE` input, it is carried out (the `EXE_CL` output) only if `CLOSE_ENAD` is TRUE.

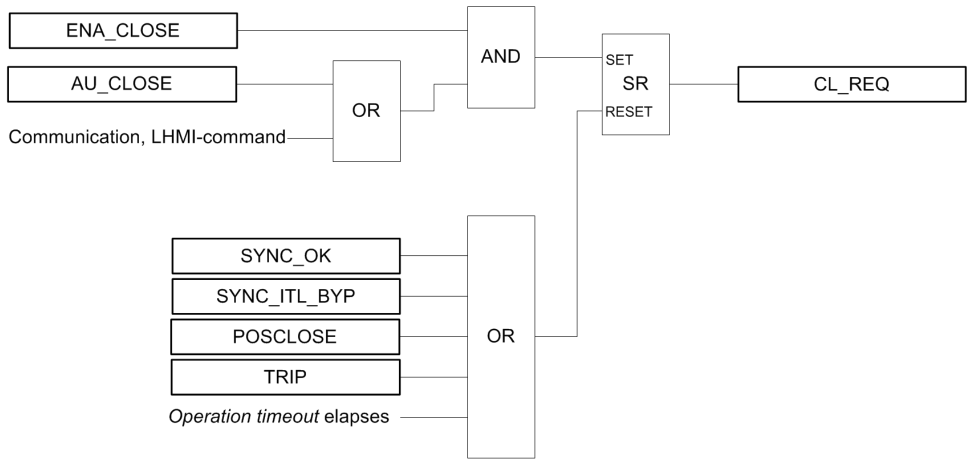


Figure 186: Condition for enabling the close request (CL_REQ) for CBXCBR

When the open command is given from communication, via LHMI or activating the `AU_OPEN` input, it is processed only if `OPEN_ENAD` is TRUE. `OP_REQ` output is also available.

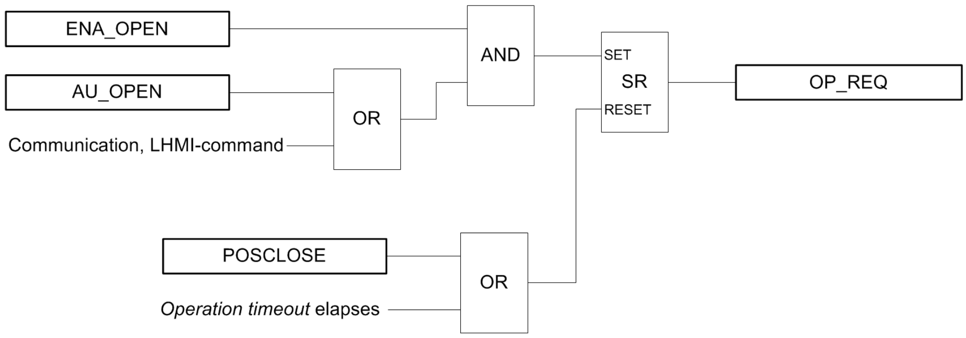


Figure 187: Condition for enabling the open request (OP_REQ) for CBXCBR

OPEN and CLOSE outputs

The EXE_OP output is activated when the open command is given (AU_OPEN, via communication or from LHMI) and OPEN_ENAD signal is TRUE. In addition, the protection trip commands can be routed through the CBXCBR function by using the TRIP input. When the TRIP input is TRUE, the EXE_OP output is activated immediately and bypassing all enabling or blocking conditions.

The EXE_CL output is activated when the close command is given (AU_CLOSE, via communication or from LHMI) and CLOSE_ENAD signal is TRUE. When the TRIP input is "TRUE", CB closing is not allowed.

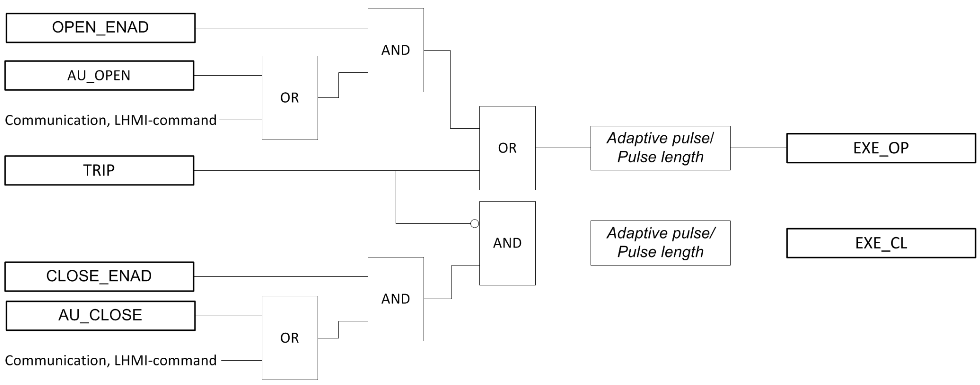


Figure 188: OPEN and CLOSE outputs logic for CBXCBR

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 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.

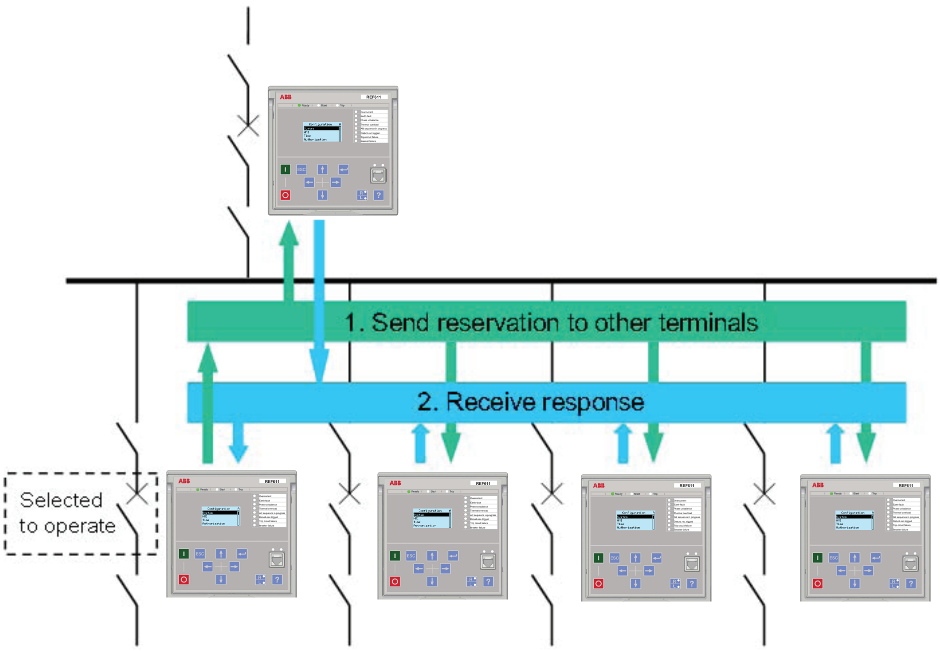


Figure 189: Control procedure in the SBO method

Local/Remote operations

The local/remote selection affects CBXCBR.

- Local: the opening and closing via communication is disabled.
- Remote: the opening and closing via LHMI is disabled.
- `AU_OPEN` and `AU_CLOSE` inputs function regardless of the local/remote selection.

8.1.5 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 CBXCBR. 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.

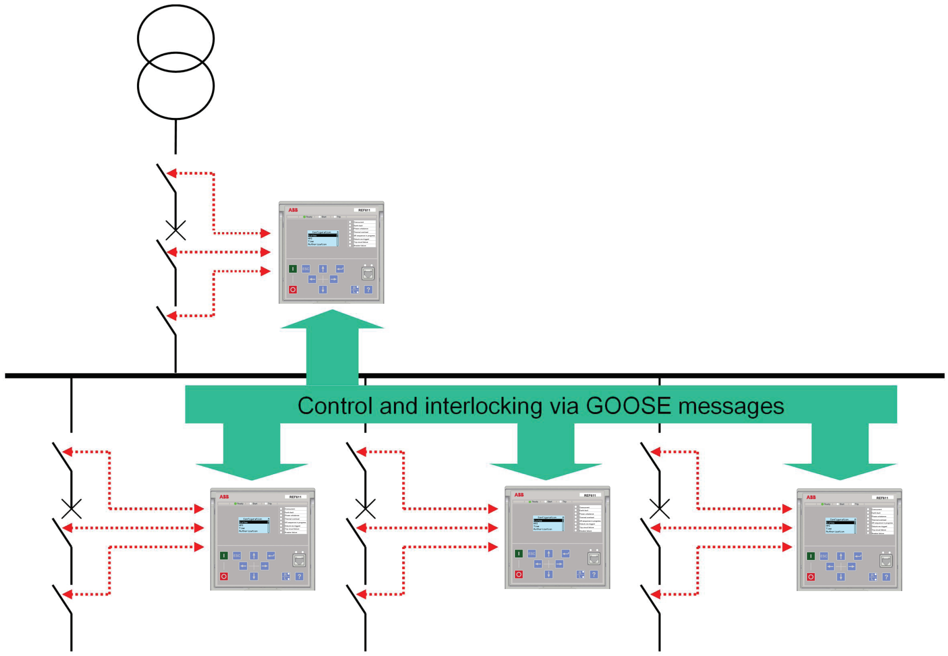


Figure 190: Status indication based interlocking via GOOSE messaging

8.1.6 Signals

Table 458: CBXCBR Input signals

Name	Type	Default	Description
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for close position of apparatus from I/O
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
AU_OPEN	BOOLEAN	0=False	Auxiliary open
AU_CLOSE	BOOLEAN	0=False	Auxiliary close
TRIP	BOOLEAN	0=False	Trip signal
SYNC_OK	BOOLEAN	1=True	Synchronism-check OK
SYNC_ITL_BYP	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE

Table 459: CBXCBR 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
OP_REQ	BOOLEAN	Open request
CL_REQ	BOOLEAN	Close request
OPENPOS	BOOLEAN	Signal for open position of apparatus from I/O
CLOSEPOS	BOOLEAN	Signal for close position of apparatus from I/O
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

8.1.7 Settings

Table 460: CBXCBR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation mode on/off
Select timeout	10000...300000	ms	10000	30000	Select timeout in ms
Pulse length	10...60000	ms	1	200	Open and close pulse length
Control model	0=status-only 1=direct-with-normal-security 4=sbo-with-enhanced-security			4=sbo-with-enhanced-security	Select control model
Operation timeout	10...60000	ms	1	500	Timeout for negative termination
Identification				CBXCBR1 switch position	Control Object identification

Table 461: CBXCBR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation counter	0...10000		1	0	Breaker operation cycles
Adaptive pulse	0=False 1=True			1=True	Stop in right position
Event delay	0...10000	ms	1	200	Event delay of the intermediate position
Vendor				0	External equipment vendor
Serial number				0	External equipment serial number
Model				0	External equipment model

8.1.8 Monitored data

Table 462: CBXCBR Monitored data

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

8.1.9 Technical revision history

Table 463: CBXCBR Technical revision history

Technical revision	Change
B	Interlocking bypass input (ITL_BYPASS) and opening enabled (OPEN_ENAD)/closing enabled (CLOSE_ENAD) outputs added. ITL_BYPASS bypasses the ENA_OPEN and ENA_CLOSE states.
C	Internal improvement.
D	Added inputs TRIP and SYNC_OK. Renamed input ITL_BYPASS to SYNC_ITL_BYP. Added outputs CL_REQ and OP_REQ. Outputs OPENPOS and CLOSEPOS are forced to “FALSE” in case status is Faulty (11).

8.2 Autoreclosing DARREC

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Autoreclosing	DARREC	O -> I	79

8.2.2 Function block

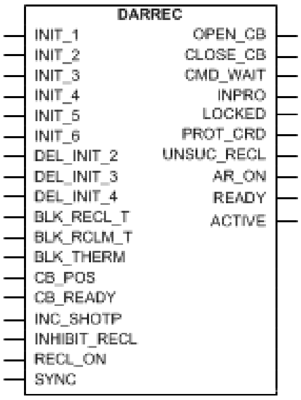


Figure 191: Function block

8.2.3 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 DARREC 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 starting of the protection function, the autoreclosing function can execute the final trip of the circuit breaker in a short operate time, provided that the fault still persists when the last selected reclosing has been carried out.

8.2.3.1 Protection signal definition

The *Control line* setting defines which of the initiation signals are protection start 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 464: 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 earth-fault).

8.2.3.2 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.

8.2.3.3 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.

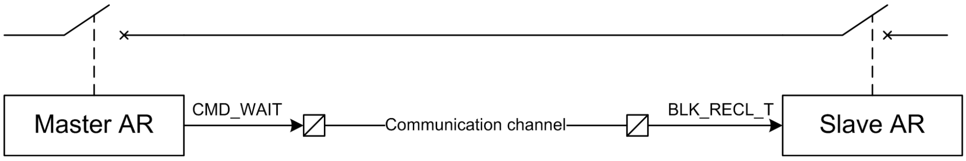


Figure 192: Master and slave scheme

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.

8.2.3.4 Thermal overload blocking

An alarm or start signal from the thermal overload protection (T1PTTR) 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 Thm 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.

8.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off". Setting *Operation* to "Off" resets non-volatile counters.

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: “On”, “External Ctl” and ”Off”. The setting value “On” enables the reclosing operation and “Off” disables it. When the setting value “External Ctl” is selected, the reclosing operation is controlled with the RECL_ON input. AR_ON is activated when reclosing operation is enabled.

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

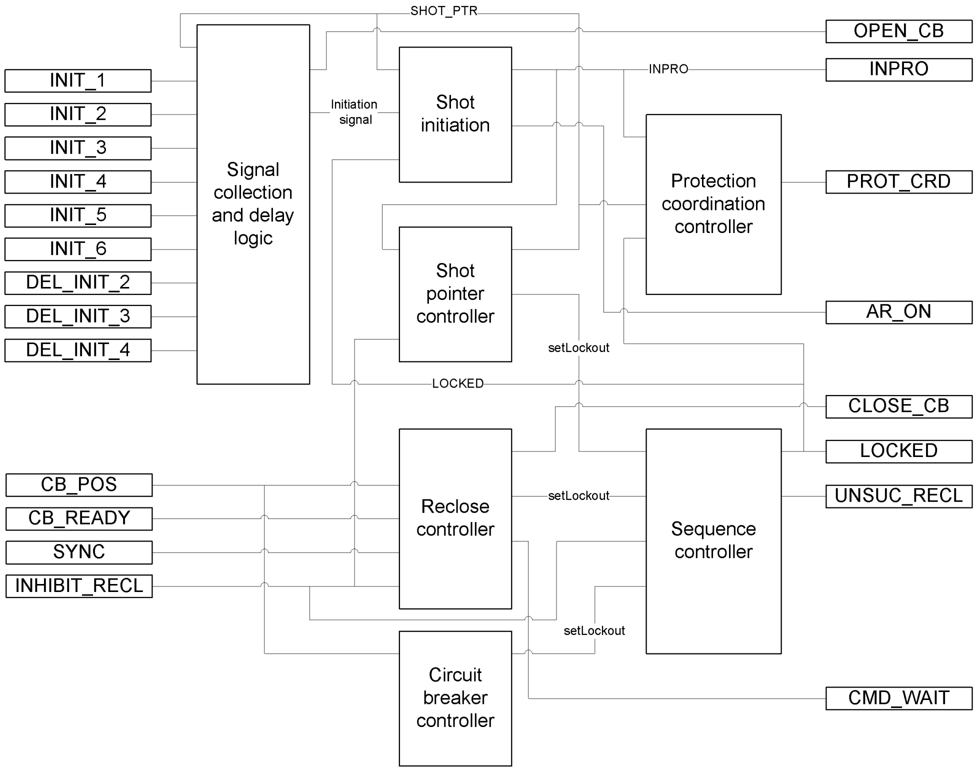


Figure 193: Functional module diagram

8.2.4.1 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, starting the protection stage is also used for the shot initiation. This is the only time when the DEL_INIT inputs are used.

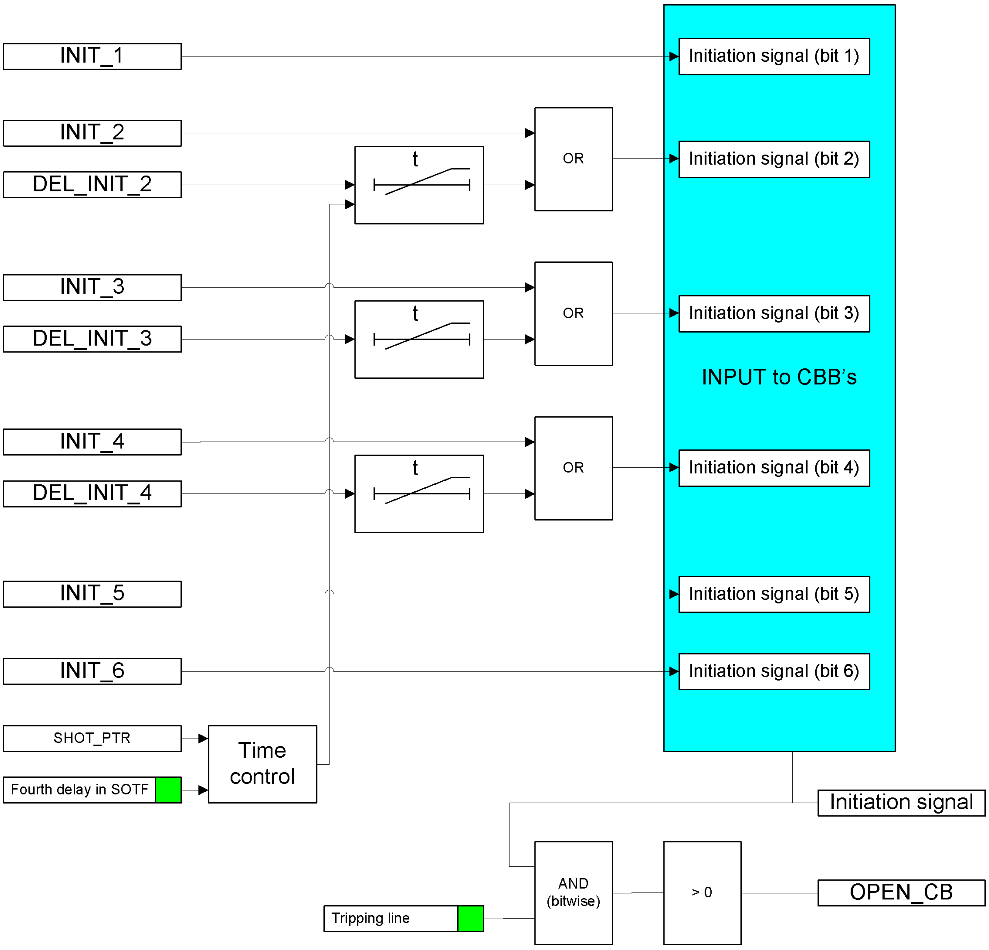


Figure 194: Schematic diagram of delayed initiation input signals

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 start 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.

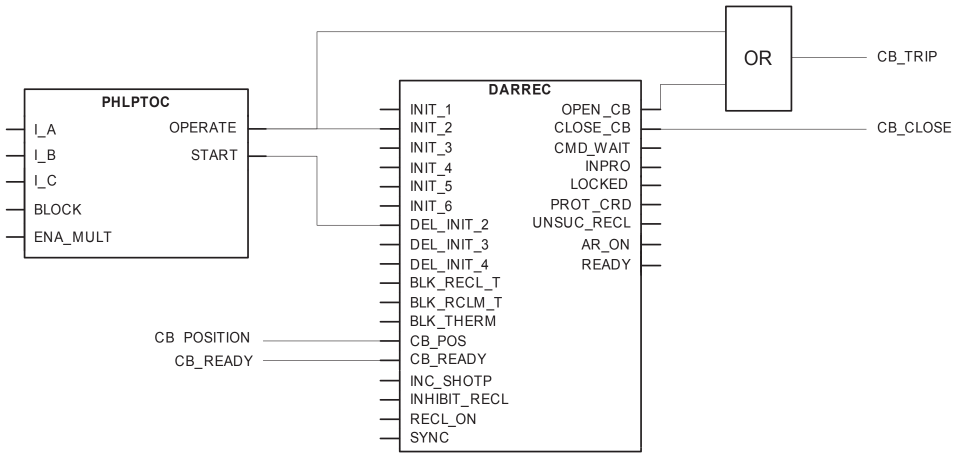


Figure 195: Autoreclosing configuration example

Delayed `DEL_INIT_2...4` signals are used only when the autoreclosing shot is initiated with the start signal of a protection stage. After a start 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 start 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 started.

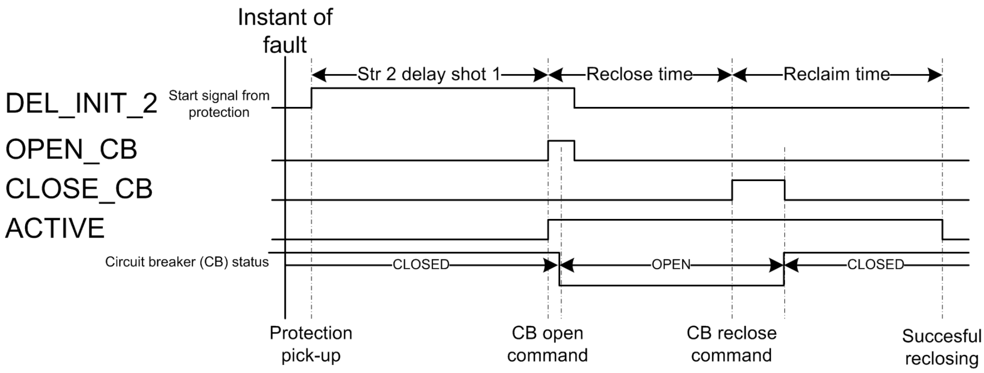


Figure 196: Signal scheme of autoreclosing operation initiated with protection start signal

The autoreclosing shot is initiated with a start signal of the protection function after the start delay time has elapsed. The autoreclosing starts when the *Str 2 delay shot 1* setting elapses.

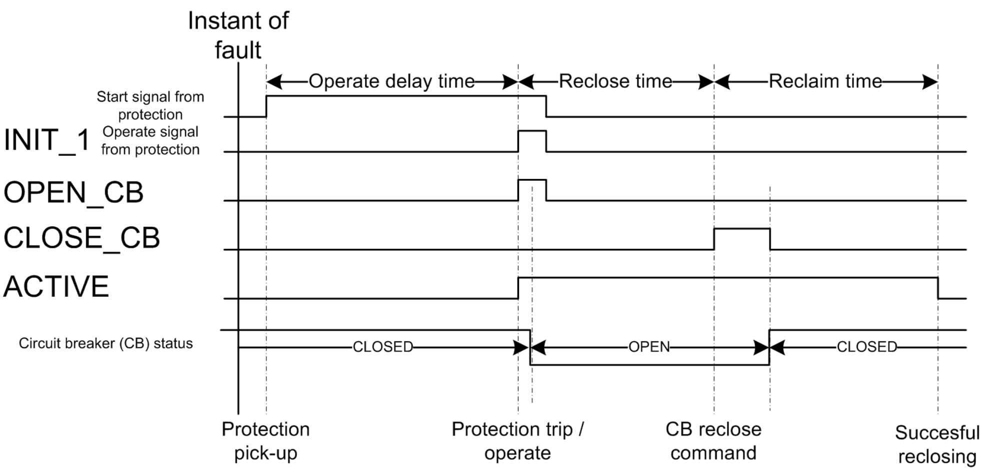


Figure 197: Signal scheme of autoreclosing operation initiated with protection operate signal

The autoreclosing shot is initiated with a trip signal of the protection function. The autoreclosing starts when the protection operate delay time elapses.

Normally, all trip and start signals are used to initiate an autoreclosing shot and trip the circuit breaker. `ACTIVE` output indicates reclosing sequence in progress. 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.

8.2.4.2 Shot initiation

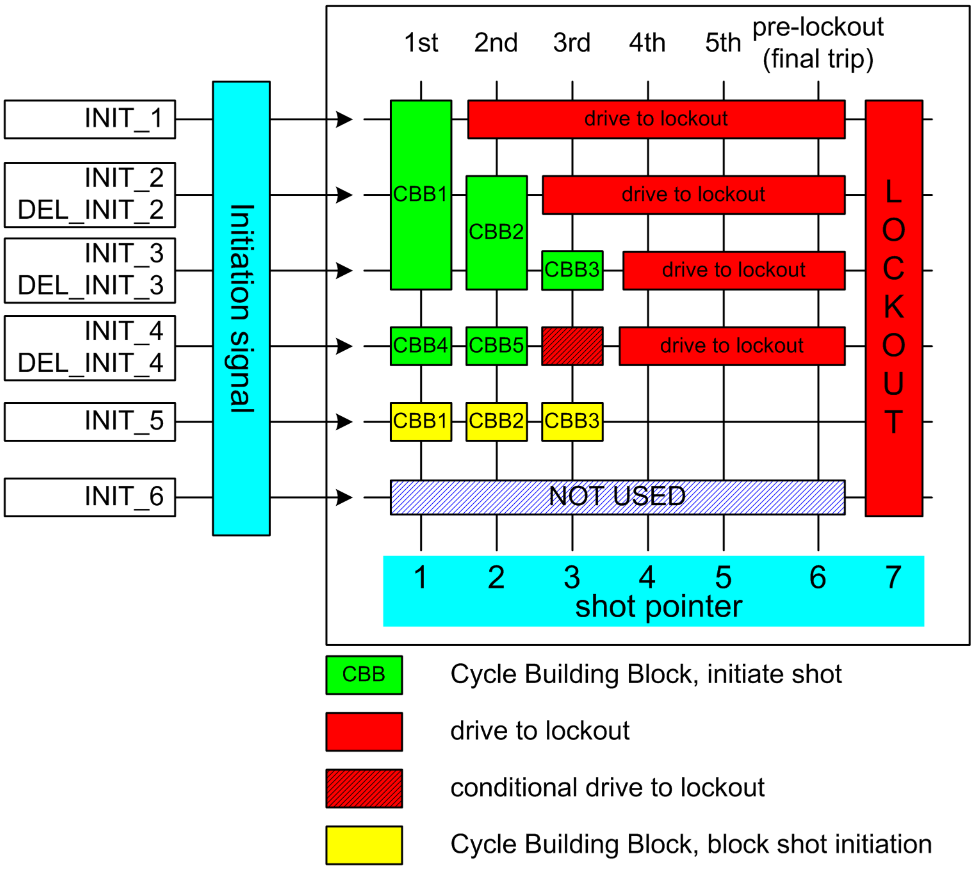


Figure 198: Example of an autoreclosing program with a reclose scheme matrix

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: 111000 = 7)
- *Blk signals CBB1* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB1* = 1

CBB2 settings are:

- *Second reclose time* = 10s
- *Init signals CBB2* = 6 (the second and third bits: 011000 = 6)
- *Blk signals CBB2* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB2* = 2

CBB3 settings are:

- *Third reclose time* = 30s
- *Init signals CBB3* = 4 (the third bit: 001000 = 4)
- *Blk signals CBB3* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB3* = 3

CBB4 settings are:

- *Fourth reclose time* = 0.5s
- *Init signals CBB4* = 8 (the fourth bit: 000100 = 8)
- *Blk signals CBB4* = 0 (no blocking signals related to this CBB)
- *Shot number CBB4* = 1

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

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

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

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

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

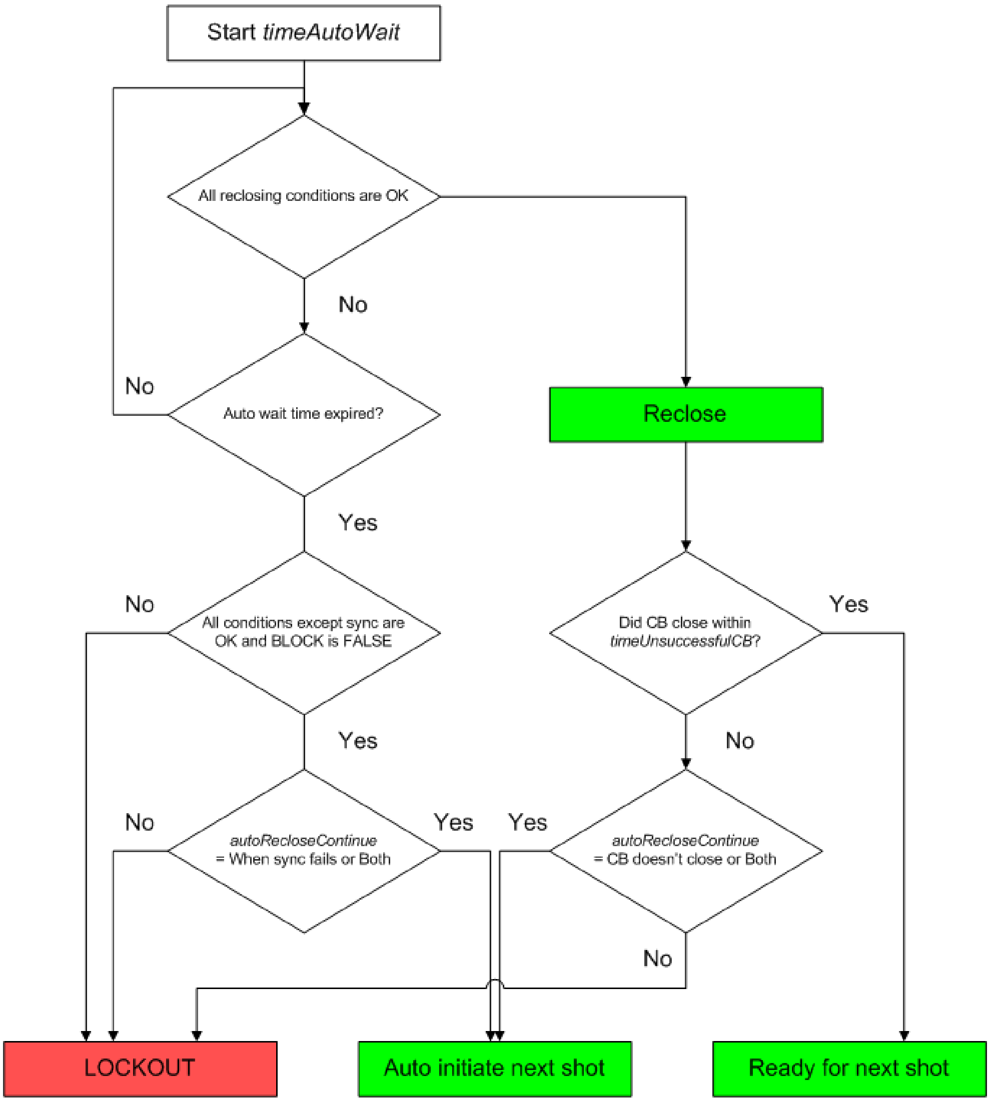


Figure 199: Logic diagram of auto-initiation sequence detection

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.

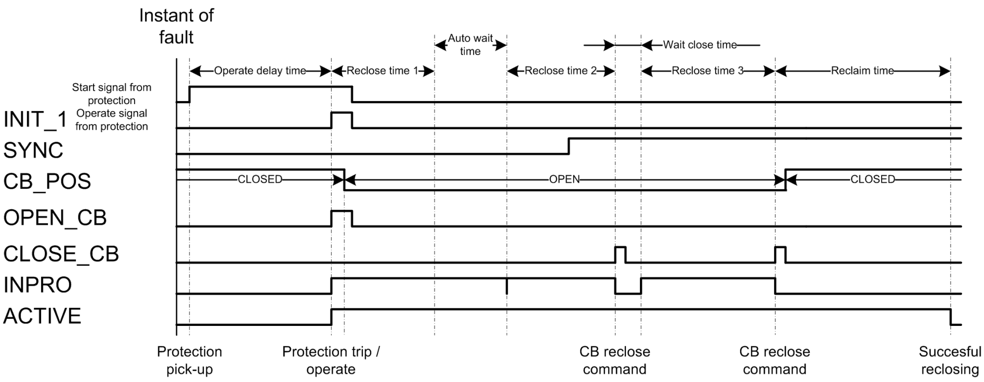


Figure 200: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

8.2.4.3 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.

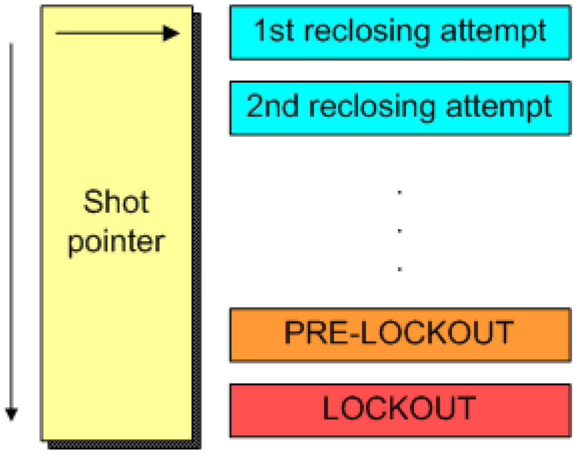


Figure 201: Shot pointer function

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.

8.2.4.4 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. This is indicated by active READY output.

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.

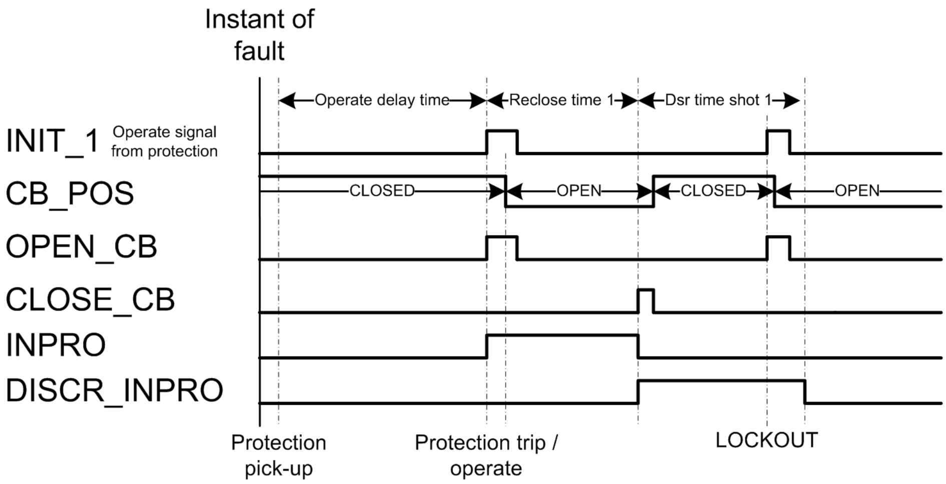


Figure 202: Initiation during discrimination time - AR function goes to lockout

The discrimination time starts when the close command CLOSE_CB has been given. If a start 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.

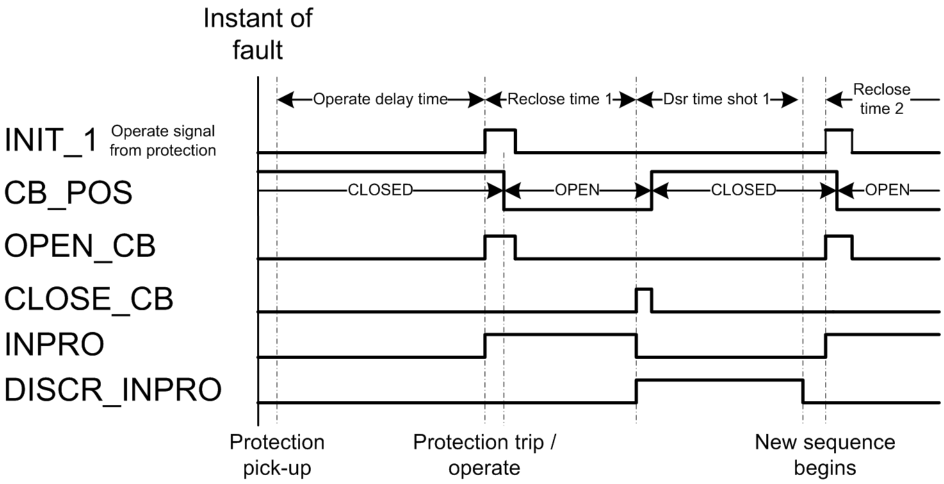


Figure 203: Initiation after elapsed discrimination time - new shot begins

8.2.4.5 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 *RecRs* parameter. The same functionality can also be found in the Clear menu (DARREC1 reset).
- 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 *RecRs* 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.

8.2.4.6 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 PHLPTOC and PHIPTOC are used. PHIPTOC is given an instantaneous characteristic and PHLPTOC is given a time delay.

The `PROT_CRD` output is activated, if the `SHOT_PTR` value is the same or 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

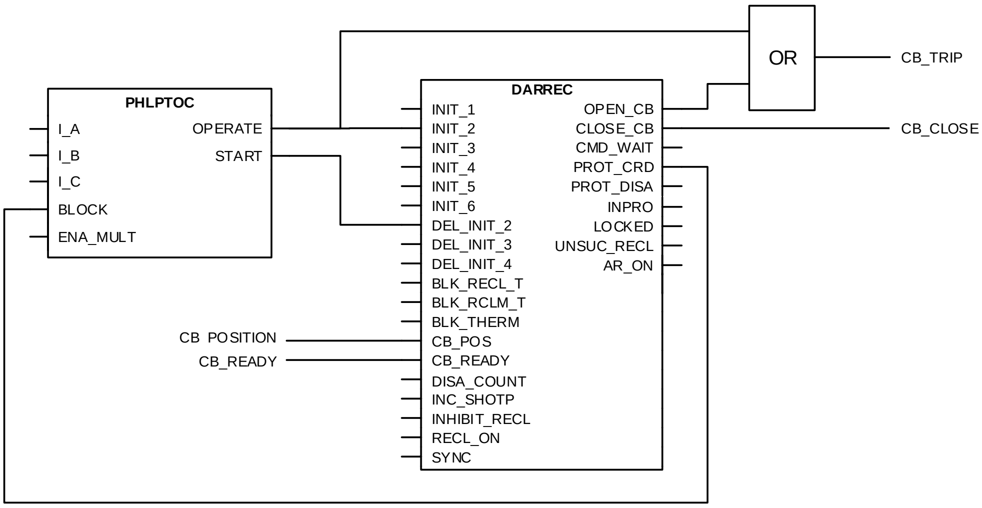


Figure 204: Configuration example of using the `PROT_CRD` output for protection blocking

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

8.2.4.7 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 earthing 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.

8.2.5 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 *CntRs* parameter.The same functionality can also be found in the clear menu (DARREC1 counters).

8.2.6 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 DARREC autoreclose function the implementing method of autoreclose sequences is patented by ABB

Table 465: Important definitions related to auto-reclosing

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 earthing 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.

8.2.6.1 Shot initiation

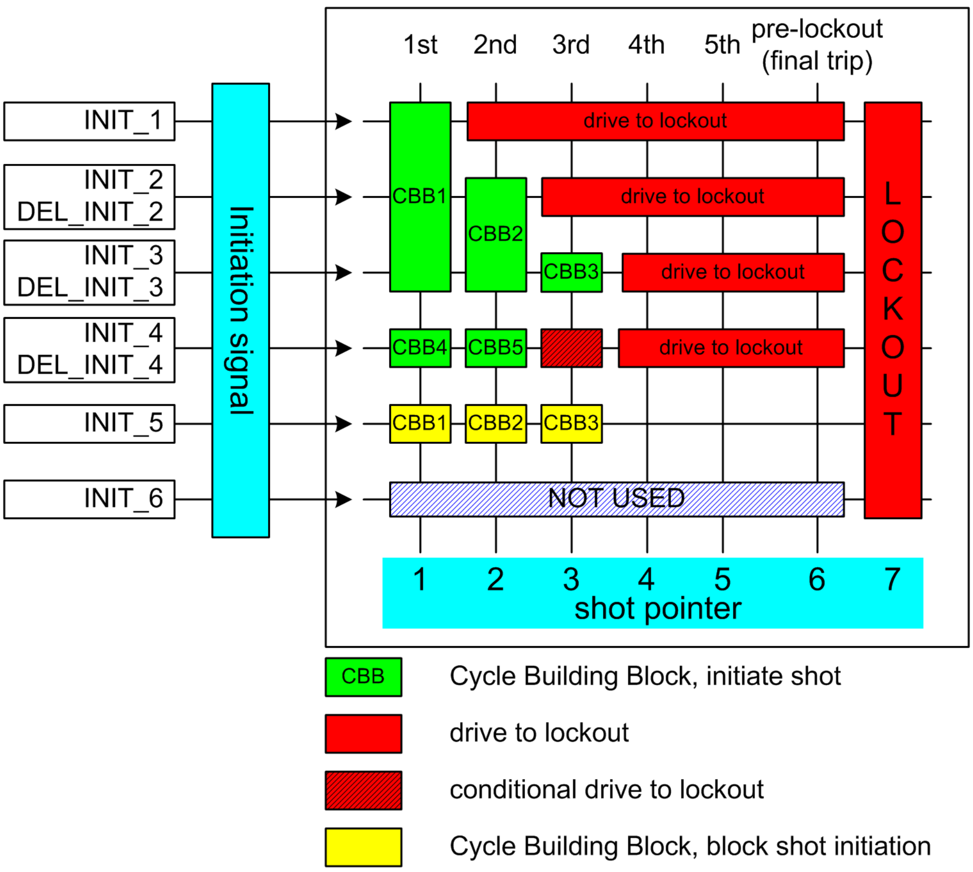


Figure 205: Example of an autoreclosing program with a reclose scheme matrix

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: 111000 = 7)
- *Blk signals CBB1* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB1* = 1

CBB2 settings are:

- *Second reclose time* = 10s
- *Init signals CBB2* = 6 (the second and third bits: 011000 = 6)
- *Blk signals CBB2* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB2* = 2

CBB3 settings are:

- *Third reclose time* = 30s
- *Init signals CBB3* = 4 (the third bit: 001000 = 4)
- *Blk signals CBB3* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB3* = 3

CBB4 settings are:

- *Fourth reclose time* = 0.5s
- *Init signals CBB4* = 8 (the fourth bit: 000100 = 8)
- *Blk signals CBB4* = 0 (no blocking signals related to this CBB)
- *Shot number CBB4* = 1

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

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

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

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

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

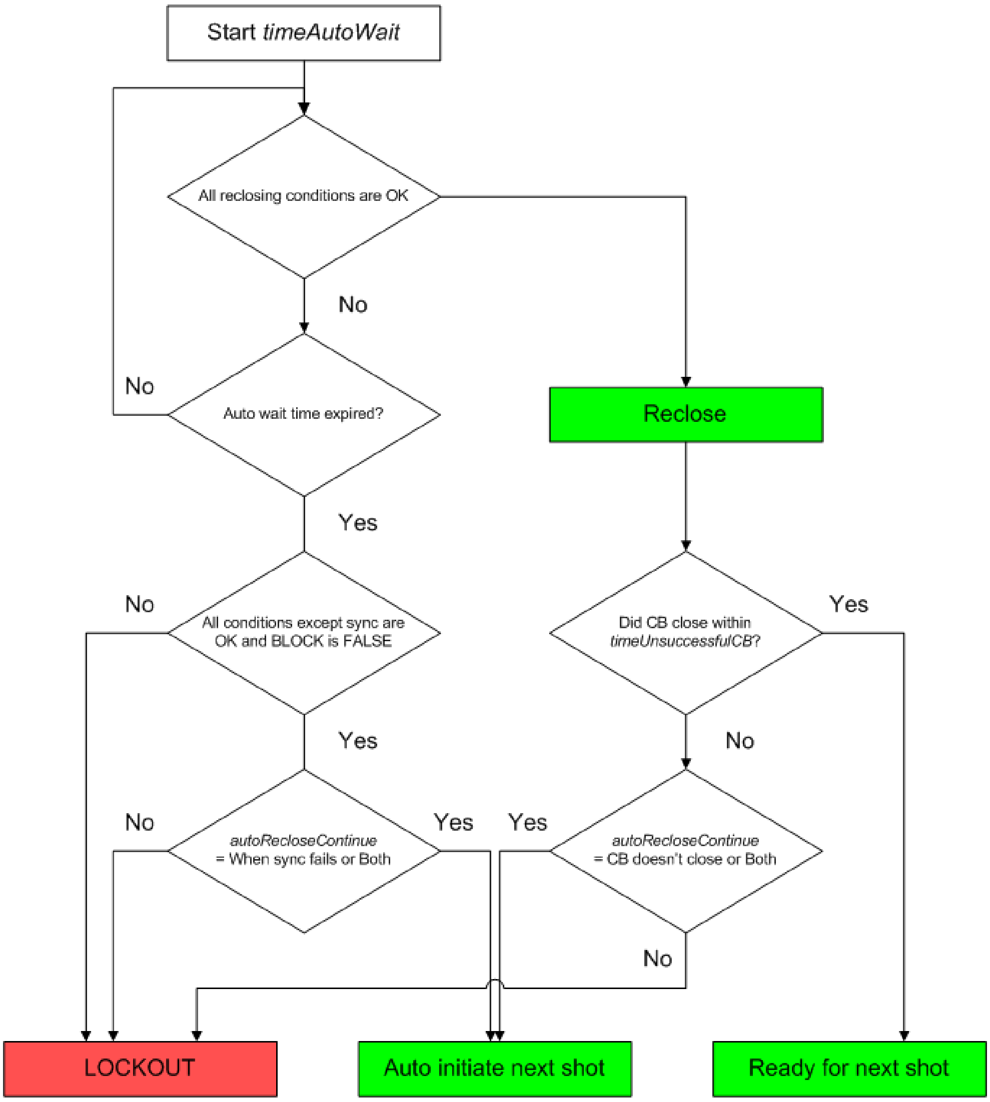


Figure 206: Logic diagram of auto-initiation sequence detection

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.

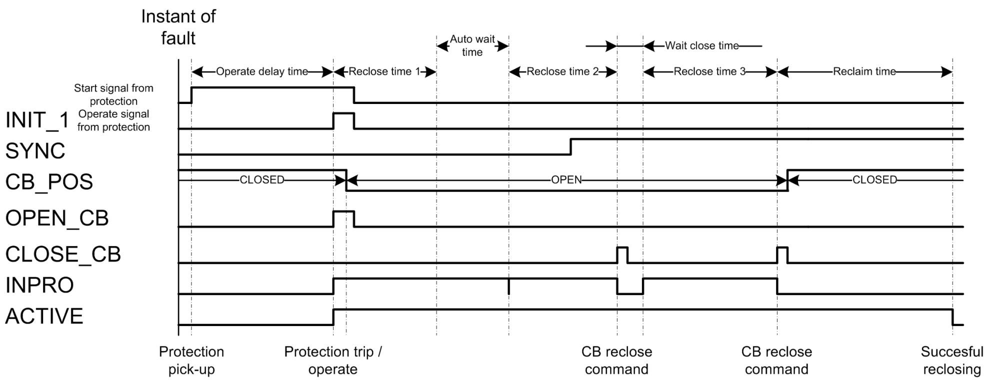


Figure 207: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

8.2.6.2 Sequence

The auto reclose sequence is implemented by using CBBs. The highest possible amount of CBBs is seven. If the user wants to have, for example, a sequence of three shots, 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 auto-reclose 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 auto-reclose 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 auto-reclose function can perform up to five auto-reclose shots or cycles.

8.2.6.3 Configuration examples

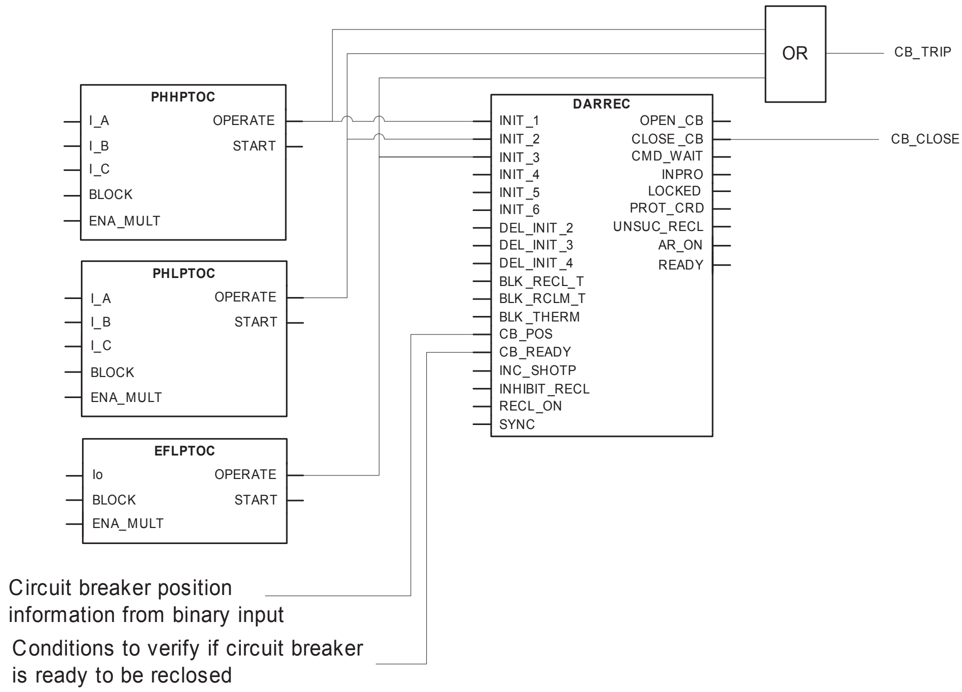


Figure 208: Example connection between protection and autoreclosing functions in protection relay configuration

It is possible to create several sequences for a configuration.

Autoreclose sequences for overcurrent and non-directional earth-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 reclosing time for all protection functions, namely I>>, I> and Io>. The initiation of the shots is done by activating the operating signals of the protection functions.

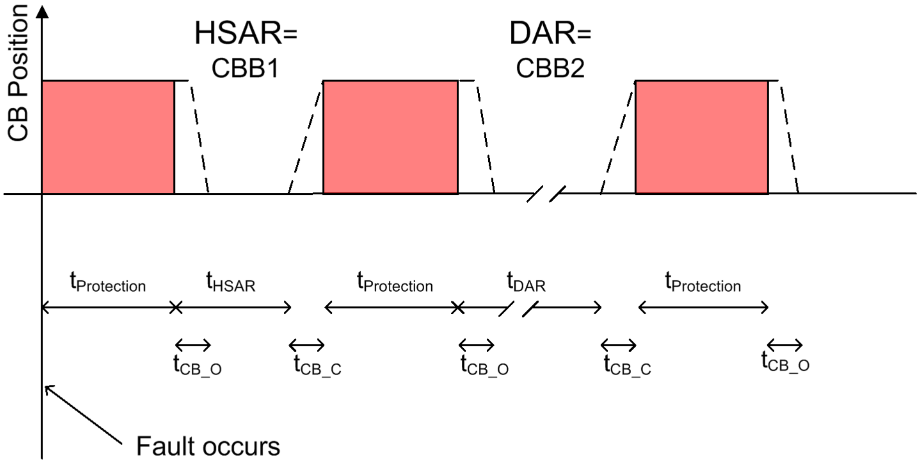


Figure 209: Autoreclosing sequence with two shots

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 466 as follows:

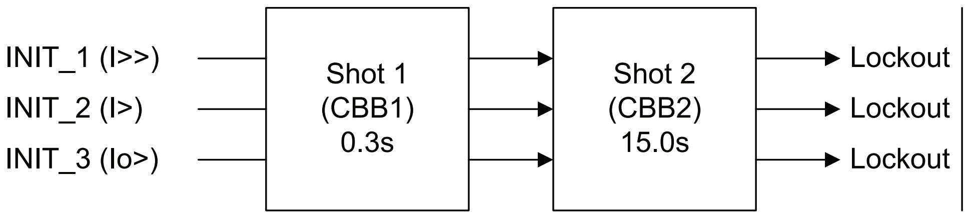


Figure 210: Two shots with three initiation lines

Table 466: 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 (I>>). 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 (I>) and the low stage of the non-directional earth-fault protection (Io>). It has the same reclosing 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 I> or Io>, is set as a delayed autoreclosing and executed after an unsuccessful high-speed autoreclosing of a corresponding sequence.

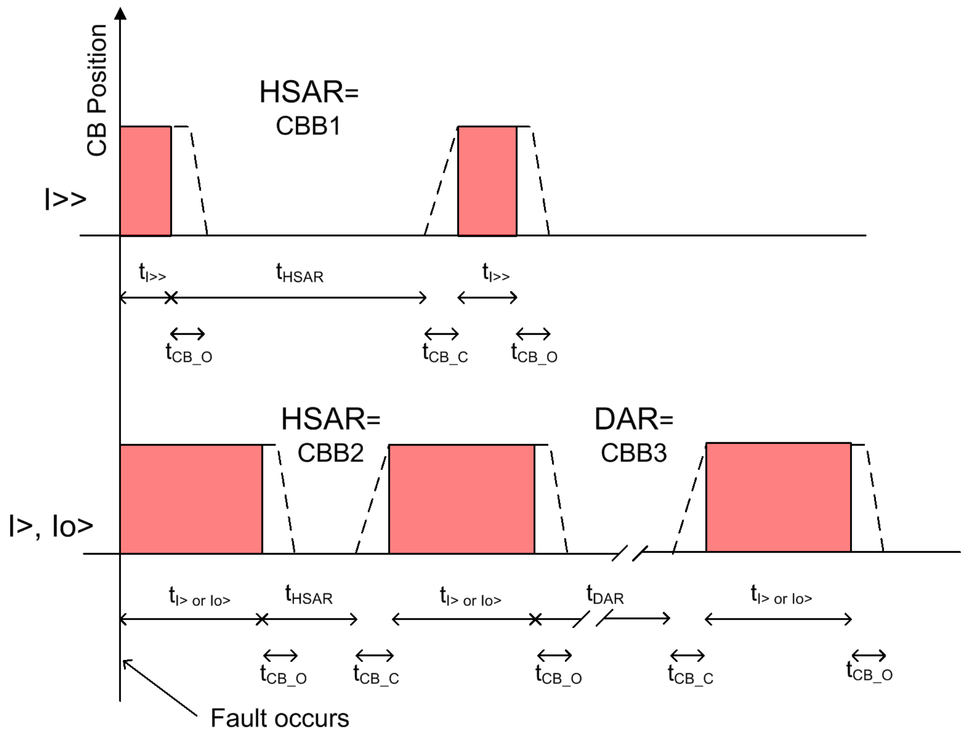


Figure 211: Autoreclosing sequence with two shots with different shot settings according to initiation signal

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 I>> protection stage to clear the fault
$t_{I>}$ or $_{Io>}$	Operating time for the I> or Io> 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.

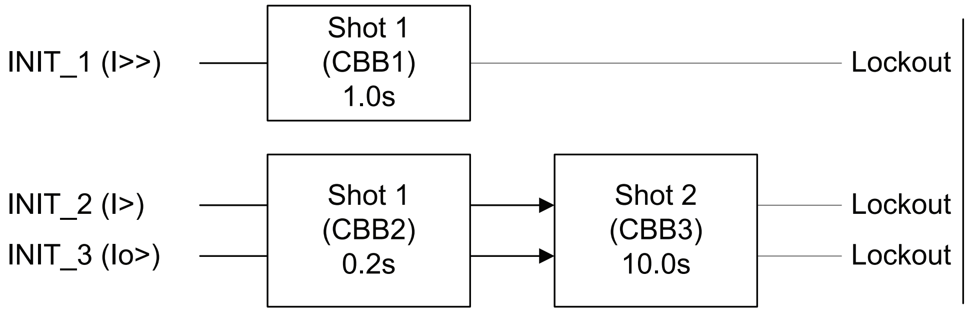


Figure 212: Three shots with three initiation lines

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 467: 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

8.2.6.4 Delayed initiation lines

The auto-reclose function consists of six individual auto-reclose 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 auto-reclosing point of view, it does not matter whether `INIT_x` or `DEL_INIT_x` line is used for shot initiation or blocking.

The auto-reclose 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.

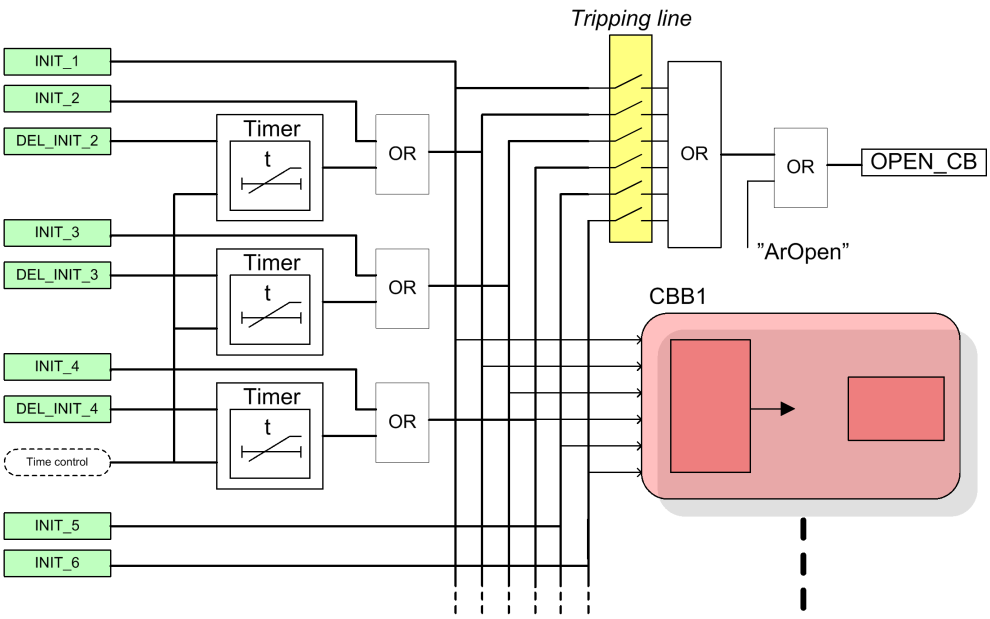


Figure 213: Simplified logic diagram of initiation lines

Each delayed initiation line has four different time settings:

Table 468: 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.

8.2.6.5 Shot initiation from protection start signal

In it simplest, all auto-reclose 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 start signals instead of protection trips for initiating shots shortens the trip times.

Example 1

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

- protection operate 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 starts 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 start 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 starts 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 starts 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 starts again, *Str 2 delay shot 3* elapses before the protection operate time and the final trip follows. The total trip time is the protection start delay + 0.10 seconds + the time it takes to open the circuit breaker.

8.2.6.6 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 start 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 start signal is connected to the `DEL_INIT_2` input.

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

8.2.7 Signals

Table 469: DARREC 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 470: DARREC Output signals

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

8.2.8 Settings

Table 471: DARREC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off/On
Reclosing operation	1=Off 2=External Ctl 3=On			1=Off	Reclosing operation (Off, External Ctl / On)
Close pulse time	10...10000	ms	10	200	CB close pulse time
Reclaim time	100...1800000	ms	100	10000	Reclaim time
Terminal priority	1=None 2=Low (follower) 3=High (master)			1=None	Terminal priority
Synchronisation set	0...127		1	0	Selection for synchronizing requirement for reclosing
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		1	0	Tripping line, defines INIT inputs which cause OPEN_CB activation
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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
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		1	0	Initiation lines for CBB1
Init signals CBB2	0...63		1	0	Initiation lines for CBB2
Init signals CBB3	0...63		1	0	Initiation lines for CBB3
Init signals CBB4	0...63		1	0	Initiation lines for CBB4
Init signals CBB5	0...63		1	0	Initiation lines for CBB5
Init signals CBB6	0...63		1	0	Initiation lines for CBB6
Init signals CBB7	0...63		1	0	Initiation lines for CBB7
Shot number CBB1	0...5		1	0	Shot number for CBB1
Shot number CBB2	0...5		1	0	Shot number for CBB2
Shot number CBB3	0...5		1	0	Shot number for CBB3
Shot number CBB4	0...5		1	0	Shot number for CBB4
Shot number CBB5	0...5		1	0	Shot number for CBB5
Shot number CBB6	0...5		1	0	Shot number for CBB6
Shot number CBB7	0...5		1	0	Shot number for CBB7
Frq Op counter limit	0...250		1	0	Frequent operation counter lockout limit
Frq Op counter time	1...250	min	1	1	Frequent operation counter time
Frq Op recovery time	1...250	min	1	1	Frequent operation counter recovery time
Auto init	0...63		1	0	Defines INIT lines that are activated at auto initiation

Table 472: DARREC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 BLK_RECL_T release
Max trip time	100...10000	ms	100	10000	Maximum wait time for deactivation of protection signals
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
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
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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Protection crd limit	1...5		1	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
Control line	0...63		1	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
Blk signals CBB1	0...63		1	0	Blocking lines for CBB1
Blk signals CBB2	0...63		1	0	Blocking lines for CBB2
Blk signals CBB3	0...63		1	0	Blocking lines for CBB3
Blk signals CBB4	0...63		1	0	Blocking lines for CBB4
Blk signals CBB5	0...63		1	0	Blocking lines for CBB5
Blk signals CBB6	0...63		1	0	Blocking lines for CBB6
Blk signals CBB7	0...63		1	0	Blocking lines 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

8.2.9 Monitored data

Table 473: DARREC 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

Table continues on next page

Name	Type	Values (Range)	Unit	Description
STATUS	Enum	-1=Not defined 1=Ready 2=InProgress 3=Successful 4=WaitingForTrip 5=TripFromProtection 6=FaultDisappeared 7=WaitToComplete 8=CBclosed 9=CycleUnsuccessful 10=Unsuccessful 11=Aborted		AR status signal for IEC61850
INPRO_1	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 1
INPRO_2	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 2
INPRO_3	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 3
INPRO_4	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 4
INPRO_5	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 5
DISCR_INPRO	BOOLEAN	0=False 1=True		Signal indicating that discrimination time is in progress
CUTOUT_INPRO	BOOLEAN	0=False 1=True		Signal indicating that cut-out time is in progress
SUC_RECL	BOOLEAN	0=False 1=True		Indicates a successful reclosing sequence
UNSUC_CB	BOOLEAN	0=False 1=True		Indicates an unsuccessful CB closing
CNT_SHOT1	INT32	0...2147483647		Resetable operation counter, shot 1
CNT_SHOT2	INT32	0...2147483647		Resetable operation counter, shot 2
CNT_SHOT3	INT32	0...2147483647		Resetable operation counter, shot 3
CNT_SHOT4	INT32	0...2147483647		Resetable operation counter, shot 4
CNT_SHOT5	INT32	0...2147483647		Resetable operation counter, shot 5
COUNTER	INT32	0...2147483647		Resetable operation counter, all shots
SHOT_PTR	INT32	1...7		Shot pointer value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
MAN_CB_CL	BOOLEAN	0=False 1=True		Indicates CB manual closing during reclosing sequence
SOTF	BOOLEAN	0=False 1=True		Switch-onto-fault
DARREC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

8.2.10 Technical data

Table 474: DARREC Technical data

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

8.2.11 Technical revision history

Table 475: DARREC Technical revision history

Technical revision	Change
B	The `PROT_DISA` output removed and removed the related settings
C	The default value of the *CB closed Pos status* setting changed from "True" to "False"
D	SHOT_PTR output range 0...7 (earlier 0...6)
E	Monitored data ACTIVE transferred to be ACT visible output. SHOT_PTR output range 1...7.
F	Internal improvement

Section 9 General function block features

9.1 Definite time characteristics

9.1.1 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 `OPERATE` output of the function is activated when the time calculation exceeds the set *Operate 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.

The purpose of the delayed reset is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods, during which the fault current falls below the set start current, including hysteresis. Without the delayed reset function, the operate timer would reset when the current drops off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer can also reset the operate timer.

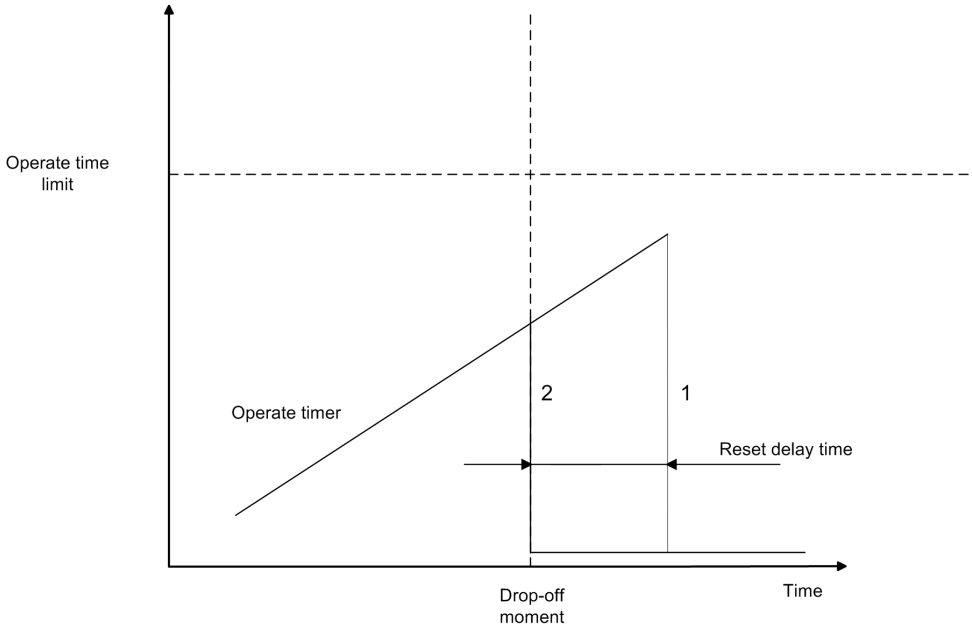


Figure 214: Operation of the counter in drop-off

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.

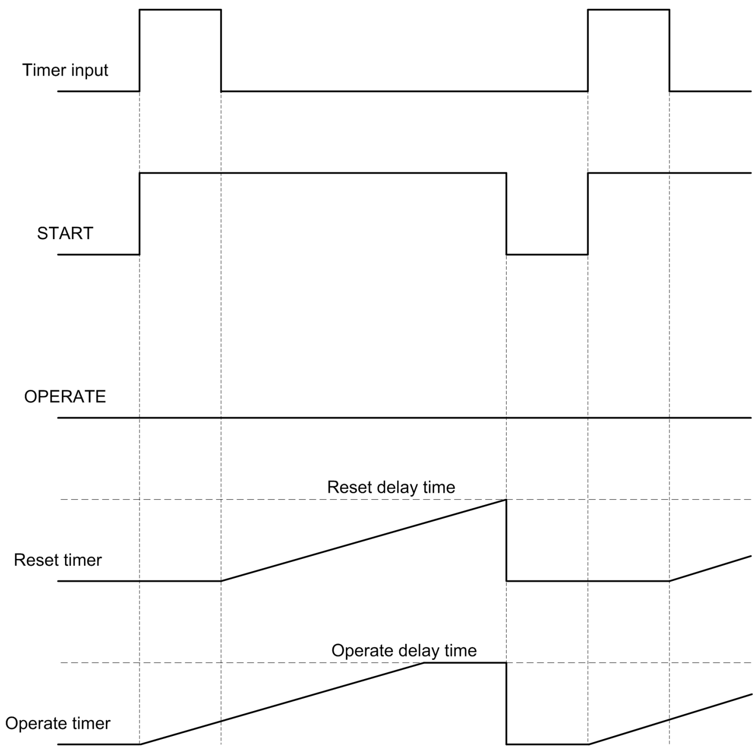


Figure 215: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 215, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Start value*. The input signal is inactive when the current is below the set *Start value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the START output and the operate 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 operate timer is reset. Since this happens before another start occurs, the OPERATE output is not activated.

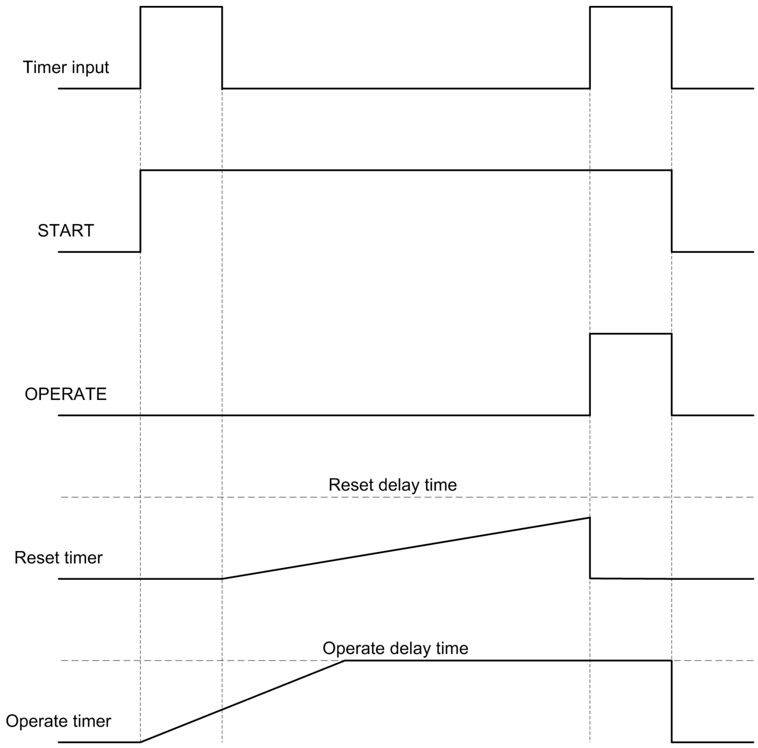


Figure 216: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 216, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Start value*. The input signal is inactive when the current is below the set *Start value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the START output and the operate 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 OPERATE output, since the operate timer already has elapsed.

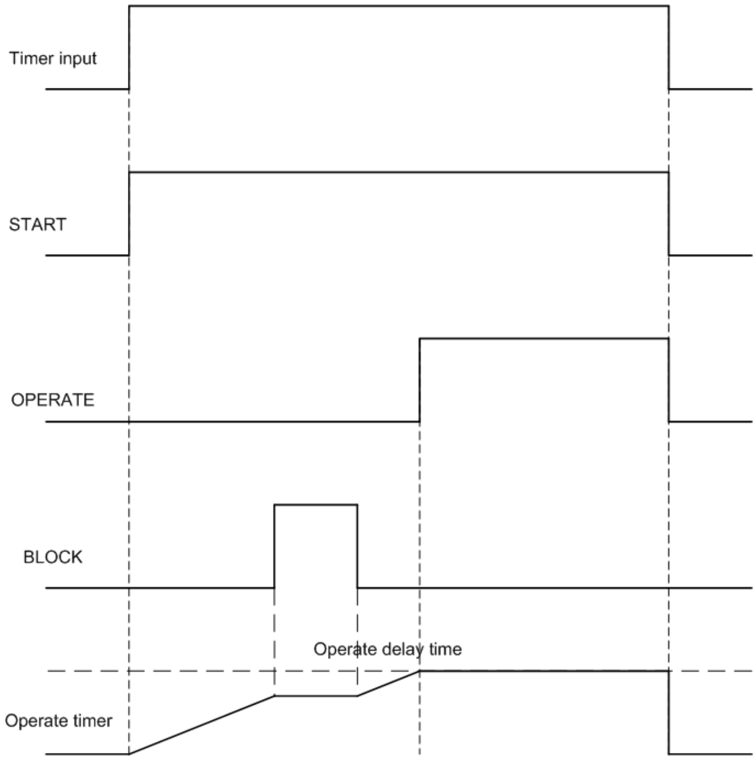


Figure 217: Operating effect of the `BLOCK` *input when the selected blocking mode is "Freeze timer"*

If the `BLOCK` input is activated when the operate timer is running, as described in Figure 217, 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 operate timer is reset in the same way as described in Figure 215, regardless of the `BLOCK` input .

The selected blocking mode is "Freeze timer".

9.2 Current based inverse definite minimum time characteristics

9.2.1 IDMT curves for overcurrent protection

In inverse-time modes, the operation time depends on the momentary value of the current: the higher the current, the faster the operation time. The operation time calculation or integration starts immediately when the current exceeds the set *Start value* and the `START` output is activated.

The OPERATE 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 operate time* setting defines the minimum operating time for the IDMT curve, that is, the operation time is always at least the *Minimum operate time* setting.
- Alternatively, the *IDMT Sat point* is used for giving the leveling-out point as a multiple of the *Start value* setting. (Global setting: **Configuration/System/*IDMT Sat point***). The default parameter value is 50. This setting affects only the overcurrent and earth-fault IDMT timers.

IDMT operation time at currents over 50 x In is not guaranteed.

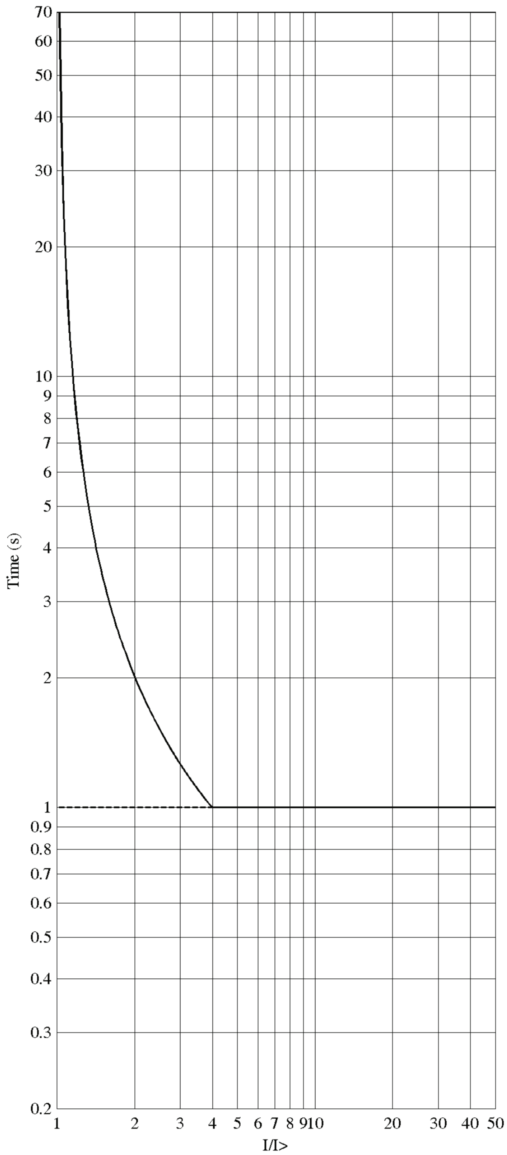


Figure 218: Operation time curve based on the IDMT characteristic leveled out with the Minimum operate time setting is set to 1000 milliseconds (the IDMT Sat point setting is set to maximum).

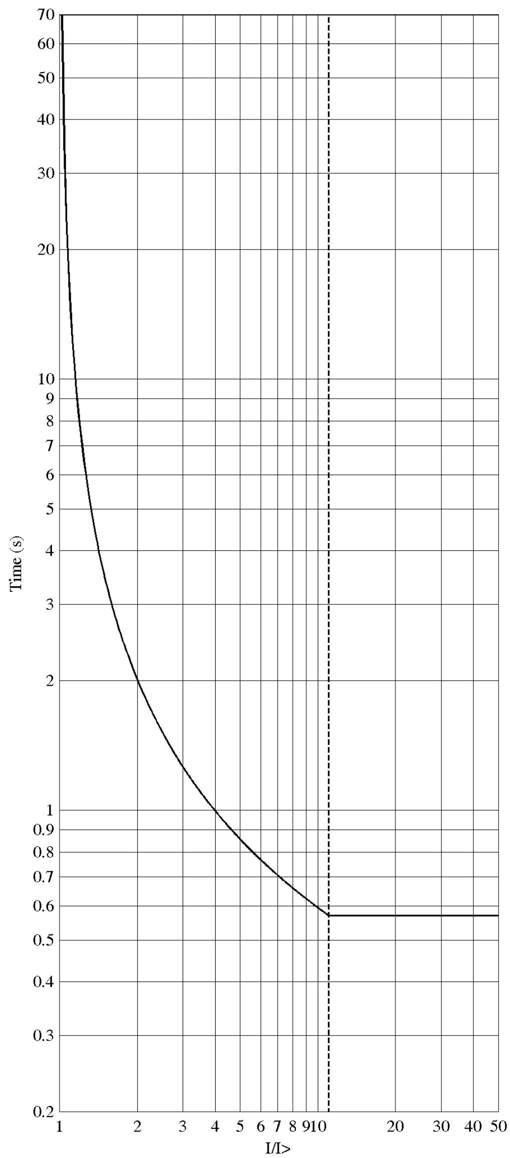


Figure 219: Operation time curve based on the IDMT characteristic leveled out with IDMT Sat point setting value “11” (the Minimum operate time setting is set to minimum).

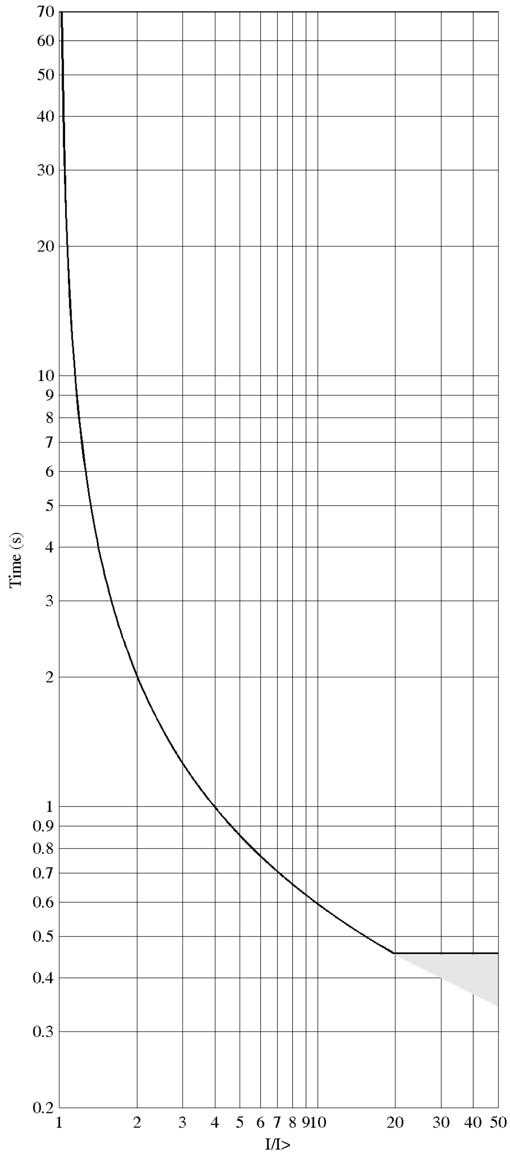


Figure 220: Example of how the inverse time characteristic is leveled out with currents over 50 x In and the Setting Start value setting "2.5 x In". (the IDMT Sat point setting is set to maximum and the Minimum operate time setting is set to minimum).

The grey zone in Figure 220 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>.

9.2.1.1 Standard inverse-time characteristics

For inverse-time operation, both IEC and ANSI/IEEE standardized inverse-time characteristics are supported.

The operate 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 40)

t[s]	Operate time in seconds
I	measured current
I>	set *Start value*
k	set *Time multiplier*

Table 476: 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

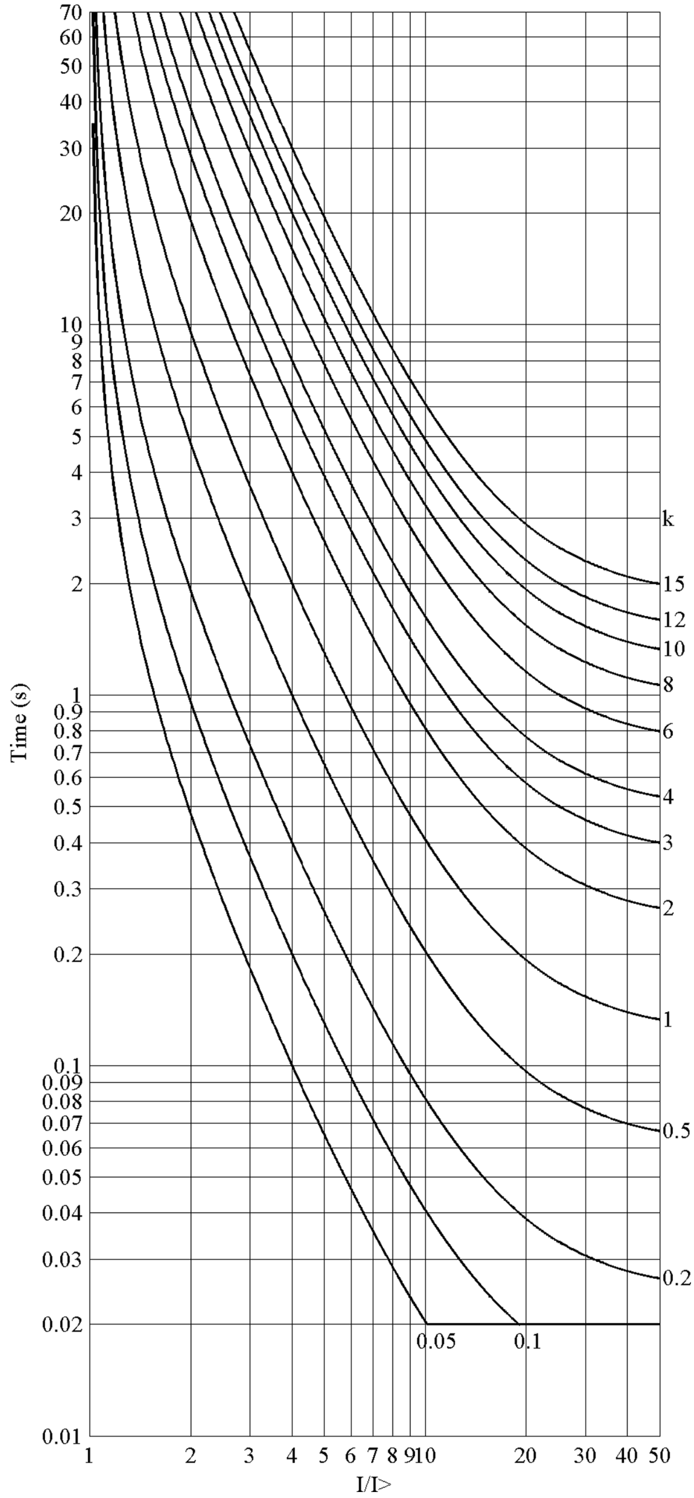


Figure 221: ANSI extremely inverse-time characteristics

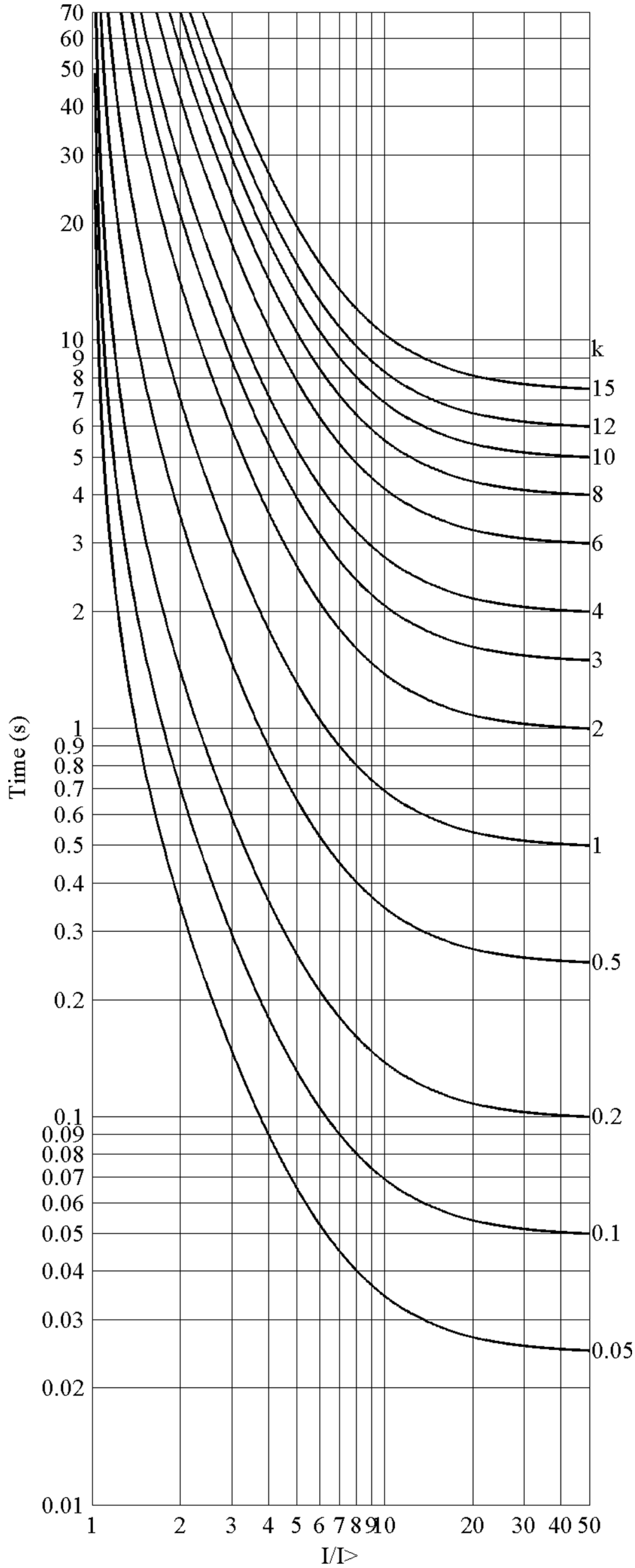


Figure 222: ANSI very inverse-time characteristics

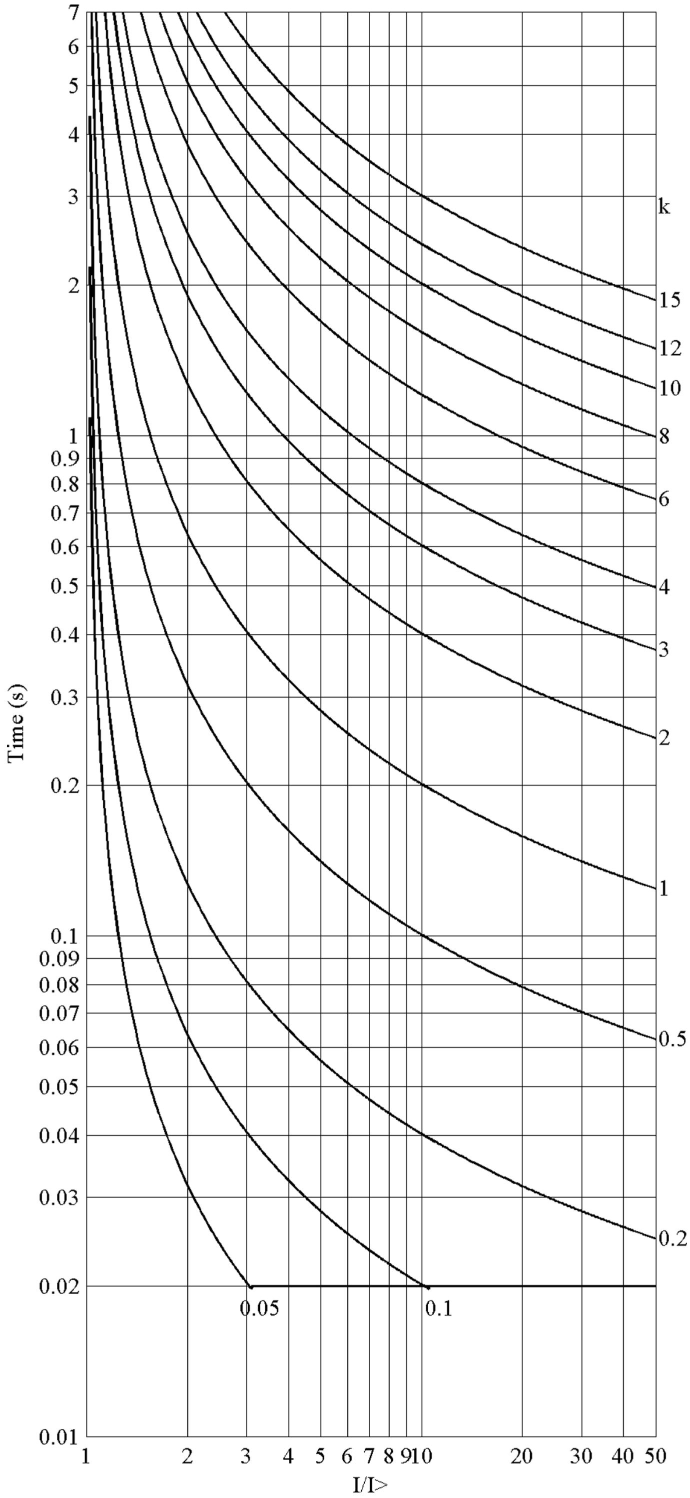


Figure 223: ANSI normal inverse-time characteristics

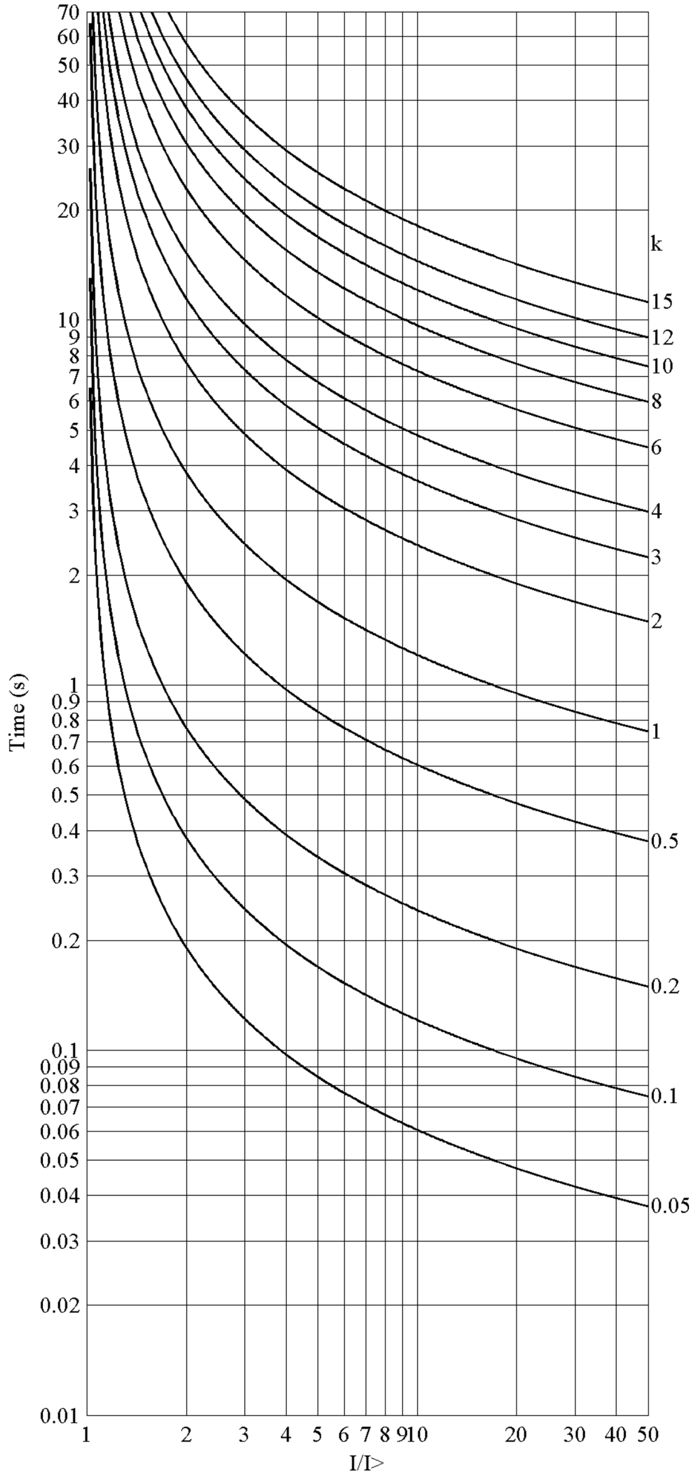


Figure 224: ANSI moderately inverse-time characteristics

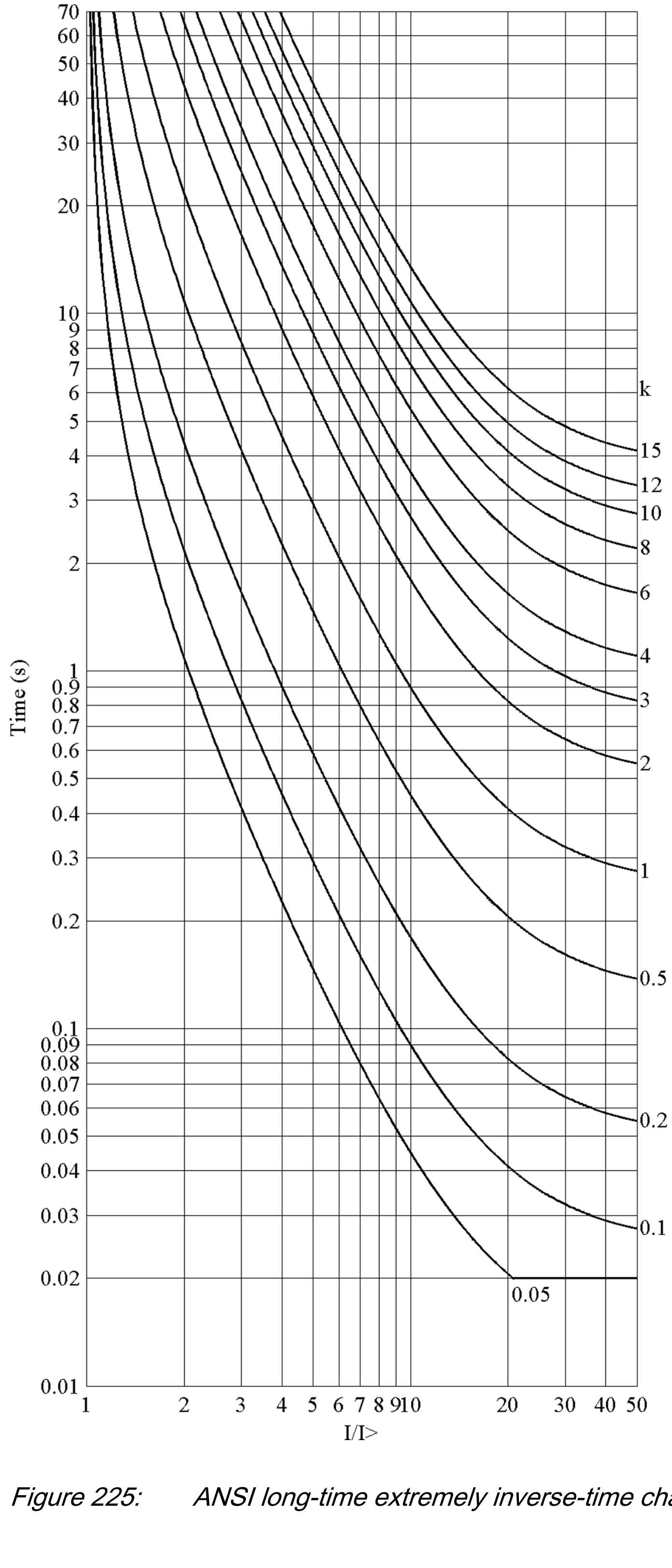


Figure 225: ANSI long-time extremely inverse-time characteristics

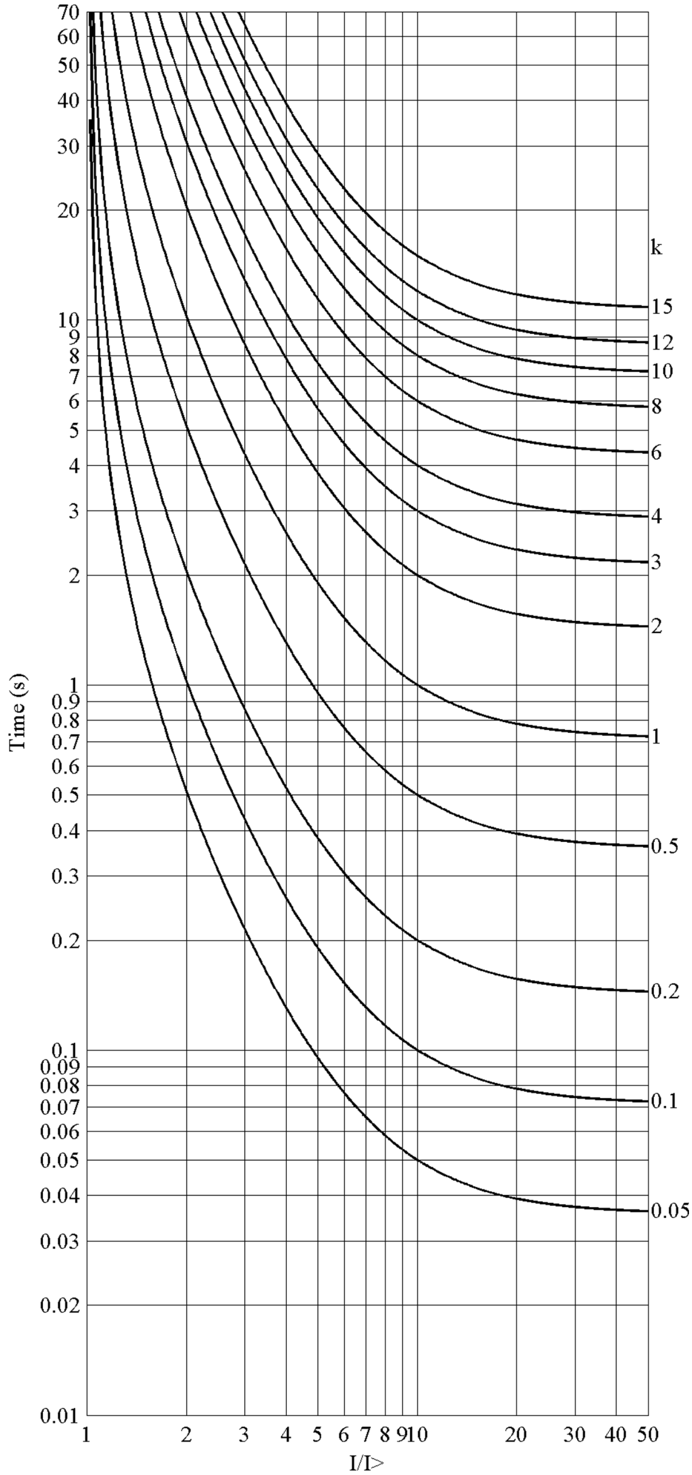


Figure 226: ANSI long-time very inverse-time characteristics

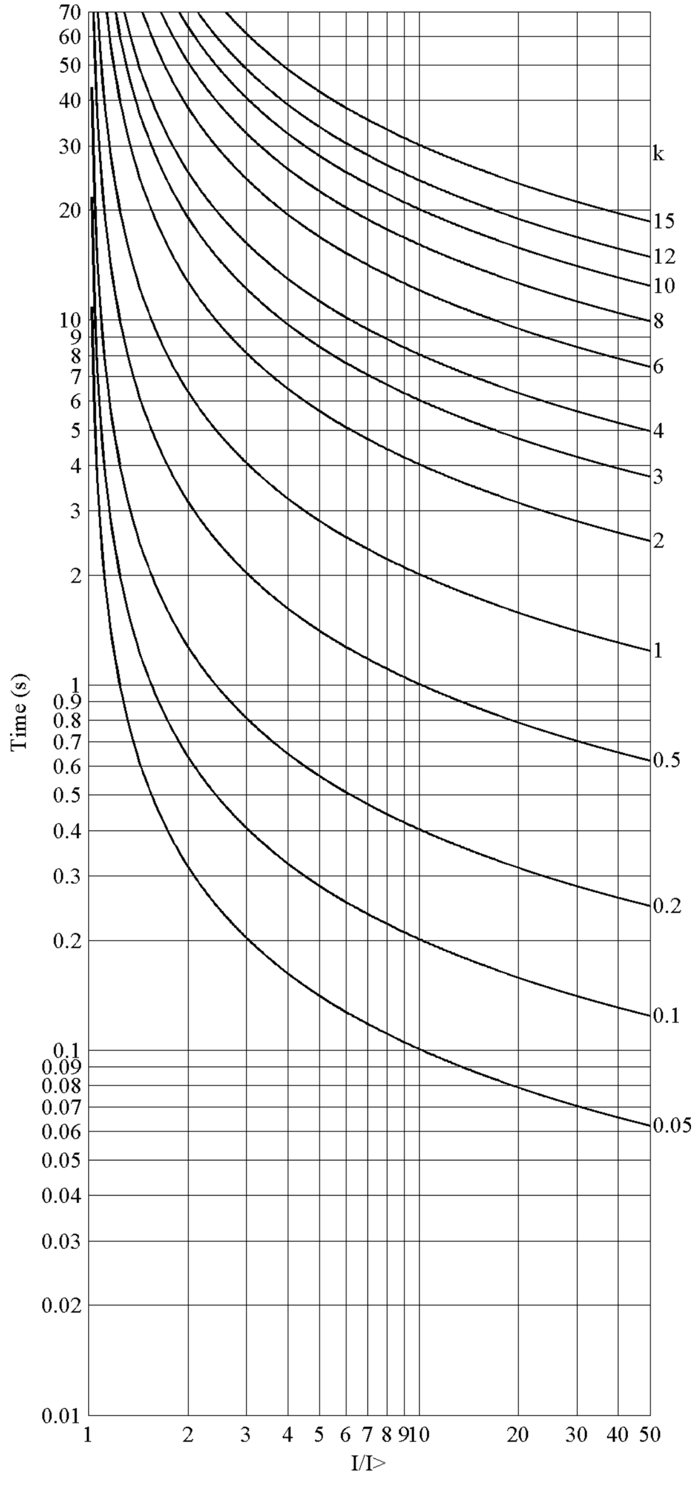


Figure 227: ANSI long-time inverse-time characteristics

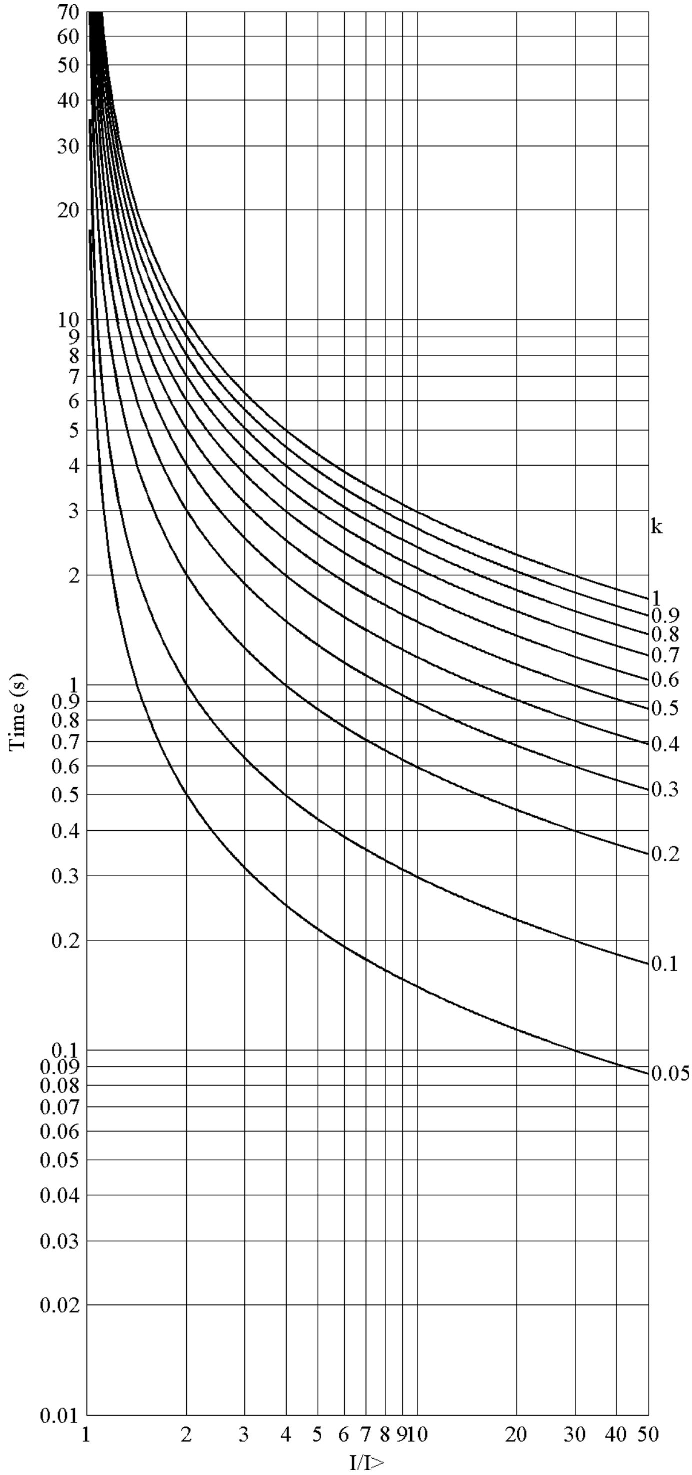


Figure 228: IEC normal inverse-time characteristics

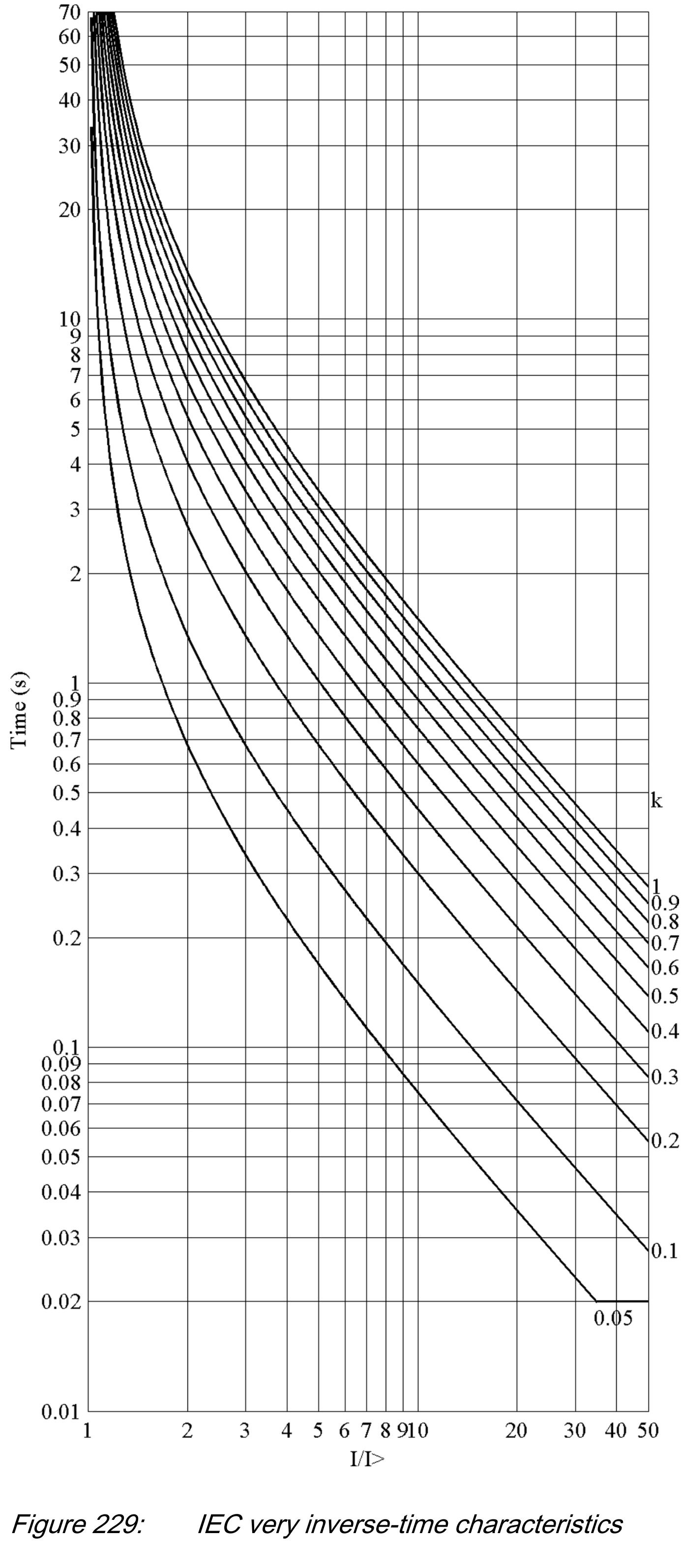


Figure 229: IEC very inverse-time characteristics

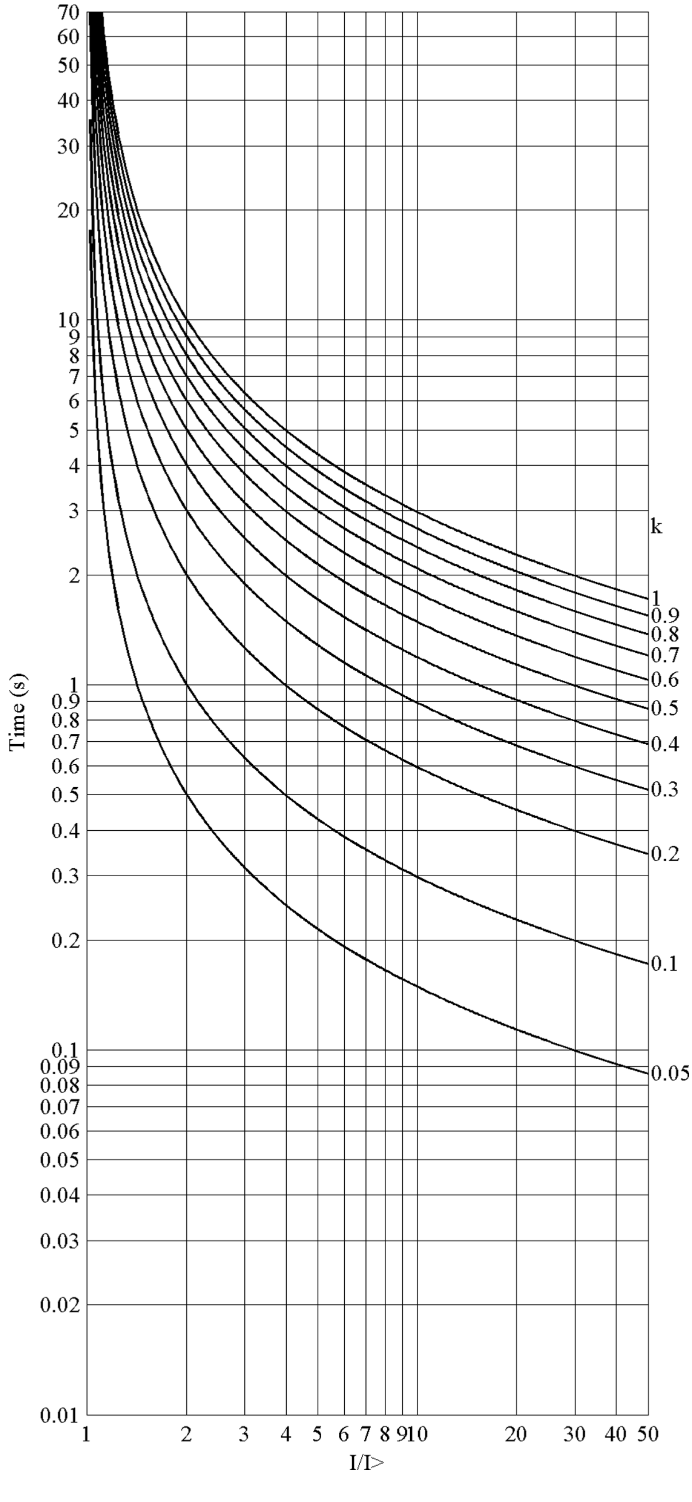


Figure 230: IEC inverse-time characteristics

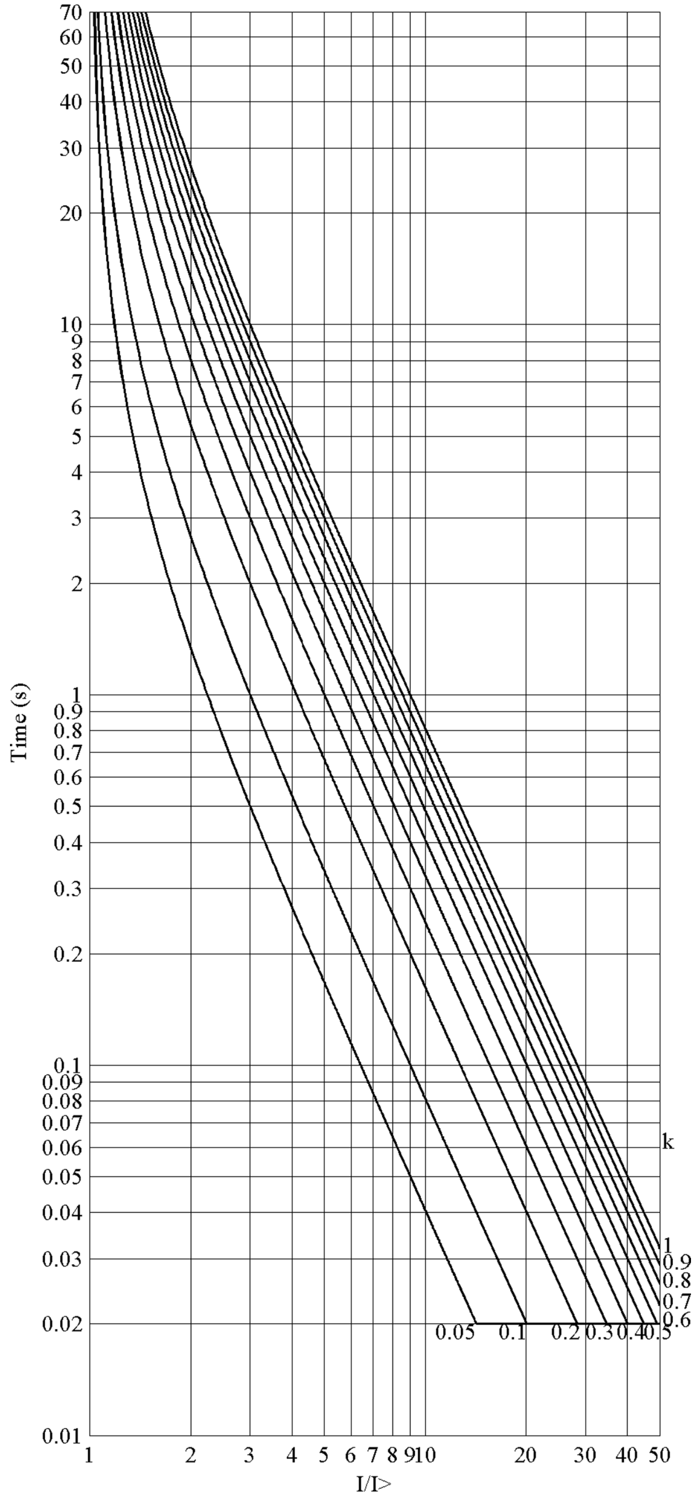


Figure 231: IEC extremely inverse-time characteristics

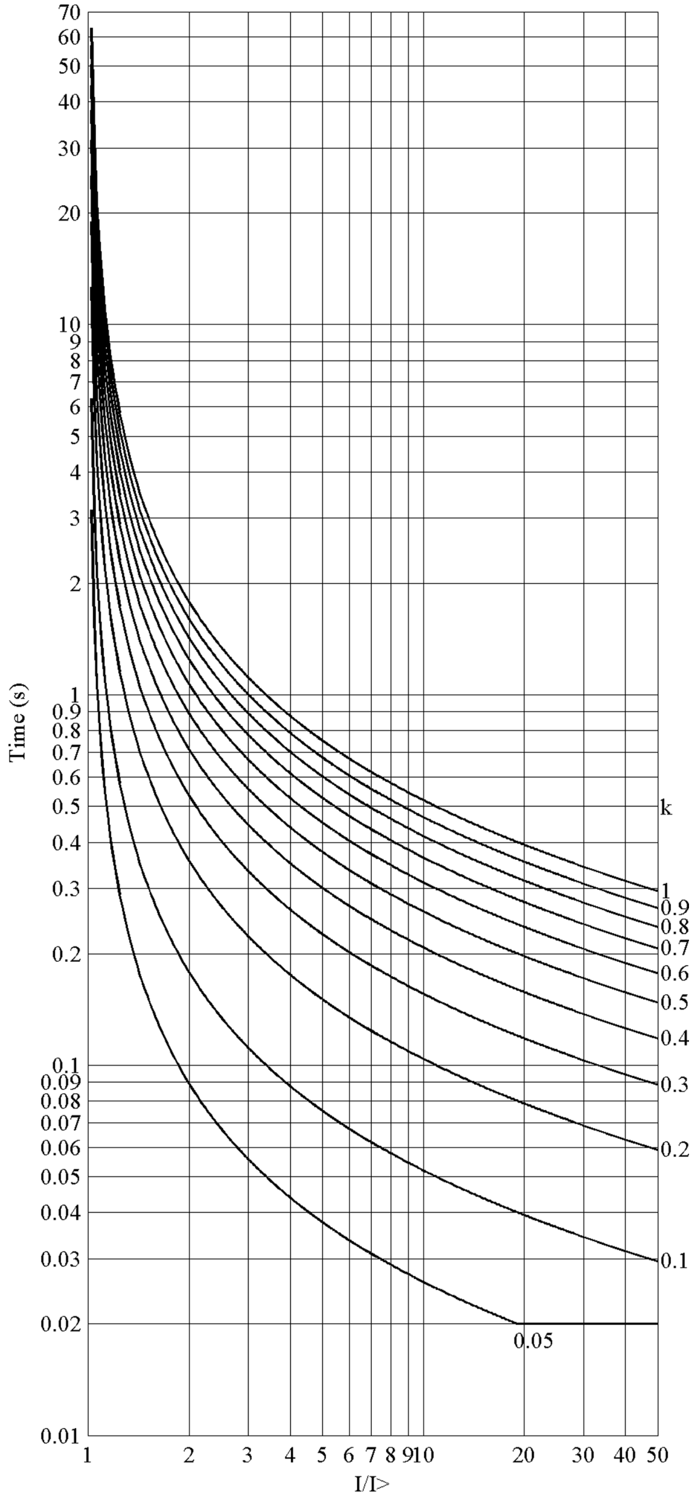


Figure 232: IEC short-time inverse-time characteristics

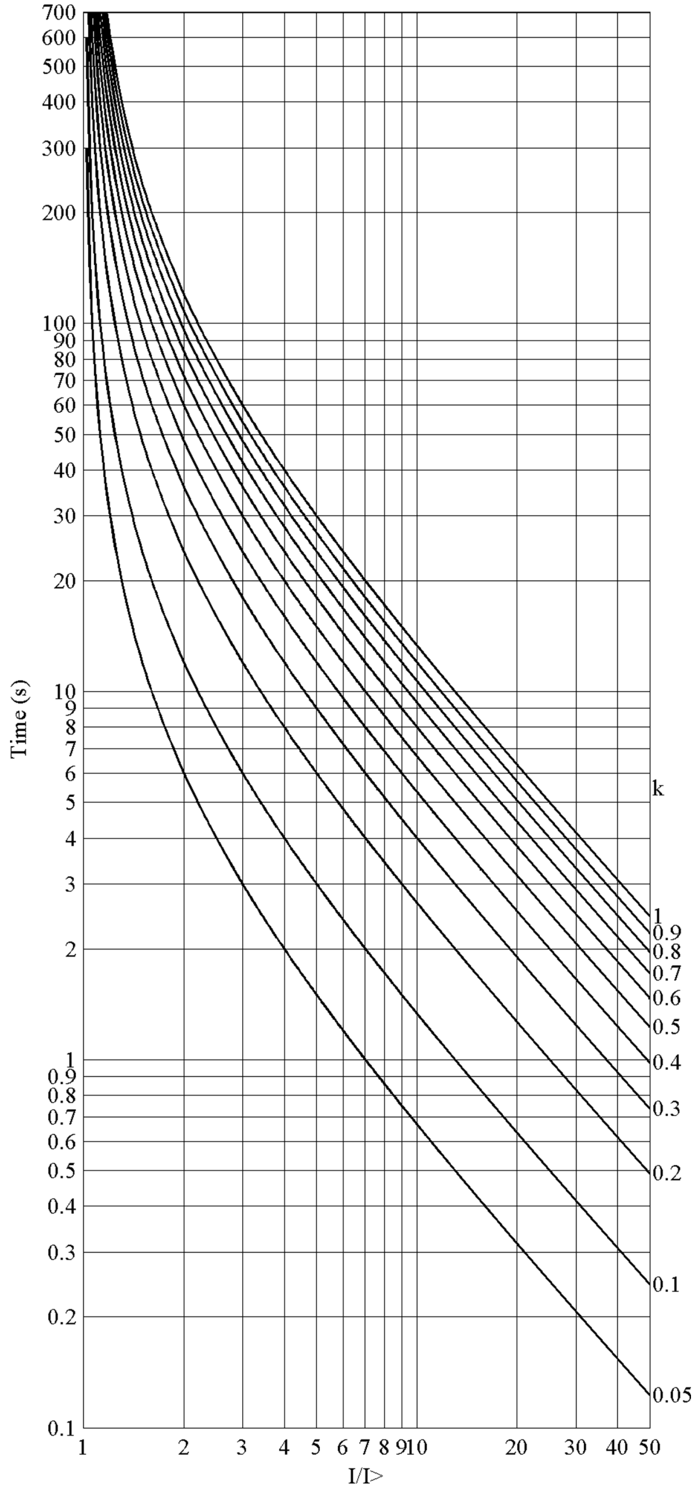


Figure 233: IEC long-time inverse-time characteristics

9.2.1.2 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 41)

t[s]	Operate 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 *Start value*
k	set *Time multiplier*

9.2.1.3 RI and RD-type inverse-time characteristics

The RI-type simulates the behavior of electromechanical relays. The RD-type is an earth-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 42)

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 43)

t[s]	Operate time (in seconds)
k	set *Time multiplier*
I	Measured current
I>	set *Start value*

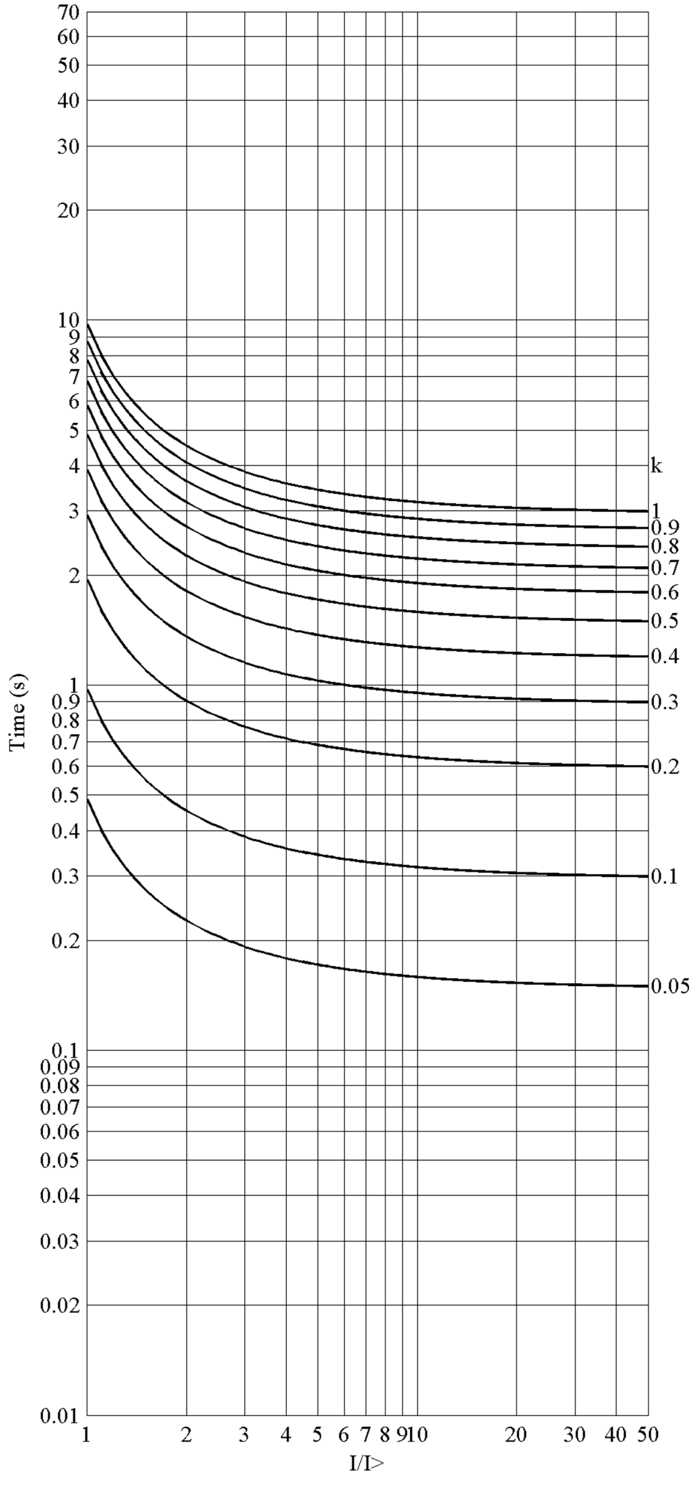


Figure 234: RI-type inverse-time characteristics

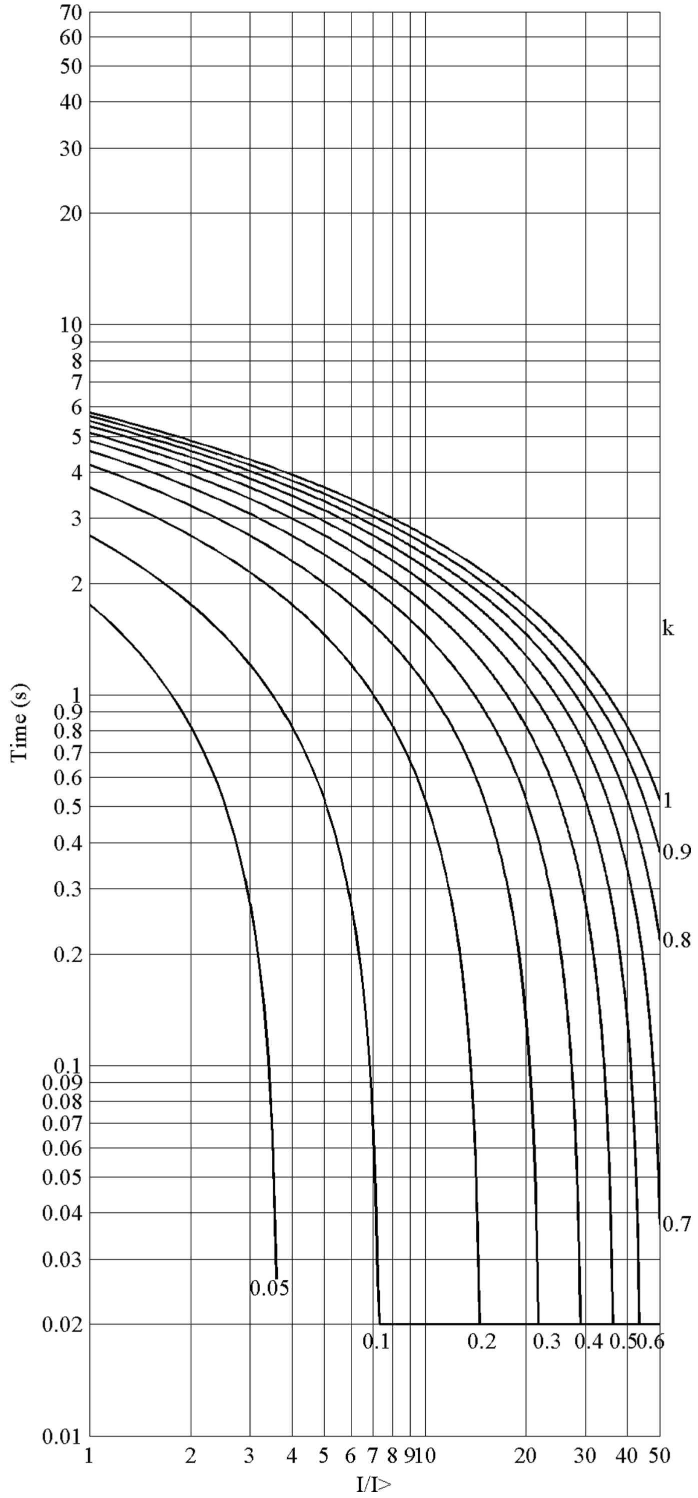


Figure 235: RD-type inverse-time characteristics

9.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting.

Table 477: 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 operate inverse-time counter is frozen for the time determined with the *Reset delay time* setting after the current drops below the set *Start value*, including hysteresis.The integral sum of the inverse-time counter is reset, if another start 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 44)

t[s] Reset time (in seconds)

k set *Time multiplier*

I Measured current

I> set *Start value*

Table 478: 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

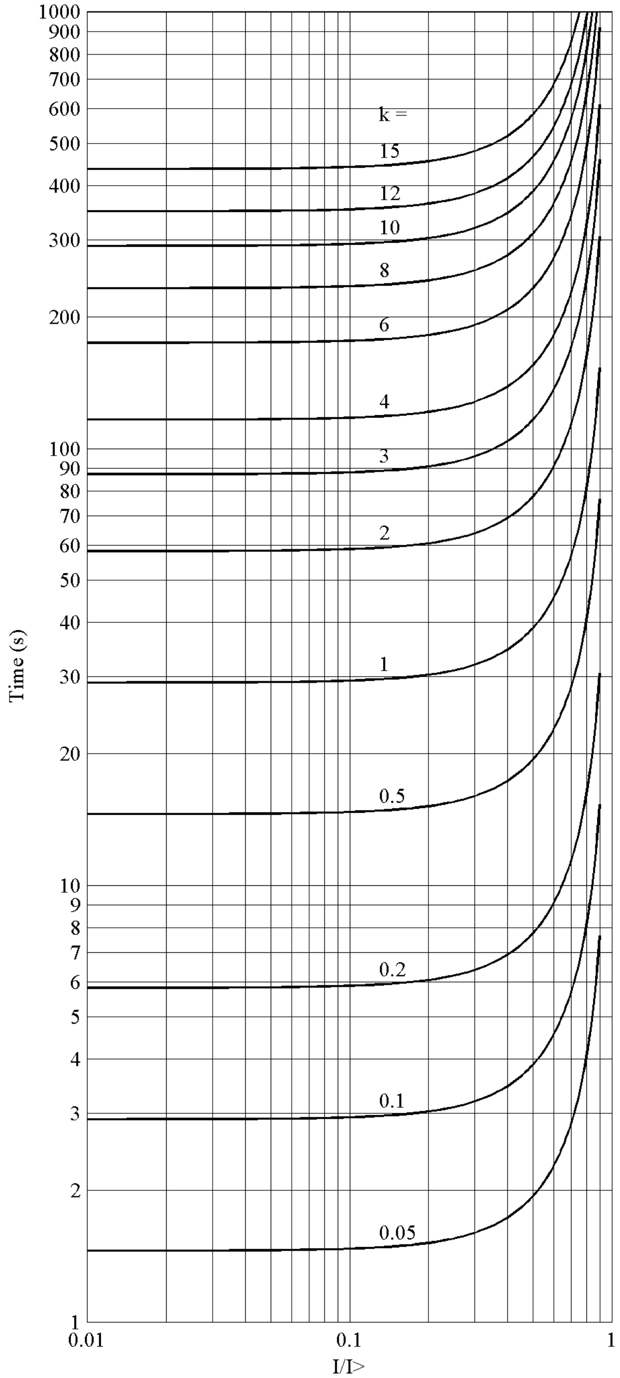


Figure 236: ANSI extremely inverse reset time characteristics

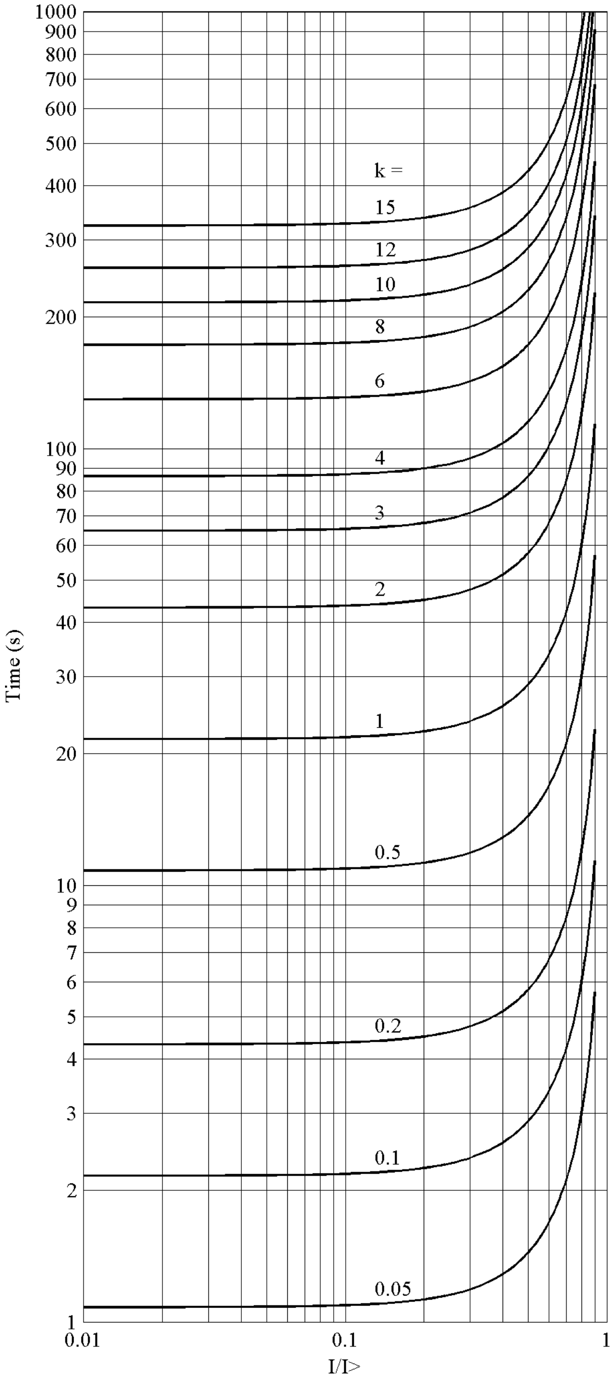


Figure 237: ANSI very inverse reset time characteristics

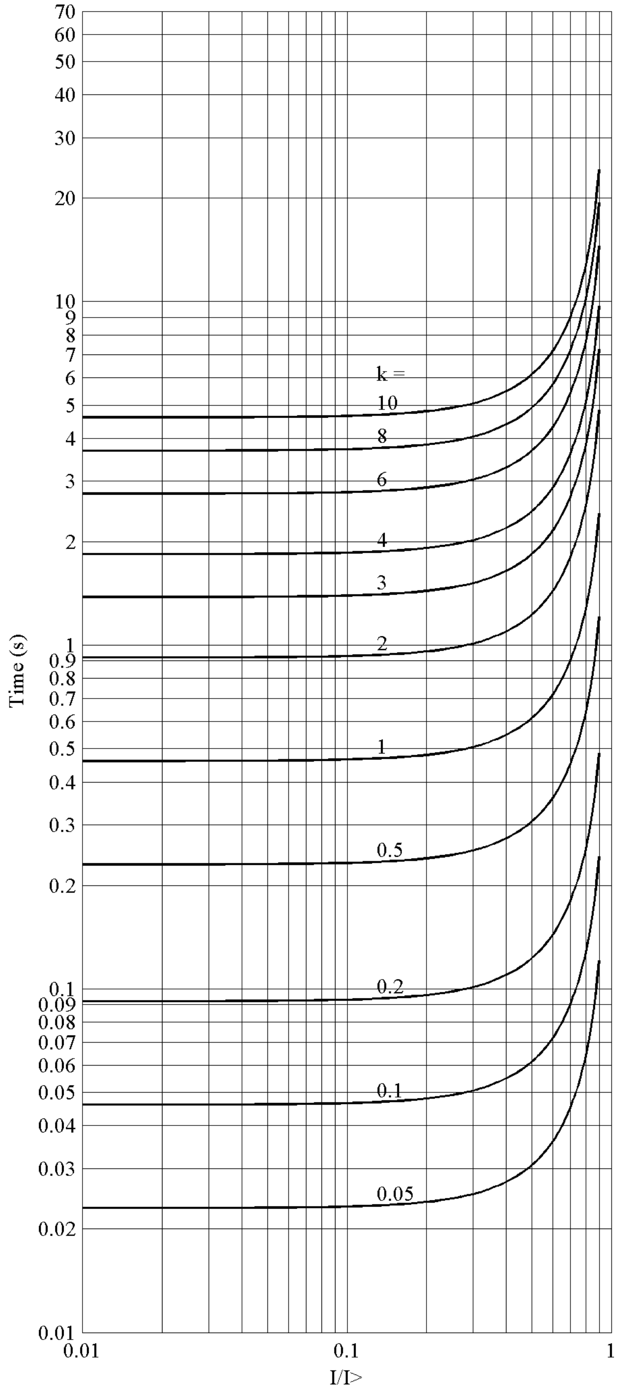


Figure 238: ANSI normal inverse reset time characteristics

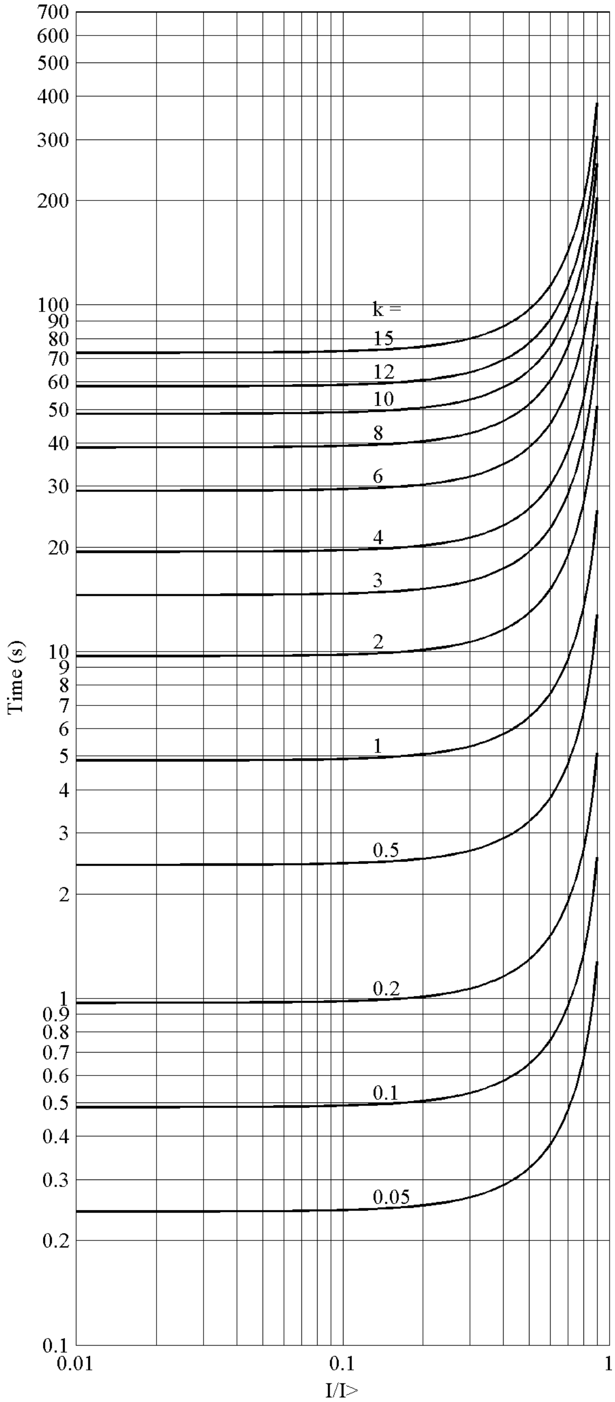


Figure 239: ANSI moderately inverse reset time characteristics

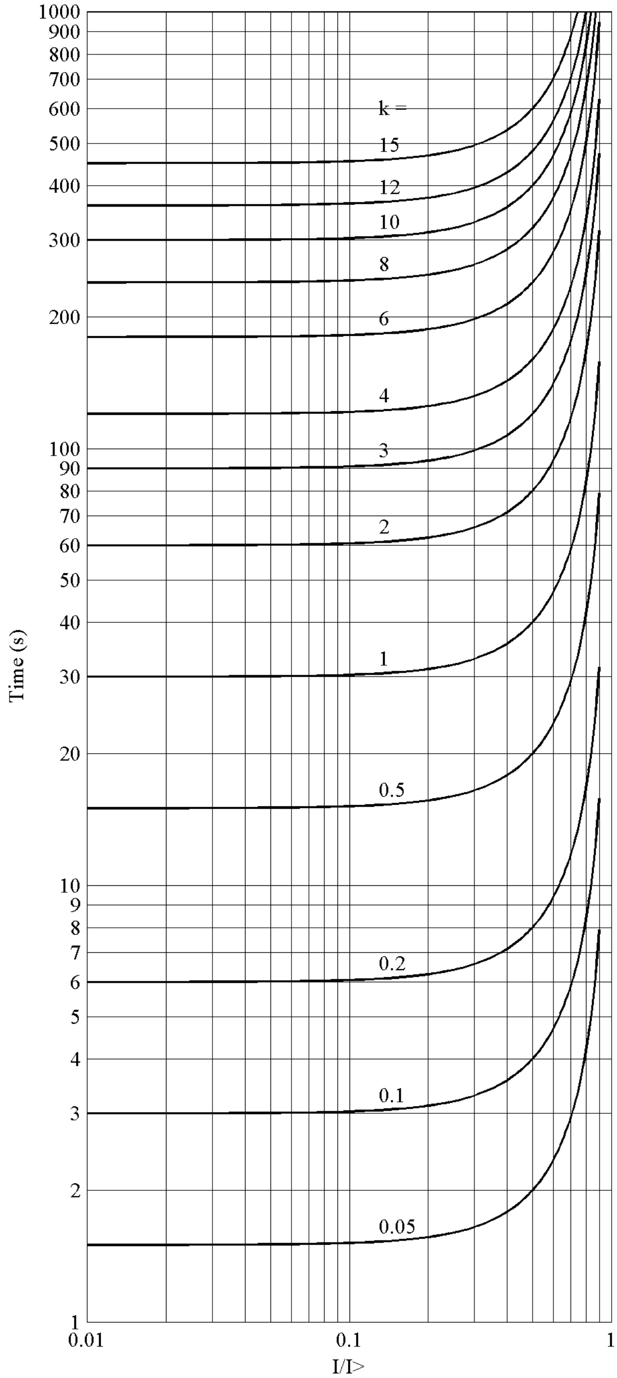


Figure 240: ANSI long-time extremely inverse reset time characteristics

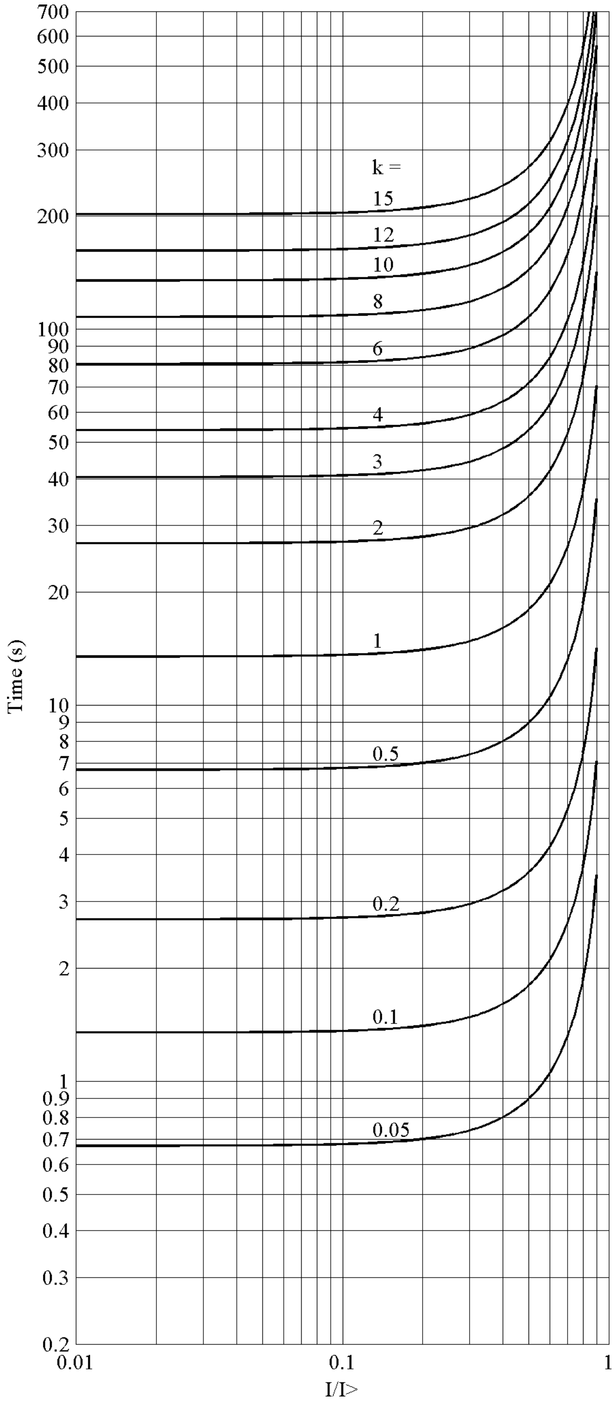


Figure 241: ANSI long-time very inverse reset time characteristics

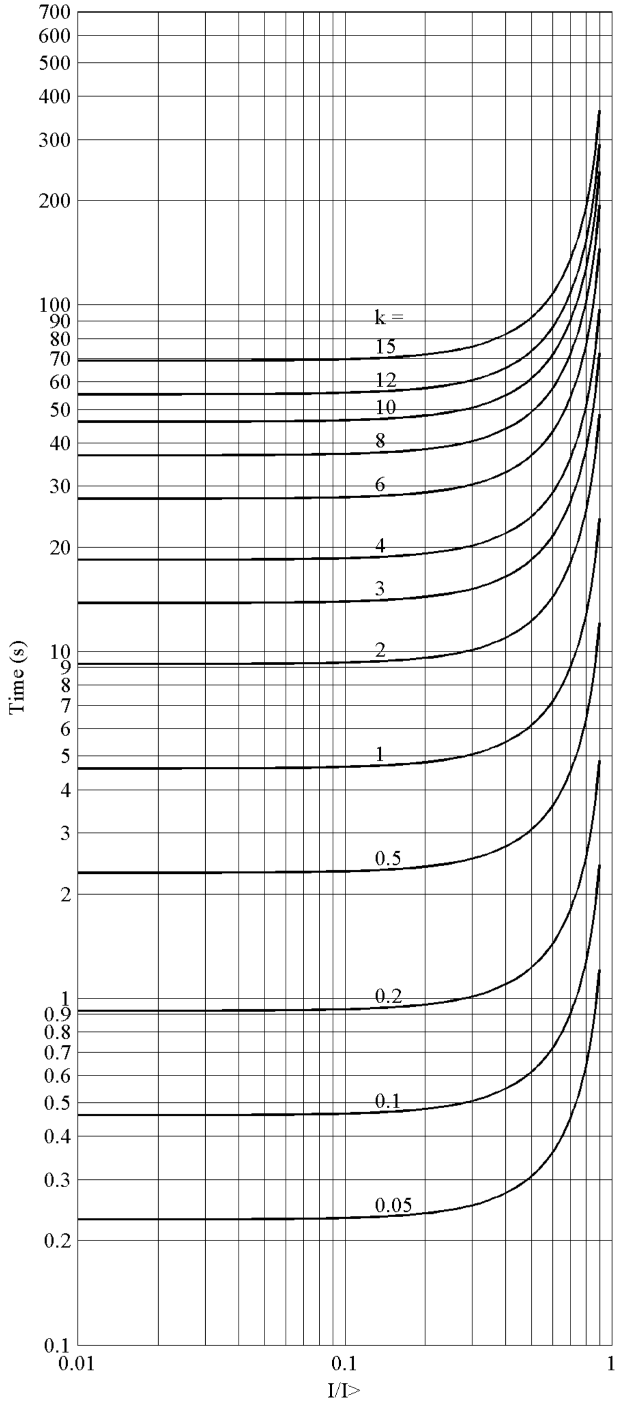


Figure 242: ANSI long-time inverse reset time characteristics

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 45)

t[s]	Reset time (in seconds)
k	set *Time multiplier*
D	set *Curve parameter D*
I	Measured current
I>	set *Start value*

9.2.3 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 `START` output. It still becomes active when the current exceeds the set *Start value*, and inactive when the current falls below the set *Start value* and the set *Reset delay time* has expired.

9.3 Voltage based inverse definite minimum time characteristics

9.3.1 IDMT curves for overvoltage protection

In inverse-time modes, the operate time depends on the momentary value of the voltage, the higher the voltage, the faster the operate time. The operate time calculation or integration starts immediately when the voltage exceeds the set value of the *Start value* setting and the START output is activated.

The OPERATE 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 operate time* setting defines the minimum operate time for the IDMT mode, that is, it is possible to limit the IDMT based operate time for not becoming too short. For example:

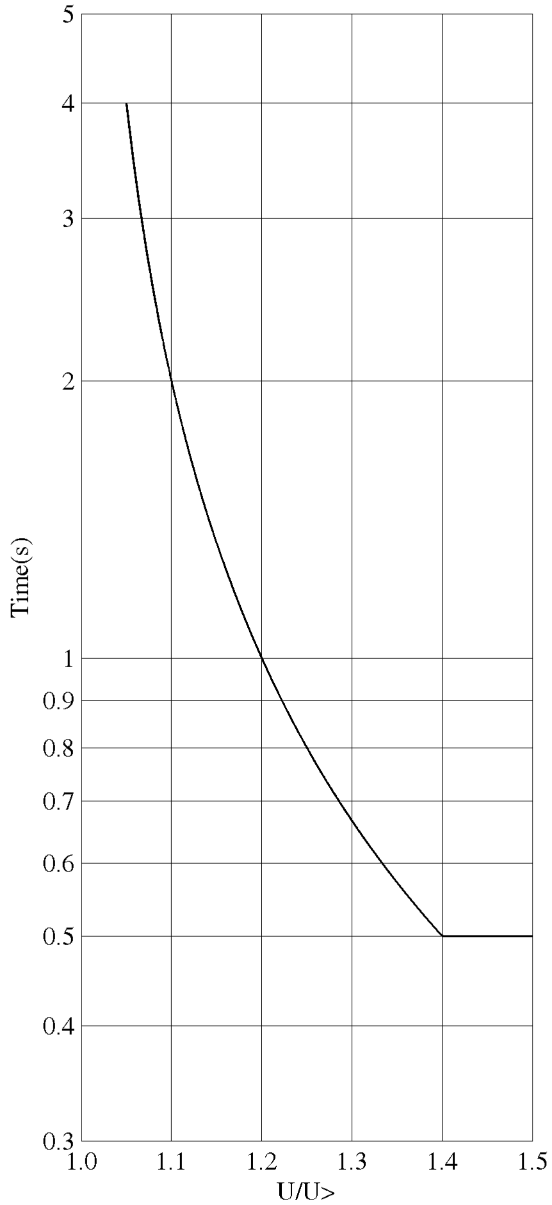


Figure 243: Operate time curve based on IDMT characteristic with Minimum operate time set to 0.5 second

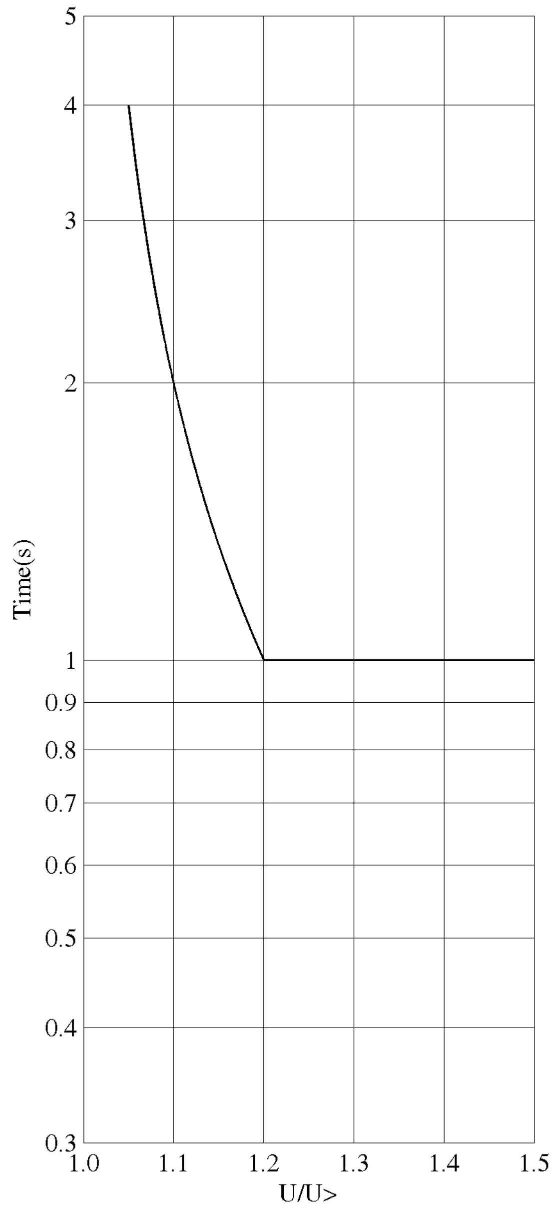


Figure 244: Operate time curve based on IDMT characteristic with Minimum operate time set to 1 second

9.3.1.1 Standard inverse-time characteristics for overvoltage protection

The operate times for the standard overvoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse operate time can be calculated with the formula:

$$t\left[s\right]=\frac{k\cdot A}{\left(B\times\frac{U-U>}{U>}-C\right)^{E}}+D$$

(Equation 46)

t [s] operate time in seconds

U measured voltage

U> the set value of *Start value*

k the set value of *Time multiplier*

Table 479: 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

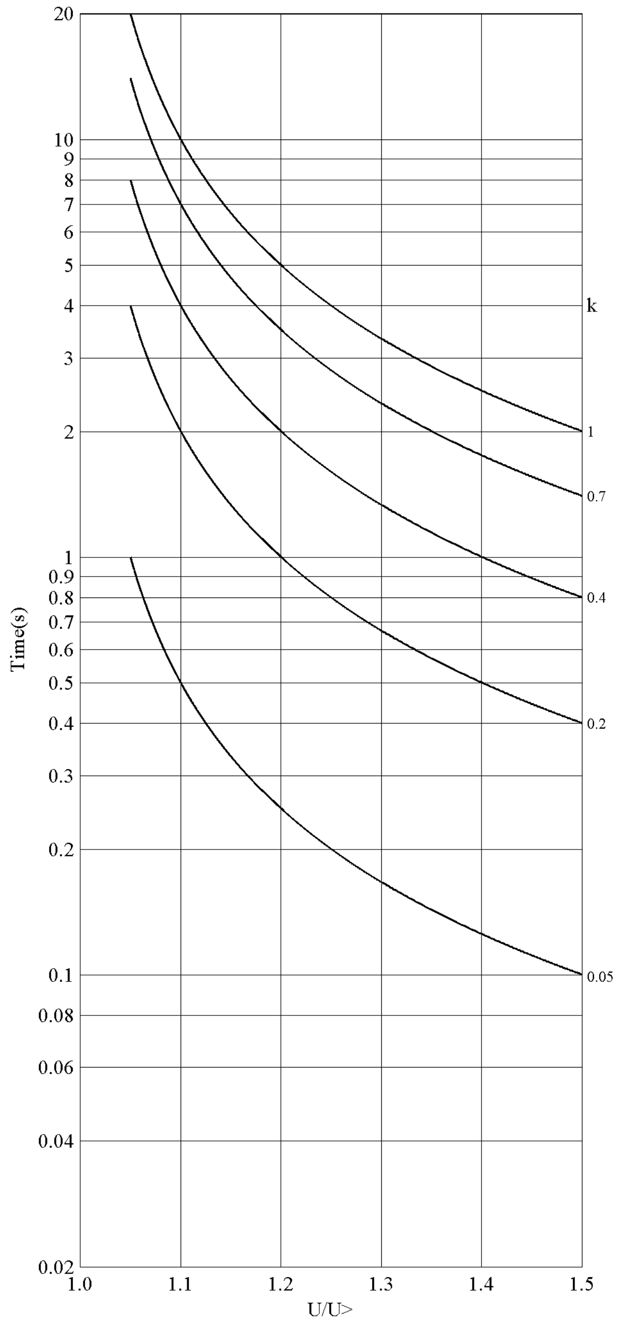


Figure 245: Inverse curve A characteristic of overvoltage protection

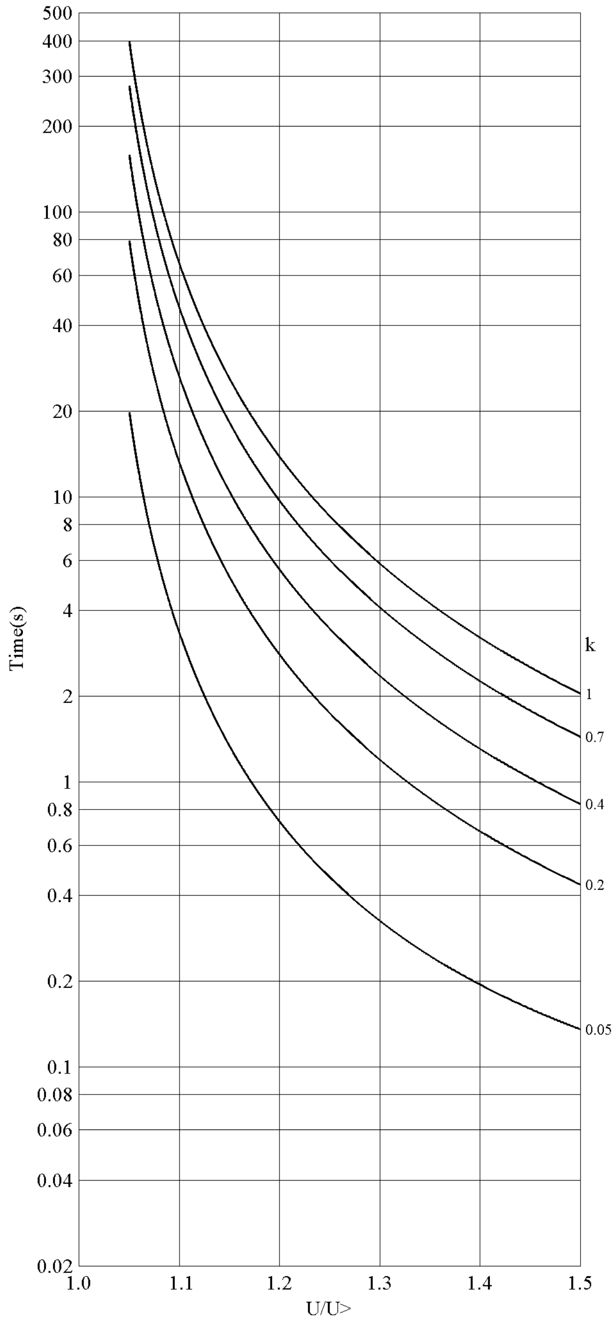


Figure 246: Inverse curve B characteristic of overvoltage protection

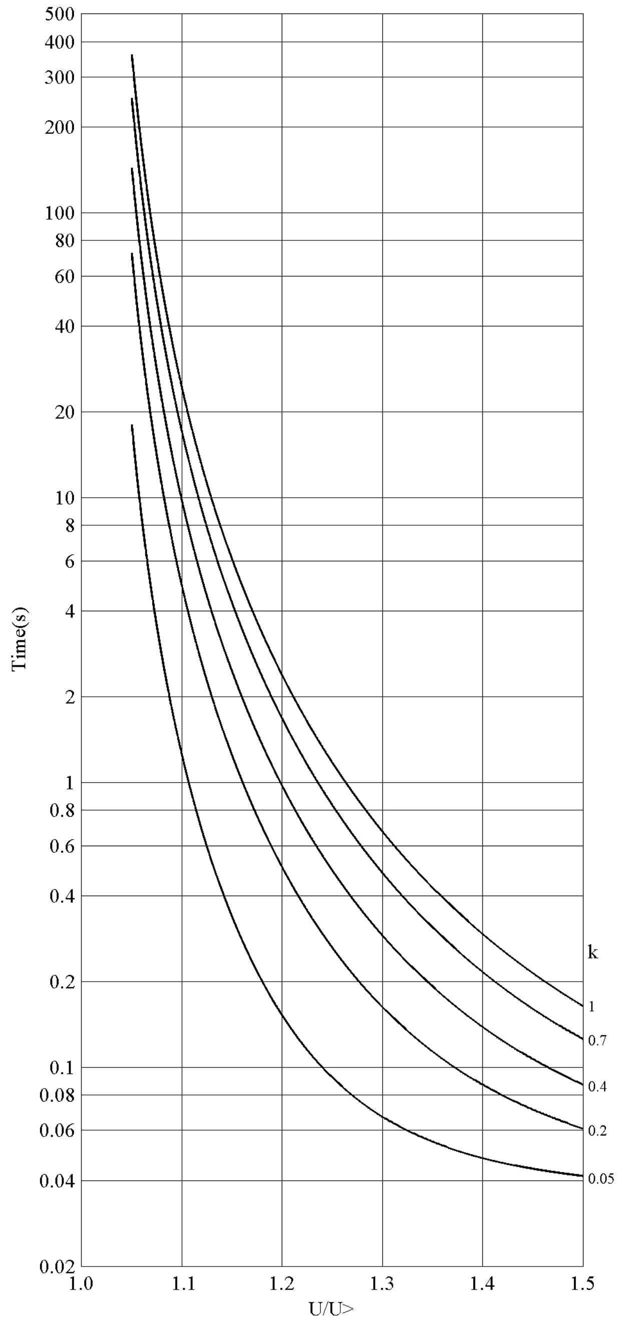


Figure 247: Inverse curve C characteristic of overvoltage protection

9.3.1.2 User programmable inverse-time characteristics for overvoltage protection

The user can define the curves by entering the parameters using the standard formula:

$$t\left[s\right]=\frac{k\cdot A}{\left(B\times\frac{U-U>}{U>}-C\right)^{E}}+D$$

(Equation 47)

t[s] operate 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*
U measured voltage
U> the set value of *Start value*
k the set value of *Time multiplier*

9.3.1.3 IDMT curve saturation of overvoltage protection

For the overvoltage IDMT mode of operation, the integration of the operate time does not start until the voltage exceeds the value of *Start 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 *Start 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 *Start value* to *Curve Sat Relative* in percent over *Start value*, the equation uses *Start value* * (1.0 + *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio U/U> 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 operate 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.

9.3.2 IDMT curves for undervoltage protection

In the inverse-time modes, the operate time depends on the momentary value of the voltage, the lower the voltage, the faster the operate time. The operate time calculation or integration starts immediately when the voltage goes below the set value of the *Start value* setting and the `START` output is activated.

The `OPERATE` 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 operate time* setting defines the minimum operate time possible for the IDMT mode. For setting a value for this parameter, the user should carefully study the particular IDMT curve.

9.3.2.1 Standard inverse-time characteristics for undervoltage protection

The operate times for the standard undervoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse operate time can be calculated with the formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{U< -U}{U<} - C\right)^{E}} + D$$

(Equation 48)

t [s]	operate time in seconds
U	measured voltage
U<	the set value of the *Start value* setting
k	the set value of the *Time multiplier* setting

Table 480: 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

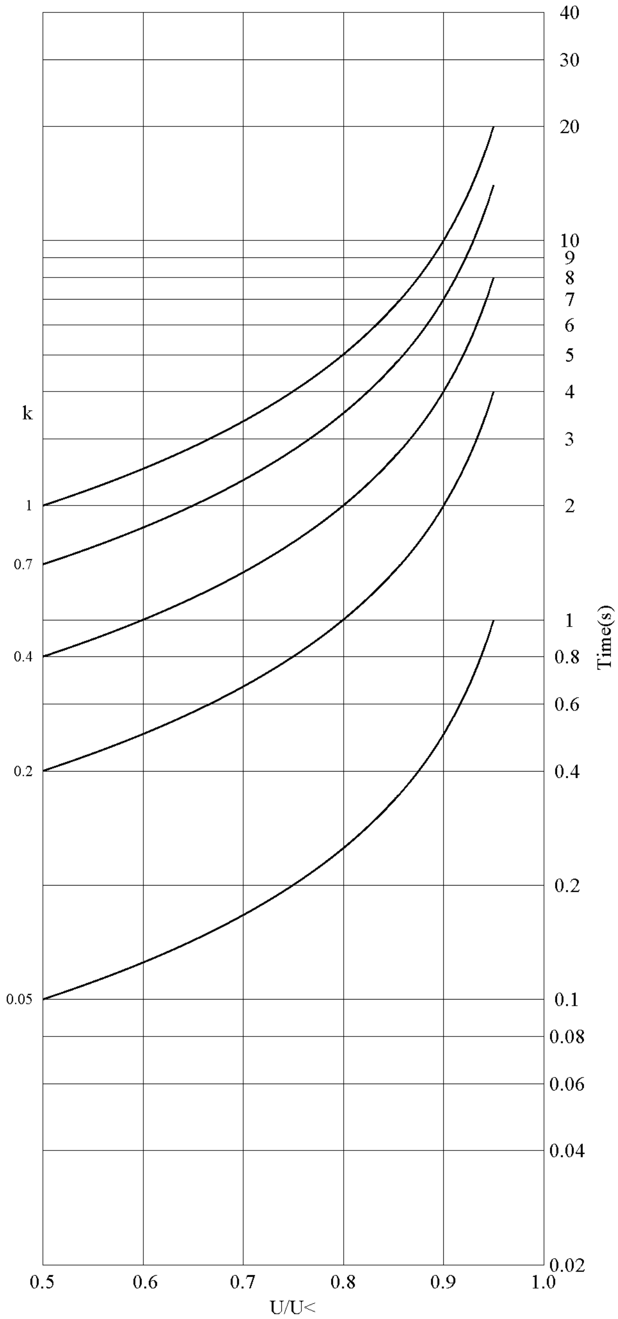


Figure 248: : Inverse curve A characteristic of undervoltage protection

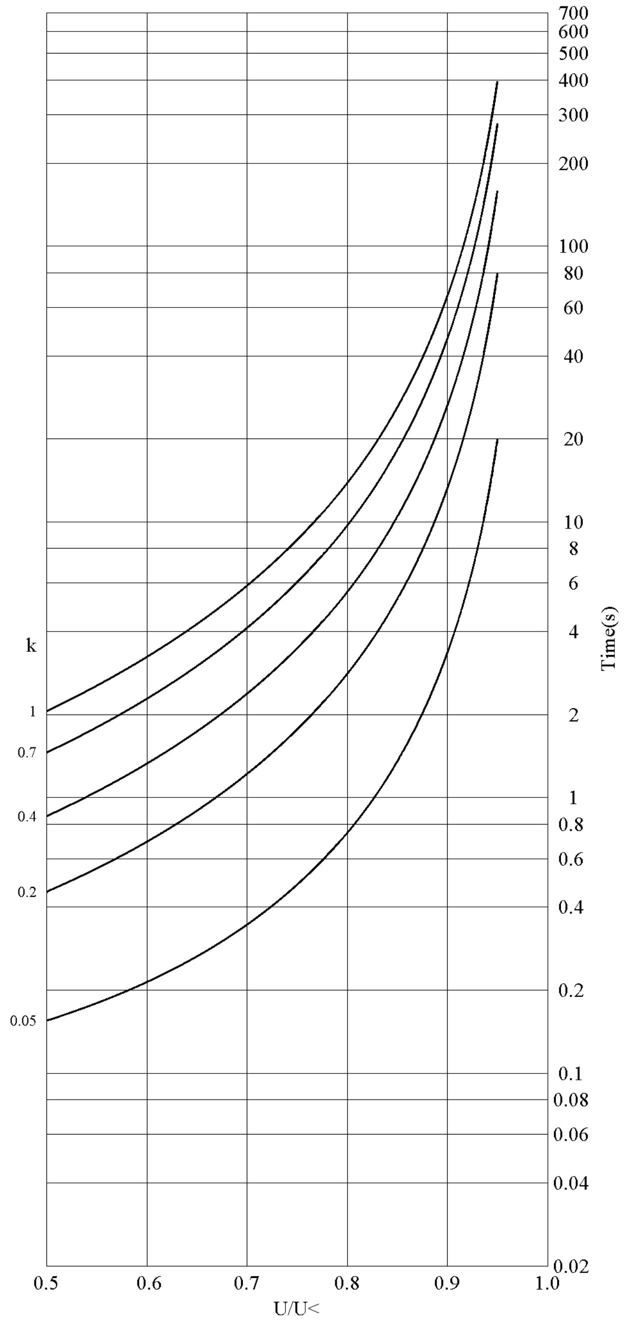


Figure 249: Inverse curve B characteristic of undervoltage protection

9.3.2.2 User-programmable inverse-time characteristics for undervoltage protection

The user can define curves by entering parameters into the standard formula:

$$t[s] = \frac{k \cdot A}{\left(B \times \frac{U< - U}{U<} - C \right)^{E}} + D$$

(Equation 49)

t[s]	operate 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*
U	measured voltage
U<	the set value of *Start value*
k	the set value of *Time multiplier*

9.3.2.3 IDMT curve saturation of undervoltage protection

For the undervoltage IDMT mode of operation, the integration of the operate time does not start until the voltage falls below the value of *Start 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 *Start 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 *Start value* to *Curve Sat Relative* in percents under *Start value*, the equation uses *Start value* * (1.0 - *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio U/U> 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 operate 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.

9.4 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. The df/dt measurement range always starts from 0.6 × 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 $0.02 \times U_n$ 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 or zero (depending on the *Def frequency Sel* setting) 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 `OPERATE` outputs are blocked until the frequency restores to a valid range.

9.5 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 50)

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 start current or the peak value is above two times the set *Start value*. The peak backup is enabled only when the function is used in the DT mode in high and instantaneous stages for faster operation.

9.6 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 51)

The residual voltage is calculated from the phase-to-earth voltages when the VT connection is selected as “Wye” with the equation:

$$\overline{Uo} = (\overline{U}_A + \overline{U}_B + \overline{U}_C)/3$$

(Equation 52)

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 53)

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

(Equation 54)

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

(Equation 55)

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

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

(Equation 56)

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

(Equation 57)

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

(Equation 58)

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:

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

(Equation 59)

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

(Equation 60)

The phase-to-earth voltages are calculated from the phase-to-phase voltages when *VT connection* is selected as "Delta" according to the equations.

$$\overline{U}_A = \overline{U}_0 + \left(\overline{U}_{AB} - \overline{U}_{CA}\right) / 3$$

(Equation 61)

$$\overline{U}_B = \overline{U}_0 + \left(\overline{U}_{BC} - \overline{U}_{AB}\right) / 3$$

(Equation 62)

$$\overline{U}_C = \overline{U}_0 + \left(\overline{U}_{CA} - \overline{U}_{BC}\right) / 3$$

(Equation 63)

If the $\overline{U}_0$ channel is not valid, it is assumed to be zero.

The phase-to-phase voltages are calculated from the phase-to-earth voltages when *VT connection* is selected as "Wye" according to the equations.

$$\overline{U}_{AB} = \overline{U}_A - \overline{U}_B$$

(Equation 64)

$$\overline{U}_{BC} = \overline{U}_B - \overline{U}_C$$

(Equation 65)

$$\overline{U}_{CA} = \overline{U}_C - \overline{U}_A$$

(Equation 66)

Section 10 Requirements for measurement transformers

10.1 Current transformers

10.1.1 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.

10.1.1.1 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 481: 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.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy.

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

10.1.1.2 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 start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to operate, the start current should be set using the formula:

Current start value < 0.7 × (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 operate 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 start 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 operate 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 starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the operate 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.

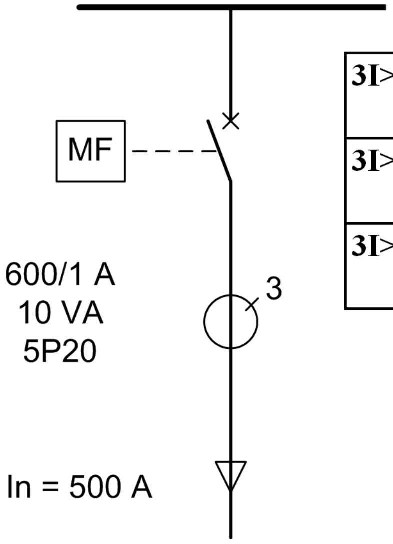
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

F_a > 20 × *Current start value* / I_{1n}

The *Current start value* is the primary start current setting of the protection relay.

10.1.1.3 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.



3I>	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
3I>>	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
3I>>>	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 250: 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 start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 250). 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 start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 250.

For the application point of view, the suitable setting for instantaneous stage (I>>>) 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.

10.1.2 Current transformer requirements for differential protection

The sensitivity and the reliability of the protection depends on the characteristics of the current transformers. The CTs must have an identical transformation ratio. It is recommended that all the CTs have an identical constructions, that is, they have an equal burden and characteristics and are of the same type, preferably from the same manufacturing batch. If the CT characteristics and burden values are not equal, calculations for each branch in the scheme should be performed separately and the worst-case results should be used. In Figure 251, the CT winding resistance and the burden of the branches are not equal, and hence, the maximum burden equal to 3.2 Ω should be used for calculating the stabilized voltage.

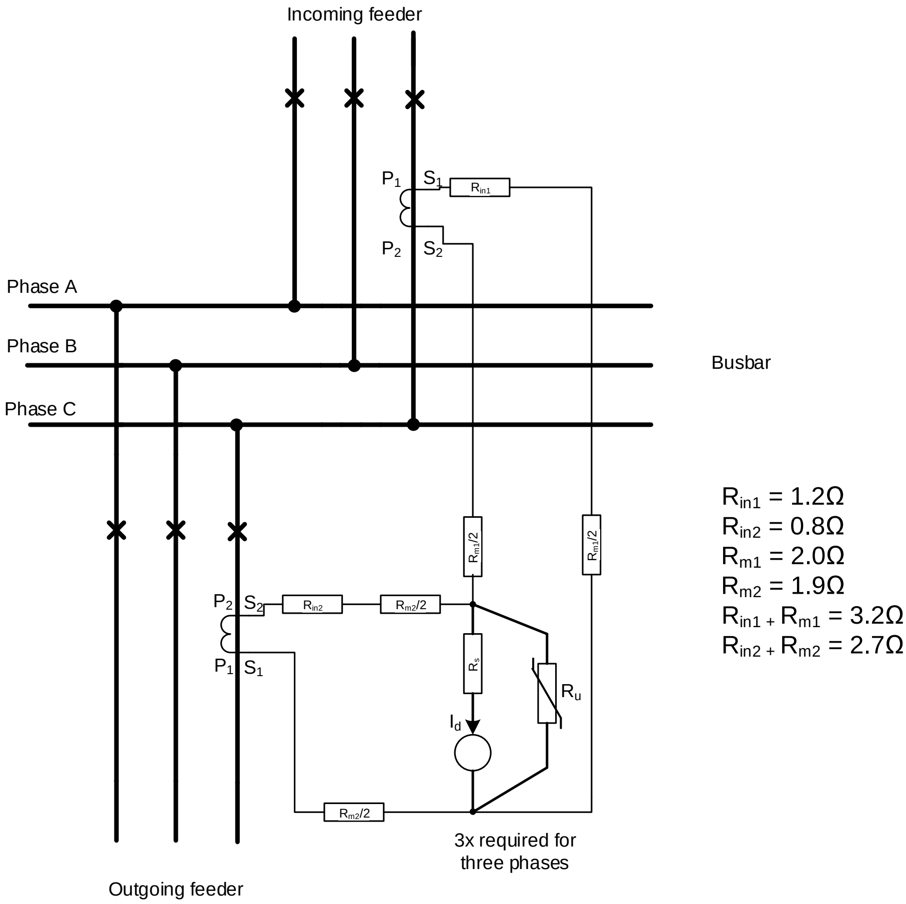


Figure 251: High-impedance busbar differential protection with different CT burden value on each feeder

First, the stabilizing voltage, that is, the voltage appearing across the measuring branch during the out-of-zone fault, is calculated assuming that one of the CTs connected in parallel is fully saturated. The stabilizing voltage can be calculated using the formula:

$$U_s = \frac{I_{k\max}}{n}(R_{in} + R_m)$$

(Equation 67)

I_{kmax} the highest through-fault current in primary amps. The highest earth-fault or short circuit current during the out-of-zone fault.

n the turns ratio of the CT

R_{in} the secondary winding resistance of the CT in ohms

R_m the total resistance of the secondary circuit wires in ohms

The current transformers must be able to force enough current to operate the protection relay through the differential circuit during a fault condition inside the protection zone. To ensure this, the knee point voltage U_{kn} must be at least two times higher than the stabilizing voltage U_s.

The required knee point voltage U_{kn} of the current transformer is calculated using the formula

$$U_{kn} \geq 2 \times U_s$$

(Equation 68)

U_{kn} the knee point voltage

U_s the stabilizing voltage

The factor two is used when a delay in the operating time of the protection is not acceptable. To prevent the knee point voltage from rising too high, CTs with the secondary winding resistance same as the resistance of the measuring loop should be used.

As the impedance of the protection relay is low, a stabilizing resistor is needed. The value of the stabilizing resistor is calculated using the formula:

$$R_s = \frac{U_s}{I_{rs}}$$

(Equation 69)

R_s the resistance of the stabilizing resistor

U_s the stabilizing voltage of the protection relay

I_{rs} the value of the *Operate value* setting in secondary amps

The stabilizing resistor should be capable to dissipate high energy within a very short time; therefore, a wire wound-type resistor must be used. The minimum rated power should be a few tens of watts because of the possible CT inaccuracy which might cause some current through the stabilizing resistor in a normal load situation.

If U_{kn} is high or U_s is low, a resistor with a higher power rating is needed. Often the resistor manufacturers allow 10 times the rated power for 5 seconds. Thus, the power of the resistor can be calculated using the formula:

$$\frac{U_{kn}^2}{R_s \times 10}$$

(Equation 70)

The actual sensitivity of the protection is affected by the protection relay setting, the magnetizing currents of the CTs connected in parallel and the shunting effect of the voltage-dependent resistor (VDR). The value of the primary current I_{prim} at which the protection relay operates at a certain setting can be calculated using the formula

$$I_{prim} = n \times (I_{rs} + I_u + m \times I_m)$$

(Equation 71)

I_{prim}	the primary current at which the protection is to start
n	the turn ratio of the current transformer
I_{rs}	the value of the *Operate value* setting
I_u	the leakage current flowing through the VDR at the U_s voltage
m	the number of current transformers included in the protection per phase
I_m	the magnetizing current per current transformer at the U_s voltage

The I_e value given in many catalogs is the excitation current at the knee point voltage. Assuming $U_{kn} \approx 2 \times U_s$, the value of $I_m \approx \frac{I_e}{2}$ gives an approximate value for Equation 71.

The selection of current transformers can be divided into procedures:

1. The rated current I_n of the feeder should be known. The value of I_n also affects how high I_{kmax} is.
2. The rated primary current I_{1n} of the CT must be higher than the rated current of the feeder.
   The choice of the CT also specifies R_{in}.
3. The required U_{kn} is calculated using Equation 68. If U_{kn} of the CT is not high enough, enough, another CT has to be selected. The value of U_{kn} is given by the manufacturer in the case of Class X current transformers or it can be estimated using Equation 72.
4. The sensitivity I_{prim} is calculated using Equation 71. If the achieved sensitivity is sufficient, the present CT is chosen. If a better sensitivity is needed, a CT with a bigger core is chosen.

If other than Class X CTs are used, an estimate for U_{kn} is calculated using the equation:

$$U_{kn} = 0.8 \times F_n \times I_{2n} \times \left(R_{in} + \frac{S_n}{I_{2n}^2} \right)$$

(Equation 72)

F_n the rated accuracy limit factor corresponding to the rated burden S_n

I_{2n} the rated secondary current of the CT

R_{in} the secondary internal resistance of the CT

S_n the volt-amp rating of the CT

The formulas are based on selecting the CTs according to Equation 68, results in an absolutely stable scheme. In some cases, it is possible to achieve stability with the knee point voltages lower than stated in the formulas. The conditions in the network, however, must be known well enough to ensure the stability.

1. If $U_{kn} \geq 2 \times U_s$, faster protection relay operations are secure.
2. If $U_{kn} \geq 1.5 \times U_s$ and $< 2 \times U_s$, protection relay operation can be slightly prolonged and should be studied case by case.
   If $U_{kn} < 1.5 \times U_s$, the protection relay operation is jeopardized. Another CT has to be chosen.

The need for the VDR depends on certain conditions.

First, voltage U_{max}, ignoring the CT saturation during the fault, is calculated using the formula

$$U_{max} = \frac{I_{k\,max\,in}}{n} \times (R_{in} + R_m + R_s) \approx \frac{I_{k\,max\,in}}{n} \times R_s$$

(Equation 73)

I_{kmaxin} the maximum fault current inside the zone in primary amps

n the turns ratio of the CT

R_{in} the internal resistance of the CT in ohms

R_m the resistance of the longest loop of the CT secondary circuit in ohms

R_s the resistance of the stabilized resistor in ohms

Next, the peak voltage û, which includes the CT saturation, is calculated using the formula (given by P.Mathews, 1955):

$$\hat{u} = 2\sqrt{2U_{kn}(U_{max} - U_{kn})}$$

(Equation 74)

U_{kn} the knee point voltage of the CT

The VDR is recommended when the peak voltage û ≥ 2kV, which is the insulation level for which the protection relay is tested.

The maximum fault current in case of a fault inside the zone is considered to be 12.6 kA in primary, CT is of 1250/5 A (ratio n = 240), knee point voltage is 81 V and the stabilizing resistor is 330 Ohms.

$$U_{\max} = \frac{12600A}{240} \times 330\ \Omega = 17325\ V$$

(Equation 75)

$$\hat{u} = 2\sqrt{2 \times 81 \times (17325 - 81)} \approx 3.34kV$$

(Equation 76)

As the peak voltage û is 3.2 kV, VDR must be used. If the $R_s$is smaller, VDR could be avoided. However, the value of R_s depends on the operation current and stabilizing voltage of the protection relay. Thus, either a higher setting should be used or the stabilizing voltage should be lowered.

As the peak voltage û = 3.2 kV, VDR must be used. If the R_s is smaller, VDR can be avoided.

The value of R_s depends on the protection relay operating current and the stabilizing voltage. Therefore, either a higher setting in the protection relay or a lower stabilizing voltage must be used.

Section 11 Protection relay's physical connections

11.1 Module slot numbering

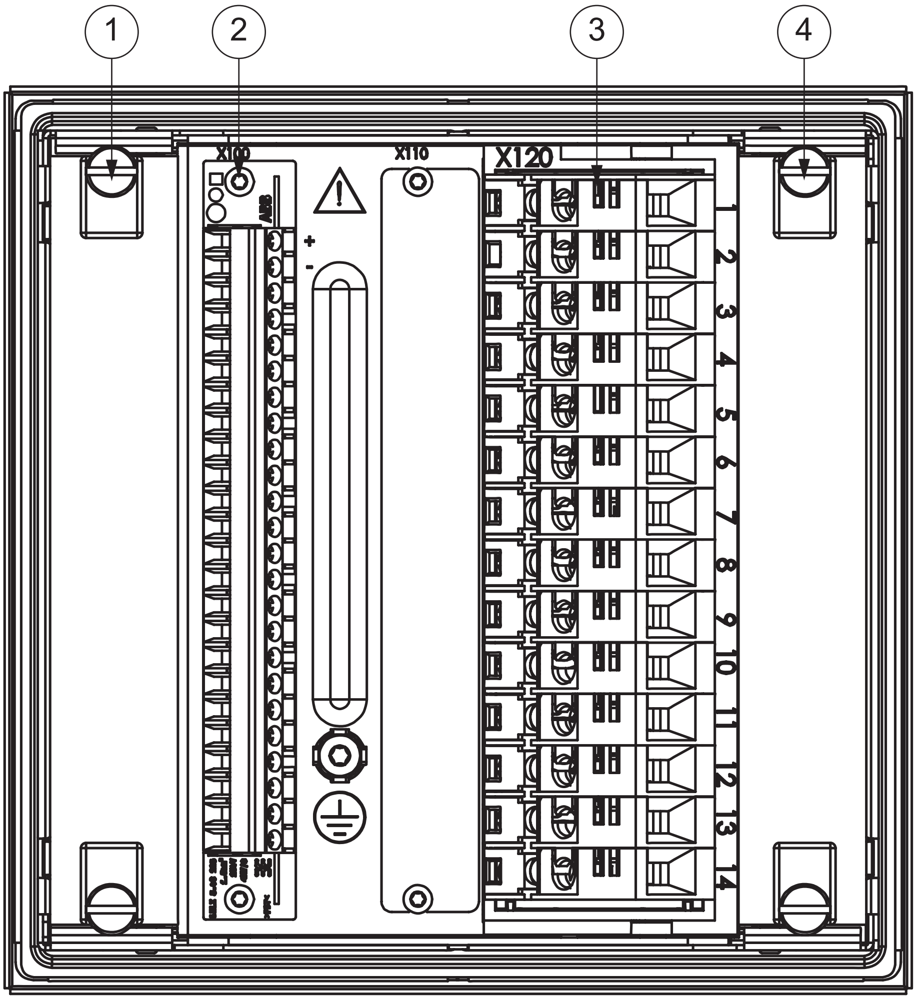


Figure 252: Module slot numbering

1 X000

2 X100

3 X120

4 X130

11.2 Protective earth connections

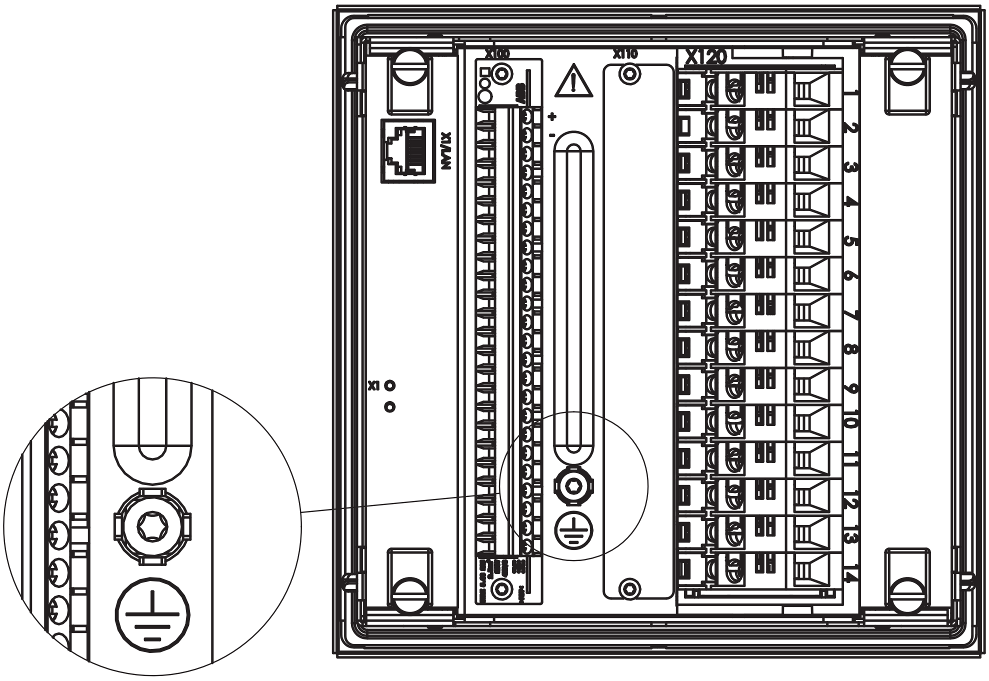


Figure 253: The protective earth screw is located between connectors X100 and X110

The earth lead must be at least 6.0 mm^2 and as short as possible.

11.3 Binary and analog connections

All binary and analog connections are described in the product specific application manuals.

11.4 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
- EIA-485 serial connection

Fibre optic equipment and cables are very sensitive to dust and dirt. Handle them with care. If the fibre is disconnected from the modem, set the protective hood on the transmitter/receiver. Keep the protective hood on during transportation.

If contaminated, clean optical connectors with a cleaning stick. Recommended cleaning fluids are methyl alcohol, ethyl alcohol, isopropyl alcohol or isobutyl alcohol.

11.4.1 Ethernet RJ-45 front connection

The protection relay is provided with an RJ-45 connector on the LHMI. The connector is intended 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 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.

11.4.2 Ethernet rear connections

The Ethernet station bus communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection, depending on the product variant and the selected communication interface option. A shielded twisted-pair cable CAT 5e is used with the RJ-45 connector and an optical multi-mode cable (≤2 km) with the LC type connector.

In addition, communication modules with multiple Ethernet connectors enable the forwarding of Ethernet traffic. These variants include an internal Ethernet switch that handles the Ethernet traffic between an 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 protection relays of this product series to the same network.Internal Ethernet switch MAC table size is 512 entries. All Ethernet ports share this one common MAC table.

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 rear Ethernet port is 192.168.2.10 with the TCP/IP protocol. The data transfer rate is 10 or 100 Mbps full duplex.

11.4.3 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 1200 meters.

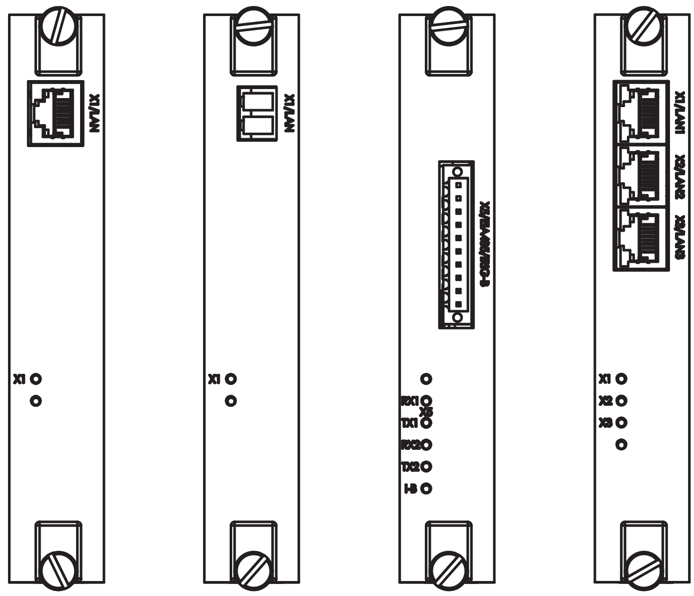
11.4.4 Communication interfaces and protocols

The communication protocols supported depend on the optional rear communication module.

Table 482: Supported station communication interfaces and protocols

Interfaces/protocols	Ethernet		Serial
	100BASE-TX RJ-45	100BASE-FX LC	RS-485
IEC 61850	●	●	-
MODBUS RTU/ASCII	-	-	●
MODBUS TCP/IP	●	●	-
● = Supported			

11.4.5 Rear communication modules



COM0001 COM0002 COM0003 COM0031

Figure 254: Communication module options

Table 483: Station bus communication interfaces included in communication modules

Module ID	RJ-45	LC	EIA-485
COM0001	1	-	-
COM0002	-	1	-
COM0003	-	-	1
COM0031	3	-	-

Table 484: LED descriptions for COM0001-COM003

LED	Connector	Description[1)]
X1	X1	X1/LAN link status and activity (RJ-45 and LC)
RX1	X5	COM2 2-wire/4-wire receive activity
TX1	X5	COM2 2-wire/4-wire transmit activity
RX2	X5	COM1 2-wire receive activity
TX2	X5	COM1 2-wire transmit activity
I-B	X5	IRIG-B signal activity

1) Depending on the COM module and jumper configuration

Table 485: LED descriptions for COM0031

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

11.4.5.1 COM0003 jumper locations and connections

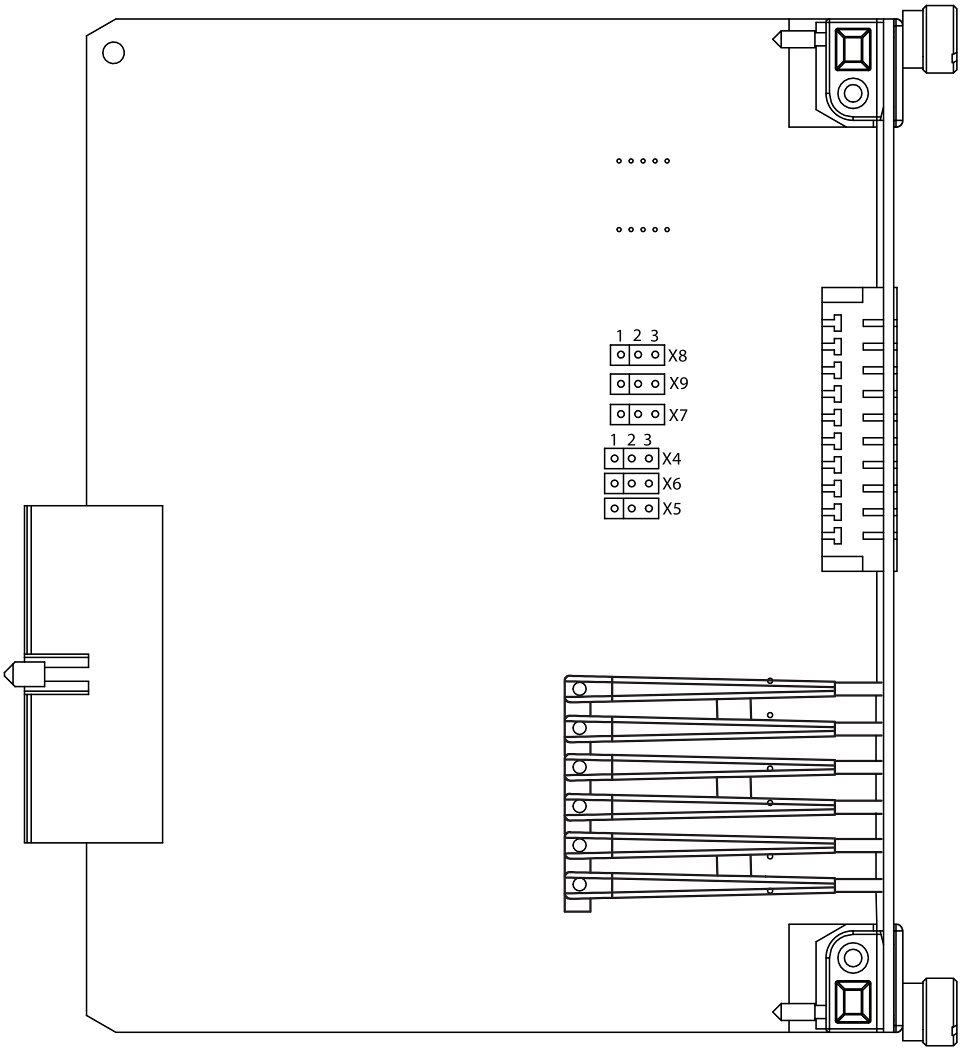


Figure 255: Jumper connectors on communication module

Table 486: 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 487: 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 disabled1)	
X6	1-2	Bus termination enabled	
	2-3	Bus termination disabled1)	
Table continues on next page			

Group	Jumper connection	Description	Notes
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 earth from one node and through capacitor from other nodes.

The optional communication modules include support for EIA-485 serial communication (X5 connector). Depending on the configuration, the communication modules can host either two 2-wire-ports or one 4-wire-port.

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.

Table 488: EIA-485 connections for COM0001-COM0003

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)			

11.4.6 Recommended third-party industrial Ethernet switches

- RuggedCom RS900
- RuggedCom RS1600
- RuggedCom RSG2100

Section 12 Technical data

Table 489: Dimensions

Description	Value	
Width	Frame	177 mm
	Case	164 mm
Height	Frame	177 mm (4U)
	Case	160 mm
Depth		201 mm (153 + 48 mm)
Weight	Complete protection relay	4.1 kg
	Plug-in unit only	2.1 kg

Table 490: Power supply

Description	Type 1	Type 2
Nominal auxiliary voltage U_n	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 relay	50 ms at U_n	
Auxiliary voltage variation	38...110% of U_n (38...264 V AC)	50...120% of U_n (12...72 V DC)
	80...120% of U_n (38.4...300 V DC)	
Start-up threshold		19.2 V DC (24 V DC × 80%)
Burden of auxiliary voltage supply under quiescent (P_q)/ operating condition	DC <12.5 W (nominal)/<15.0 W (max.) AC <13.5 W (nominal)/<16.0 W (max.)	DC <10.2 W (nominal)/<10.8 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 491: 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	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 residual current input
2) Residual current and/or phase current

Table 492: 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	16...176 V DC
Reaction time	<3 ms

Table 493: Signal output X100: SO1

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 494: Signal outputs and IRF output

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A
Make and carry 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 495: Double-pole power output relays with TCS function

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC (two contacts connected in series)	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC
Trip-circuit supervision (TCS): • Control voltage range • Current drain through the supervision circuit • Minimum voltage over the TCS contact	 20...250 V AC/DC ~1.5 mA 20 V AC/DC (15...20 V)

Table 496: Single-pole power output relays

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC

Table 497: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front	TCP/IP protocol	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s
Rear	TCP/IP protocol	Shielded twisted pair CAT 5e cable with RJ-45 connector or fiber optic cable with LC connector	100 MBits/s

Table 498: 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

1) Depending on the optional communication module

Table 499: Fiber optic communication link

Connector	Fiber type	Wave length	Typical max. length[1)]	Permitted path attenuation[2)]
LC	MM 62.5/125 or 50/125 μm glass fiber core	1300 nm	2 km	<8 dB

1) Maximum length depends on the cable attenuation and quality, the amount of splices and connectors in the path.
2) Maximum allowed attenuation caused by connectors and cable together

Table 500: IRIG-B

Description	Value
IRIG time code format	B004, B005[1)]
Isolation	500V 1 min
Modulation	Unmodulated
Logic level	5 V TTL
Current consumption	<4 mA
Power consumption	<20 mW

1) According to the 200-04 IRIG standard

Table 501: Degree of protection of flush-mounted protection relay

Description	Value
Front side	IP 54
Rear side, connection terminals	IP 20

Table 502: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)
Short-time service temperature range	-40...+85ºC (<16 h)[1)2)]
Relative humidity	<93%, non-condensing
Atmospheric pressure	86...106 kPa
Altitude	Up to 2000 m
Transport and storage temperature range	-40...+85ºC

1) Degradation in MTBF and HMI performance outside the temperature range of -25...+55ºC
2) For relays with an LC communication interface, the maximum operating temperature is +70ºC

Section 13 Protection relay and functionality tests

Table 503: Electromagnetic compatibility tests

Description	Type test value	Reference
1 MHz/100 kHz burst disturbance test • Common mode • Differential mode	 2.5 kV 2.5 kV	IEC 61000-4-18 IEC 60255-26, class III IEEE C37.90.1-2002
3 MHz, 10 MHz and 30 MHz burst disturbance test • Common mode	 2.5 kV	IEC 61000-4-18 IEC 60255-26, class III
Electrostatic discharge test • Contact discharge • Air discharge	 8 kV 15 kV	IEC 61000-4-2 IEC 60255-26 IEEE C37.90.3-2001
Radio frequency interference test	10 V (rms) f = 150 kHz...80 MHz 10 V/m (rms) f = 80...2700 MHz 10 V/m f = 900 MHz 20 V/m (rms) f = 80...1000 MHz	IEC 61000-4-6 IEC 60255-26, class III IEC 61000-4-3 IEC 60255-26, class III ENV 50204 IEC 60255-26, class III IEEE C37.90.2-2004
Fast transient disturbance test • All ports	 4 kV	IEC 61000-4-4 IEC 60255-26 IEEE C37.90.1-2002
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 60255-26
Power frequency (50 Hz) magnetic field immunity test • Continuous • 1...3 s	 300 A/m 1000 A/m	IEC 61000-4-8

Table continues on next page

Description	Type test value	Reference
Pulse magnetic field immunity test	1000 A/m 6.4/16 µs	IEC 61000-4-9
Damped oscillatory magnetic field immunity test		IEC 61000-4-10
• 2 s	100 A/m	
• 1 MHz	400 transients/s	
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 only	IEC 61000-4-16 IEC 60255-26, class A
• Common mode	300 V rms	
• Differential mode	150 V rms	
Conducted common mode disturbances	15 Hz...150 kHz Test level 3 (10/1/10 V rms)	IEC 61000-4-16
Emission tests		EN 55011, class A IEC 60255-26 CISPR 11 CISPR 12
• Conducted		
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	
• Radiated		
30...230 MHz	<40 dB (µV/m) quasi peak, measured at 10 m distance	
230...1000 MHz	<47 dB (µV/m) quasi peak, measured at 10 m distance	
1…3 GHz	<76 dB (µV/m) peak <56 dB (µV/m) average, measured at 3 m distance	
3…6 GHz	<80 dB (µV/m) peak <60 dB (µV/m) average, measured at 3 m distance	

Table 504: Insulation tests

Description	Type test value	Reference
Dielectric tests	2 kV, 50 Hz, 1 min 500 V, 50 Hz, 1 min, communication	IEC 60255-27
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J 1 kV, 1.2/50 μs, 0.5 J, communication	IEC 60255-27
Insulation resistance measurements	>100 MΩ, 500 V DC	IEC 60255-27
Protective bonding resistance	<0.1 Ω, 4 A, 60 s	IEC 60255-27

Table 505: Mechanical tests

Description	Requirement	Reference
Vibration tests (sinusoidal)	Class 2	IEC 60068-2-6 (test Fc) IEC 60255-21-1
Shock and bump test	Class 2	IEC 60068-2-27 (test Ea shock) IEC 60068-2-29 (test Eb bump) IEC 60255-21-2
Seismic test	Class 2	IEC 60255-21-3

Table 506: Environmental tests

Description	Type test value	Reference
Dry heat test	• 96 h at +55ºC • 16 h at +85ºC 1)	IEC 60068-2-2
Dry cold test	• 96 h at -25ºC • 16 h at -40ºC	IEC 60068-2-1
Damp heat test	• 6 cycles (12 h + 12 h) at +25°C…+55°C, humidity >93%	IEC 60068-2-30
Change of temperature test	• 5 cycles (3 h + 3 h) at -25°C...+55°C	IEC60068-2-14
Storage test	• 96 h at -40ºC • 96 h at +85ºC	IEC 60068-2-1 IEC 60068-2-2

1) For relays with an LC communication interface the maximum operating temperature is +70ºC

Table 507: Product safety

Description	Reference
LV directive	2006/95/EC
Standard	EN 60255-27 (2013) EN 60255-1 (2009)

Table 508: EMC compliance

Description	Reference
EMC directive	2004/108/EC
Standard	EN 60255-26 (2013)

Section 14 Applicable standards and regulations

EN 60255-1

EN 60255-26

EN 60255-27

EMC council directive 2004/108/EC

EU directive 2002/96/EC/175

IEC 60255

Low-voltage directive 2006/95/EC

IEC 61850

Section 15 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
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
CBB	Cycle building block
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
CPU	Central processing unit
CSV	Comma-separated values
CT	Current transformer
DAN	Doubly attached node
DFT	Discrete Fourier transform
DHCP	Dynamic Host Configuration Protocol
DPC	Double-point control
DT	Definite time
EEPROM	Electrically erasable programmable read-only memory
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
FIFO	First in, first out
FLC	Full load current
FPGA	Field-programmable gate array
FTP	File transfer protocol
FTPS	FTP Secure

GOOSE	Generic Object-Oriented Substation Event
GPS	Global Positioning System
HMI	Human-machine interface
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
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, IEC 61754-20
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MM	1. Multimode 2. Multimode optical fiber
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
P2P	peer-to-peer

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 starting on two conditions: the peak-to-peak value is above the set start current or the peak value is above two times the set start value
PPS	Pulse per second
PRP	Parallel redundancy protocol
R/L	Remote/Local
RAM	Random access memory
RCA	Also known as MTA or base angle. Characteristic angle.
REB611	Busbar and multipurpose differential protection and control relay
REF611	Feeder protection and control relay
REM611	Motor protection and control relay
REU611	Voltage protection and control relay
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
ROM	Read-only memory
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTC	Real-time clock
RTD	Resistance temperature detector
SAN	Single attached node
SBO	Select-before-operate
SCADA	Supervision, control and data acquisition
SCL	XML-based substation description configuration language defined by IEC 61850

SMT	Signal Matrix tool in PCM600
SNTP	Simple Network Time Protocol
SOTF	Switch onto fault
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
TLV	Type length value
UTC	Coordinated universal time
VDR	Voltage-depended resistor
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

ABB Distribution Solutions
Distribution Automation
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

www.abb.com/mediumvoltage
www.abb.com/relion

1MRS757454 D