Relion® Protection and Control

Advanced Recloser Protection and Control RER620

Technical Manual

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ABB

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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 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-6 and EN 60255-27 for the low voltage directive. The relay is designed in accordance with the international standards of the IEC 60255 series and ANSI C37.90.

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 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

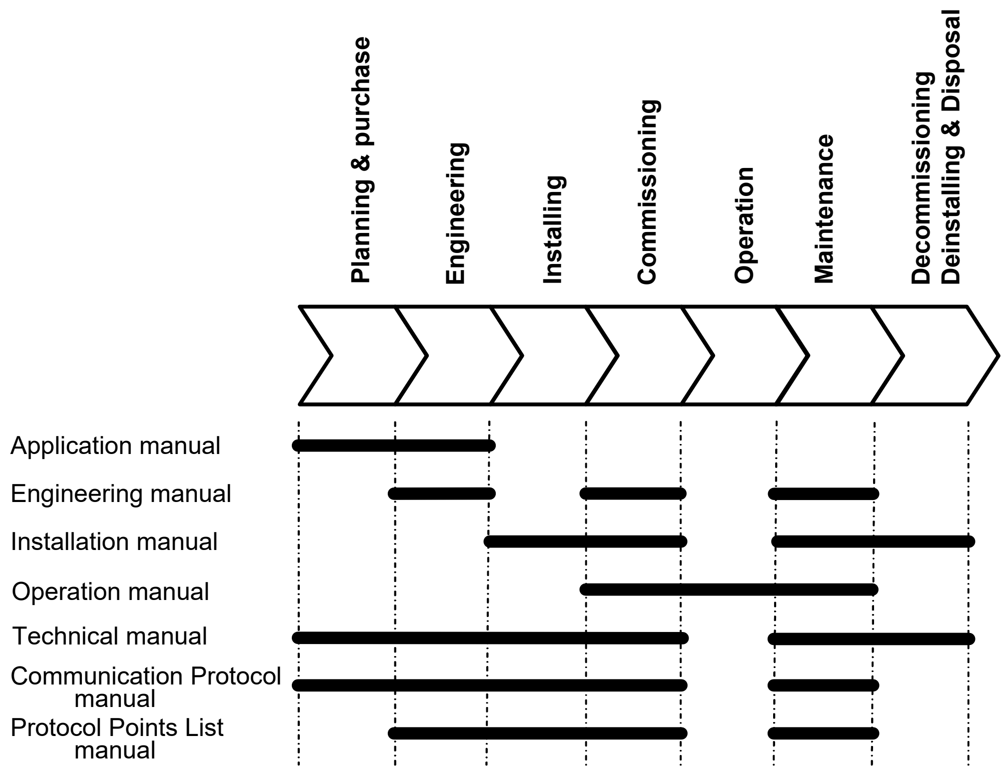


Figure 1: The intended use of manuals in different lifecycles

The engineering manual contains instructions on how to engineer the relays using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert relays to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and DNP3.

The installation manual contains instructions on how to install the relay. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the relay should be installed.

The operation manual contains instructions on how to operate the relay once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the relay. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

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.

The communication protocol manual describes a communication protocol supported by the relay. The manual concentrates on vendor-specific implementations. The point list manual describes the outlook and properties of the data points specific to the relay. The manual should be used in conjunction with the corresponding communication protocol manual.

1.3.2 Document revision history

Document revision/date	Product series version	History
A/12/29/2010	1.0	First release
B/10/25/2011	1.1	Content updated to correspond to the product series version
C/08/29/2014	1.2	Content updated to correspond to the product series version
D/10/09/2015	1.2	Content updated
E/10/09/2015	1.2	Content updated
F/07/20/2017	1.3	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 Safety indication 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 to 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 should be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Manual conventions

Conventions used in relay manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual 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, for example:
  To navigate between the options, use ↑ and ↓.
- HMI menu paths are presented in bold, for example:
  Select **Main menu** > **Settings**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press ↵.
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks, for example:
  The corresponding parameter values are “Enabled” and “Disabled”.
- Relay input/output messages and monitored data names are shown in Courier font, for example:
  When the function picks up, the `PICKUP` output is set to TRUE.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned then the dimension is in mm.
- Analog inputs to protection functions are shown in the technical manual for clarity however these inputs and connections do not appear in the application logic. The connection of these analog signals is fixed internally to the corresponding function blocks and cannot be altered by users.

Function block

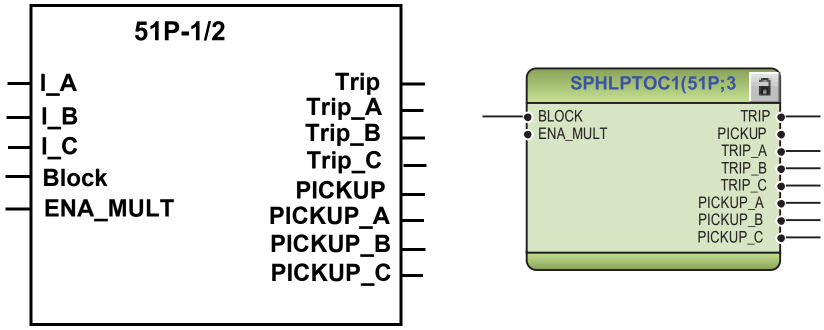


Figure 2: Function block as it appears in the manual (left) and in the ACT (right)

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: RER620 functions, codes and symbols

Function	IEC61850	IEC60617	ANSI/C37.2
Current Protection			
Single-phase non-directional time overcurrent protection with 1-ph trip option, low stage	SPHLPTOC1	3I>(1)	51P
Single-phase non-directional time overcurrent protection with 1-ph trip option, high stage 1	SPHLPTOC2	3I>(2)	50P-1
Single-phase non-directional time overcurrent protection with 1-ph trip option, high stage 2	SPHHPTOC1	3I>>(1)	50P-2
Single-phase non-directional instantaneous overcurrent protection with 1-ph trip option	SPHIPTOC1	3I>>>(1)	50P-3
Non-directional time overcurrent ground-fault protection, low stage	XEFLPTOC2	Io>(2)	51N
Non-directional time overcurrent ground-fault protection, high stage 1	XEFLPTOC3	Io>(3)	50N-1
Non-directional time overcurrent ground-fault protection, high stage 2	XEFHPTOC3	Io>>(3)	50N-2
Non-directional instantaneous time overcurrent ground-fault protection	XEFIPTOC2	Io>>>(2)	50N-3
Non-directional sensitive earth-fault	EFLPTOC3	Io>(3)	50SEF
Negative sequence non-directional time overcurrent protection 1	XNSPTOC1	I2 >(1)	46-1
Negative sequence non-directional time overcurrent protection 2	XNSPTOC2	I2 >(2)	46-2
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Three-phase inrush detector	INPHAR	3I2f >	INR
Directional Protection			
Single-phase directional overcurrent protection, low stage 1	SDPHLPDOC1	3I >->(1)	67/51P-1
Single-phase directional overcurrent protection, low stage 2	SDPHLPDOC2	3I >->(2)	67/51P-2
Directional ground-fault protection, low stage 1	XDEFLPDEF1	Io>->(1)	67/51N-1
Directional ground-fault protection, low stage 2	XDEFLPDEF2	Io>->(2)	67/51N-2
Cold Load Timers			
Cold load timer 1 Phase A (in seconds)	TPSGAPC1	TPS(1)	62CLD-1
Cold load timer 2 Phase A (in minutes)	TPMGAPC1	TPM(1)	62CLD-2
Cold load timer 1 Phase B (in seconds)	TPSGAPC2	TPS(2)	62CLD-3
Cold load timer 2 Phase B (in minutes)	TPMGAPC2	TPM(2)	62CLD-4
Cold load timer 1 Phase C (in seconds)	TPSGAPC3	TPS(3)	62CLD-5
Cold load timer 2 Phase C (in minutes)	TPMGAPC3	TPM(3)	62CLD-6
Voltage Protection			
Single-phase overvoltage 1, source 1 low stage	SPHPTOV1	3U >(1)	59-1
Single-phase overvoltage 2, source 1 high stage	SPHPTOV2	3U >(2)	59-2
Single-phase overvoltage 3, source 2 low stage	SPHPTOV3	3U >(3)	59-3
Single-phase undervoltage 1, source 1 low stage	SPHPTUV1	3U <(1)	27-1
Single-phase undervoltage 2, source 1 high stage	SPHPTUV2	3U <(2)	27-2
Single-phase undervoltage 3, source 2 low stage	SPHPTUV3	3U <(3)	27-3
Positive sequence overvoltage protection, source1	PSPTOV1	U1>(1)	59PS-1
Positive sequence overvoltage protection, source 2	PSPTOV2	U1>(2)	59PS-2
Negative sequence overvoltage protection, source1	NSPTOV1	U2>(1)	47
Negative sequence overvoltage protection, source 2	NSPTOV2	U2>(2)	47-2
Zero sequence overvoltage protection, source1	ROVPTOV1	Uo>(1)	59N-1
Zero sequence overvoltage protection, source 2	ROVPTOV2	Uo>(2)	59N-2

Function	IEC61850	IEC60617	ANSI/C37.2
Frequency Protection			
Underfrequency, Overfrequency, Frequency rate of change, Source 1, Stage 1	FRPFRQ1	f</f>,df/dt(1)	81-1
Underfrequency, Overfrequency, Frequency rate of change, Source 1, Stage 2	FRPFRQ2	f</f>,df/dt(2)	81-2
Load Shed & Restoration, Source 1, Stage 1	LSHDPFRQ1	UFLS/R(1)	81S-1
Load Shed & Restoration, Source 1, Stage 2	LSHDPFRQ2	UFLS/R(2)	81S-2
Other Protection			
High Impedance Fault Detector	PHIZ1	PHIZ1	HIZ
Circuit breaker failure protection	SCCBRBRF1	3I>/Io>BF	50BFT
Circuit breaker close failure protection	SCCBRBCF1	SCCBRBCF1	50BFC
Directional positive sequence power protection	DPSRDIR1	P>->	32P
Directional negative/zero sequence power protection	DNZSRDIR1	Q>->	32N
Control			
Autoreclosing, 1ph and/or 3ph	SDARREC1	O -> I	79
Synch-check/voltage check (Source 1 is defined as bus, Source 2 as line)	SECRSYN1	SYNC	25
Circuit Breaker 1 (3 state inputs / 3 control outputs)	SCBXCBR1	I<->O CB	52
Loop control	DLCM	LCM	LCM
Supervision and Monitoring			
CB condition monitoring	SPSCBR1	CBCM	52CM
Fuse failure supervision, Source 1	SEQRFUF1	FUSEF	60
Measurement			
Three-phase current	CMMXU1	3I	IA,IB,IC
Demand metering, Max/Min metering	CMSTA1		
Sequence current	CSMSQI1	I1,I2,I0	I1, I2, I0
Ground current	RESCMMXU1	Io	IG
Three-phase voltage, Source 1	VMMXU1	3U	VA,VB,VC
Three-phase voltage, Source 2	VMMXU2	3U(B)	VA,VB,VC(2)
Sequence voltages, Source 1	VSMSQI1	U1,U2,U0	V1,V2,V0
Sequence voltages, Source 2	VSMSQI2	U1,U2,U0(B)	V1,V2,V0(2)
Single and Three-phase power, Power factor and three phase energy, Source 1	APEMMXU1	P,SP,E	P,SP,E
Frequency, Source 1	FMMXU1	f	f
Recorders			
Digital fault recorder (DFR)	RDRE	DR	DFR
Sequence of Events (SER)	SER	SER	SER
Fault Recorder	FLTMSTA	FLTMSTA	FLTMSTA
Fault Locator (FLOC)	DRFLO1	FLO	FLO
Other Functions			
Battery voltage, current. Test the battery	ZBAT1	UPS	UPS
Universal Power Drive	XGGIO115	X115(UPD)	X115(UPD)
Programmable buttons (16 buttons)	FKEYGGIO1	FKEYGGIO1	FKEYGGIO1
Move function block (8 outputs)	MVGAPC1	MVGAPC1	MVGAPC1
Move function block (8 outputs)	MVGAPC2	MVGAPC2	MVGAPC2

Function	IEC61850	IEC60617	ANSI/C37.2
Pulse timer (8 timers)	PTGAPC1	PTGAPC1	PTGAPC1
Pulse timer (8 timers)	PTGAPC2	PTGAPC2	PTGAPC2
Generic control points (16 outputs)	SPCGGIO1	SPCGGIO1	SPCGGIO1
Generic control points (16 outputs)	SPCGGIO2	SPCGGIO2	SPCGGIO2
Set reset flip flops (8 outputs)	SRGAPC1	SRGAPC1	SRGAPC1
Set reset flip flops (8 outputs)	SRGAPC2	SRGAPC2	SRGAPC2
Time delay off timers (8 timers)	TOFGAPC1	TOFGAPC1	TOFGAPC1
Time delay off timers (8 timers)	TOFGAPC2	TOFGAPC2	TOFGAPC2
Time delay on timers (8 timers)	TONGAPC1	TONGAPC1	TONGAPC1
Time delay on timers (8 timers)	TONGAPC2	TONGAPC2	TONGAPC2
Multipurpose generic up-down counter	UDFCNT1	UDFCNT1	UDFCNT1
Multipurpose generic up-down counter	UDFCNT2	UDFCNT2	UDFCNT2
Multipurpose generic up-down counter	UDFCNT3	UDFCNT3	UDFCNT3
Multipurpose generic up-down counter	UDFCNT4	UDFCNT4	UDFCNT4
Multipurpose generic up-down counter	UDFCNT5	UDFCNT5	UDFCNT5
Multipurpose generic up-down counter	UDFCNT6	UDFCNT6	UDFCNT6
Multipurpose generic up-down counter	UDFCNT7	UDFCNT7	UDFCNT7
Multipurpose generic up-down counter	UDFCNT8	UDFCNT8	UDFCNT8
Multipurpose generic up-down counter	UDFCNT9	UDFCNT9	UDFCNT9
Multipurpose generic up-down counter	UDFCNT10	UDFCNT10	UDFCNT10
Multipurpose generic up-down counter	UDFCNT11	UDFCNT11	UDFCNT11
Multipurpose generic up-down counter	UDFCNT12	UDFCNT12	UDFCNT12

Section 2 RER620 overview

2.1 Overview

RER620 is a product family of relays designed for protection, control, measurement and supervision of utility substations and industrial switchgear and equipment. The design of the relays has been guided by the IEC 61850 standard for communication and interoperability of substation automation devices.

The relays feature draw-out-type design with a variety of mounting methods, compact size and ease of use. Depending on the product, optional functionality is available at the time of order for both software and hardware, for example, autoreclosure and additional I/Os.

The RER620 relays support a range of communication protocols including IEC 61850 with GOOSE messaging, Modbus®, DNP3, PG&E 2179 and IEC 101/104.

2.1.1 Product series version history

Product version	Product history
1.0	First product from RER620 released
1.1	PG&E 2179 Protocol, Up/down counters, Single Phase power measurement added
1.2	CVD Voltage Clamping function added Lowered Zero Clamping limit for Current Measurements, Cyber Security Enhancements included
1.3	Added new configuration RA02

2.1.2 PCM600 and relay connectivity package version

- Protection and Control Relay Manager PCM600 2.7 or later versions of PCM600
- Relay Connectivity Package RER620 Ver. 1.3 or later

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

2.2 Local HMI

Figure 3: LHMI

The LHMI of the relay contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

2.2.1 LCD

The LHMI includes a graphical LCD that supports two character sizes. The character size depends on the selected language.

Table 2: Characters and rows on the view

Character size	Rows in view	Characters on row
Large, variable width (13x14 pixels)	4 rows 8 rows with large screen	min 8

The display view is divided into four basic areas.

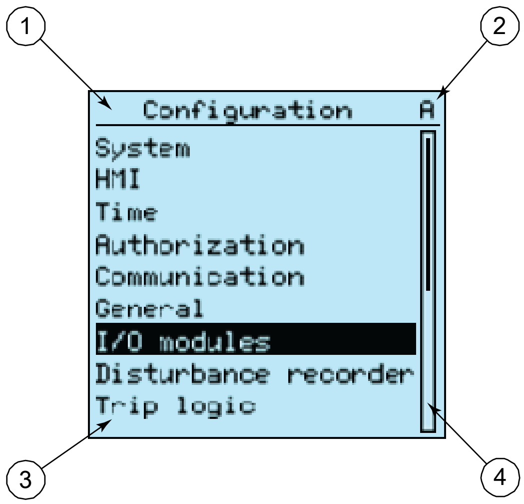


Figure 4: Display layout

1 Header
2 Icon
3 Content
4 Scroll bar (displayed when needed)

2.2.2 LEDs

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

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

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

and 

. They represent the status of the circuit breaker.

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 primary object, for example, a circuit breaker, disconnector or switch. The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

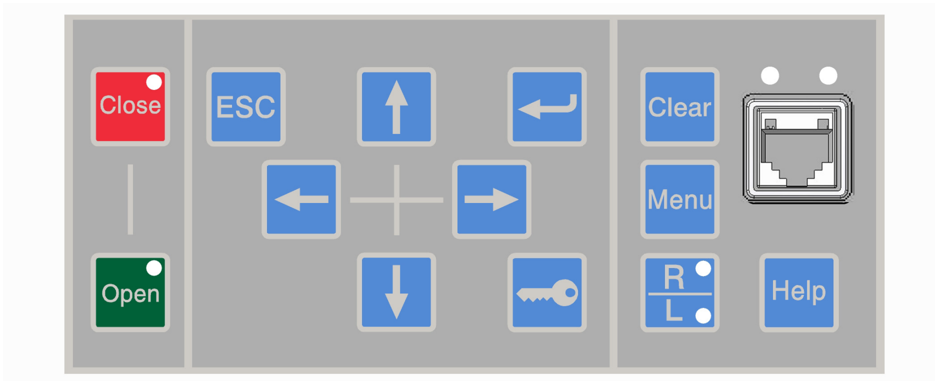


Figure 5: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.3 Web HMI

The WHMI enables the user to access the relay via a web browser. The supported web browser versions are Internet Explorer 9.0, 10.0 and 11.0.

WHMI is enabled by default.

WHMI offers several functions.

- Alarm indications and event lists
- System supervision
- Parameter settings
- Measurement display
- Oscillographic records
- Phasor diagram

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

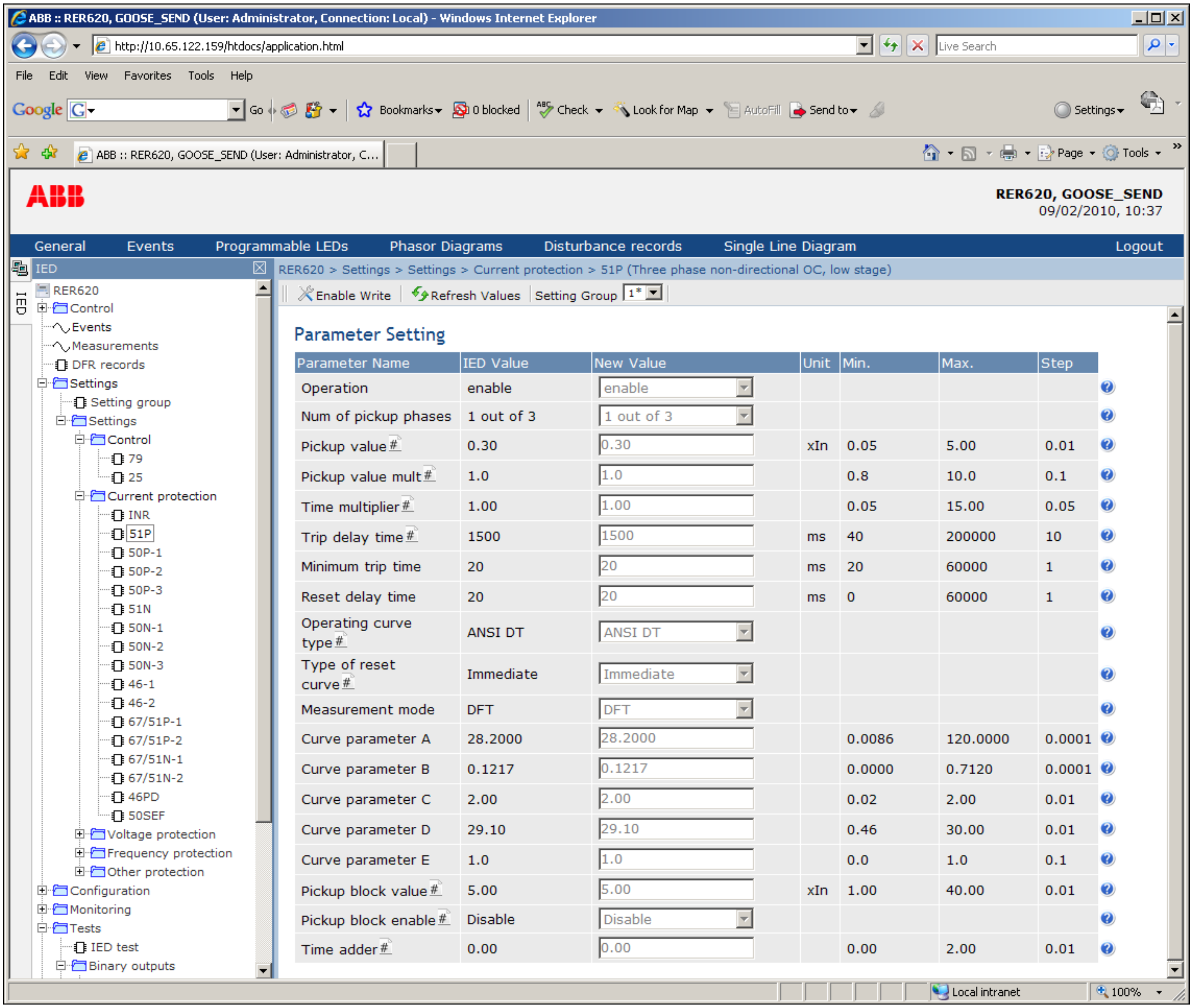


Figure 6: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.4 Authorization

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

The default passwords can be changed with Administrator user rights.

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

Table 3: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.5 Communication

The relay supports different communication protocols: IEC 61850, Modbus® and DNP 3.0 Level 2, IEC 104- all using TCP/IP. DNP3, PG&E 2179, IEC101and Modbus are supported through serial communication. Operational information and controls are available through these protocols.

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

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

Section 3 Basic functions

3.1 General parameters

Table 4: phase currents: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary current	2=1A 3=5A			3=5A	Rated secondary current
Primary current	1.0...6000.0	A	0.1	600.0	Rated primary current
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A amplitude correction factor
Amplitude corr. B	0.900...1.100		0.001	1.000	Phase B amplitude correction factor
Amplitude corr. C	0.900...1.100		0.001	1.000	Phase C amplitude correction factor
Reverse polarity	0=False 1=True			0=False	

Table 5: ground current: Non group settings

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

Table 6: phase voltages: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.001...440.000	kV	0.001	13.200	Primary rated voltage
Secondary voltage	1=100V 2=110V 3=115V 4=120V	V		4=120 V	Secondary rated voltage
VT connection	1=Wye 2=Delta			1=Wye	Wye or delta VT connection
Amplitude corr. A	0.500...1.500		0.001	1.000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Amplitude corr. B	0.500...1.500		0.001	1.000	Phase B Voltage phasor magnitude correction of an external voltage transformer
Amplitude corr. C	0.500...1.500		0.001	1.000	Phase C Voltage phasor magnitude correction of an external voltage transformer

Table 7: ground voltage: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary voltage	1=100V 2=110V 3=115V 4=120V			1=100V	Secondary voltage
Primary voltage	0.001...440.000	kV	0.001	11.547	Primary voltage
Amplitude corr.	0.900...1.100		0.001	1.000	Amplitude correction

Table 8: Alarm LED: Input signals

Name	Type	Default	Description
Alarm LED 1	BOOLEAN	0=False	Status of Alarm LED 1
Alarm LED 2	BOOLEAN	0=False	Status of Alarm LED 2
Alarm LED 3	BOOLEAN	0=False	Status of Alarm LED 3
Alarm LED 4	BOOLEAN	0=False	Status of Alarm LED 4
Alarm LED 5	BOOLEAN	0=False	Status of Alarm LED 5
Alarm LED 6	BOOLEAN	0=False	Status of Alarm LED 6
Alarm LED 7	BOOLEAN	0=False	Status of Alarm LED 7
Alarm LED 8	BOOLEAN	0=False	Status of Alarm LED 8
Alarm LED 9	BOOLEAN	0=False	Status of Alarm LED 9
Alarm LED 10	BOOLEAN	0=False	Status of Alarm LED 10
Alarm LED 11	BOOLEAN	0=False	Status of Alarm LED 11

Table 9: Alarm LED: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 1
Description				Alarm LEDs LED 1	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 2
Description				Alarm LEDs LED 2	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 3
Description				Alarm LEDs LED 3	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 4
Description				Alarm LEDs LED 4	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 5
Description				Alarm LEDs LED 5	Description of alarm

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

Table 10: Authorization: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Local override	0=False 1=True			1=True	Disable authority
Remote override	0=False 1=True			1=True	Disable authority
Local viewer				0	Set password
Local operator				0	Set password
Local engineer				0	Set password
Local admin				0	Set password
Remote viewer				0	Set password
Remote operator				0	Set password
Remote engineer				0	Set password
Remote admin				0	Set password

Table 11: Binary input: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Threshold voltage	18...176	Vdc	2	48	Digital input threshold voltage
Input osc. level	2...50	events/s	1	30	Digital input oscillation suppression threshold
Input osc. hyst	2...50	events/s	1	10	Digital input oscillation suppression hysteresis

Table 12: Ethernet front port: Non group 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 13: Ethernet rear port: Non group 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 14: General system: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Rated frequency	1=50Hz 2=60Hz			2=60Hz	Rated frequency of the network
Phase rotation	1=ABC 2=ACB			1=ABC	Phase rotation order
Blocking mode	1=Freeze timer 2=Block all 3=Block trip			1=Freeze timer	Behavior for function BLOCK inputs
Bay name				RER620	Bay name in system
SG follow input	0=False 1=True			0=False	Enable setting group change to follow the input state
Phase Order Mode	1=ABC 2=BCA 3=CAB 4=ACB 5=CBA 6=BAC			1=ABC	Selection for phase correction order

When the Phase Order Mode setting is changed, the relay must be rebooted to activate the new setting.

Table 15: HMI: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
FB naming convention	1=IEC61850 2=IEC60617 4=ANSI			4=ANSI	FB naming convention used in relay
Default view	1=Measurements 2=Main menu			1=Measurements	LHMI default view
Backlight timeout	1...60	min	1	60	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	10	Web HMI login timeout
SLD symbol format	1=IEC 2=ANSI			2=ANSI	Single Line Diagram symbol format

Table 16: IEC 61850-8-1 MMS: Non group settings

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

Table 17: DNP3: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
DNP physical layer	1=Serial 2=TCP/IP 3=Both			2=TCP/IP	DNP physical layer
Unit address	1...65519		1	1	DNP unit address
Master address	1...65519		1	3	DNP master and UR address
Serial port	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for serial interface, when physical layer is serial.
Need time interval	0...65535	min	1	30	Period to set IIN need time bit
Time format	0=UTC 1=Local			1=Local	UTC or local. Coordinate with master.
CROB select timeout	1...65535	sec	1	10	Control Relay Output Block select timeout
Data link confirm	0=Never 1=Only Multiframe 2=Always			0=Never	Data link confirm mode
Data link confirm TO	100...65535	ms	1	3000	Data link confirm timeout
Data link retries	0...65535		1	3	Data link retries count
Data link Rx to Tx delay	0...255	ms	1	0	Turnaround transmission delay
Data link inter char delay	0...20	char	1	4	Inter character delay for incoming messages
App layer confirm	1=Disable 2=Enable			1=Disable	Application layer confirm mode
App confirm TO	100...65535	ms	1	5000	Application layer confirm and UR timeout
App layer fragment	256...2048	bytes	1	2048	Application layer fragment size
UR mode	1=Disable 2=Enable			1=Disable	Unsolicited responses mode
UR retries	0...65535		1	3	Unsolicited retries before switching to UR offline mode
UR TO	0...65535	ms	1	5000	Unsolicited response timeout
UR offline interval	0...65535	min	1	15	Unsolicited offline interval
UR Class 1 Min events	0...999		1	2	Min number of class 1 events to generate UR
UR Class 1 TO	0...65535	ms	1	50	Max holding time for class 1 events to generate UR
UR Class 2 Min events	0...999		1	2	Min number of class 2 events to generate UR
UR Class 2 TO	0...65535	ms	1	50	Max holding time for class 2 events to generate UR
UR Class 3 Min events	0...999		1	2	Min number of class 3 events to generate UR
UR Class 3 TO	0...65535	ms	1	50	Max holding time for class 3 events to generate UR
Legacy master UR	1=Disable 2=Enable			1=Disable	Legacy DNP master unsolicited mode support. When enabled relay does not send initial unsolicited message.
Legacy master SBO	1=Disable 2=Enable			1=Disable	Legacy DNP Master SBO sequence number relax enable
Default Var Obj 01	1...2		1	1	1=BI; 2=BI with status.
Default Var Obj 02	1...2		1	2	1=BI event; 2=BI event with time.
Default Var Obj 30	1...4		1	2	1=32 bit AI; 2=16 bit AI; 3=32 bit AI without flag; 4=16 bit AI without flag.
Default Var Obj 32	1...4		1	4	1=32 bit AI event; 2=16 bit AI event; 3=32 bit AI event with time; 4=16 bit AI event with time.

When the DNP unit address or DNP master and UR address setting is changed, the relay must be rebooted to activate the new setting.

Table 18: MODBUS settings

Parameter	Values (Range)	Unit	Step	Default	Description
InOv	0=False 1=True			0=False	Modbus Internal Overflow: TRUE-System level overflow occurred (indication only)
Serial port 1	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 1
Parity 1	0=none 1=odd 2=even			2=even	Parity for Serial interface 1
Address 1	1...255			1	Modbus unit address on Serial interface 1
Link mode 1	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 1
Start delay 1	0...20	char		4	Start frame delay in chars on Serial interface 1
End delay 1	0...20	char		3	End frame delay in chars on Serial interface 1
Serial port 2	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 2
Parity 2	0=none 1=odd 2=even			2=even	Parity for Serial interface 2
Address 2	1...255			2	Modbus unit address on Serial interface 2
Link mode 2	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 2
Start delay 2	0...20			4	Start frame delay in chars on Serial interface 2
End delay 2	0...20			3	End frame delay in chars on Serial interface 2
MaxTCPClients	0...5			5	Maximum number of Modbus TCP/IP clients
TCPWriteAuthority	0=No clients 1=Reg. clients 2=All clients			2=All clients	Write authority setting for Modbus TCP/IP clients
EventID	0=Address 1=UID			0=Address	Event ID selection
TimeFormat	0=UTC 1=Local			1=Local	Time format for Modbus time stamps

Parameter	Values (Range)	Unit	Step	Default	Description
ClientIP1				000.000.000.000	Modbus Registered Client 1
ClientIP2				000.000.000.000	Modbus Registered Client 2
ClientIP3				000.000.000.000	Modbus Registered Client 3
ClientIP4				000.000.000.000	Modbus Registered Client 4
ClientIP5				000.000.000.000	Modbus Registered Client 5
CtlStructPWd1				****	Password for Modbus control struct 1[1]
CtlStructPWd2				****	Password for Modbus control struct 2
CtlStructPWd3				****	Password for Modbus control struct 3
CtlStructPWd4				****	Password for Modbus control struct 4
CtlStructPWd5				****	Password for Modbus control struct 5
CtlStructPWd6				****	Password for Modbus control struct 6
CtlStructPWd7				****	Password for Modbus control struct 7
CtlStructPWd8				****	Password for Modbus control struct 8
Internal Overflow	0=False 1=True			0=False	Modbus Internal Overflow: TRUE-System level overflow occurred (indication only)

1. The amount of available control structures may vary depending on the relay type.

Table 19: PG&E 2179 Protocol settings

Parameter	Values (Range)	Unit	Step	Default	Description
Serial port 1	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 1
End delay 1	0...20	char		4	End frame delay in chars on Serial interface 1
Device Address 1	1...65535		1	1	PG&E Protocol unit address on Serial interface 1
Selection Timeout	1...65	Sec	1	5	Selection Timeout for control SBO operation

Table 20: COM1/COM2 serial communication: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Fiber mode	0=No fiber 1=Fiber light ON loop 2=Fiber light OFF loop 3=Fiber light ON star 4=Fiber light OFF star			0=No fiber	Fiber mode for COM1
Serial mode	1=RS485 2Wire 2=RS485 4Wire 3=RS232 no handshake 4=RS232 with handshake			1=RS485 2Wire	Serial mode for COM1
CTS delay	0...60000			0	CTS delay for COM1
RTS delay	0...60000			0	RTS delay for COM1
Baud rate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baud rate for COM1

Table 21: Serial communication: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Fiber mode	0=No fiber 1=Fiber light ON loop 2=Fiber light OFF loop 3=Fiber light ON star 4=Fiber light OFF star			0=No fiber	Fiber mode for COM2
Serial mode	1=RS485 2Wire 2=RS485 4Wire 3=RS232 no handshake 4=RS232 with handshake			1=RS485 2Wire	Serial mode for COM2
CTS delay	0...60000			0	CTS delay for COM2
RTS delay	0...60000			0	RTS delay for COM2

Parameter	Values (Range)	Unit	Step	Default	Description
Baud rate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baud rate for COM2

Table 22: Time: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Date				0	Date
Time				0	Time
Time format	1=HH:MM:SS:MSAM 2=HH:MM:SS:MSPM			1=HH:MM:SS:MSAM	Time format
Date format	1=DD.MM.YYYY 2=DD/MM/YYYY 3=YYYY-MM-DD 4=MM.DD.YYYY 5=MM/DD/YYYY 6=YYYY-MM-DD 7=YYYY-DD-MM 8=YYYY/DD/MM			5=MM/DD/YYYY	Date format
Local time offset	-720...720	min		-300	Local time offset in minutes
Synch source	0=None 1=SNTP 2=Modbus 5=IRIG-B 9=DNP			1=SNTP	Time synchronization source
IP SNTP primary				10.58.125.165	IP address for SNTP primary server
IP SNTP secondary				192.168.2.165	IP address for SNTP secondary server
DST on time				02:00	Daylight savings time on, time (hh:mm)
DST on date				01.05.	Daylight savings time on, date (dd:mm)
DST on day	0=No in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			7=Sun	Daylight savings time on, day of week
DST offset	-720...720	min		60	Daylight savings time offset, in minutes
DST off time				02:00	Daylight savings time off, time (hh:mm)
DST off date				25.09.	Daylight savings time off, date (dd:mm)
DST off day	0=No in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			7=Sun	Daylight savings time off, day of week

DST Settings

DST settings depends on the time sync source. For example:

1. If time sync source is set to local time, we should set "Local time offset" and "DST offset" to 0, the system time will be the same as the sync source.
2. If the time sync source is set to UTC, we can set the following values,
   Local time offset = -300 (for Eastern time zone)
   DST on time = 2:00

DST on date = 03/08

DST on day = Sun

DST offset = 60 min

DST off time = 2:00

DST off date = 11/01

DST off day = Sun

3. If no time sync source, we can set the following DST values,

DST on time = 2:00

DST on date = 03/08

DST on day = Sun

DST offset = 60 min

DST off time = 2:00

DST off date = 11/01

DST off day = Sun

These settings will take care of all the DST time changes automatically, no need to adjust every year.

Table 23: Generic timers, TPGAPC1...4

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

Table 24: X100 PSM: Output signals

Name	Type	Default	Description
X100-PO1	BOOLEAN	0=False	Connectors 6-7
X100-PO2	BOOLEAN	0=False	Connectors 8-9
X100-SO1	BOOLEAN	0=False	Connectors 10c-11nc-12no
X100-SO2	BOOLEAN	0=False	Connectors 13c-14no
X100-PO3	BOOLEAN	0=False	Connectors 15-17/18-19
X100-PO4	BOOLEAN	0=False	Connectors 20-22/23-24

Table 25: X110 BIO: Output signals

Name	Type	Default	Description
X110-SO1	BOOLEAN	0=False	Connectors 14c-15no-16nc
X110-SO2	BOOLEAN	0=False	Connectors 17c-18no-19nc
X110-SO3	BOOLEAN	0=False	Connectors 20c-21no-22nc
X110-SO4	BOOLEAN	0=False	Connectors 23-24

Table 26: X110 BIO: Input signals

Name	Type	Description
X110-Input 1	BOOLEAN	Connectors 1-2
X110-Input 2	BOOLEAN	Connectors 3-4
X110-Input 3	BOOLEAN	Connectors 5-6c
X110-Input 4	BOOLEAN	Connectors 7-6c
X110-Input 5	BOOLEAN	Connectors 8-9c
X110-Input 6	BOOLEAN	Connectors 10-9c
X110-Input 7	BOOLEAN	Connectors 11-12c
X110-Input 8	BOOLEAN	Connectors 13-12c

Table 27: X110 BIO: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Input 1 filter time	5...1000	ms		5	Connectors 1-2
Input 2 filter time	5...1000	ms		5	Connectors 3-4
Input 3 filter time	5...1000	ms		5	Connectors 5-6c
Input 4 filter time	5...1000	ms		5	Connectors 7-6c
Input 5 filter time	5...1000	ms		5	Connectors 8-9c
Input 6 filter time	5...1000	ms		5	Connectors 10-9c
Input 7 filter time	5...1000	ms		5	Connectors 11-12c
Input 8 filter time	5...1000	ms		5	Connectors 13-12c
Input 1 inversion	0=False 1=True			0=False	Connectors 1-2
Input 2 inversion	0=False 1=True			0=False	Connectors 3-4
Input 3 inversion	0=False 1=True			0=False	Connectors 5-6c
Input 4 inversion	0=False 1=True			0=False	Connectors 7-6c
Input 5 inversion	0=False 1=True			0=False	Connectors 8-9c
Input 6 inversion	0=False 1=True			0=False	Connectors 10-9c
Input 7 inversion	0=False 1=True			0=False	Connectors 11-12c
Input 8 inversion	0=False 1=True			0=False	Connectors 13-12c

Table 28: X120 AIM: Input signals

Name	Type	Description
X120-Input 1	BOOLEAN	Connectors 1-2c
X120-Input 2	BOOLEAN	Connectors 3-2c
X120-Input 3	BOOLEAN	Connectors 4-2c
X120-Input 4	BOOLEAN	Connectors 5-6

Table 29: X120 AIM: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Input 1 filter time	5...1000	ms		5	Connectors 1-2c
Input 2 filter time	5...1000	ms		5	Connectors 3-2c
Input 3 filter time	5...1000	ms		5	Connectors 4-2c
Input 4 filter time	5...1000	ms		5	Connectors 5-6
Input 1 inversion	0=False 1=True			0=False	Connectors 1-2c
Input 2 inversion	0=False 1=True			0=False	Connectors 3-2c
Input 3 inversion	0=False 1=True			0=False	Connectors 4-2c
Input 4 inversion	0=False 1=True			0=False	Connectors 5-6

3.2 Self-supervision

The 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 communications channels.

There are two types of fault indications.

- Internal faults
- Warnings

3.2.1 Internal faults

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

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

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

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

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

The self-supervision signal output operates on the closed circuit principle. Under normal conditions the relay is energized and the contact gap 3-5 in slot X100 is closed. If the auxiliary power supply fail or an internal fault is detected, the contact gap 3-5 is opened.

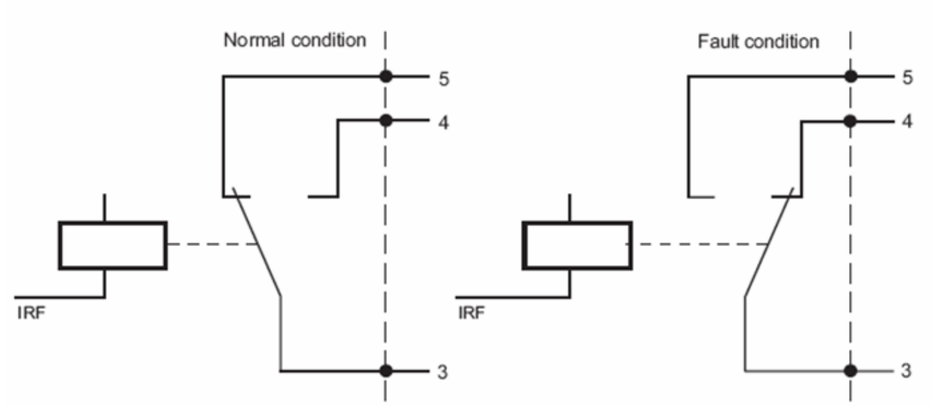


Figure 7: Output contact

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

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

3.2.2 Warnings

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

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

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

Table 30: 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 Supply voltage break	11	The auxiliary supply voltage has dropped to the failure level.
Internal fault Settings error	32	Settings error has occurred.
Internal Fault SO-relay(s),X105	40	Faulty Signal Output relay(s) in card located in slot X105.
Internal Fault SO-relay(s),X115	41	Faulty Signal Output relay(s) in card located in slot X115.
Internal Fault SO-relay(s),X100	43	Faulty Signal Output relay(s) in card located in slot X100.
Internal Fault SO-relay(s),X110	44	Faulty Signal Output relay(s) in card located in slot X110.
Internal Fault SO-relay(s),X120	45	Faulty Signal Output relay(s) in card located in slot X120.
Internal Fault SO-relay(s),X130	46	Faulty Signal Output relay(s) in card located in slot X130.
Internal Fault PO-relay(s),X105	50	Faulty Power Output relay(s) in card located in slot X105.
Internal Fault PO-relay(s),X115	51	Faulty Power Output relay(s) in card located in slot X115.
Internal Fault PO-relay(s),X100	53	Faulty Power Output relay(s) in card located in slot X100.
Internal Fault PO-relay(s),X110	54	Faulty Power Output relay(s) in card located in slot X110.
Internal Fault PO-relay(s),X120	55	Faulty Power Output relay(s) in card located in slot X120.
Internal Fault PO-relay(s),X130	56	Faulty Power Output relay(s) in card located in slot X130.
Internal Fault Light sensor error	57	Faulty ARC light sensor input(s).
Internal Fault Conf. error,X105	60	Card in slot X105 is wrong type.
Internal Fault Conf. error,X115	61	Card in slot X115 is wrong type.
Internal Fault Conf. error,X000	62	Card in slot X000 is wrong type.
Internal Fault Conf. error,X100	63	Card in slot X100 is wrong type or does not belong to the original composition.
Internal Fault Conf. error,X110	64	Card in slot X110 is wrong type, is missing or does not belong to the original composition.
Internal Fault Conf. error,X120	65	Card in slot X120 is wrong type, is missing or does not belong to the original composition.

Fault indication	Fault code	Additional information
Internal Fault Conf. error,X130	66	Card in slot X130 is wrong type.
Internal Fault Card error,X105	70	Card in slot X105 is faulty.
Internal Fault Card error,X115	71	Card in slot X115 is faulty.
Internal Fault Card error,X000	72	Card in slot X000 is faulty.
Internal Fault Card error,X100	73	Card in slot X100 is faulty.
Internal Fault Card error,X110	74	Card in slot X110 is faulty.
Internal Fault Card error,X120	75	Card in slot X120 is faulty.
Internal Fault Card error,X130	76	Card in slot X130 is faulty.
Internal Fault LHMI module	79	LHMI module is faulty. The fault indication may not be seen on the LHMI during the fault.
Internal Fault RAM error	80	Error in the RAM memory on the CPU card.
Internal Fault ROM error	81	Error in the ROM memory on the CPU card.
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 UPD card error in X115	110	UPD card error in X115
Internal Fault UPD self-check fail in X115	111	UPD self-check fail in X115

Table 31: Warning indications and codes

Warning indication	Warning code	Additional information
Warning Internal system warning	2	An internal system warning condition has occurred.
Warning Time synch error	5	A time synch error warning condition has occurred.
Warning Watchdog reset	10	A watchdog reset has occurred.
Warning Power down det.	11	The auxiliary supply voltage has dropped too low.
Warning IEC61850 error	20	Error when building the IEC 61850 data model.
Warning Modbus error	21	Error in the Modbus communication.
Warning DNP3 error	22	Error in the DNP3 communication.
Warning Dataset error	24	Error in the Data set(s).
Warning Report cont. error	25	Error in the Report control block(s).
Warning GOOSE contr. error	26	Error in the GOOSE control block(s).
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 ACT error	31	ACT error
Warning GOOSE Tx/Rx error	32	Error in GOOSE message transmitting or receiving.
Warning AFL error	33	Error in AFL configuration
Warning Unack card comp.	40	A new composition has not been acknowledged/accepted.
Warning Protection comm.	50	Error in protection communication.
Warning UPD Voltage Low in X115	112	UPD Voltage Low in X115
Warning UPS Communication error in X115	113	UPS Communication error in X115
Warning UPS Command failure in X115	114	UPS Command failure in X115
Warning Breaker Operation Failure	115	Breaker Operation Failure, possibly due to incorrect setting for UPD or UPD profile setting.

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

3.3 LED indication control

The 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 pre configured in a such way that all the protection functions general pickup and trip signals are combined with this function (available as output signals `OUT_PICKUP` and `OUT_TRIP`). These signals are always internally connected to Pickup and Trip LEDs. LEDPTRC collects and combines phase information from different protection functions (available as output signals `OUT_PU_A /_B /_C` and `OUT_TRP_A /_B /_C`). There is also combined ground fault information collected from all the ground fault functions available in the relay configuration (available as output signals `OUT_PU_NEUT` and `OUT_TRP_NEUT`).

3.4 Time synchronization

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

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

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

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

DNP3 can be used as a time synchronization source.

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

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

IRIG-B time synchronization requires the IRIG-B format B000/B001 with IEEE-1344 extensions. The synchronization time can be either UTC time or local time. As no reboot is necessary, the time synchronization starts immediately after the IRIG-B sync source is selected and the IRIG-B signal source is connected.

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

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

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

3.5 Parameter setting groups

There are four relay variant specific setting groups. For each setting group, the parameter setting can be made independently.

The active setting group can be changed by parameter (setting groups 1...6) or via binary input (setting groups 1...6), if a binary input is enabled for it.

To use a binary input to change setting groups use ACT (Application Configuration Tool) to program a Hardware Channel Binary input to the Protection block.

Table 32: Active setting group binary input state

BI state	Active setting group
OFF	1
ON	2

The setting group parameter is overridden when a binary input is used for changing the active setting group.

Table 33: Settings

Parameter	Setting	Value	Default	Description	Access rights
Setting group	Active group	1...4	1	Selected active group	RWRW

Not all parameters belong to a setting group. For example protection function enable/disable settings are not part of a setting group.

3.6 Recorded data

The relay has the capacity to store the records of 32 latest fault events. The records enable the user to analyze the 32 most recent power system events. Each fault record (FLTMSTA) is marked with an up-counting fault number. Slot fault record 1 always contains the newest record, and fault record 32 the oldest. The time stamp is taken from the beginning of the fault.

The fault recording period begins from the pickup event of any protection function and ends if any protection function trips or the pickup(s) is restored before the trip event. The type of fault that triggers the fault recording is selected with the setting parameter *Trig mode*. When “From all faults” is selected, all types of detected faults trigger a new fault recording. When “From trip” is selected, only faults that cause an trip event trigger a new fault recording.Finally when From only pickup is selected, only faults that cause a protection function restoring before the actual trip signal are recorded.

Fault recorder (FLR) collects some minimum and maximum current and voltage values during the recording period. DFT, RMS or Peak-to-Peak can be set as the generic measuring mode with setting parameter *Measurement mode*. The recording of the maximum and minimum phase currents, maximum ground current and maximum ground voltage is affected by the selected measuring mode and the maximum current and voltage values are still collected 50 ms after the recording period is closed. In addition, the maximum demand current is separately recorded with time stamp.

Fault recorder also provides *Operation* parameter that can be used for setting the recorder into Enable/Disable and BLOCK input that can be used for blocking the recording triggering by using logic, for example during the auto-reclosing sequence. The recorded data can be separately cleared with parameters in the Clear menu.

The data recorded depend on the product and the standard configuration.

Table 34: FR Non group settings

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

Table 35: FR Monitored data

Name	Type	Values (Range)	Unit	Description
Number	INT32	0...999999		Fault record number
Time	Timestamp			Time of recording
Max bias current A	FLOAT32	0.000...50.000		Maximum phase A bias current
Max bias current B	FLOAT32	0.000...50.000		Maximum phase B bias current
Max bias current C	FLOAT32	0.000...50.000		Maximum phase C bias current
Max current IA	FLOAT32	0.000...50.000	xIn	Maximum phase A current
Max current IB	FLOAT32	0.000...50.000	xIn	Maximum phase B current
Max current IC	FLOAT32	0.000...50.000	xIn	Maximum phase C current
Current IA	FLOAT32	0.000...50.000	xIn	Phase A current
Current IB	FLOAT32	0.000...50.000	xIn	Phase B current
Current IC	FLOAT32	0.000...50.000	xIn	Phase C current
Max current IG	FLOAT32	0.000...50.000	xIn	Maximum residual current
Current IG	FLOAT32	0.000...50.000	xIn	Ground current
Current I2	FLOAT32	0.000...50.000	xIn	Negative sequence current
Current IN	FLOAT32	0.000...50.000	xIn	Calculated residual current
Voltage VA	FLOAT32	0.000...4.000	xVn	Phase A voltage
Voltage VB	FLOAT32	0.000...4.000	xVn	Phase B voltage
Voltage VC	FLOAT32	0.000...4.000	xVn	Phase C voltage
Voltage VAB	FLOAT32	0.000...4.000	xVn	Phase A to phase B voltage
Voltage VBC	FLOAT32	0.000...4.000	xVn	Phase B to phase C voltage
Voltage VCA	FLOAT32	0.000...4.000	xVn	Phase C to phase A voltage
Voltage VG	FLOAT32	0.000...4.000	xVn	Ground voltage
Voltage V0	FLOAT32	0.000...4.000	xVn	Zero sequence voltage
Voltage V1	FLOAT32	0.000...4.000	xVn	Positive sequence voltage
Voltage V2	FLOAT32	0.000...4.000	xVn	Negative sequence voltage
49 thermal level	FLOAT32	0.00...99.99		49 calculated temperature of the protected object relative to the operate level
87LOZREF duration	FLOAT32	0.00...100.00	%	87LOZREF Pickup duration
51P duration	FLOAT32	0.00...100.00	%	51P Pickup duration
50P-3 duration	FLOAT32	0.00...100.00	%	50P-3 Pickup duration
67/51P duration	FLOAT32	0.00...100.00	%	67/51P Pickup duration
67/50P-1 duration	FLOAT32	0.00...100.00	%	67/50P-1 Pickup duration

Name	Type	Values (Range)	Unit	Description
67/50P-2 duration	FLOAT32	0.00...100.00	%	67/50P-2 Pickup duration
51G duration	FLOAT32	0.00...100.00	%	51G Pickup duration
51N duration	FLOAT32	0.00...100.00	%	51N Pickup duration
50SEF duration	FLOAT32	0.00...100.00	%	50SEF Pickup duration
50G-3 duration	FLOAT32	0.00...100.00	%	50G-3 Pickup duration
50N-3 duration	FLOAT32	0.00...100.00	%	50N-3 Pickup duration
46-1 duration	FLOAT32	0.00...100.00	%	46-1 Pickup duration
46-2 duration	FLOAT32	0.00...100.00	%	46-2 Pickup duration
46PD duration	FLOAT32	0.00...100.00	%	46PD Pickup duration
46PD rat. I2/I1	FLOAT32	0.00...999.99	%	46PD ratio I2/I1
67/51N duration	FLOAT32	0.00...100.00	%	67/51N Pickup duration
67/50N -1 duration	FLOAT32	0.00...100.00	%	67/50N -1 Pickup duration
67/50N -2 duration	FLOAT32	0.00...100.00	%	67/50N -2 Pickup duration
59N duration	FLOAT32	0.00...100.00	%	59N Pickup duration
59-1 duration	FLOAT32	0.00...100.00	%	59-1 Pickup duration
59-2 duration	FLOAT32	0.00...100.00	%	59-2 Pickup duration
27-1 duration	FLOAT32	0.00...100.00	%	27-1 Pickup duration
27-2 duration	FLOAT32	0.00...100.00	%	27-2 Pickup duration
47 duration	FLOAT32	0.00...100.00	%	47 Pickup duration

3.7 Non-volatile memory

In addition to the setting values, the relay can store some data in the non-volatile memory.

- Up to 512 events are stored. The stored events are visible in LHMI and WHMI only.
- Recorded data
  - Fault records
  - Maximum demands
- Circuit breaker condition monitoring
- Latched alarm and trip LEDs' status
- Trip circuit lockout
- Counter values

3.8 Binary input

3.8.1 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 relay.

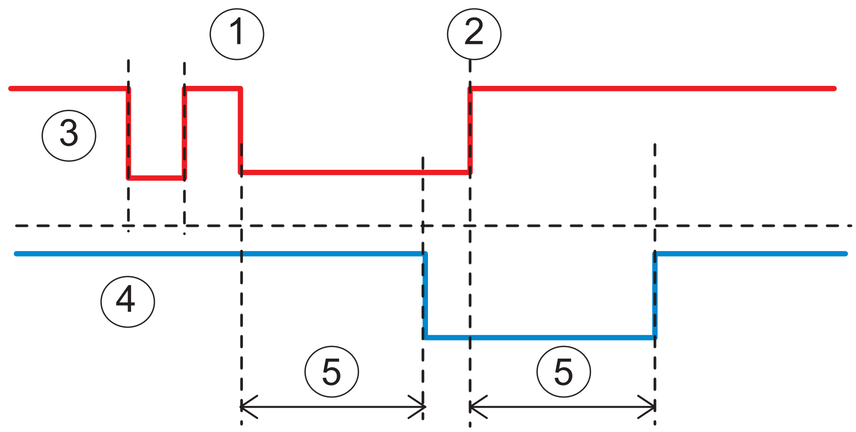


Figure 8: Binary input filtering

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 36: Input filter parameter values

Parameter	Values	Default
Input # filter	1...15000 ms	5 ms

3.8.2 Binary input inversion

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

Table 37: Binary input states

Control voltage	Input # invert	State of binary input
No	0	False (0)
Yes	0	True (1)
No	1	True (0)
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.

3.8.3 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 38: Oscillation parameter values

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

3.9 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.

3.9.1 GOOSERCV_BIN function block

3.9.1.1 Function block

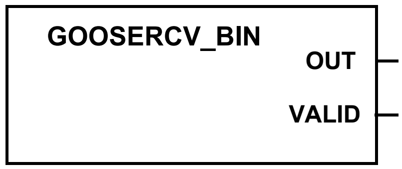


Figure 9: Function block

3.9.1.2 Functionality

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

3.9.1.3 Signals

Table 39: GOOSERCV_BIN Input signals

Name	Type	Default	Description
IN	BOOLEAN	0	Input signal

Table 40: GOOSERCV_BIN Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
VALID	BOOLEAN	Output signal

3.9.2 GOOSERCV_DP function block

3.9.2.1 Function block

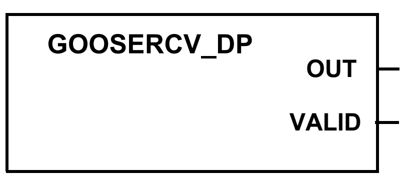


Figure 10: Function block

3.9.2.2 Functionality

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

3.9.2.3 Signals

Table 41: GOOSERCV_DP Input signals

Name	Type	Default	Description
IN	Dbpos	00	Input signal

Table 42: GOOSERCV_DP Output signals

Name	Type	Description
OUT	Dbpos	Output signal
VALID	BOOLEAN	Output signal

3.9.3 GOOSERCV_MV function block

3.9.3.1 Function block

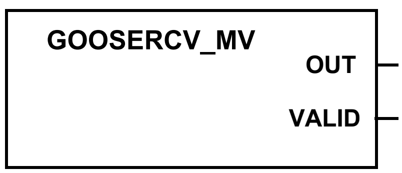


Figure 11: Function block

3.9.3.2 Functionality

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

3.9.3.3 Signals

Table 43: GOOSERCV_MV Input signals

Name	Type	Default	Description
IN	FLOAT32	0	Input signal

Table 44: GOOSERCV_MV Output signals

Name	Type	Description
OUT	FLOAT32	Output signal
VALID	BOOLEAN	Output signal

3.9.4 GOOSERCV_INT8 function block

3.9.4.1 Function block

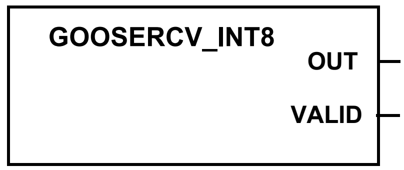


Figure 12: Function block

3.9.4.2 Functionality

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

3.9.4.3 Signals

Table 45: GOOSERCV_INT8 Input signals

Name	Type	Default	Description
IN	INT8	0	Input signal

Table 46: GOOSERCV_INT8 Output signals

Name	Type	Description
OUT	INT8	Output signal
VALID	BOOLEAN	Output signal

3.9.5 GOOSERCV_INTL function block

3.9.5.1 Function block

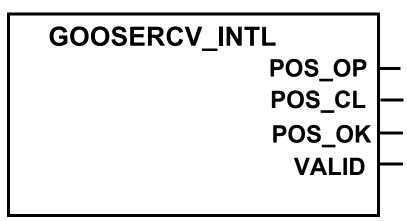


Figure 13: Function block

3.9.5.2 Functionality

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

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

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

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

3.9.5.3 Signals

Table 47: GOOSERCV_INTL Input signals

Name	Type	Default	Description
IN	Dbpos	00	Input signal

Table 48: GOOSERCV_INTL Output signals

Name	Type	Description
OP	BOOLEAN	Position open output signal
CL	BOOLEAN	Position closed output signal
OK	BOOLEAN	Position OK output signal
VALID	BOOLEAN	Output signal

3.9.6 GOOSERCV_CMV function block

3.9.6.1 Function block

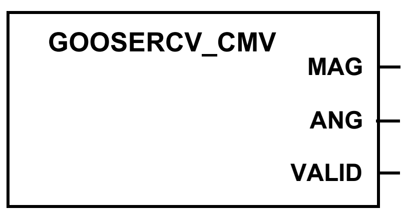


Figure 14: function block

3.9.6.2 Functionality

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

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

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

3.9.6.3 Signals

Table 49: GOOSERCV_CMV Input signals

Name	Type	Default	Description
MAG_IN	FLOAT32	0	Input signal (amplitude)
ANG_IN	FLOAT32	0	Input signal (angle)

Table 50: GOOSERCV_CMV Output signals

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

3.9.7 GOOSERCV_ENUM function block

3.9.7.1 Function block

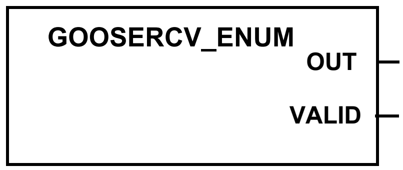


Figure 15: Function block

3.9.7.2 Functionality

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

3.9.7.3 Signals

Table 51: GOOSERCV_ENUM Input signals

Name	Type	Default	Description
IN	Enum	0	Input signal

Table 52: GOOSERCV_ENUM Output signals

Name	Type	Description
OUT	Enum	Output signal
VALID	BOOLEAN	Output signal

3.9.8 GOOSERCV_INT32 function block

3.9.8.1 Function block

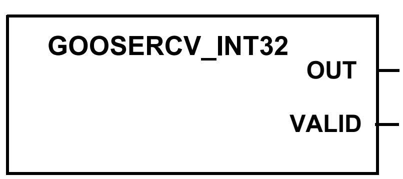


Figure 16: Function block

3.9.8.2 Functionality

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

3.9.8.3 Signals

Table 53: GOOSERCV_INT32 Input signals

Name	Type	Default	Description
IN	INT32	0	Input signal

Table 54: GOOSERCV_INT32 Output signals

Name	Type	Description
OUT	INT32	Output signal
VALID	BOOLEAN	Output signal

3.10 Type conversion function blocks

3.10.1 QTY_GOOD function block

3.10.1.1 Function block

Figure 17: Function block

3.10.1.2 Functionality

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

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

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

3.10.1.3 Signals

Table 55: QTY_GOOD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 56: QTY_GOOD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.10.2 QTY_BAD function block

3.10.2.1 Function block

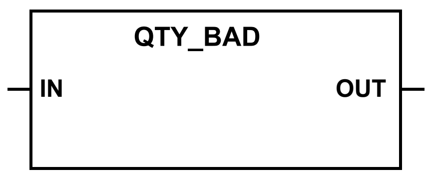


Figure 18: Function block

3.10.2.2 Functionality

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

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

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

3.10.2.3 Signals

Table 57: QTY_BAD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 58: QTY_BAD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.10.3 T_HEALTH function block

3.10.3.1 Function block

Figure 19: Function block

3.10.3.2 Functionality

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

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

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

3.10.3.3 Signals

Table 59: T_HEALTH Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 60: T_HEALTH Output signals

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

3.10.4 T_F32_INT8 function block

Function block

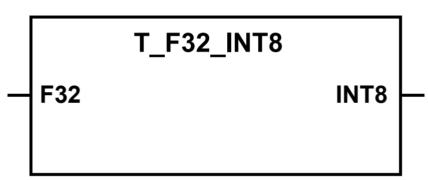


Figure 20: Function block

3.10.4.1 Functionality

T_F32_INT8 is a type conversion function.

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

Table 61: T_F32_INT8 Input signals

Name	Type	Default	Description
F32	FLOAT32	0.0	Input signal

Table 62: T_F32_INT8 Output signals

Name	Type	Description
INT8	INT8	Output signal

3.10.4.2 Settings

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

3.11 Configurable logic blocks

3.11.1 Standard configurable logic blocks

3.11.1.1 OR function block

Function block

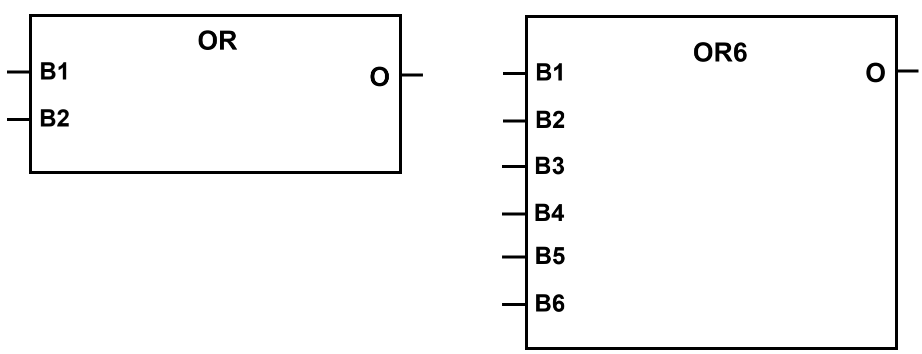


Figure 21: Function blocks

3.11.1.2 Functionality

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

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

OR has two inputs and OR6 has six inputs.

Signals

Table 63: OR Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2

Table 64: OR 6 Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2
B3	BOOLEAN	0	Input signal 3
B4	BOOLEAN	0	Input signal 4
B5	BOOLEAN	0	Input signal 5
B6	BOOLEAN	0	Input signal 6

Table 65: OR Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 66: OR6 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.3 AND function block

Function block

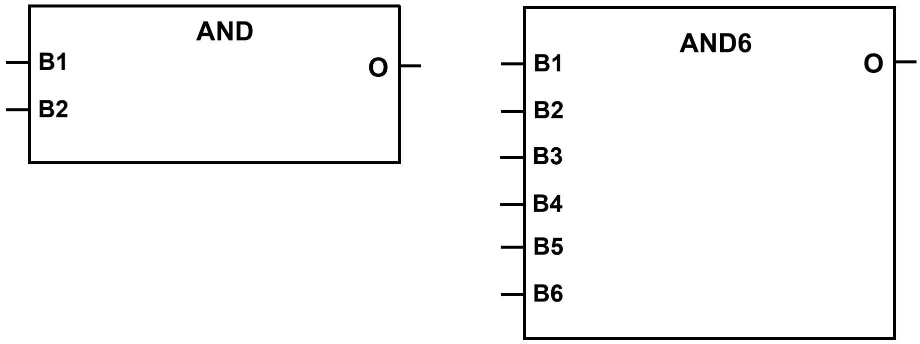


Figure 22: Function blocks

Functionality

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

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

AND has two inputs and AND6 has six inputs.

Signals

Table 67: AND Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2

Table 68: AND6 Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2
B3	BOOLEAN	0	Input signal 3
B4	BOOLEAN	0	Input signal 4
B5	BOOLEAN	0	Input signal 5
B6	BOOLEAN	0	Input signal 6

Table 69: AND Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 70: AND6 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.4 XOR function block

Function block

Figure 23: Function block

Functionality

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

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

Signals

Table 71: XOR Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2

Table 72: XOR Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.5 NOT function block

Function block

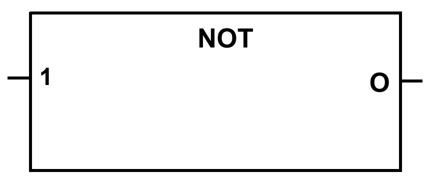


Figure 24: Function block

Functionality

NOT is used to generate combinatory expressions with Boolean variables.

NOT inverts the input signal.

Signals

Table 73: NOT Input signals

Name	Type	Default	Description
1	BOOLEAN	0	Input signal

Table 74: NOT Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.6 MAX3 function block

Function block

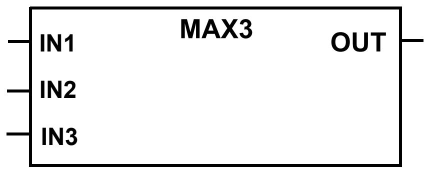


Figure 25: Function block

Functionality

The maximum function MAX3 selects the maximum value from three analog values. Disconnected inputs and inputs whose quality is bad are ignored. If all inputs are disconnected or the quality is bad, MAX3 output value is set to -2^21.

Signals

Table 75: MAX3 Input signals

Name	Type	Default	Description
IN1	FLOAT32	0	Input signal 1
IN2	FLOAT32	0	Input signal 2
IN3	FLOAT32	0	Input signal 3

Table 76: MAX3 Output signals

Name	Type	Description
OUT	FLOAT32	Output signal

Settings

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

3.11.1.7 MIN3 function block

Function block

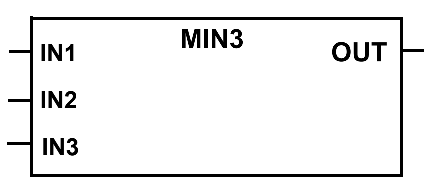


Figure 26: Function block

Functionality

The minimum function MIN3 selects the minimum value from three analog values. Disconnected inputs and inputs whose quality is bad are ignored. If all inputs are disconnected or the quality is bad, MIN3 output value is set to 2^21.

Signals

Table 77: MIN3 Input signals

Name	Type	Default	Description
IN1	FLOAT32	0	Input signal 1
IN2	FLOAT32	0	Input signal 2
IN3	FLOAT32	0	Input signal 3

Table 78: MIN3 Output signals

Name	Type	Description
OUT	FLOAT32	Output signal

Settings

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

3.11.1.8 R_TRIG function block

Function block

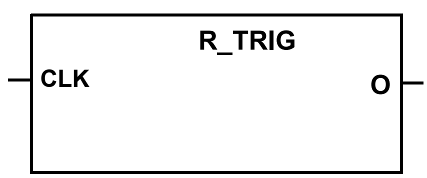


Figure 27: Function block

Functionality

R_Trig is used as a rising edge detector.

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

Signals

Table 79: R_TRIG Input signals

Name	Type	Default	Description
CLK	BOOLEAN	0	Input signal

Table 80: R_TRIG Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.9 F_TRIG function block

Function block

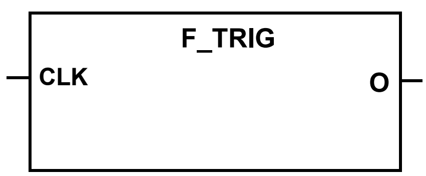


Figure 28: Function block

Functionality

F_Trig is used as a falling edge detector.

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

Signals

Table 81: F_TRIG Input signals

Name	Type	Default	Description
CLK	BOOLEAN	0	Input signal

Table 82: F_TRIG Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Settings

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

3.11.1.10 T_POS_XX function blocks

Function block

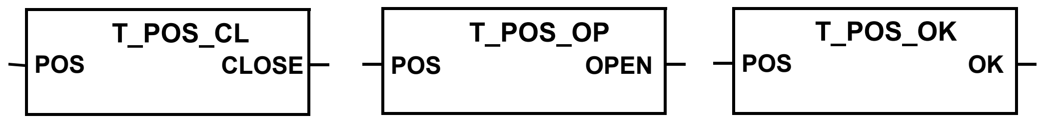


Figure 29: Function blocks

Functionality

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

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

Table 83: Cross reference between circuit breaker position and the output of the function block

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

Signals

Table 84: T_POS_CL Input signals

Name	Type	Default	Description
POS	Double binary	0	Input signal

Table 85: T_POS_OP Input signals

Name	Type	Default	Description
CLK	Double binary	0	Input signal

Table 86: T_POS_OK Input signals

Name	Type	Default	Description
CLK	Double binary	0	Input signal

Table 87: T_POS_CL Output signals

Name	Type	Description
CLOSE	BOOLEAN	Output signal

Table 88: T_POS_OPOutput signals

Name	Type	Description
OPEN	BOOLEAN	Output signal

Table 89: T_POS_OK Output signals

Name	Type	Description
OK	BOOLEAN	Output signal

Settings

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

3.11.1.11 SR function block

Function block

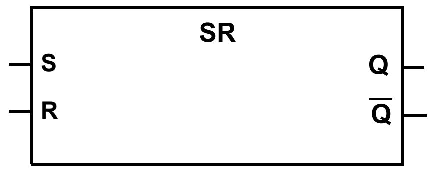


Figure 30: Function block

Functionality

The SR flip-flop output Q can be set or reset from the s or R inputs. s input has a higher priority over the R input. Output NOTQ is the negation of output Q.

The statuses of outputs Q and NOTQ are not retained in the nonvolatile memory.

Table 90: Truth table for SR flip-flop

S	R	Q
0	0	0[1)]
0	1	0
1	0	1
1	1	1

[1)] Keep state/no change

Table 91: T_POS_OK Input signals

Name	Type	Default	Description
S	BOOLEAN	0 =False	Set Q output when set
R	BOOLEAN	0 =False	Resets Q output when set

Table 92: T_POS_CL Output signals

Name	Type	Description
Q	BOOLEAN	Q status
NOTQ	BOOLEAN	NOTQ status

3.11.1.12 PH_ORD_IN block

Function block

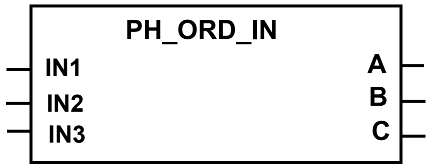


Figure 31: Function block

Functionality

Normally, the relay expects to receive voltages, currents and breaker positions in the order specified by the setting "Phase Rotation". In reality, transmission lines are needed to be transposed to ensure the line impedance to be as symmetrical as possible under normal condition. With the system setting "Phase Order Mode", the relay (RER620) can properly indicate phase measurement and protection function operations, but it does not have a default mean to recognize the breaker (pole) position order.

This function reorders physical pole position inputs based on the global General System "Phase Order Mode" setting value to the normal system phase order.

The phase order from actual pole position inputs could be any of possible six combinations like ABC, BAC, CAB etc. With this function and the phase order mode setting, the ACT logic does not need to be changed for different physical phase orders. The order of the inputs of this function must match the General System "Phase Order Mode" setting value. The outputs of the function are always in the normal phase order (ABC) and thus they can be connected to the phase order neutral function blocks like SCBXCBR, SDARRREC etc.

This function should be used in conjunction with the function PH_ORD_OUT.

Signals

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

Table 93: PH_ORD_IN Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0	Input signal 1
IN2	BOOLEAN	0	Input signal 2
IN3	BOOLEAN	0	Input signal 3

Table 94: PH_ORD_IN Output signals

Name	Type	Description
A	BOOLEAN	Phase A
B	BOOLEAN	Phase B
C	BOOLEAN	Phase C

Settings

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

3.11.1.13 PH_ORD_OUT block

Function block

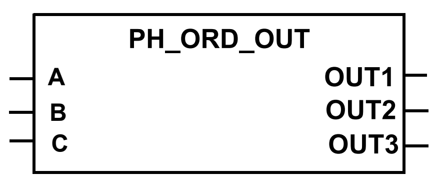


Figure 32: Function block

Functionality

Normally, the relay expects to receive voltages, currents and breaker positions in the order specified by the setting "Phase Rotation". In reality, transmission lines are needed to be transposed to ensure the line impedance to be as symmetrical as possible under normal condition. With the system setting "Phase Order Mode", the relay (RER620) can properly indicate phase measurement and protection function operations, and with help of the function block PH_ORD_IN (see the detail in section 3.11.1.12), all the related control functions such as SCBXCBR, SDARRREC etc. provide the system rotation setting based operations which need to be matched the physical breaker (pole) position order.

This function reorders physical phase the outputs based according to the Global System "Phase Rotation" setting.

The phase order from actual field outputs could be any of possible six combinations like ABC, BAC, CAB etc. With this function and the phase order mode setting, the ACT logic does not need to be changed for different physical phase orders. The function receives inputs from control function blocks in the normal phase order (ABC) and provide outputs based on the actual field phase order combination .The order of the outputs of this function must match the General System "Phase Order Mode" setting value so that the equipment to be controlled can be properly operated.

This function should be used in conjunction with the function PH_ORD_IN.

Signals

Table 95: PH_ORD_OUT Input signals

Name	Type	Default	Description
A	BOOLEAN	0	Phase A
B	BOOLEAN	0	Phase B
C	BOOLEAN	0	Phase C

Table 96: PH_ORD_OUT Output signals

Name	Type	Description
OUT1	BOOLEAN	Output signal 1
OUT2	BOOLEAN	Output signal 2
OUT3	BOOLEAN	Output signal 3

Settings

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

When the System "Phase Order Mode" Setting changed, the relay must be rebooted to activate the new setting and the above functions will detect correct phase order.

3.11.2 Local/remote control function block CONTROL

3.11.2.1 Function block

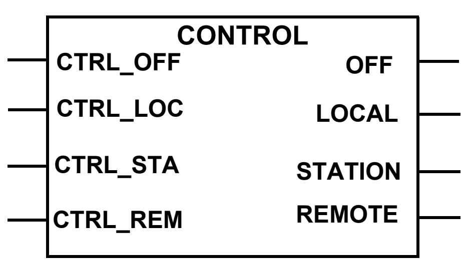


Figure 33: Function block

3.11.2.2 Functionality

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

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

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

Table 97: Truth table for CONTROL

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

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

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

3.11.2.3 Signals

Table 98: CONTROL input signals

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

Output signals

Table 99: CONTROL output signals

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

3.11.2.4 Settings

Table 100: CONTROL settings

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

3.11.2.5 Monitored data

Table 101: CONTROL Monitored data

Parameter	Type	Values (Range)	Unit	Description
Command response	ENUM	1 = "Select open" 2 = "Select close" 3 = "Operate open" 4 = "Operate close" 5 = "Direct open" 6 = "Direct close" 7 = "Cancel" 8 = "Position reached" 9 = "Position timeout" 10 = "Object status only" 11 = "Object direct" 12 = "Object select" 13 = "RL local allowed" 14 = "RL remote allowed" 15 = "RL off" 16 = "Function off" 17 = "Function blocked" 18 = "Command progress" 19 = "Select timeout" 20 = "Missing authority" 21 = "Close not enabled" 22 = "Open not enabled" 23 = "Internal fault" 24 = "Already close" 25 = "Wrong client" 26 = "RL station allowed" 27 = "RL change"		Latest command response
LR state	ENUM	1 = "OFF" 2 = "Local" 3 = "Remote" 4 = "Station"		LR state monitoring for PCM

3.12 Factory settings restoration

In case of configuration data loss or any other file system error that prevents the 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.

Section 4 Protection functions

4.1 Current protection

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

4.1.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single-phase non-directional overcurrent protection - Low stage	SPHLPTOC	3I>	51P
Single-phase non-directional overcurrent protection - High stage	SPHHPTOC	3I>>	50P-1/50P-2
Single-phase non-directional overcurrent protection - Instantaneous stage	SPHIPTOC	3I>>>	50P-3

4.1.1.2 Function block

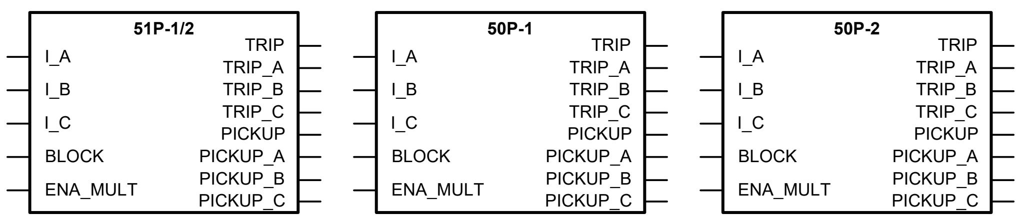


Figure 34: Function block

4.1.1.3 Functionality

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

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

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

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

4.1.1.4 Operation principle

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

The single-phase non-directional overcurrent protection function is used as one-phase and three-phase overcurrent and short circuit protection. The phase-tripping mode is selected with the Configuration setting *Recloser type*.

The operation in either tripping mode can be described by using a module diagram (see Figure 35). Some modules have different functionality depending on whether the function is in one-phase or three-phase tripping mode. All the blocks in the diagram are explained in the next sections.

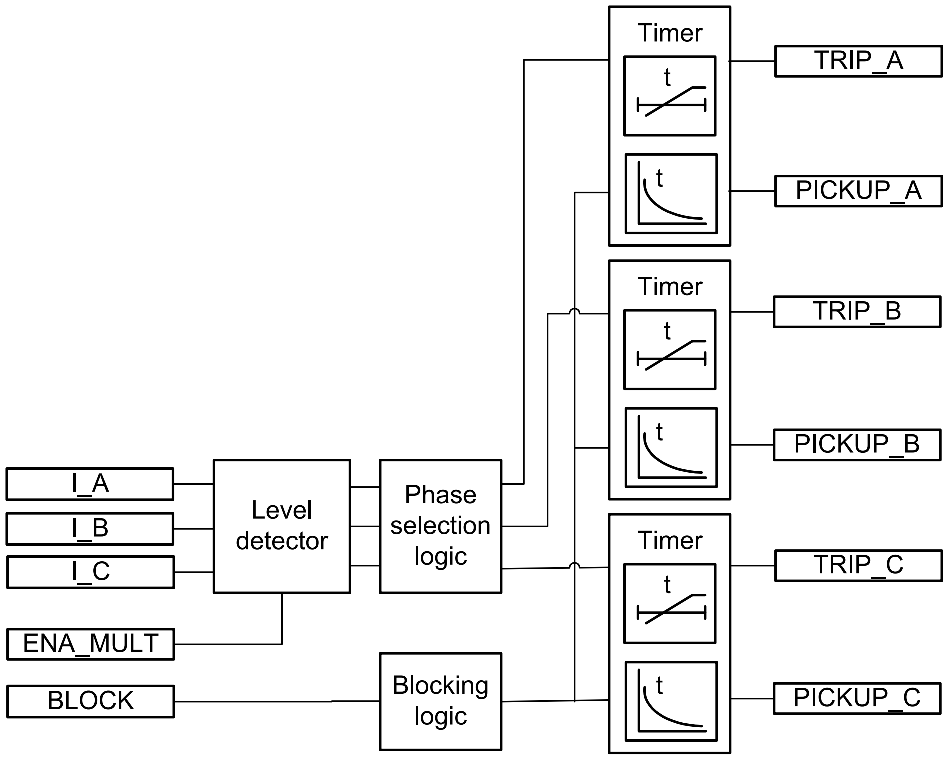


Figure 35: Functional module diagram. I_A, I_B and I_C represent phase currents.

Level detector

The measured phase currents are compared phase-wise with the set *Pickup value*.and, if enabled, the *Pickup block value*. If the measured value exceeds the set *Pickup value*, and is less than the *Pickup block value*, the level detector reports the pickup to the phase selection logic. If the `ENA_MULT` input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

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

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

The *Pickup block value* is not affected by the `ENA_MULT` input or the *Pickup value Mult* setting.

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

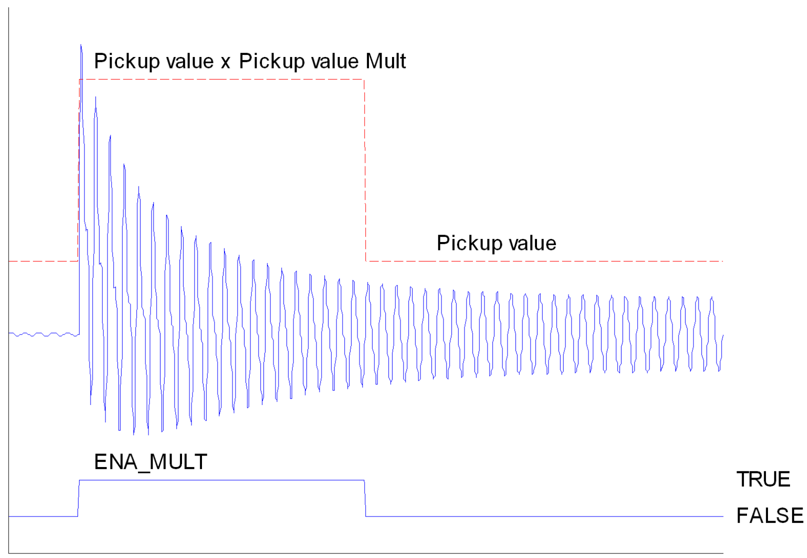


Figure 36: Pickup value behavior with `ENA_MULT` input activated

Phase selection logic

This logic is only active in three-phase tripping mode. If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of pickup phases* setting, the phase selection logic activates the timer module.

When in single-phase tripping mode, the *Num of pickup phases* setting has no affect on operation and the outputs of the level detector are passed directly to the corresponding timer module.

Timer

Once activated, the timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve and the *Time adder* time has expired, the `TRIP` 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 happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to *"*Immediate*"*, *"*Def time reset*"* or *"*Inverse reset*"*. The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the `PICKUP` output is deactivated.

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

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

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

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the percentual ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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

4.1.1.5 Measurement modes

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

Table 102: Measurement modes supported by 51P/50P stages

Measurement mode	Supported measurement modes		
	51P	50P-1	50P-2
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 General function block features section in this manual.

4.1.1.6 Timer characteristics

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

The 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 103: Timer characteristics supported by different stages

Operating curve type supported by	51P	50P-1	50P-2
(1) ANSI Extremely Inverse	x	x	x
(2) ANSI Very Inverse	x	x	
(3) ANSI Normal Inverse	x	x	x
(4) ANSI Moderately Inverse	x	x	
(5) ANSI Definite Time	x	x	x
(6) Long Time Extremely Inverse	x	x	
(7) Long Time Very Inverse	x	x	
(8) Long Time Inverse	x	x	
(9) IEC Normal Inverse	x	x	x
(10) IEC Very Inverse	x	x	x
(11) IEC Inverse	x	x	
(12) IEC Extremely Inverse	x	x	x
(13) IEC Short Time Inverse	x	x	
(14) IEC Long Time Inverse	x	x	
(15) IEC Definite Time	x	x	x
(17) User programmable	x	x	x
(18) RI type	x	x	
(19) RD type	x	x	
(-1) Recloser 1 (102)	x	x	
(-2) Recloser 2 (135)	x	x	
(-3) Recloser 3 (140)	x	x	
(-4) Recloser 4 (106)	x	x	
(-5) Recloser 5 (114)	x	x	
(-6) Recloser 6 (136)	x	x	
(-7) Recloser 7 (152)	x	x	
(-8) Recloser 8 (113)	x	x	
(-9) Recloser 8+ (111)	x	x	
(-10) Recloser 8*	x	x	
(-11) Recloser 9 (131)	x	x	
(-12) Recloser 11 (141)	x	x	
(-13) Recloser 13 (142)	x	x	
(-14) Recloser 14 (119)	x	x	
(-15) Recloser 15 (112)	x	x	
(-16) Recloser 16 (139)	x	x	
(-17) Recloser 17 (103)	x	x	
(-18) Recloser 18 (151)	x	x	
(-19) Recloser A (101)	x	x	
(-20) Recloser B (117)	x	x	
(-21) Recloser C (133)	x	x	
(-22) Recloser D (116)	x	x	

Operating curve type supported by	51P	50P-1	50P-2
(-23) Recloser E (132)	x	x	
(-24) Recloser F (163)	x	x	
(-25-Recloser G (121)	x	x	
(-26) Recloser H (122)	x	x	
(-27) Recloser J (164)	x	x	
(-28) Recloser Kg (165)	x	x	
(-29) Recloser Kp (162)	x	x	
(-30) Recloser L (107)	x	x	
(-31) Recloser M (118)	x	x	
(-32) Recloser N (104)	x	x	
(-33) Recloser P (115)	x	x	
(-34) Recloser R (105)	x	x	
(-35) Recloser T (161)	x	x	
(-36) Recloser V (137)	x	x	
(-37) Recloser W (138)	x	x	
(-38) Recloser Y (120)	x	x	
(-39) Recloser Z (134)	x	x	

50P-3 supports only definite time characteristic.

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

Table 104: Reset time characteristics supported by different stages

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

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

4.1.1.7 Application

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

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

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

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

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

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

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

Transformer and busbar overcurrent protection with reverse blocking principle

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

Depending on the overcurrent stage in question, the selectivity of the scheme in Figure 11 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 105: Proposed functionality of numerical transformer and busbar overcurrent protection. DT = definite time, IDMT = inverse definite minimum time

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

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

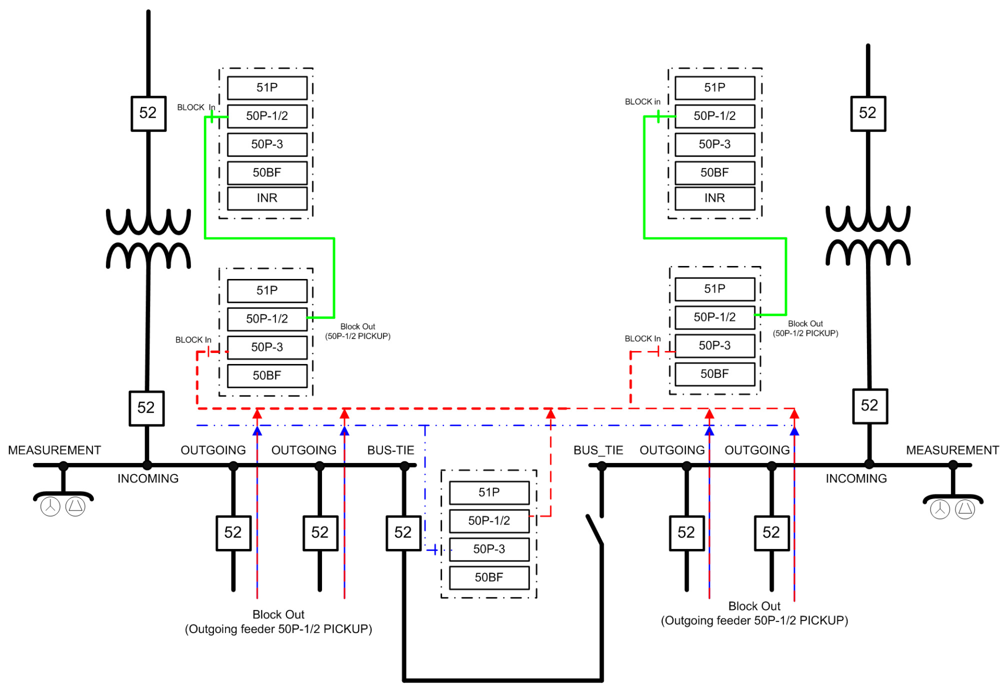


Figure 37: Numerical overcurrent protection functionality for a typical sub-transmission/distribution substation (feeder protection not shown). Blocking output = digital output signal from the start of a protection stage, Blocking in = digital input signal to block the operation of a protection stage

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 practically zero. Also, the effects of switching inrush currents on the setting values can be reduced by using the relay logic, which recognizes the transformer energizing inrush current and blocks the operation or multiplies the current pickup value setting of the selected overcurrent stage with a predefined multiplier setting.

Finally, a dependable trip of the overcurrent protection is secured by both a proper selection of the settings and an adequate ability of the measuring transformers to reproduce the fault current. This is important in order to maintain selectivity and also for the protection to operate without additional time delays. For additional information about available measuring modes and current transformer requirements, see the General function block features section 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 12 shows an example of this. A brief coordination study has been carried out between the incoming and outgoing feeders.

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

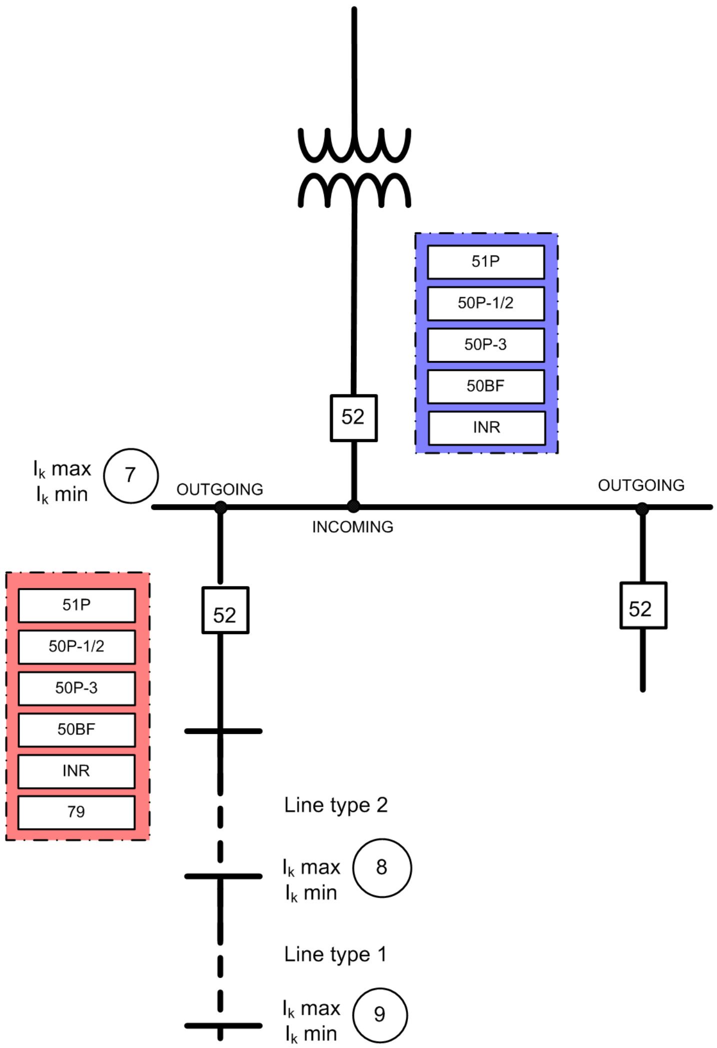


Figure 38: Functionality of numerical multiple-stage overcurrent protection

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

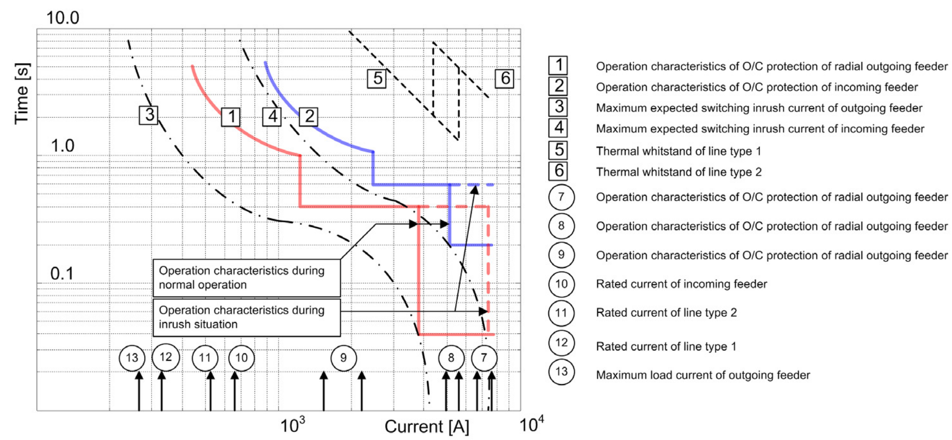


Figure 39: Example coordination of numerical multiple-stage overcurrent protection

4.1.1.8 Signals

Table 106: 51P Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 107: 50P-1/2 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 108: 50P-3 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 109: 51P Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 110: 50P-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 111: 50P-3 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.1.9 Settings

Table 112: 51P & 50P-1 Group settings

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

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type -1=Recloser 1 (102) -2=Recloser 2 (135) -3=Recloser 3 (140) -4=Recloser 4 (106) -5=Recloser 5 (114) -6=Recloser 6 (136) -7=Recloser 7 (152) -8=Recloser 8 (113) -9=Recloser 8+ (111) -10=Recloser 8* -11=Recloser 9 (131) -12=Recloser 11 (141) -13=Recloser 13 (142) -14=Recloser 14 (119) -15=Recloser 15 (112) -16=Recloser 16 (139) -17=Recloser 17 (103) -18=Recloser 18 (151) -19=Recloser A (101) -20=Recloser B (117) -21=Recloser C (133) -22=Recloser D (116) -23=Recloser E (132) -24=Recloser F (163) -25-Recloser G (121) -26=Recloser H (122) -27=Recloser J (164) -28=Recloser Kg (165) -29=Recloser Kp (162) -30=Recloser L (107) -31=Recloser M (118) -32=Recloser N (104) -33=Recloser P (115) -34=Recloser R (105) -35=Recloser T (161) -36=Recloser V (137) -37=Recloser W (138) -38=Recloser Y (120) -39=Recloser Z (134)			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Pickup block enable	0=Disabled 1=Enabled			0=Disabled	Enables start block function
Pickup block value	1.00...40.00	A	0.01	5	Value over which trip will be blocked
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Table 113: 51P & 50P-1 Non group settings

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

Table 114: 50P-2 group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Table 115: 50P-2 Non group settings

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

Table 116: 50P-3 Group settings

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

Table 117: 50P-3 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
Num of pickup phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for trip activation
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.1.10 Monitored data

Table 118: 51P Monitored data

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

Table 119: 50P-1/2 Monitored data

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

Table 120: 50P-3 Monitored data

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

4.1.1.11 Technical data

Table 121: 51P/50P Technical data

Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz			
	51P	±1.5% of the set value or ±0.002 x I_n		
	50P-1/2 and 50P-3	±1.5% of set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n)		
Pickup time [1,2]		Minimum	Typical	Maximum
	50P-3: I_{Fault} = 2 x set *Pickup value* I_{Fault} = 10 x set *Pickup value*	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	51P and 50P-1/2: I_{Fault} = 2 x set *Pickup value*	22 ms	24 ms	25 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 30 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [3]		
Suppression of harmonics		RMS: No suppression DFT: -50dB at f = n x 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 x I_n, f_n = 60 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact
3. Maximum *Pickup value* = 2.5 x I_n, *Pickup value* multiples in range of 1.5 to 20

4.1.1.12 Technical revision history

Table 122: 50P–3 Technical revision history

Technical revision	Change
C	Minimum and default values changed to 20 ms for the *Trip delay time* setting. Minimum value changed to 1.00 x I_n for the *Pickup value* setting.

Table 123: 50P–2 Technical revision history

Technical revision	Change
C	*Measurement mode* "P-to-P + backup" replaced with "Peak-to-Peak"

Table 124: 51P & 50P-1 Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Trip delay time* setting

4.1.2 Single-phase directional overcurrent protection 67/51P-1 and 67/51P-2

4.1.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single-phase directional overcurrent protection - Low stage 1	SDPHLPDOC1	3I> ->(1)	67/51P-1
Single-phase directional overcurrent protection - Low stage 2	SDPHLPDOC2	3I> ->(2)	67/51P-2

4.1.2.2 Function block

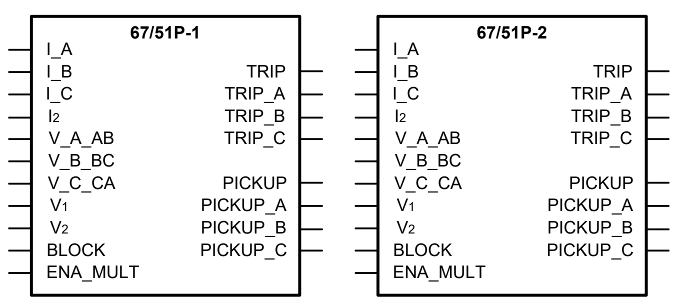


Figure 40: Function block

4.1.2.3 Functionality

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

67/51P and 67/50P picks up when the value of the current exceeds the set limit and directional criterion is fulfilled. The trip time characteristics for low stage 67/51P and

67/50P-1 and high stage 67/50P-2 can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

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

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

4.1.2.4 Operation principle

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

The single-phase directional overcurrent protection function is used as one-phase and three-phase overcurrent and short circuit protection. The phase-tripping mode is selected with the Configuration setting *Recloser type*.

The operation in either tripping mode can be described by using a module diagram (see Figure 41). Some modules have different functionality depending on whether the function is in one-phase or three-phase tripping mode. All the blocks in the diagram are explained in the next sections.

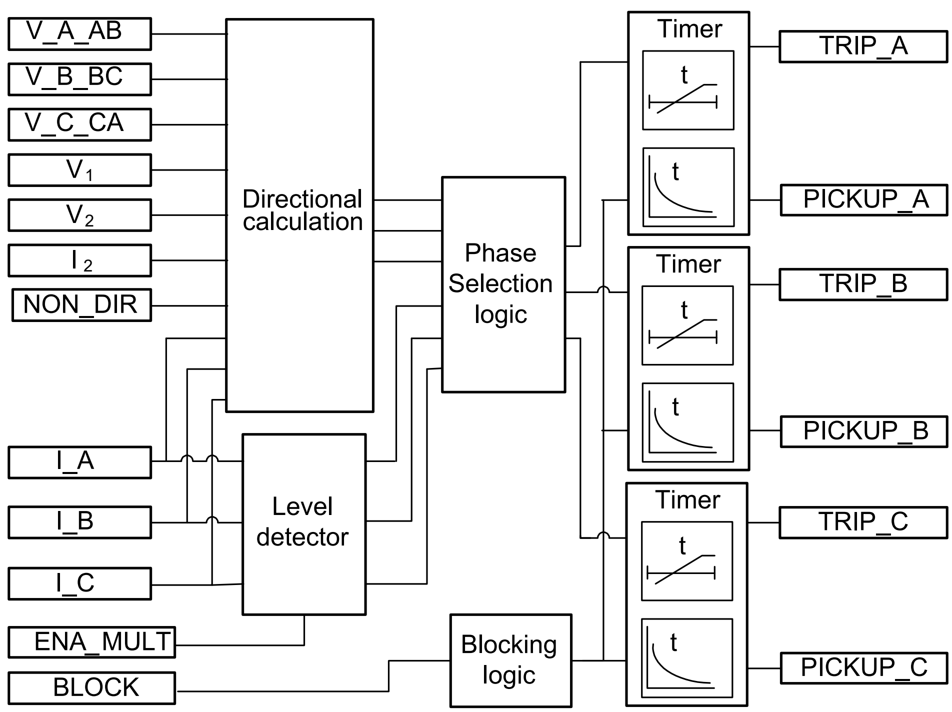


Figure 41: Functional module diagram

Directional calculation

The directional calculation compares the current phasors to the polarizing phasor. The user can select the suitable one from 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 125: Polarizing quantities

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

The directional operation can be selected with the *Directional mode* setting. The user can select either “Non-directional”, “Forward” or “Reverse” operation. By setting the value of *Allow Non Dir* to “True”, the non-directional operation is allowed when the directional information is invalid.

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

Reliable operation requires both the operating and polarizing quantities to exceed certain minimum amplitude levels. The minimum amplitude level for the operating quantity (current) is set with the *Min Trip Current* setting. The minimum amplitude level for the polarizing quantity (voltage) is set with the *Min 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.

DPHxPDOC is provided with a memory function to secure a reliable and correct directional relay operation in case of a close short circuit or an earth fault characterized by an extremely low voltage. At sudden loss of the polarization quantity, the angle difference is calculated on the basis of a fictive voltage. The fictive voltage is calculated using the positive phase sequence voltage measured before the fault occurred, assuming that the voltage is not affected by the fault. The memory function enables the function to 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 voltage memory arises and these are kept frozen until the time set with *Voltage Mem time* elapses.

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 Trip Voltage* and hysteresis for longer than *Voltage Mem time* or if the fault current disappears while the fictive voltage is in use. When the voltage is below *Min Trip Voltage* and hysteresis and the fictive voltage is unusable, the fault direction cannot be determined. The fictive voltage can be unusable for two reasons:

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

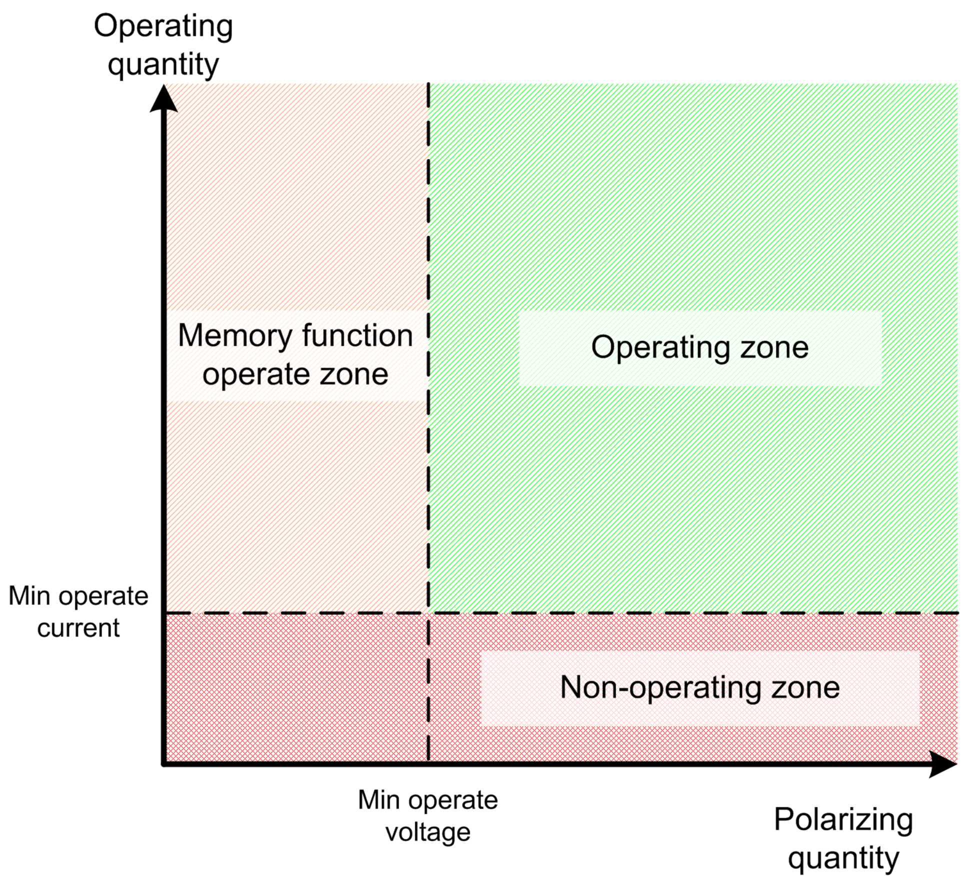


Figure 42: Operating zones at minimum magnitude levels

Level detector

The measured phase currents are compared phase-wise with the set *Pickup value*.and, if enabled, the *Pickup block value*. If the measured value exceeds the set *Pickup value*, and is less than the *Pickup block value*, the level detector reports the pickup to the phase selection logic. If the ENA_MULT input is active, the *Pickup value* setting is multiplied by the *Pickup value Mult* setting.

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

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

The *Pickup block value* is not affected by the ENA_MULT input or the *Pickup value Mult* setting.

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

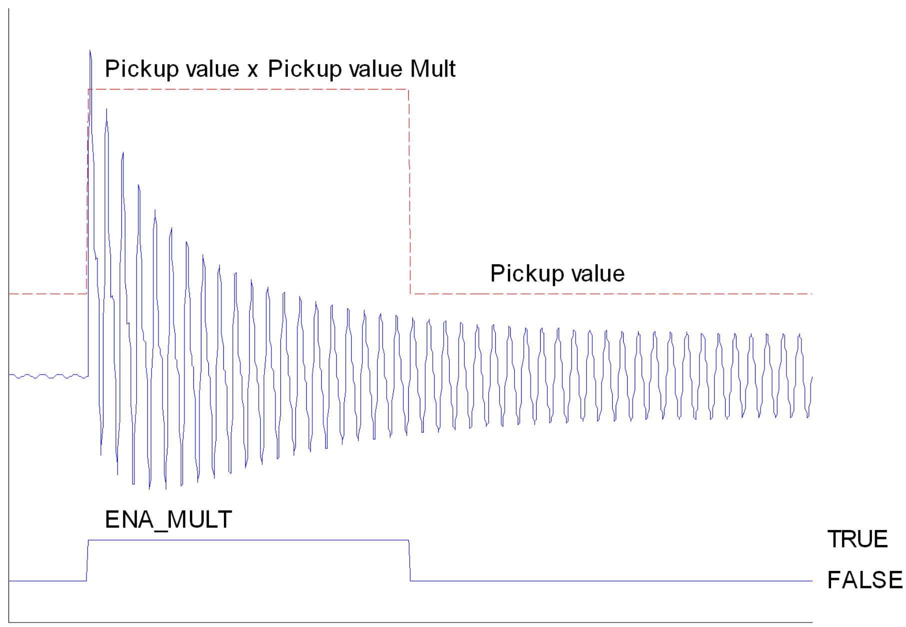


Figure 43: Pickup value behavior with ENA_MULT input activated

Phase selection logic

This logic is only active in three-phase tripping mode. If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of pickup phases* setting, the phase selection logic activates the timer module.

When in single-phase tripping mode, the *Num of pickup phases* setting has no affect on operation and the outputs of the level detector are passed directly to the corresponding timer module.

Timer

Once activated, the timer activates the PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve and the *Time added* time has expired, the TRIP 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 happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to “Immediate”, “Def time reset” or “Inverse reset”. The reset curve type “Immediate” causes an immediate reset. With the reset curve type “Def time reset”, the reset time depends on the *Reset delay time* setting. With the reset curve type “Inverse reset”, the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

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

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

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

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the percentage ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

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

4.1.2.5 Measuring 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 126: Measurement modes supported by 67/51P and 67/50P stages

Measurement mode	Supported measurement modes	
	67/51P and 67/50P-1	67/50P-2
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.

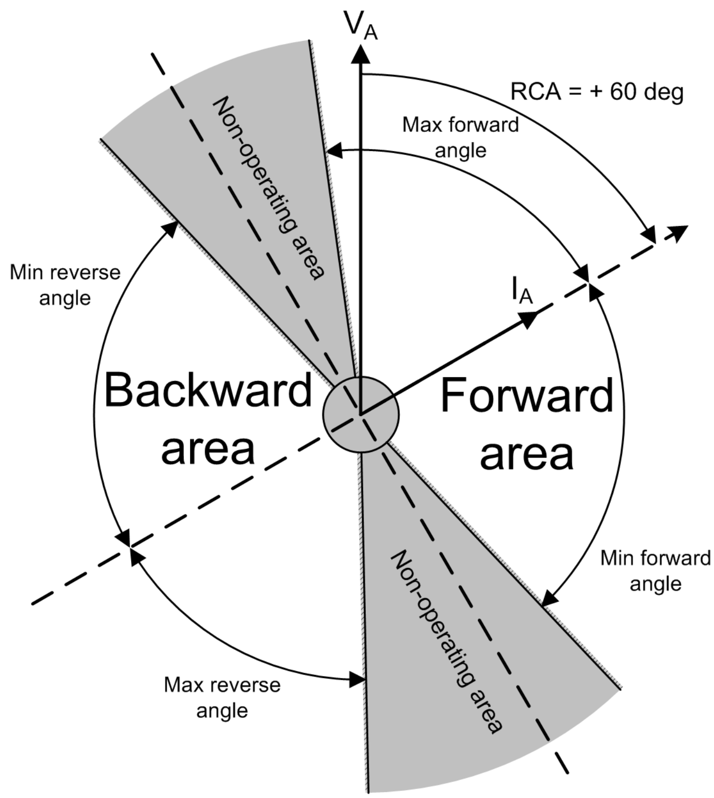


Figure 44: Configurable operating sectors

Table 127: 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 128: Momentary phase combined direction value for monitored data view

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

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

Self-polarizing as polarizing method

Table 129: Equations for calculating angle difference for self-polarizing method

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

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

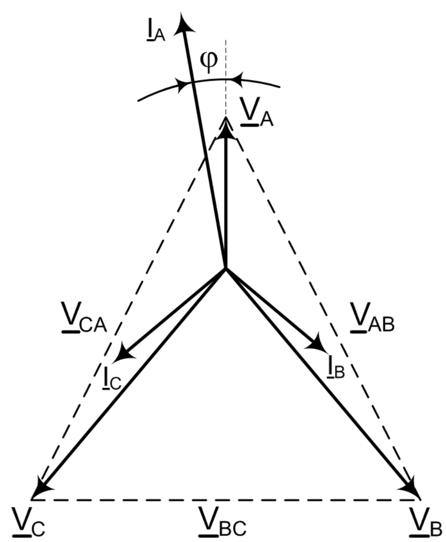


Figure 45: Single-phase ground fault, phase A

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

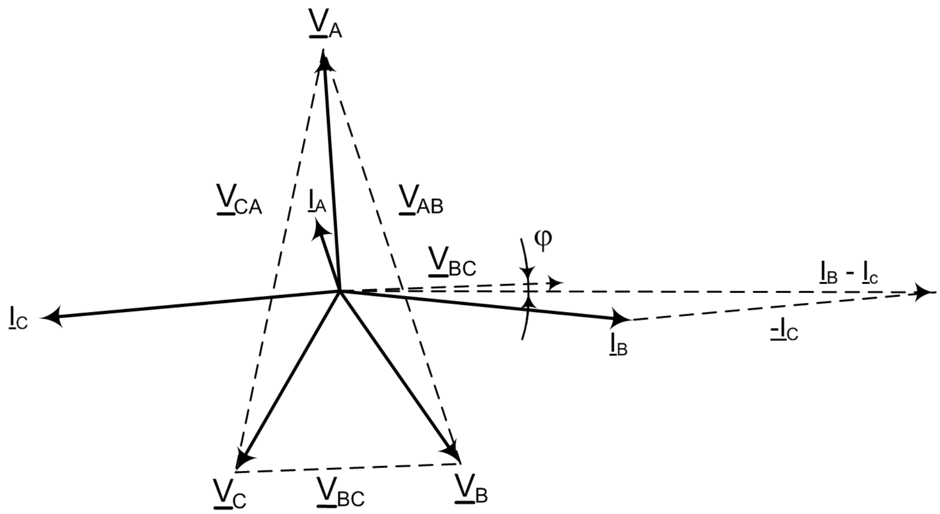


Figure 46: Two-phase short circuit, short circuit is between phases B and C

Cross-polarizing as polarizing quantity

Table 130: Equations for calculating angle difference for cross-polarizing method

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

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

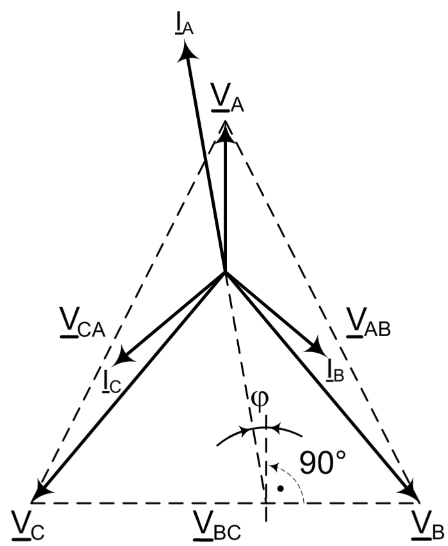


Figure 47: Single-phase ground fault, phase A

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

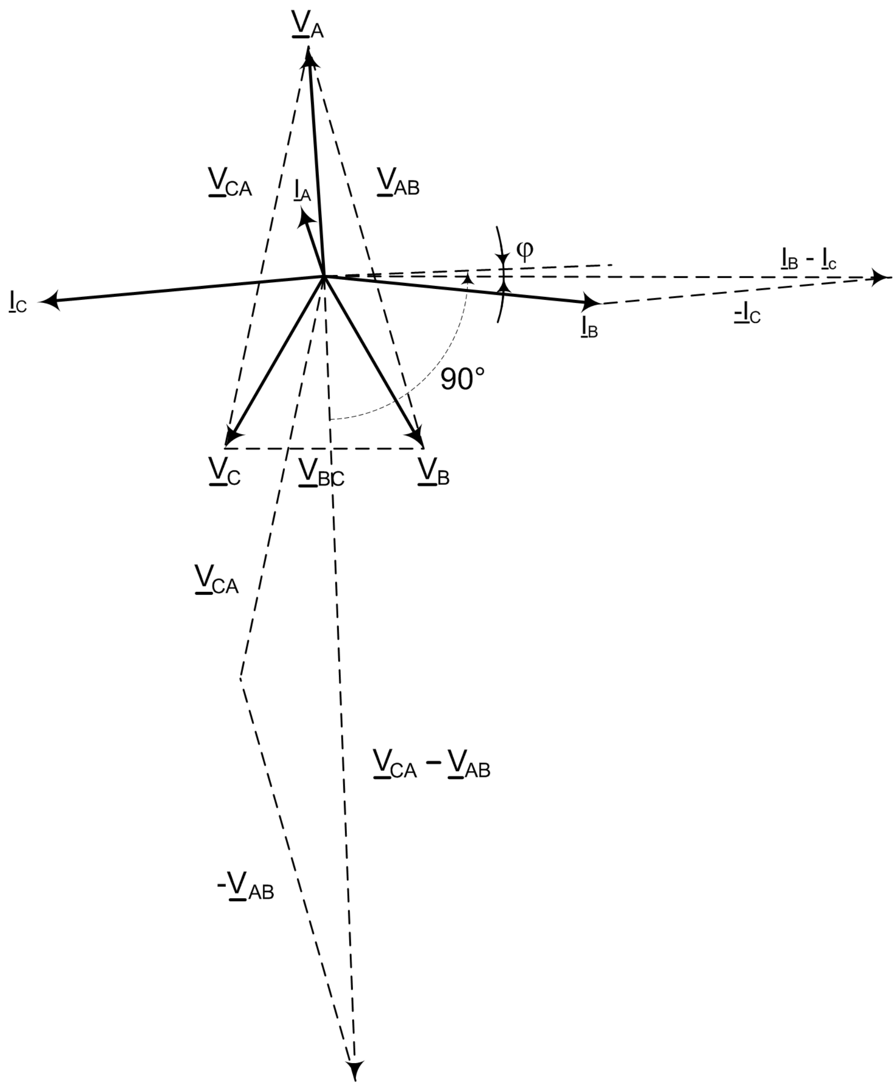


Figure 48: Two-phase short circuit, short circuit is between phases B and C

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

Negative-sequence voltage as polarizing quantity

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

$$ANGLE\_X = \varphi(-\underline{V}2) - \varphi(\underline{I}2) - \varphi_{RCA} \qquad \text{(Equation 1)}$$

This means that the actuating polarizing quantity is -V2.

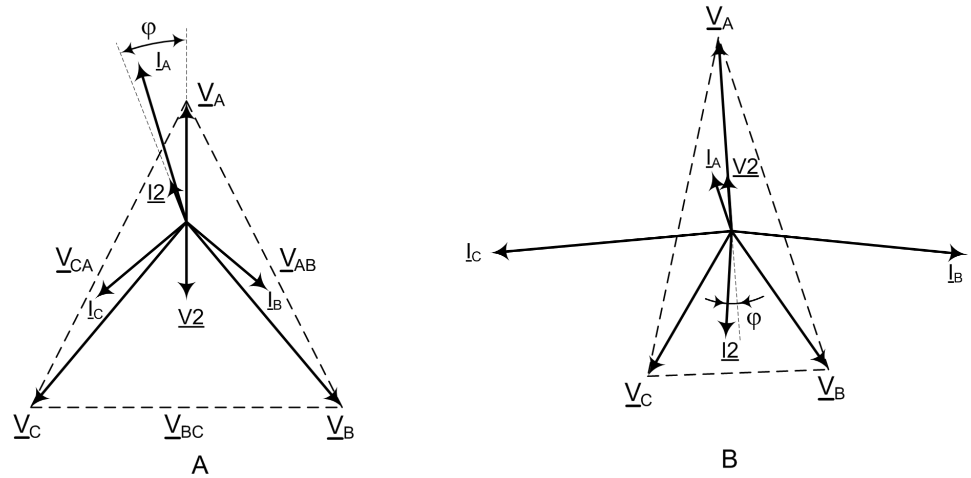


Figure 49: *Phasors in a single-phase ground fault, phases A-N, and two-phase short circuit, phases B and C, when the actuating polarizing quantity is the negative-sequence voltage -V2*

Positive-sequence voltage as polarizing quantity

Table 131: Equations for calculating angle difference for positive-sequence quantity polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{V1}$	$ANGLE\_A = \varphi(\underline{V}1) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	$\underline{I}_B$	$\underline{V1}$	$ANGLE\_B = \varphi(\underline{V}1) - \varphi(\underline{I}_B) - \varphi_{RCA} - 120^\circ$
C	$\underline{I}_C$	$\underline{V1}$	$ANGLE\_C = \varphi(\underline{V}1) - \varphi(\underline{I}_C) - \varphi_{RCA} + 120^\circ$
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{V1}$	$ANGLE\_A = \varphi(\underline{V}1) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 30^\circ$
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{V1}$	$ANGLE\_B = \varphi(\underline{V}1) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} - 90^\circ$
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{V1}$	$ANGLE\_C = \varphi(\underline{V}1) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 150^\circ$

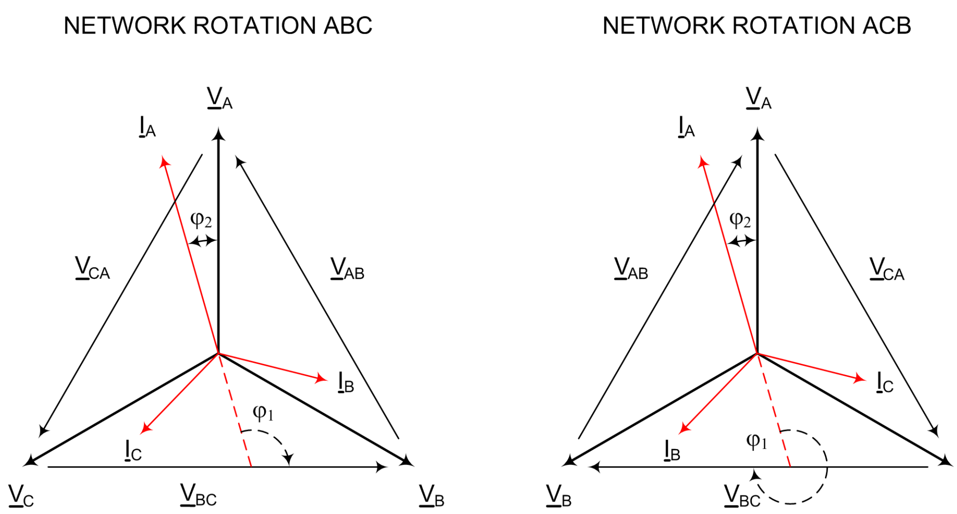


Figure 50: Phasors in a single-phase ground fault, phase A to ground, and a two-phase short circuit, phases B-C, are short-circuited when the polarizing quantity is the positive-sequence voltage V1

Network rotating direction

Typically, the network rotating direction is counterclockwise and defined as “ABC”. If the network rotating direction is reversed, meaning clockwise, that is, “ACB”, the equations for calculating the angle difference need 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 is 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 relay using the parameter in the HMI menu: **Configuration** > **System** > **Phase rotation**. The default parameter value is “ABC”.

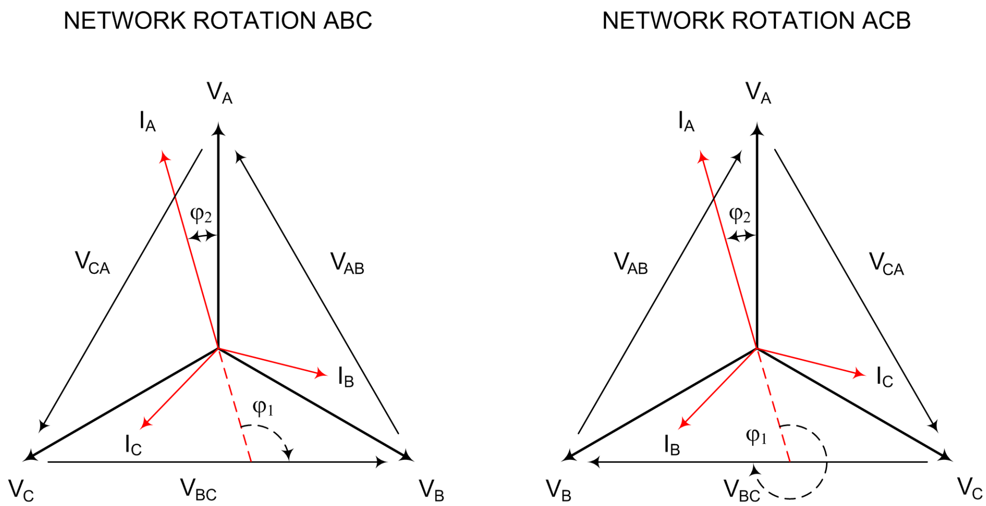


Figure 51: Examples of network rotating direction

4.1.2.7 Application

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

In radial networks, phase overcurrent 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 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 relays in a closed ring system.

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

Parallel lines or transformers

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

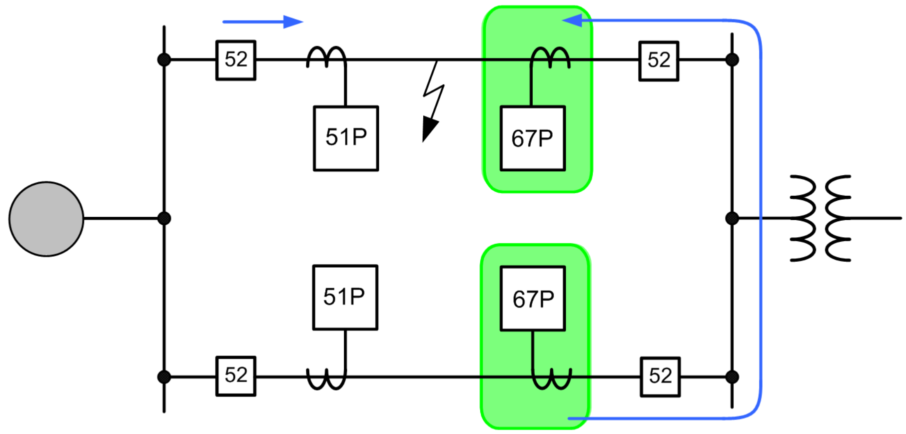


Figure 52: Overcurrent protection of parallel lines using directional relays

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

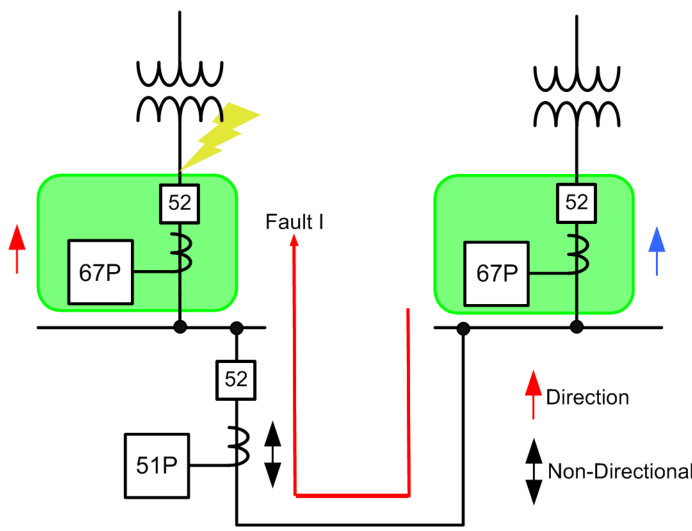


Figure 53: Overcurrent protection of parallel operating transformers

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 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.

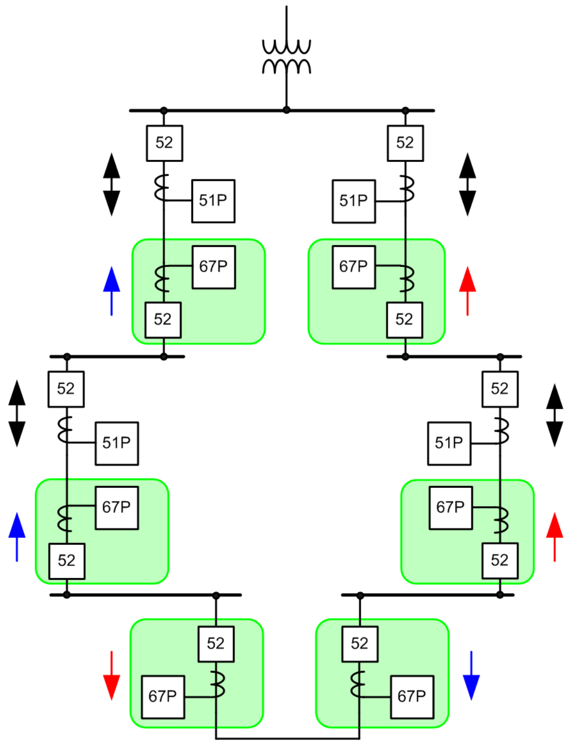


Figure 54: Closed ring network topology where feeding lines are protected with directional overcurrent relays

4.1.2.8 Signals

Table 132: 67/51P-1 and 67/50P-1 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative phase sequence current
V_A_AB	SIGNAL	0	Phase to ground voltage A or phase to phase voltage AB
V_B_BC	SIGNAL	0	Phase to ground voltage B or phase to phase voltage BC
V_C_CA	SIGNAL	0	Phase to ground voltage C or phase to phase voltage CA
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 133: 67/50P-2 Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative phase sequence current
V_A_AB	SIGNAL	0	Phase to ground voltage A or phase to phase voltage AB
V_B_BC	SIGNAL	0	Phase to ground voltage B or phase to phase voltage BC
V_C_CA	SIGNAL	0	Phase to ground voltage C or phase to phase voltage CA
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 134: 67/51P-1 and 67/50P-1 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 135: 67/50P-2 Output signals

Name	Type	Description
PICKUP	BOOLEAN	Pickup
TRIP	BOOLEAN	Trip

4.1.2.9 Settings

Table 136: 67/51P-1 and 67/50P-1 Group settings

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

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type -1=Recloser 1 (102) -2=Recloser 2 (135) -3=Recloser 3 (140) -4=Recloser 4 (106) -5=Recloser 5 (114) -6=Recloser 6 (136) -7=Recloser 7 (152) -8=Recloser 8 (113) -9=Recloser 8+ (111) -10=Recloser 8* -11=Recloser 9 (131) -12=Recloser 11 (141) -13=Recloser 13 (142) -14=Recloser 14 (119) -15=Recloser 15 (112) -16=Recloser 16 (139) -17=Recloser 17 (103) -18=Recloser 18 (151) -19=Recloser A (101) -20=Recloser B (117) -21=Recloser C (133) -22=Recloser D (116) -23=Recloser E (132) -24=Recloser F (163) -25-Recloser G (121) -26=Recloser H (122) -27=Recloser J (164) -28=Recloser Kg (165) -29=Recloser Kp (162) -30=Recloser L (107) -31=Recloser M (118) -32=Recloser N (104) -33=Recloser P (115) -34=Recloser R (105) -35=Recloser T (161) -36=Recloser V (137) -37=Recloser W (138) -38=Recloser Y (120) -39=Recloser Z (134)			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode

Parameter	Values (Range)	Unit	Step	Default	Description
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 137: 67/51P-1 and 67/50P-1 Non group settings

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

Table 138: 67/50P-2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	1.00	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	40...200000	ms	10	40	Trip delay time
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 139: 67/50P-2 Non group settings

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

4.1.2.10 Monitored data

Table 140: 67/51P-1 and 67/50P-1 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
67/51P-1 and 67/50P-1	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

Table 141: 67/50P-2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
67/50P-2	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

4.1.2.11 Technical data

Table 142: 67/51P and 67/50P Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current/voltage measured: f_n ±2Hz		
	67/51P and 67/50P-1	Current: ±1.5% of the set value or ±0.002 x I_n Voltage: ±1.5% of the set value or ±0.002 x V_n Phase angle: ±2°		
	67/50P-2	Current: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n) Voltage: ±1.5% of the set value or ±0.002 x V_n Phase angle: ±2°		
Pickup time[1][2]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 x set *Pickup value*	37 ms	40 ms	42 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms[3]		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

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

4.1.3 Non-directional neutral overcurrent protection 51N/50N

4.1.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional ground-fault protection - Low stage	XEFLPTOC	I0>	51N/G
Non-directional ground-fault protection - High stage	XEFHPTOC	I0>>	50N/G-1/2
Non-directional ground-fault protection - Instantaneous stage	XEFIPTOC	I0>>>	50N/G-3

4.1.3.2 Function block

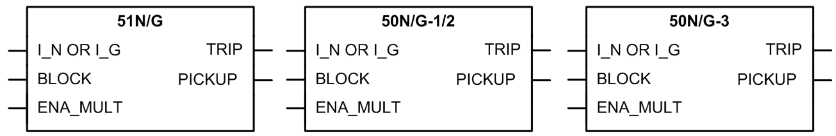


Figure 55: Function block

4.1.3.3 Functionality

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

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

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

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

4.1.3.4 Operation principle

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

The operation of non-directional ground-fault protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

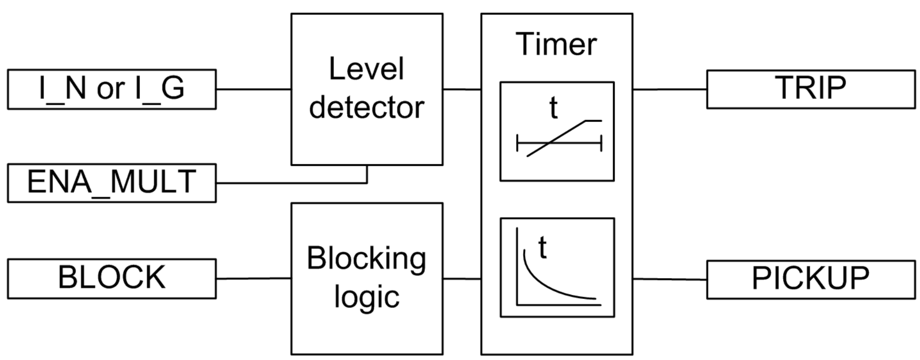


Figure 56: Functional module diagram. I_0 represents the residual current.

Level detector

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

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

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

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

Timer

Once activated, the timer activates the `PICKUP` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve and the *Time added* time has expired, the `TRIP` 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 happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to *"*Immediate*"*, *"*Def time reset*"* or *"*Inverse reset*"*. The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the `PICKUP` output is deactivated.

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

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

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

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the percentual ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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

4.1.3.5 Measurement modes

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

Table 143: Measurement modes supported by 51N/50N or 51G/50G stages

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

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

4.1.3.6 Timer characteristics

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

The 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 144: Timer characteristics supported by different stages

Operating curve type supported by	51N/G	50N/G-1	50N-G-2
(1) ANSI Extremely Inverse	x	x	x
(2) ANSI Very Inverse	x	x	
(3) ANSI Normal Inverse	x	x	x
(4) ANSI Moderately Inverse	x	x	
(5) ANSI Definite Time	x	x	x
(6) Long Time Extremely Inverse	x	x	
(7) Long Time Very Inverse	x	x	
(8) Long Time Inverse	x	x	
(9) IEC Normal Inverse	x	x	x
(10) IEC Very Inverse	x	x	x
(11) IEC Inverse	x	x	
(12) IEC Extremely Inverse	x	x	x
(13) IEC Short Time Inverse	x	x	
(14) IEC Long Time Inverse	x	x	
(15) IEC Definite Time	x	x	x
(17) User programmable	x	x	x
(18) RI type	x	x	
(19) RD type	x	x	
(-1) Recloser 1 (102)	x	x	
(-2) Recloser 2 (135)	x	x	
(-3) Recloser 3 (140)	x	x	
(-4) Recloser 4 (106)	x	x	
(-5) Recloser 5 (114)	x	x	
(-6) Recloser 6 (136)	x	x	
(-7) Recloser 7 (152)	x	x	
(-8) Recloser 8 (113)	x	x	
(-9) Recloser 8+ (111)	x	x	
(-10) Recloser 8*	x	x	
(-11) Recloser 9 (131)	x	x	
(-12) Recloser 11 (141)	x	x	
(-13) Recloser 13 (142)	x	x	
(-14) Recloser 14 (119)	x	x	
(-15) Recloser 15 (112)	x	x	
(-16) Recloser 16 (139)	x	x	
(-17) Recloser 17 (103)	x	x	
(-18) Recloser 18 (151)	x	x	
(-19) Recloser A (101)	x	x	
(-20) Recloser B (117)	x	x	
(-21) Recloser C (133)	x	x	
(-22) Recloser D (116)	x	x	

Operating curve type supported by	51N/G	50N/G-1	50N-G-2
(-23) Recloser E (132)	x	x	
(-24) Recloser F (163)	x	x	
(-25-Recloser G (121)	x	x	
(-26) Recloser H (122)	x	x	
(-27) Recloser J (164)	x	x	
(-28) Recloser Kg (165)	x	x	
(-29) Recloser Kp (162)	x	x	
(-30) Recloser L (107)	x	x	
(-31) Recloser M (118)	x	x	
(-32) Recloser N (104)	x	x	
(-33) Recloser P (115)	x	x	
(-34) Recloser R (105)	x	x	
(-35) Recloser T (161)	x	x	
(-36) Recloser V (137)	x	x	
(-37) Recloser W (138)	x	x	
(-38) Recloser Y (120)	x	x	
(-39) Recloser Z (134)	x	x	

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

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

Table 145: Reset time characteristics supported by different stages

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

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

4.1.3.7 Application

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

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

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

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

4.1.3.8 Signals

Table 146: 51N/G and 50SEF Input signals

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

Table 147: 50N/G-1/2 Input signals

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

Table 148: 50N/G-3 Input signals

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

Table 149: 51N/G and 50SEF Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 150: 50N/G-1/2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 151: 50N/G-3 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.3.9 Settings

Table 152: 51N/G, 50N/G-1 and 50SEF Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...5.000	xIn	0.005	0.500	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type -1=Recloser 1 (102) -2=Recloser 2 (135) -3=Recloser 3 (140) -4=Recloser 4 (106) -5=Recloser 5 (114) -6=Recloser 6 (136) -7=Recloser 7 (152) -8=Recloser 8 (113) -9=Recloser 8+ (111) -10=Recloser 8* -11=Recloser 9 (131) -12=Recloser 11 (141) -13=Recloser 13 (142) -14=Recloser 14 (119) -15=Recloser 15 (112) -16=Recloser 16 (139) -17=Recloser 17 (103) -18=Recloser 18 (151) -19=Recloser A (101) -20=Recloser B (117) -21=Recloser C (133) -22=Recloser D (116) -23=Recloser E (132) -24=Recloser F (163) -25-Recloser G (121) -26=Recloser H (122) -27=Recloser J (164) -28=Recloser Kg (165) -29=Recloser Kp (162) -30=Recloser L (107) -31=Recloser M (118) -32=Recloser N (104) -33=Recloser P (115) -34=Recloser R (105) -35=Recloser T (161) -36=Recloser V (137) -37=Recloser W (138) -38=Recloser Y (120) -39=Recloser Z (134)			5=ANSI DT	Selection of time delay curve type

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup block enable	0=Disabled 1=Enabled			0=Disabled	Enables start block function
Pickup block value	1.00...40.00	A	0.01	5	Value over which trip will be blocked
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Table 153: 51N/G, 50N/G-1 and 50SEF Non group settings

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

Table 154: 50N/G-2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.50	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 9=IEC Norm Inv 10=IEC Very Inv 12=IEC Ext Inv 15=IEC DT 17=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Table 155: 50N/G-2 Non group settings

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

Table 156: 50N/G-3 Group settings

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

Table 157: 50N/G-3 Non group settings

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

4.1.3.10 Monitored data

Table 158: 51N/G and 50SEF Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
51N/G and 50SEF	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

Table 159: 50N/G-1/2 Monitored data

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

Table 160: 50N/G-3 Monitored data

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

4.1.3.11 Technical data

Table 161: 51N/G, 50N/G-1/2 & 50N/G-3 Technical data

Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz			
	51N/G	±1.5% of the set value or ±0.002 x I_n		
	50N-1/2 & 50G-1/2 and 50N/G-3	±1.5% of set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n)		
Pickup time [1][2]		Minimum	Typical	Maximum
	50N/G-3: I_{Fault} = 2 x set Pickup value I_{Fault} = 10 x set Pickup value	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	50N-1/2 & 50G-1/2 and 51N/G: I_{Fault} = 2 x set Pickup value	22 ms	24 ms	25 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 30 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [3]		
Suppression of harmonics		RMS: No suppression DFT: -50dB at f = n x 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 x I_n, f_n = 60 Hz, ground-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact
3. Maximum *Pickup value* = 2.5 x I_n, *Pickup value* multiples in range of 1.5 to 20

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

4.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional ground-fault protection - Low stage 1	XDEFLPDEF1	I0>->(1)	67/51N
Directional ground-fault protection - Low stage 2	XDEFLPDEF2	I0>->(2)	67/50N-1
Directional ground-fault protection - High stage	XDEFHPDEF1	I0>>->(1)	67/50N-2

4.1.4.2 Function block

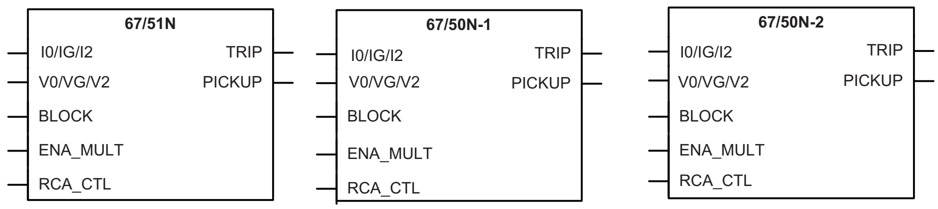


Figure 57: Function block

4.1.4.3 Functionality

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

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

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

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

4.1.4.4 Operation principle

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

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

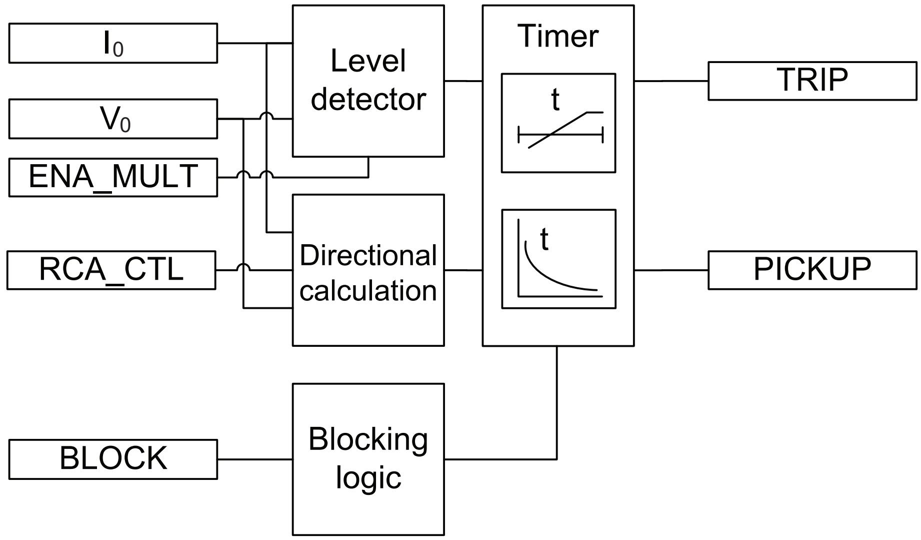


Figure 58: Functional module diagram. I_0 and V_0 represent the zero sequence current and zero sequence voltage.

Level detector

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

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

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

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

Directional calculation

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

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

Table 162: Operation modes

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

The directional operation can be selected with the *Directional mode* setting. The user can select either “Non-directional”, “Forward” or “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 directional information is invalid.

The *Characteristic angle* setting is used in “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, in which case the alternatives are -90° and 0°. The operation of RCA_CTL depends on the *Characteristic angle* setting.

The *Correction angle* setting can be used to improve selectivity when there are inaccuracies due to measurement transformers. The setting decreases the operation sector. The correction can only be used with the “IoCos” or “IoSin” modes.

The minimum signal level which allows directional operation can be set by using the *Min trip current* and *Min trip voltage* settings.

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

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

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

Table 163: 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 VG (polarizing quantity) and Io (operating quantity).
ANGLE_RCA	The angle difference between the operating angle and *Characteristic angle*, that is, ANGLE_RCA = ANGLE – *Characteristic angle*.
I_OPER	The current that is used for fault detection. If the *Operation mode* setting is "Phase angle", "Phase angle 80" or "Phase angle 88", I_OPER is the measured or calculated residual current. If the *Operation mode* setting is "IoSin", I_OPER is calculated as follows I_OPER = 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 PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve and the *Time adder* time has expired, the TRIP 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 happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the PICKUP output is deactivated.

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

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

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

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the percentage ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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

4.1.4.5 Directional ground-fault principles

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

Relay characteristic angle

The *Characteristic angle*, 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 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

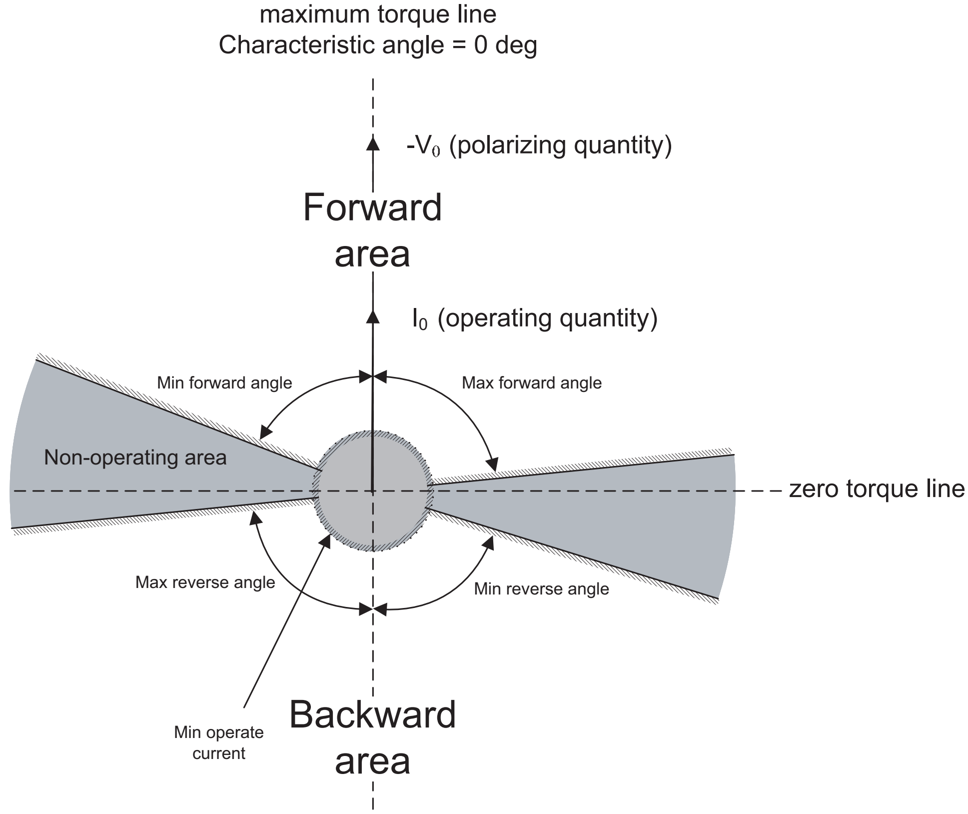


Figure 59: Definition of the relay characteristic angle, RCA=0 degrees in a compensated network

Example 2.

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

=> *Characteristic angle* = +60 deg

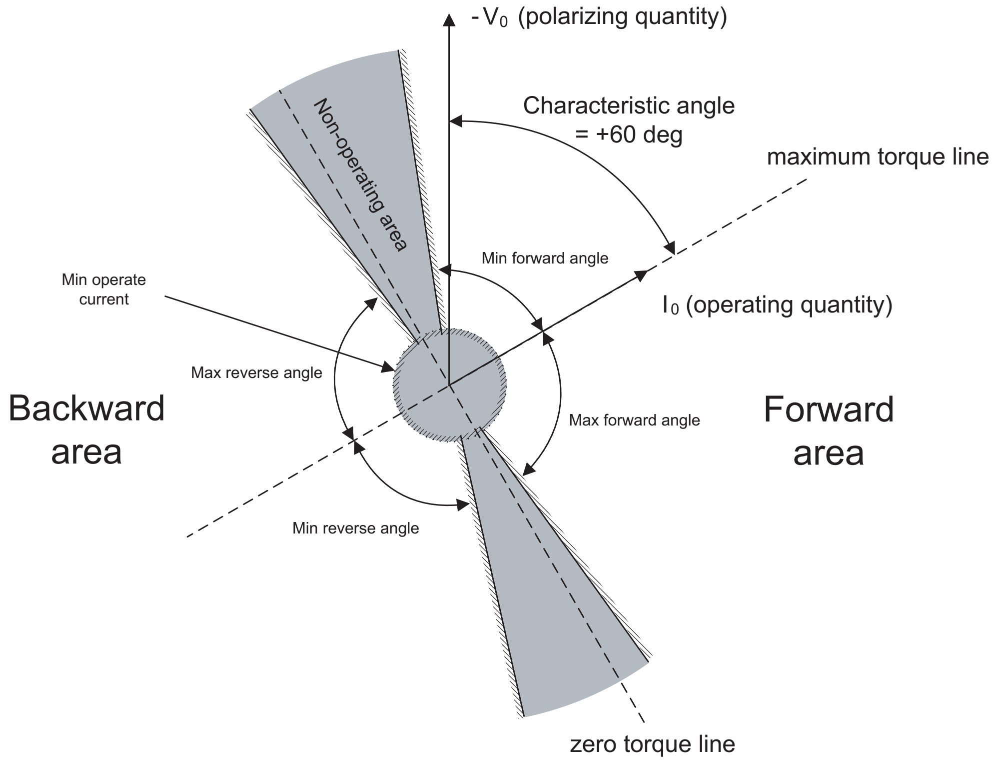


Figure 60: Definition of the relay characteristic angle, RCA=+60 degrees in a solidly grounded network

Example 3.

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

=> *Characteristic angle* = -90 deg

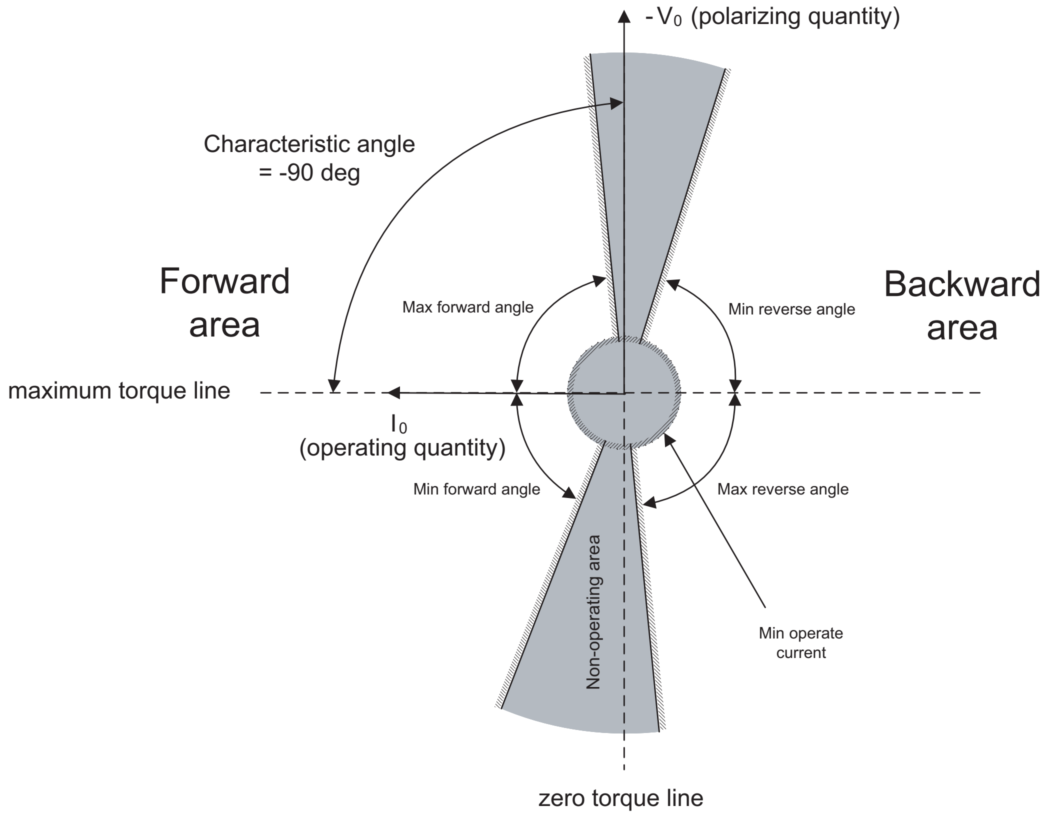


Figure 61: Definition of the relay characteristic angle, RCA=–90 degrees in an isolated network

Directional ground-fault protection in an isolated neutral network

In isolated networks, there is no intentional connection between the system neutral point and ground. The only connection is through the line-to-ground capacitances (C_0) of phases and leakage resistances (R_0). This means that the zero sequence current is mainly capacitive and has a phase shift of –90 degrees compared to the residual voltage ($-V_0$). Consequently, the relay characteristic angle (RCA) should be set to -90 degrees and the operation criteria to $I_0 \sin(\varphi)$ 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*. The figure below describes how ground fault current is defined in isolated neutral networks.

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

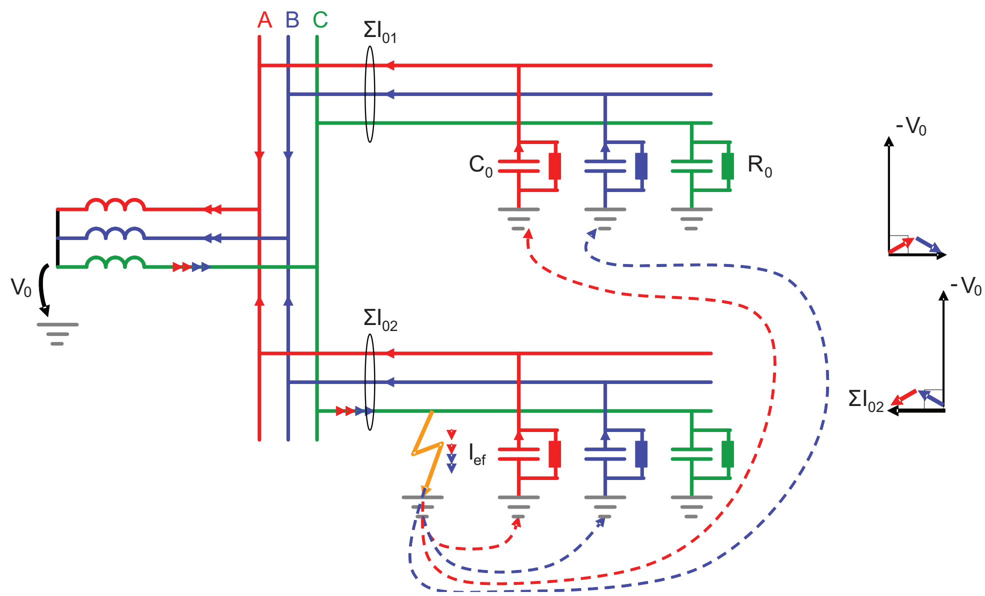


Figure 62: Ground-fault situation in an isolated network

Directional ground-fault protection in a compensated network

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

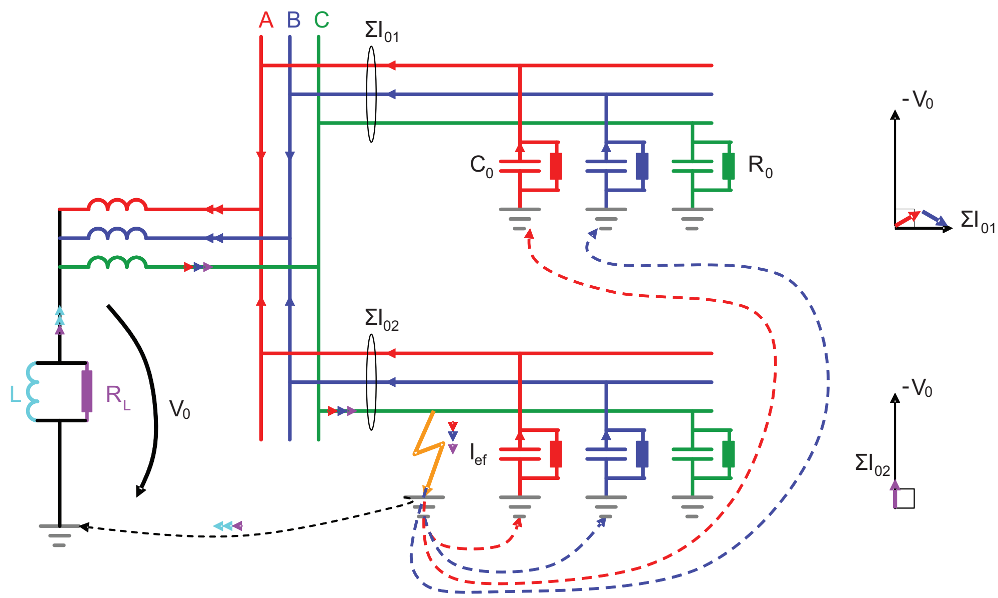


Figure 63: Ground-fault situation in a compensated network

The Petersen coil or the grounding resistor may be temporarily out of operation. To keep the protection scheme selective, it is necessary to update the characteristic angle setting accordingly. This is done with an auxiliary input in the relay which receives a signal from an auxiliary switch of the disconnector of the Petersen coil in compensated networks or of the grounding resistor in grounded networks. As a result the characteristic angle is set automatically to suit the grounding method used. The RCA_CTL input can be used to change the I_0 characteristic:

Table 164: Relay characteristic angle control in I_0sin(φ) and I_0cos(φ) operation criteria

Operation criteria setting:	RCA_CTL = FALSE	RCA_CTL = TRUE
I_0sin(φ)	Actual operation criteria: I_0sin(φ)	Actual operation criteria: I_0cos(φ)
I_0cos(φ)	Actual operation criteria: I_0cos(φ)	Actual operation criteria: I_0sin(φ)

Table 165: Characteristic angle control in phase angle operation mode

Characteristic angle setting	RCA_CTL = FALSE	RCA_CTL = TRUE
-90°	φRCA = -90°	φRCA = 0°
0°	φRCA = 0°	φRCA = -90°

Usage of the extended phase angle characteristic

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

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

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

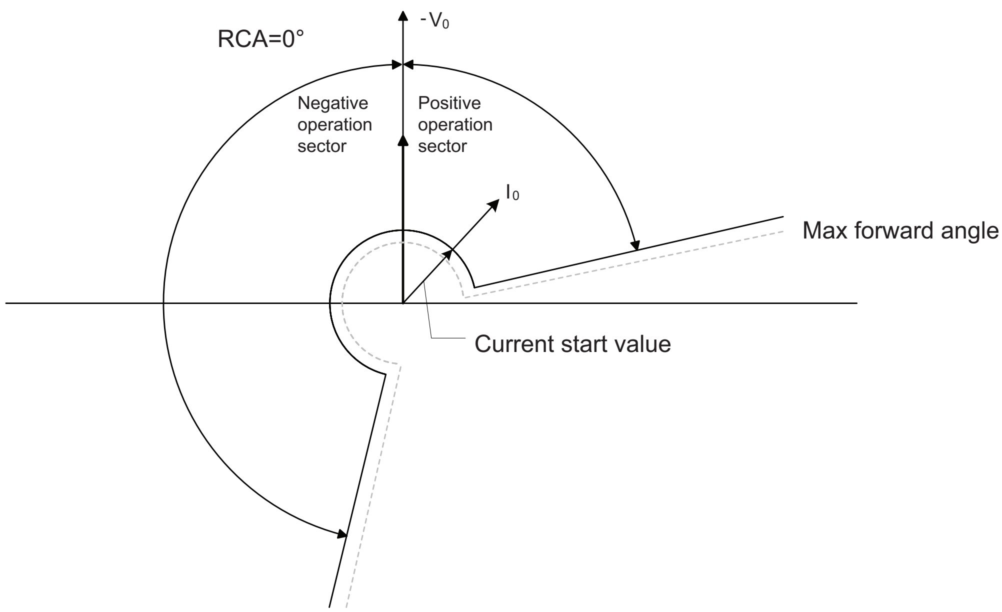


Figure 64: Extended operation area in directional ground-fault protection

4.1.4.6 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 166: Measurement modes supported by 67/51N and 67/50N stages

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

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

4.1.4.7 Timer characteristics

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

The 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 167: Timer characteristics supported by different stages

Operating curve type	Supported by	
	67/51N and 67/50N-1	67/50N-2
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	
(10) IEC Very Inverse	x	
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable curve	x	x
(18) RI type	x	
(19) RD type	x	
(-1) Recloser 1 (102)	x	
(-2) Recloser 2 (135)	x	
(-3) Recloser 3 (140)	x	
(-4) Recloser 4 (106)	x	
(-5) Recloser 5 (114)	x	
(-6) Recloser 6 (136)	x	
(-7) Recloser 7 (152)	x	
(-8) Recloser 8 (113)	x	
(-9) Recloser 8+ (111)	x	
(-10) Recloser 8*	x	
(-11) Recloser 9 (131)	x	
(-12) Recloser 11 (141)	x	
(-13) Recloser 13 (142)	x	
(-14) Recloser 14 (119)	x	
(-15) Recloser 15 (112)	x	
(-16) Recloser 16 (139)	x	
(-17) Recloser 17 (103)	x	
(-18) Recloser 18 (151)	x	
(-19) Recloser A (101)	x	
(-20) Recloser B (117)	x	
(-21) Recloser C (133)	x	

Operating curve type	Supported by	
	67/51N and 67/50N-1	67/50N-2
(-22) Recloser D (116)	x	
(-23) Recloser E (132)	x	
(-24) Recloser F (163)	x	
(-25-Recloser G (121)	x	
(-26) Recloser H (122)	x	
(-27) Recloser J (164)	x	
(-28) Recloser Kg (165)	x	
(-29) Recloser Kp (162)	x	
(-30) Recloser L (107)	x	
(-31) Recloser M (118)	x	
(-32) Recloser N (104)	x	
(-33) Recloser P (115)	x	
(-34) Recloser R (105)	x	
(-35) Recloser T (161)	x	
(-36) Recloser V (137)	x	
(-37) Recloser W (138)	x	
(-38) Recloser Y (120)	x	
(-39) Recloser Z (134)	x	

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

Table 168: Reset time characteristics supported by different stages

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

4.1.4.8 Directional ground-fault characteristics

Phase angle characteristic

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

When the phase angle criterion is used, the function indicates 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 anti-clockwise 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 anti-clockwise 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.

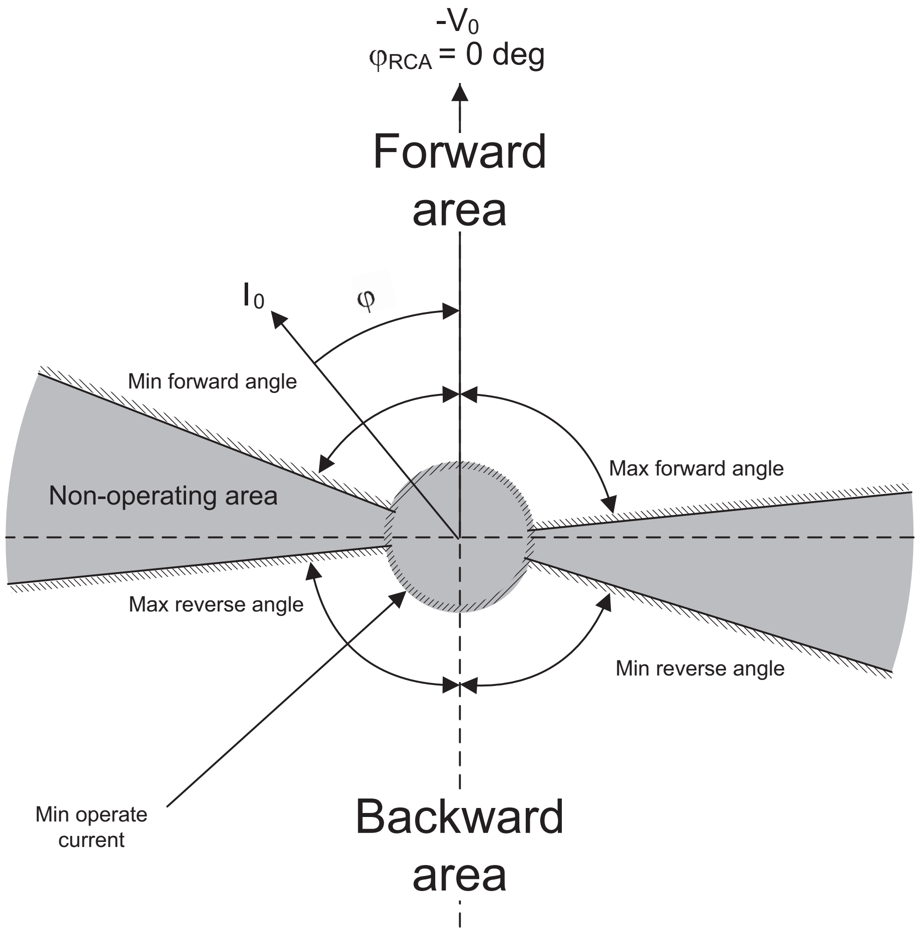


Figure 65: Configurable operating sectors in phase angle characteristic

Table 169: Momentary operating direction

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

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

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

Table 170: Characteristic angle control in phase angle operation mode

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

I_0sin(φ) and I_0cos(φ) criteria

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

The operation criteria I_0sin(φ) and I_0cos(φ) are selected with the *Operation mode* setting using the values "IoSin" or "IoCos", respectively.

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

The angle correction setting can be used to improve selectivity. The setting decreases the operation sector. The correction can only be used with the I_0sin(φ) or I_0cos(φ) criterion. The RCA_CTL input is used to change the I_0 characteristic:

Table 171: Relay characteristic angle control in I_0sin(φ) and I_0cos(φ) operation criterion

Operation criteria:	RCA_CTL = "False"	RCA_CTL = "True"
I_0sin(φ)	Actual operation criterion: I_0sin(φ)	Actual operation criterion: I_0cos(φ)
I_0cos(φ)	Actual operation criterion: I_0cos(φ)	Actual operation criterion: I_0sin(φ)

When the I_0sin(φ) or I_0cos(φ) criterion is used, the component indicates a forward or reverse-type fault through the FAULT_DIR and DIRECTION outputs, in which 1 equals a forward fault and 2 equals a reverse fault. Directional operation is not allowed (the *Allow non dir* setting is "False") when the measured polarizing or operating quantities are not valid, that is, when their magnitude is below the set minimum values. The minimum values can be defined with the *Min trip current* and *Min trip voltage* settings. In case of low magnitude, the FAULT_DIR and DIRECTION outputs are set to 0 = unknown, except when the *Allow non dir* setting is “True”. In that case, the function is allowed to operate in the directional mode as non-directional, since the directional information is invalid.

The calculated I_0sin(φ) or I_0cos(φ) current used in direction determination can be read through the I_OPER monitored data. The value can be passed directly to a decisive element, which provides the final pickup and trip signals.

The I_OPER monitored data gives an absolute value of the calculated current. Otherwise, the value of a current in a reverse area is negative.

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

Example 1.

I_0sin(φ) criterion selected, forward-type fault

```
=> FAULT_DIR = 1
```

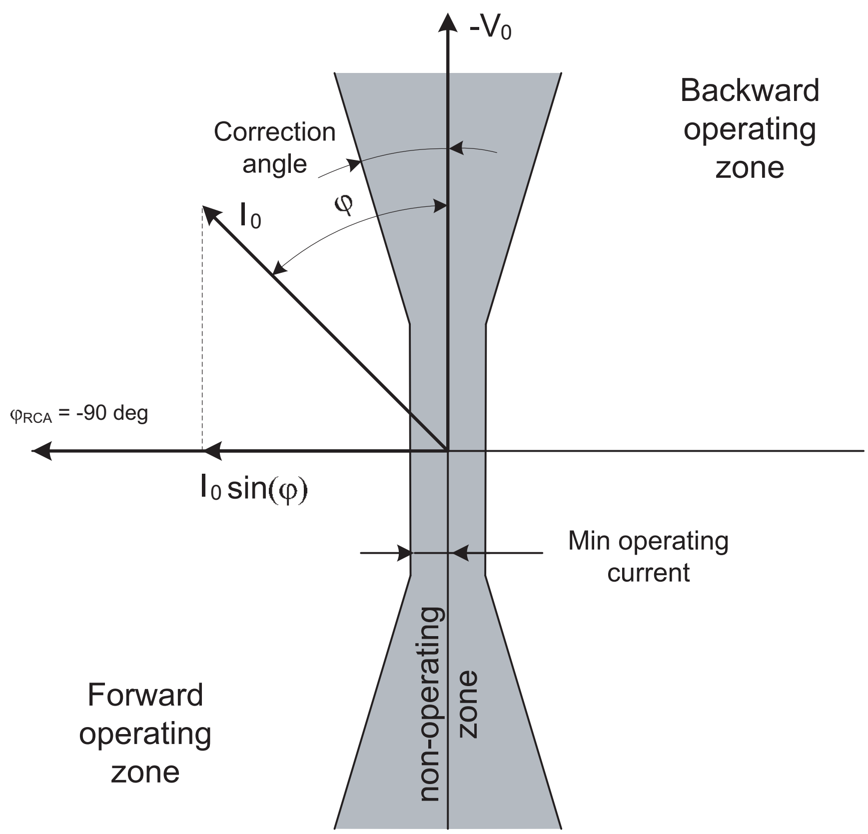


Figure 66: Operating characteristic I_0sin(φ) in forward fault

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

Example 2.

I_0sin(φ) criterion selected, reverse-type fault

```
=> FAULT_DIR = 2
```

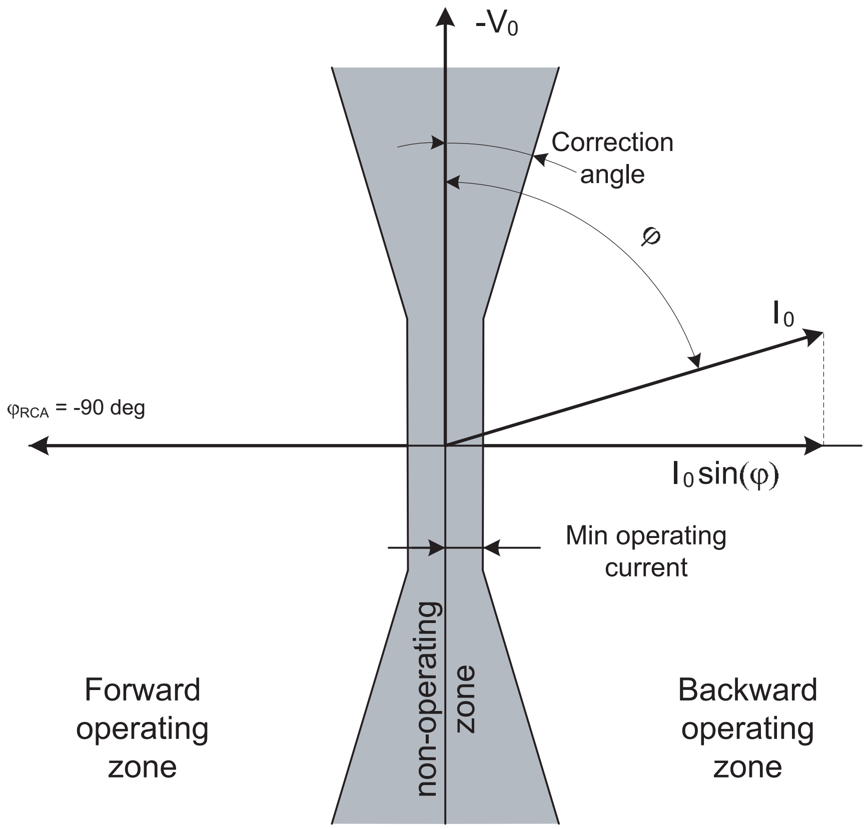


Figure 67: Operating characteristic $I_0 sin(φ)$ in reverse fault

Example 3.

$I_0\cos(\varphi)$ criterion selected, forward-type fault

```
=> FAULT_DIR = 1
```

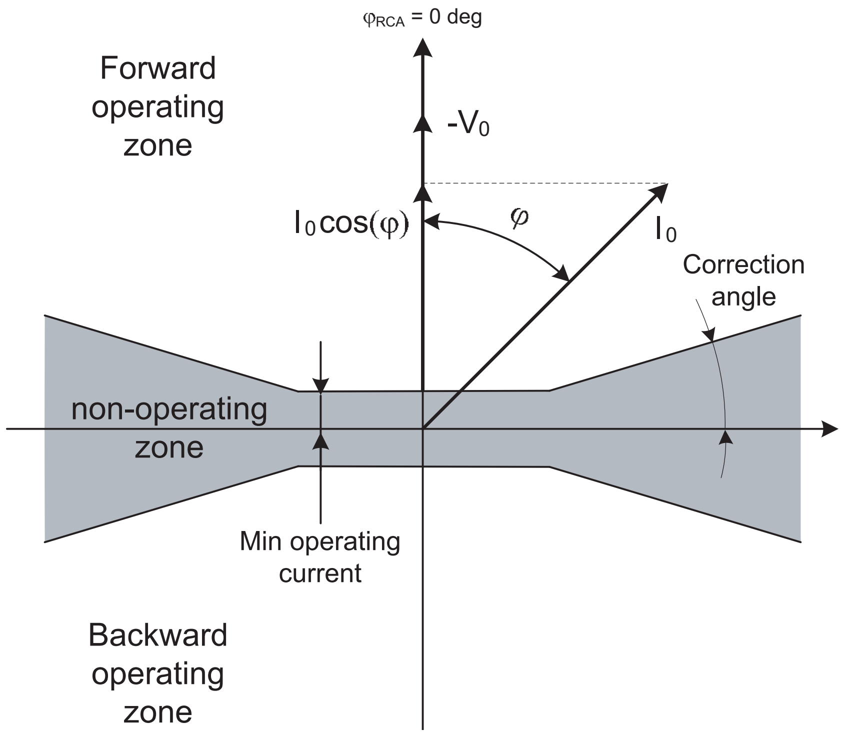


Figure 68: Operating characteristic $I_0\cos(\varphi)$ in forward fault

Example 4.

$I_0\cos(\varphi)$ criterion selected, reverse-type fault

=> FAULT_DIR = 2

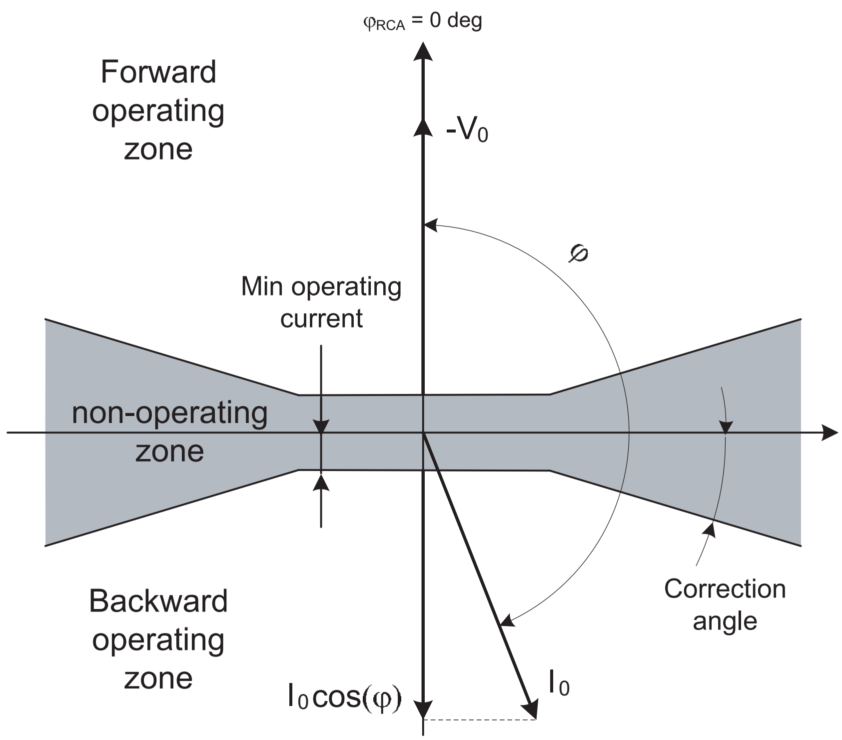


Figure 69: Operating characteristic $I_0cos(\varphi)$ in reverse fault

Phase angle, classic 80

The operation criterion phase angle classic 80 is selected with the *Operation mode* setting using the value “Phase angle 80”.

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

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

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

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

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

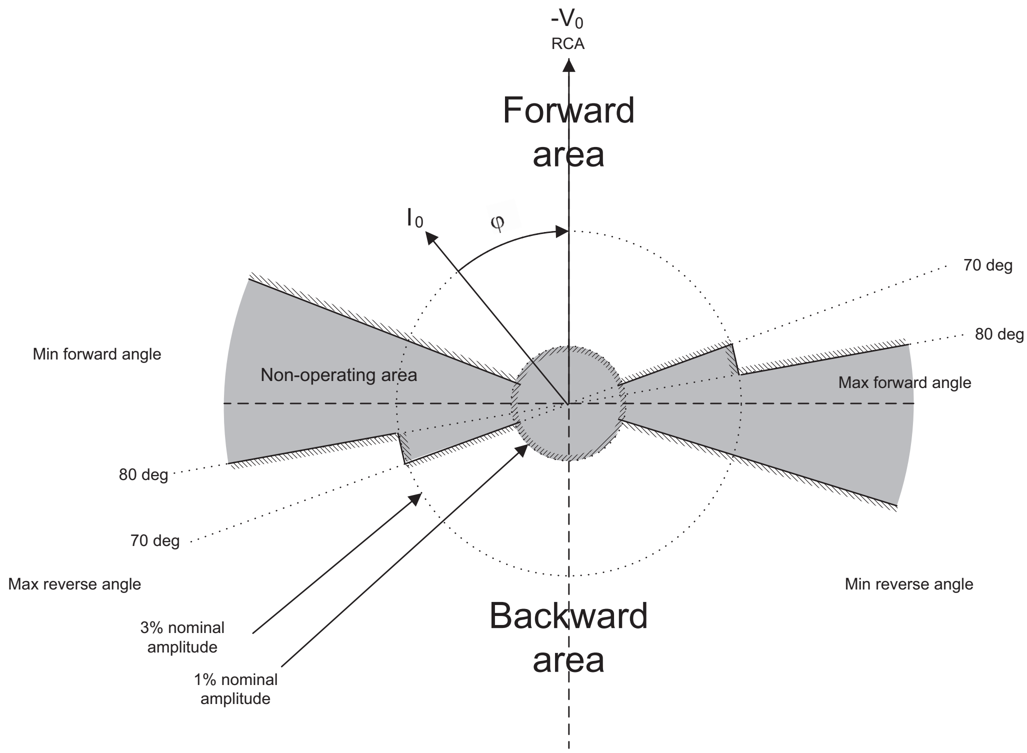


Figure 70: Operating characteristic for phase angle classic 80

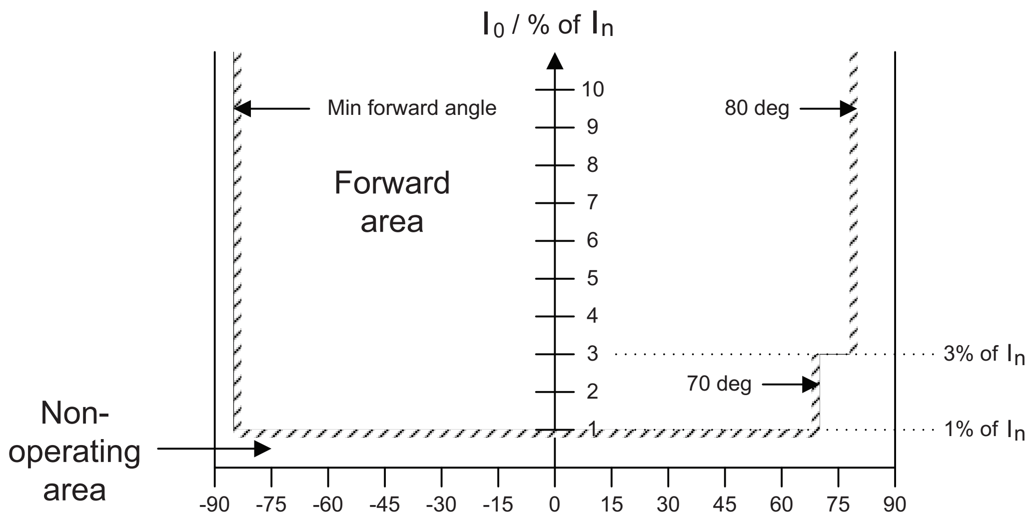


Figure 71: Phase angle classic 80 amplitude

Phase angle, classic 88

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

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

- The *Max forward angle* and *Max reverse angle* settings are not settable, but have a fixed value of 88 degrees
- The sector limits of the fixed sectors are rounded.

Sector rounding in the phase angle classic 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 1...100 percent of the nominal current, the sector limit increases linearly from 85 degrees to 88 degrees
- If the current amplitude is more than 100 percent of the nominal current, the sector limit is 88 degrees.

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

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

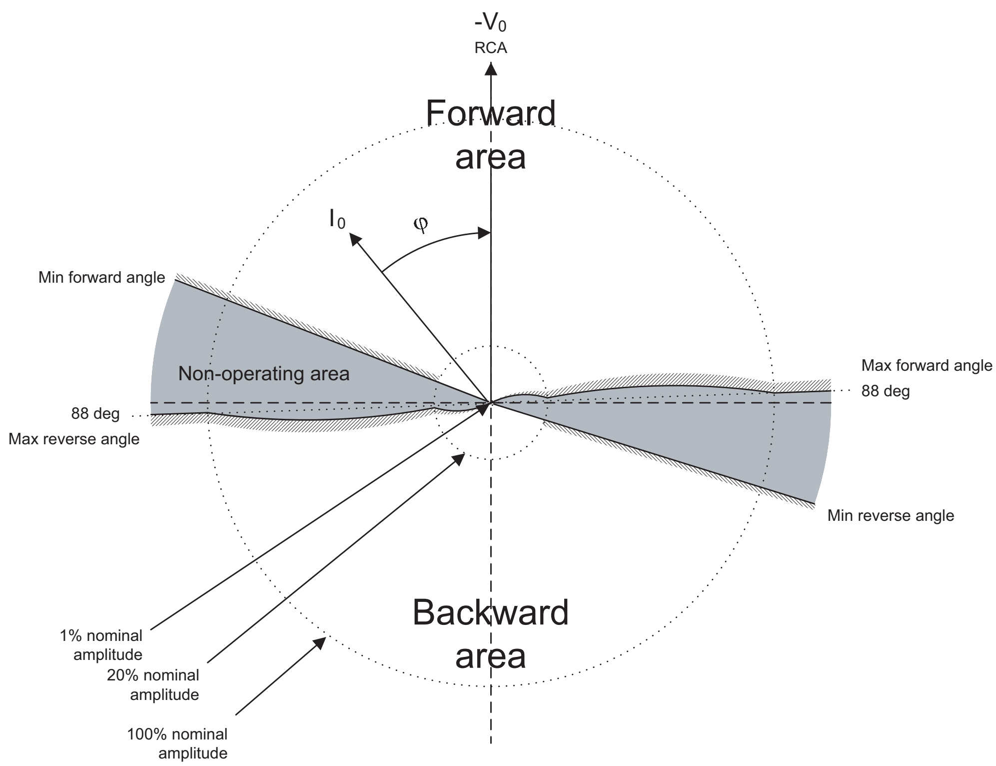


Figure 72: Operating characteristic for phase angle classic 88

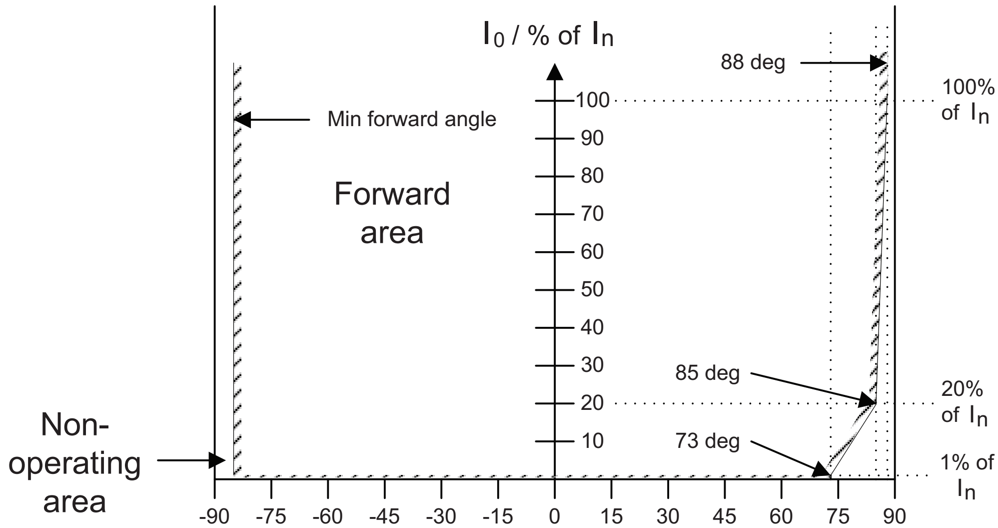


Figure 73: Phase angle classic 88 amplitude

4.1.4.9 Application

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

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

- low (67/51N and 67/50N-1)
- high (67/50N-2)

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

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

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

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

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

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

In networks where the neutral point is grounded through low resistance, the characteristic angle is also 0 degrees (for phase angle). Alternatively, $I_0\cos(\varphi)$ operation can be used.

In solidly grounded networks, the *Characteristic angle* is typically set to +60 degrees for the phase angle. Alternatively, $I_0\sin(\varphi)$ operation can be used with a reversal polarizing quantity. The polarizing quantity can be rotated 180 degrees by setting the *Pol reversal* parameter to “True” or by switching the polarity of the zero sequence voltage measurement wires. Although the $I_0\sin(\varphi)$ operation can be used in solidly grounded networks, the phase angle is recommended. In some applications, negative sequence polarization is preferred over zero sequence polarization. The relay also offers negative sequence polarization option where users can set the angle between V_2 and I_2 based on their application and practice.

Connection of measuring transformers in directional ground fault applications

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

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

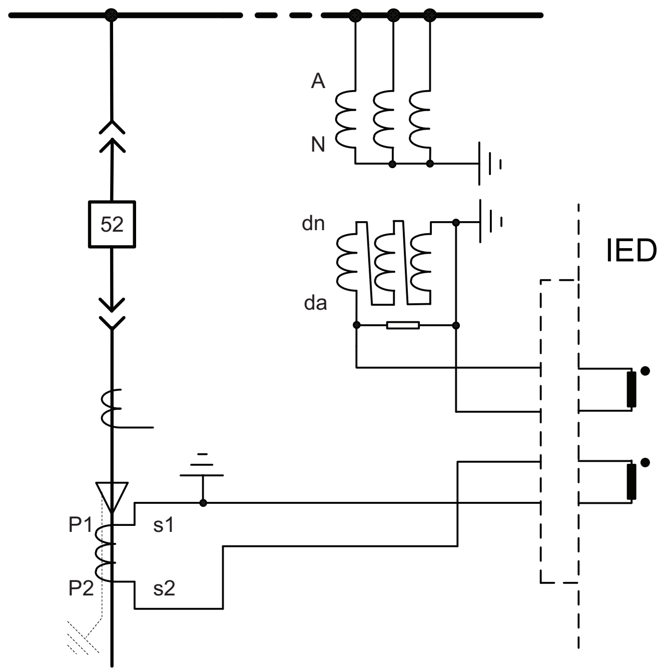


Figure 74: Connection of measuring transformers

4.1.4.10 Signals

Table 172: 67/51N and 67/50N-1 Input signals

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

Table 173: 67/50N-2 Input signals

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

Table 174: 67/51N and 67/50N-1 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

Table 175: 67/50N-2 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.4.11 Settings

Table 176: 67/51N and 67/50N-1 Group settings

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

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type -1=Recloser 1 (102) -2=Recloser 2 (135) -3=Recloser 3 (140) -4=Recloser 4 (106) -5=Recloser 5 (114) -6=Recloser 6 (136) -7=Recloser 7 (152) -8=Recloser 8 (113) -9=Recloser 8+ (111) -10=Recloser 8* -11=Recloser 9 (131) -12=Recloser 11 (141) -13=Recloser 13 (142) -14=Recloser 14 (119) -15=Recloser 15 (112) -16=Recloser 16 (139) -17=Recloser 17 (103) -18=Recloser 18 (151) -19=Recloser A (101) -20=Recloser B (117) -21=Recloser C (133) -22=Recloser D (116) -23=Recloser E (132) -24=Recloser F (163) -25-Recloser G (121) -26=Recloser H (122) -27=Recloser J (164) -28=Recloser Kg (165) -29=Recloser Kp (162) -30=Recloser L (107) -31=Recloser M (118) -32=Recloser N (104) -33=Recloser P (115) -34=Recloser R (105) -35=Recloser T (161) -36=Recloser V (137) -37=Recloser W (138) -38=Recloser Y (120) -39=Recloser Z (134)			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	60...200000	ms	10	60	Trip delay time
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Parameter	Values (Range)	Unit	Step	Default	Description
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	88	Minimum phase angle in reverse direction
Voltage pickup value	0.010...1.000	xVn	0.001	0.010	Voltage pickup value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 177: 67/51N and 67/50N-1 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum trip time	60...60000	ms	1	60	Minimum trip time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min trip current	0.005...1.000	xIn	0.001	0.005	Minimum trip current
Min trip voltage	0.01...1.00	xVn	0.01	0.01	Minimum trip voltage
Correction angle	0.0...10.0	deg	0.1	0.0	Angle correction
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
Io signal Sel	1=IG 2=I0			1=IG	Selection for used Io signal
Pol signal Sel	1=Measured VG 2=Calculated V0 3=Neg. seq. volt.			2=Calculated V0	Selection for used polarization signal

Table 178: 67/50N-2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.10...40.00	xIn	0.01	0.10	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext Inv 3=ANSI Norm Inv 5=ANSI DT 15=IEC DT 17=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Trip delay time	40...200000	ms	10	40	Trip delay time
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	88	Minimum phase angle in reverse direction
Voltage pickup value	0.010...1.000	xVn	0.001	0.010	Voltage pickup value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 179: 67/50N-2 Non group settings

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

4.1.4.12 Monitored data

Table 180: 67/51N and 67/50N-1 Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
PICKUP_DUR	FLOAT 32	0.00...100.00	%	Ratio of pickup time / trip time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE	FLOAT 32	-180.00...180.00	deg	Angle between polarizing and operating quantity
ANGLE_RCA	FLOAT 32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
I_OPER	FLOAT 32	0.00...40.00		Calculated operating current
67/51N and 67/50N-1	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

Table 181: 67/50N-2 Monitored data

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

4.1.4.13 Technical data

Table 182: 67/51N and 67/50N Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
	67/51N and 67/50N-1	Current: ±1.5% of the set value or ±0.002 x I_n Voltage ±1.5% of the set value or ±0.002 x V_n Phase angle: ±2°		
	67/50N-2	Current: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n) Voltage: ±1.5% of the set value or ±0.002 x V_n Phase angle: ±2°		
Pickup time [1,2]		Minimum	Typical	Maximum
	67/50N-2 and 67/51N and 67/50N-1: I_{Fault} = 2 x set *Pickup value*	61 ms	64 ms	66 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 30 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [3]		
Suppression of harmonics		RMS: No suppression DFT: -50dB at f = n x 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 x I_n, f_n = 60 Hz, ground-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact
3. Maximum *Pickup value* = 2.5 x I_n, *Pickup value* multiples in range of 1.5 to 20

4.1.5 Sensitive earth-fault protection 50SEF

4.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional sensitive earth-fault protection	XEFLPTOC	I_0>	50SEF

4.1.5.2 Function block

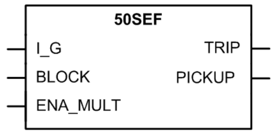


Figure 75: Function block

4.1.5.3 Functionality

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

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

4.1.5.4 Principle of operation

Same as 51N as described in 4.1.3.4 above.

4.1.5.5 Measurement modes

Same as 51N as described in 4.1.3.5 above.

4.1.5.6 Timer characteristics

Same as 51N as described in 4.1.3.6 above.

4.1.5.7 Application

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

Most of these faults are ground faults. A small percentage of the ground faults have a very large impedance. They are comparable to load impedance and consequently have very little fault current. These high impedance faults do not pose imminent danger to power system equipment. However, they are a considerable threat to people and property. If the natural unbalance in the system is low, the sensitive earth-fault protection can be used to detect the ground fault.

4.1.5.8 Signals

Same as 51N as described in 4.1.3.8 above.

4.1.5.9 Settings

Same as 51N as described in 4.1.3.9 above.

4.1.5.10 Monitored data

Same as 51N as described in 4.1.3.10 above.

4.1.5.11 Technical data

Same as 50N as described in 4.1.3.11 above.

4.1.6 Negative phase-sequence current protection 46

4.1.6.1 Identification

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

4.1.6.2 Function block

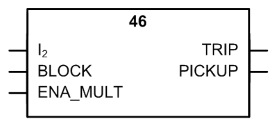


Figure 76: Function block

4.1.6.3 Functionality

The negative sequence current protection 46 is used for increasing sensitivity to detect single phasing situations, unbalanced loads due to, for example, unsymmetrical feeder voltages.

46 can also be used for detecting broken conductors.

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

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

4.1.6.4 Operation principle

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

The operation of negative phase-sequence current protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

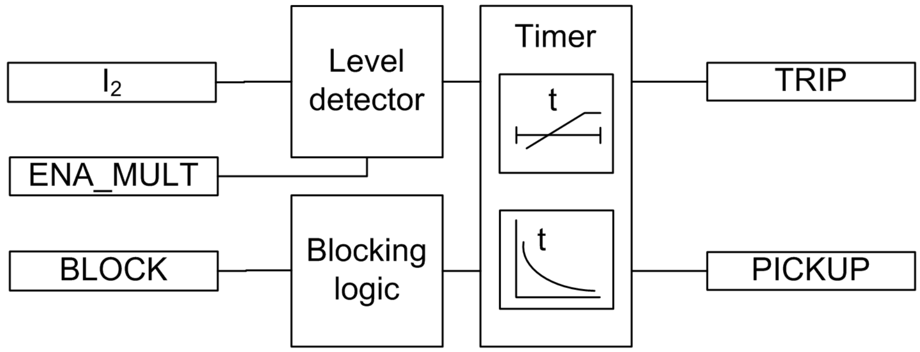


Figure 77: Functional module diagram. I_2 represents negative phase sequence current.

Level detector

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

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

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

Timer

Once activated, the timer activates the PICKUP output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Trip delay time* in the DT mode or the maximum value defined by the inverse time curve and the *Time adder* time has expired, the TRIP 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 happens, that is, a fault suddenly disappears before the trip delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to *"*Immediate*"*, *"*Def time reset*"* or *"*Inverse reset*"*. The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the `PICKUP` output is deactivated.

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

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

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

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the percentual ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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

4.1.6.5 Application

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

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

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

4.1.6.6 Signals

Table 183: 46 Input signals

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

Table 184: 46 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.6.7 Settings

Table 185: 46 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.01...5.00	xIn	0.01	0.30	Pickup value
Pickup value mult	0.8...10.0		0.1	1.0	Multiplier for scaling the pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...200000	ms	10	40	Trip delay time

Parameter	Values (Range)	Unit	Step	Default	Description
Operating curve type	1=ANSI Ext Inv 2=ANSI Very Inv 3=ANSI Norm Inv 4=ANSI Mod Inv 5=ANSI DT 6=LT Ext Inv 7=LT Very Inv 8=LT Inv 9=IEC Norm Inv 10=IEC Very Inv 11=IEC Inv 12=IEC Ext Inv 13=IEC ST Inv 14=IEC LT Inv 15=IEC DT 17=Programmable 18=RI Type 19=RD Type -1=Recloser 1 (102) -2=Recloser 2 (135) -3=Recloser 3 (140) -4=Recloser 4 (106) -5=Recloser 5 (114) -6=Recloser 6 (136) -7=Recloser 7 (152) -8=Recloser 8 (113) -9=Recloser 8+ (111) -10=Recloser 8* -11=Recloser 9 (131) -12=Recloser 11 (141) -13=Recloser 13 (142) -14=Recloser 14 (119) -15=Recloser 15 (112) -16=Recloser 16 (139) -17=Recloser 17 (103) -18=Recloser 18 (151) -19=Recloser A (101) -20=Recloser B (117) -21=Recloser C (133) -22=Recloser D (116) -23=Recloser E (132) -24=Recloser F (163) -25-Recloser G (121) -26=Recloser H (122) -27=Recloser J (164) -28=Recloser Kg (165) -29=Recloser Kp (162) -30=Recloser L (107) -31=Recloser M (118) -32=Recloser N (104) -33=Recloser P (115) -34=Recloser R (105) -35=Recloser T (161) -36=Recloser V (137) -37=Recloser W (138) -38=Recloser Y (120) -39=Recloser Z (134)			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Time adder	0.00...2.00	s	0.01	0	Time added after curve time before trip

Table 186: 46 Non group settings

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

4.1.6.8 Monitored data

Table 187: 46 Monitored data

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

4.1.6.9 Technical data

Table 188: 46 Technical data

Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x I_n		
Pickup time [1,2]		Minimum	Typical	Maximum
	I_{Fault} = 2 x set *Pickup value* I_{Fault} = 10 x set *Pickup value*	22 ms 14 ms	24 ms 16 ms	25 ms 17 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Trip time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [3]		
Suppression of harmonics		DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,…		

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

4.1.7 Phase discontinuity protection 46PD

4.1.7.1 Identification

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

4.1.7.2 Function block

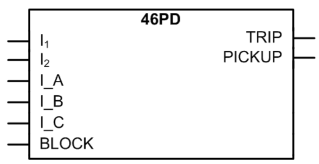


Figure 78: Function block

4.1.7.3 Functionality

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

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

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

4.1.7.4 Operation principle

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

The operation of phase discontinuity protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

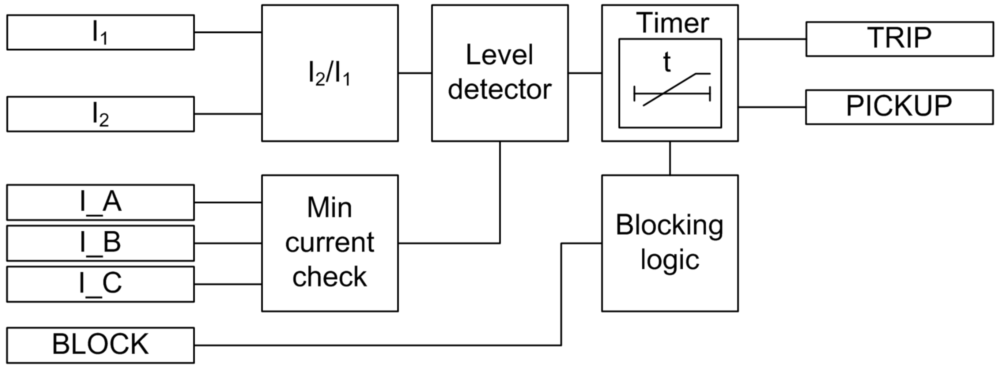


Figure 79: Functional module diagram. I_1 and I_2 represent positive and negative phase sequence currents. I_A, I_B and I_C represent phase currents.

I_2/I_1

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

Level detector

The level detector compares the calculated ratio of negative and positive phase sequence currents with the set *Pickup value*. If the calculated value exceeds the set *Pickup value* and the min current check module has exceeded the minimum phase current limit, the level detector activates the timer.

Min current check

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

Timer

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

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

4.1.7.5 Application

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

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

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

When the three phase currents are measured, the positive sequence current is calculated:

$$\bar{I}_1 = \frac{1}{3}\left(\bar{I}a + \bar{a}\bar{I}b + \bar{a}^2\bar{I}c\right)$$

(Equation 28)

The negative sequence current is calculated:

$$\bar{I}_2 = \frac{1}{3}\left(\bar{I}a + \bar{a}^2\bar{I}b + \bar{a}\bar{I}c\right)$$

(Equation 29)

$\bar{I}a, \bar{I}b, \bar{I}c$ phase current vectors

$\bar{a}$ phase rotation operator (defined to rotate a phasor component forward by 120 degrees)

The unbalance of the network is detected by monitoring the negative 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:

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

(Equation 30)

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

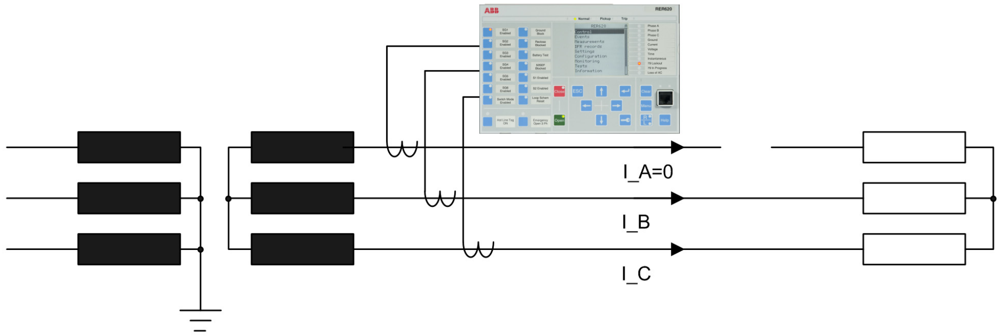


Figure 80: Broken conductor fault in phase A in a distribution or subtransmission feeder

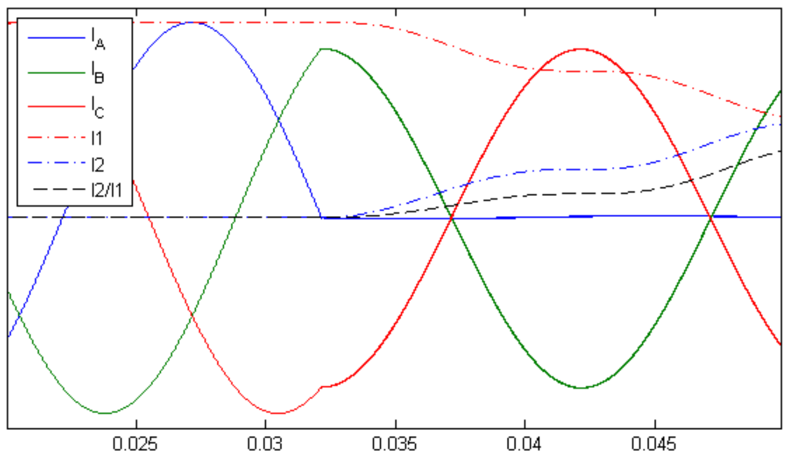


Figure 81: Three-phase current quantities during the broken conductor fault in phase A with the ratio of negative and positive sequence currents

4.1.7.6 Signals

Table 189: 46PD Input signals

Name	Type	Default	Description
I_1	SIGNAL	0	Positive phase sequence current
I_2	SIGNAL	0	Negative phase 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 190: 46PD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.1.7.7 Settings

Table 191: 46PD Group settings

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

Table 192: 46PD Non group settings

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

4.1.7.8 Monitored data

Table 193: 46PD Monitored data

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

4.1.7.9 Technical data

Table 194: 46PD Technical data

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

4.1.8 Three-phase transformer inrush detector INR

4.1.8.1 Identification

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

4.1.8.2 Function block

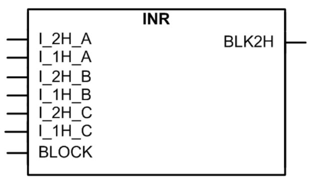


Figure 82: Function block

4.1.8.3 Functionality

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

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

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

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

4.1.8.4 Operation principle

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

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

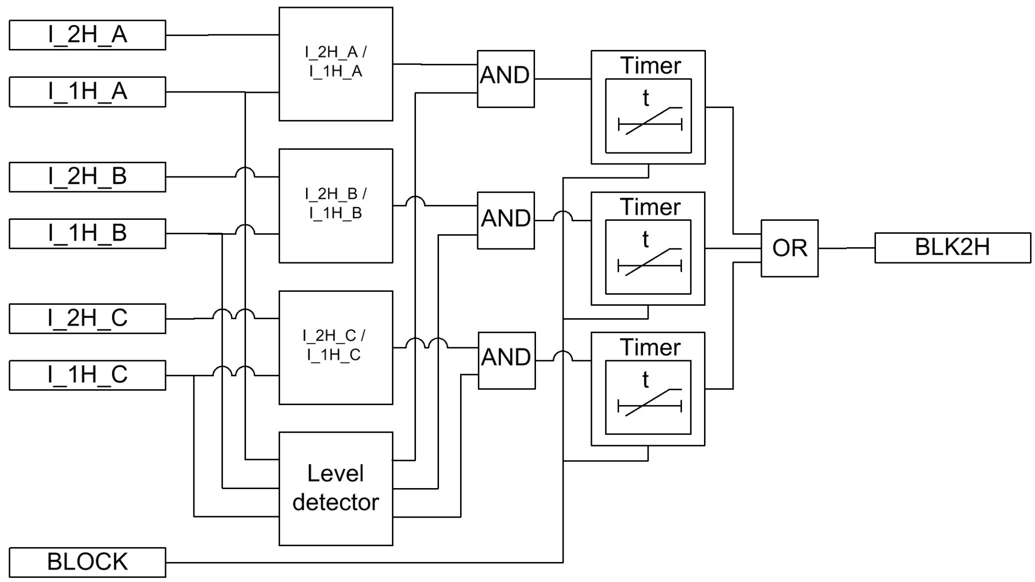


Figure 83: Functional module diagram. I_1H and I_2H represent fundamental and second harmonic values of phase currents.

I_2H/I_1H

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

Level detector

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

Timer

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

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

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

4.1.8.5 Application

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

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

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

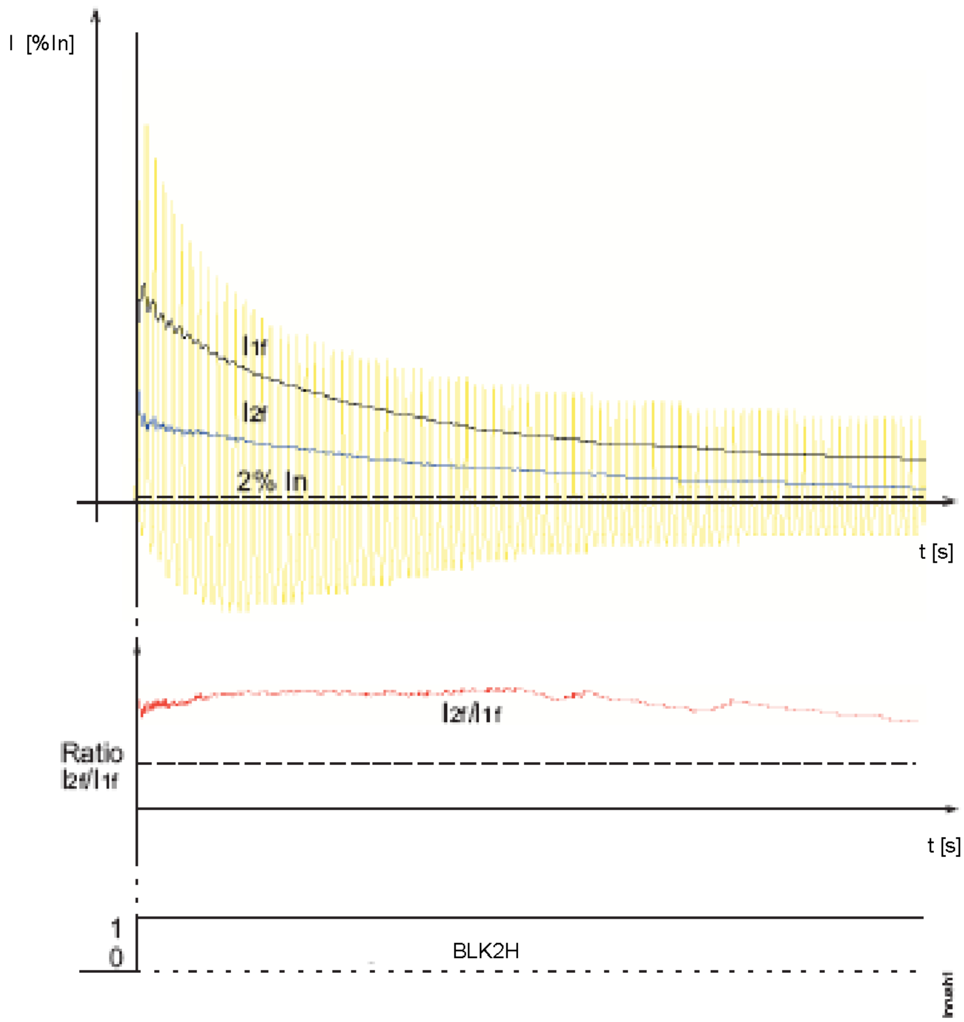


Figure 84: Inrush current in transformer

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

4.1.8.6 Signals

Table 195: INR Input signals

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

Table 196: INR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

4.1.8.7 Settings

Table 197: INR Group settings

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 198: INR Non group settings

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

4.1.8.8 Monitored data

Table 199: INR Monitored data

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

4.1.8.9 Technical data

Table 200: INR Technical data

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

4.2 Cold load timers

Cold Load timers are implemented using the general purpose timers TPSGAPC and TPMGAPC that do their timing in seconds and minutes, respectively. Refer to the Application manual for information on how these are configured using ACT.

4.3 Voltage protection

4.3.1 Single-phase overvoltage protection 59

4.3.1.1 Identification

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

4.3.1.2 Function block

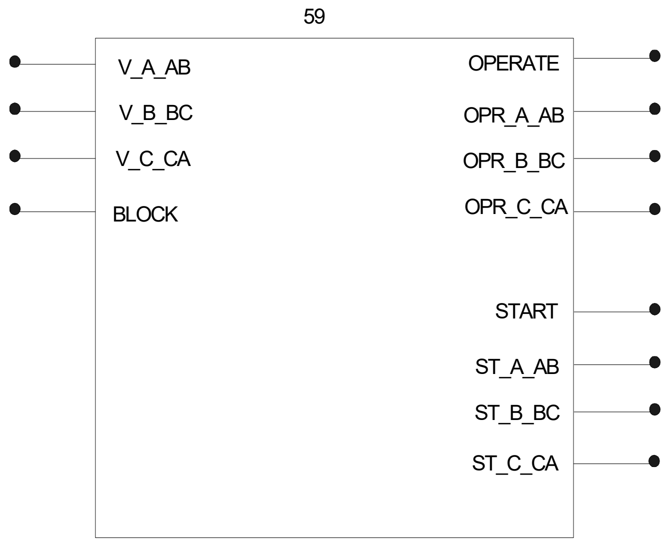


Figure 85: Function block

4.3.1.3 Functionality

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

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

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

4.3.1.4 Operation principle

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

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

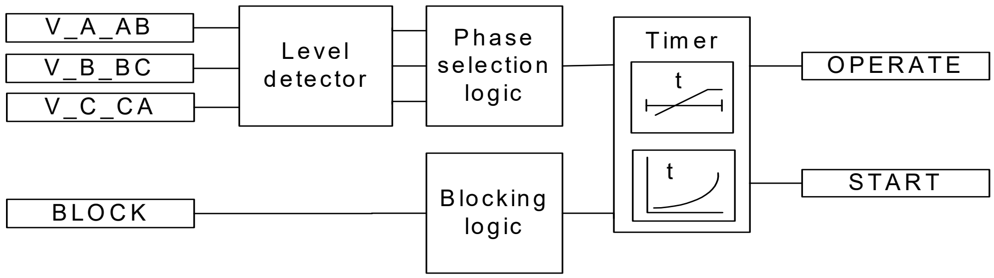


Figure 86: Functional module diagram (Three Phase trip mode)

Three Phase Mode

The following description holds good when three phase mode is chosen for the recloser.

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

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

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

For a more detailed description of the IDMT curves and the use of the *Curve Sat Relative* setting, see the General function block features 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 `PICKUP (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 General function block features section in this manual.

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

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

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

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

Single Phase Mode

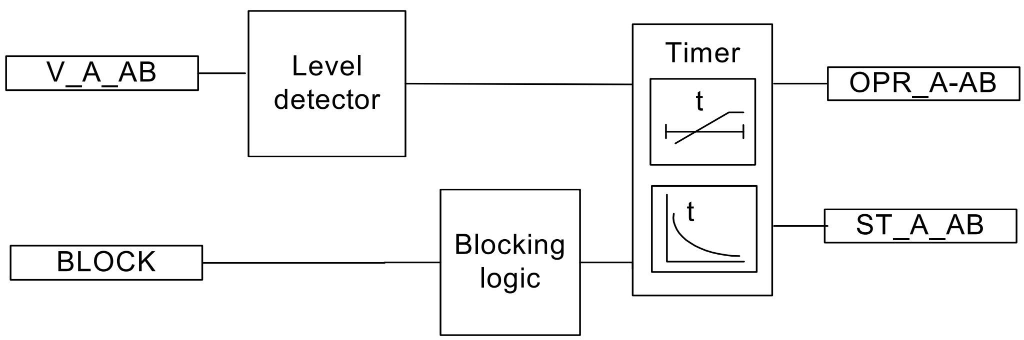


Figure 87: Functional module diagram (Single Phase)

The following description holds good when single phase mode is chosen for the recloser.

The fundamental frequency component of the measured single-phase voltage is compared to the set value of the *Start (pickup) value* setting phase-wise. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly differs from the *Pickup value* setting. After leaving the hysteresis area, the pickup condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

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

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

For a more detailed description of the IDMT curves and the use of the *Curve Sat Relative* setting, see the General function block features section in this manual.

Timer

Once activated, the timer activates the respective phase PICKUP(ST_A_AB) as shown typically above for respective phase output as well as the common PICKUP (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 General function block features section in this manual.

When the operation timer has reached the value set by *Trip delay time* in the DT mode or the maximum value defined by the IDMT, the TRIP(OPR_A_AB) for respective phase as well as the common the OPERATE output are activated.

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

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

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

Table 201: The reset time functionality when the IDMT trip time curve is selected

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

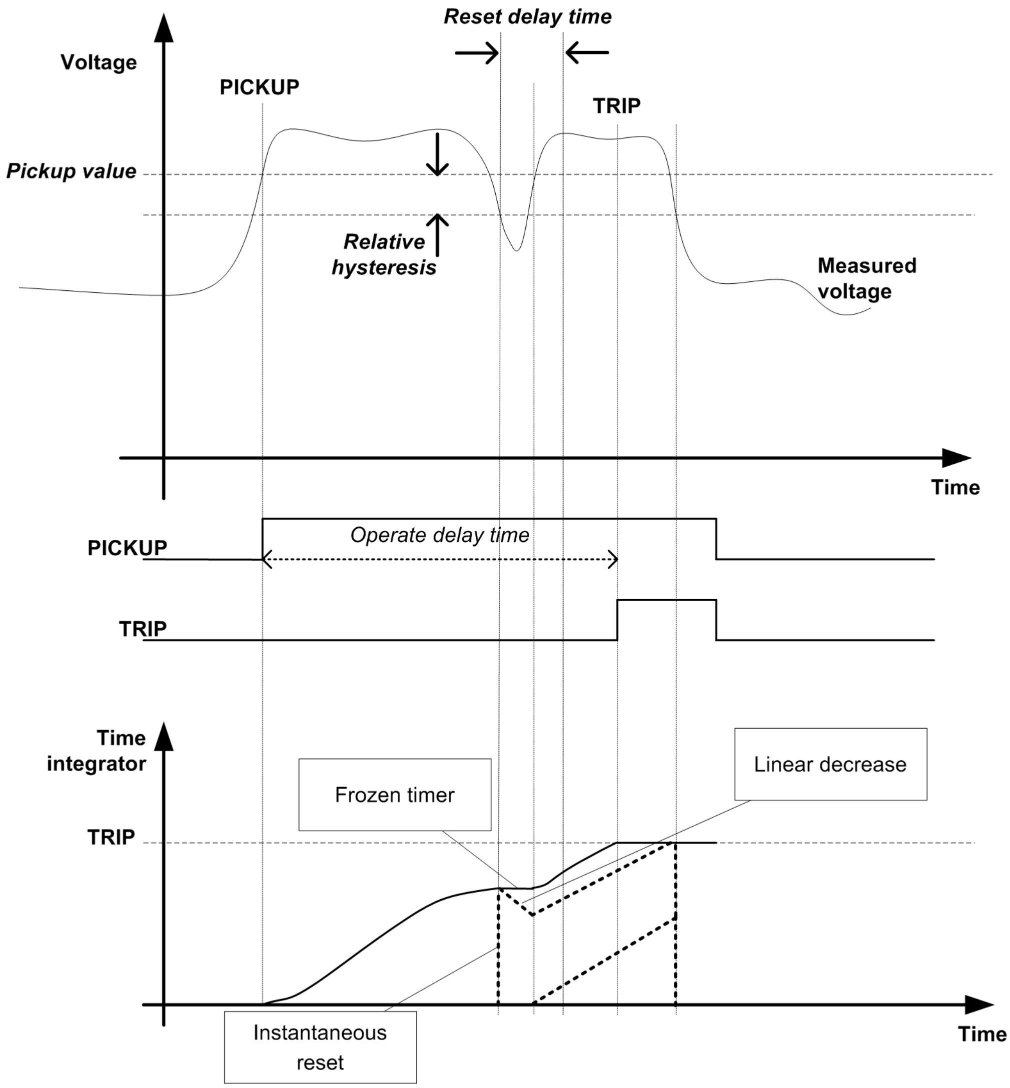


Figure 88: *Behavior of different IDMT reset modes. The value for Type of reset curve is "Def time reset". Also other reset modes are presented for the time integrator.*

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

The *Minimum operate time* setting parameter defines the minimum desired trip 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 General function block features section in this manual.

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

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting **Configuration > System > Blocking mode** which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay 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 operate 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.

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

4.3.1.5 Timer characteristics

The operating curve types supported by 59 are:

Table 202: 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

4.3.1.6 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 protection function is used to protect against power frequency overvoltages.

The power frequency overvoltage may occur in the network due to the 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.

4.3.1.7 Signals

Table 203: 59-1/2 Input signals

Name	Type	Default	Description
V_A_AB	SIGNAL	0	Phase to ground voltage A or phase to phase voltage AB
V_B_BC	SIGNAL	0	Phase to ground voltage B or phase to phase voltage BC
V_C_CA	SIGNAL	0	Phase to ground voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 204: 59-1/2 Output signals

Name	Type	Description
OPERATE	BOOLEAN	Trip
OPR_A_AB	BOOLEAN	Trip output of Phase A (or Phase AB)
OPR_B_BC	BOOLEAN	Trip output of Phase B (or Phase BC)
OPR_C_CA	BOOLEAN	Trip output of Phase C (or Phase CA)
START	BOOLEAN	Pickup
ST_A_AB	BOOLEAN	Pickup output of Phase A (or Phase AB)
ST_B_BC	BOOLEAN	Pickup output of Phase B (or Phase BC)
ST_C_CA	BOOLEAN	Pickup output of Phase C (or Phase CA)

4.3.1.8 Settings

Table 205: 59-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...1.60	xVn	0.01	1.10	Pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	40...300000	ms	10	40	Trip delay time
Operating curve type	5=ANSI DT 15=IEC DT 17=Inv. Curve A 18=Inv. Curve B 19=Inv. Curve C 20=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 206: 59-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
Num of pickup phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for trip activation
Minimum trip time	40...60000	ms	1	40	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.3.1.9 Monitored data

Table 207: 59-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
59-1/2	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

4.3.1.10 Technical data

Table 208: 59 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x V_n		
Pickup time[1,2]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 x set *Pickup value*	22 ms	24 ms	26 ms
Reset time		< 40 ms		
Reset ratio		Depends of 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 x f_n, where n = 2, 3, 4, 5,…		

1. *Pickup value* = 1.0 x V_n, Voltage before fault = 0.9 x V_n, f_n = 60 Hz, overvoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact
3. Maximum *Pickup value* = 1.20 x V_n, *Pickup value* multiples in range of 1.10 to 2.00

4.3.2 Single-phase undervoltage protection 27

4.3.2.1 Identification

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

4.3.2.2 Function block

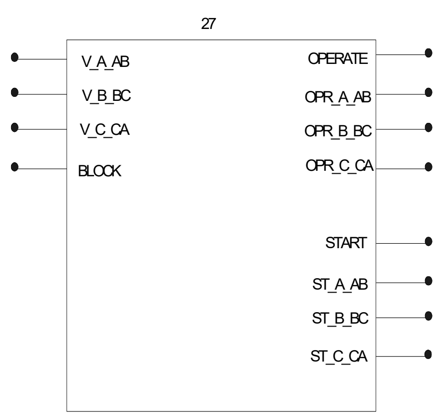


Figure 89: Function block

4.3.2.3 Functionality

The three-phase undervoltage protection (27) is used to disconnect from the network devices, for example electric motors, which are damaged when subjected to service under low voltage conditions. The 27 function 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.

4.3.2.4 Operation principle

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

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

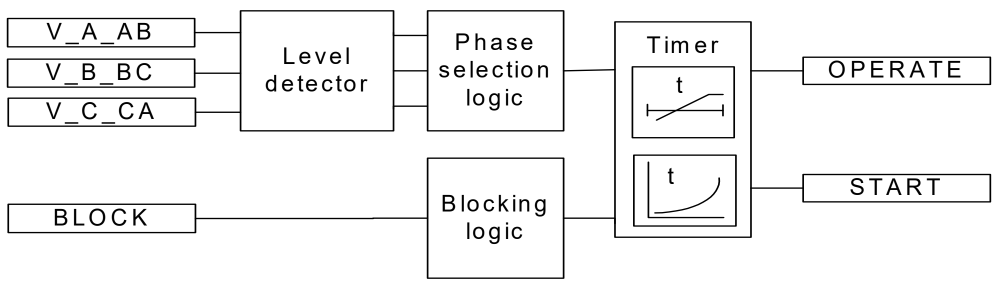


Figure 90: Functional module diagram

Three Phase Mode

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

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

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

For more detailed description on IDMT curves and usage of *Curve Sat Relative* setting, see the *General function block features* section in this manual.

The level detector contains a low-level blocking functionality for cases where one of the measured voltages is below the desired level. This feature is useful when unnecessary pickups and trips are wanted to avoid during, for example, an autoreclose sequence. The low-level blocking is activated by default (*Enable block value* is set to “True”) and the blocking level can be set with the *Voltage block value* setting.

Phase selection logic

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

Timer

Once activated, the timer activates the `PICKUP (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 General function block features section in this manual.

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

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

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

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

Single Phase Mode

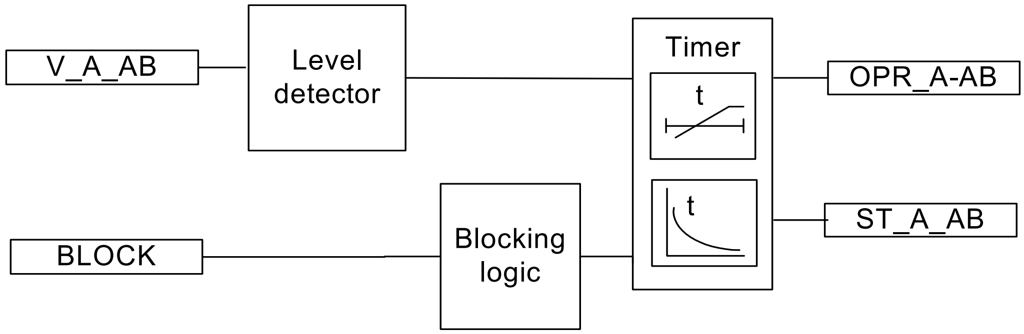


Figure 91: Functional module diagram (Single Phase)

The following description holds good when single phase mode is chosen for the recloser.

The fundamental frequency component of the measured single-phase voltage is compared to the set value of the *Start (pickup) value* setting phase-wise. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly differs from the *Pickup value* setting. After leaving the hysteresis area, the pickup condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

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

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

For a more detailed description of the IDMT curves and the use of the *Curve Sat Relative* setting, see the General function block features section in this manual.

Timer

Once activated, the timer activates the respective phase PICKUP(ST_A_AB) as shown typically above for respective phase output as well as the common PICKUP (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 General function block features section in this manual.

When the operation timer has reached the value set by *Trip delay time* in the DT mode or the maximum value defined by the IDMT, the TRIP (OPR_A_AB) for respective phase as well as the common the OPERATE output are activated.

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

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

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

Table 209: The reset time functionality when the IDMT trip time curve is selected

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

Example

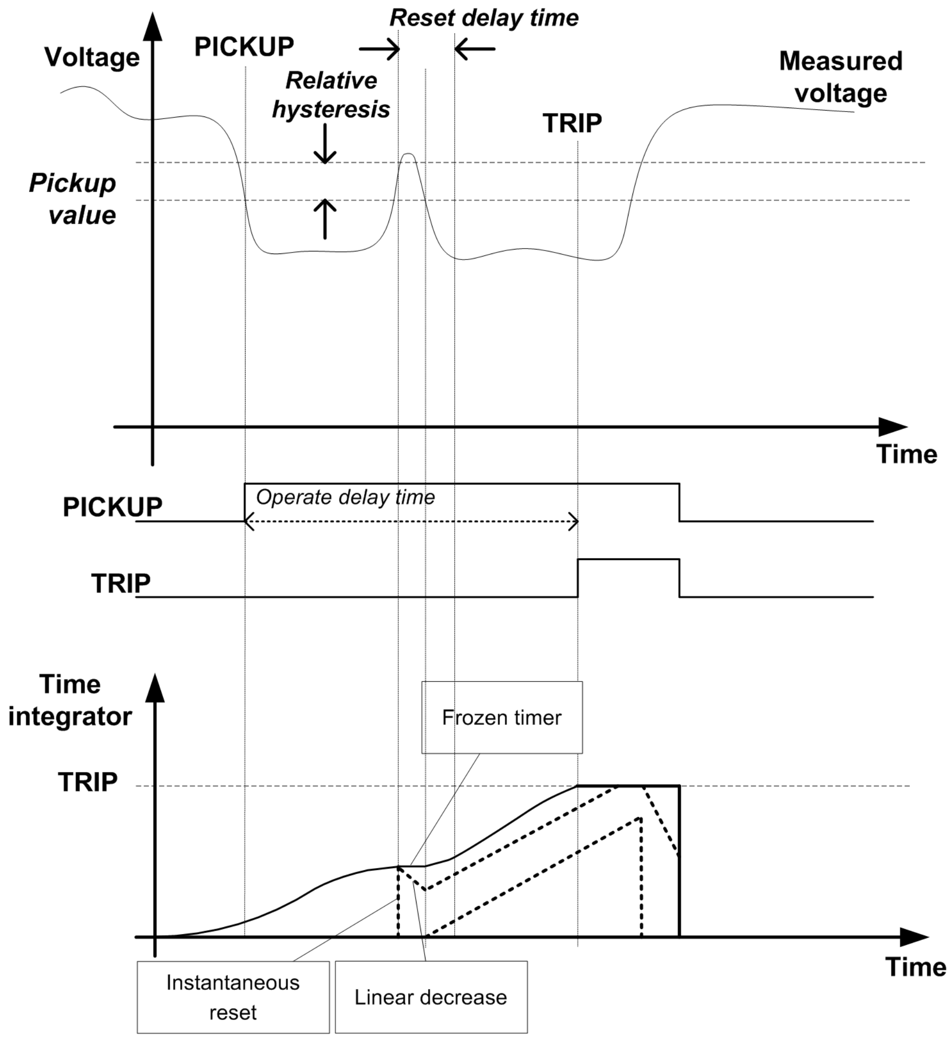


Figure 92: Behavior of different IDMT reset modes. The value for Type of reset curve is "Def time reset". Also other reset modes are presented for the time integrator.

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

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

The *Minimum 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 *General function block features* section in this manual.

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

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting **Configuration > System > Blocking mode** which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay 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 operate timer is frozen to the prevailing value. In the “Block all” mode, the whole function is blocked and the timers are reset. In the “Block TRIP output” mode, the function operates normally but the `TRIP` output is not activated.

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

4.3.2.5 Timer characteristics

The operating curve types supported by 27 are:

Table 210: 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

4.3.2.6 Application

27 is applied to power system elements, such as generators, transformers, motors and power lines, to detect low voltage conditions. Low voltage conditions are caused by abnormal operation or a fault in the power system. 27 can be used in combination with overcurrent protections. Other applications are the detection of a no-voltage condition, for example before the energization of a high voltage line, or an automatic breaker trip in case of a blackout. 27 is also used to initiate voltage correction measures, such as insertion of shunt capacitor banks, to compensate for a reactive load and thereby to increase the voltage.

27 can be used to disconnect from the network devices, such as electric motors, which are damaged when subjected to service under low voltage conditions. 27 deals with low voltage conditions at power system frequency. Low voltage conditions can be caused by:

- Malfunctioning of a voltage regulator or incorrect settings under manual control (symmetrical voltage decrease)
- Overload (symmetrical voltage decrease)
- Short circuits, often as phase-to-ground faults (unsymmetrical voltage increase).

27 prevents sensitive equipment from running under conditions that could cause overheating and thus shorten their life time expectancy. In many cases, 27 is a useful function in circuits for local or remote automation processes in the power system.

4.3.2.7 Signals

Table 211: 27-1/2 Input signals

Name	Type	Default	Description
V_A_AB	SIGNAL	0	Phase to ground voltage A or phase to phase voltage AB
V_B_BC	SIGNAL	0	Phase to ground voltage B or phase to phase voltage BC
V_C_CA	SIGNAL	0	Phase to ground voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 212: 27-1/2 Output signals

Name	Type	Description
OPERATE	BOOLEAN	Trip
OPR_A_AB	BOOLEAN	Trip output of Phase A (or Phase AB)
OPR_B_BC	BOOLEAN	Trip output of Phase B (or Phase BC)
OPR_C_CA	BOOLEAN	Trip output of Phase C (or Phase CA)
START	BOOLEAN	Pickup
ST_A_AB	BOOLEAN	Pickup output of Phase A (or Phase AB)
ST_B_BC	BOOLEAN	Pickup output of Phase B (or Phase BC)
ST_C_CA	BOOLEAN	Pickup output of Phase C (or Phase CA)

4.3.2.8 Settings

Table 213: 27-1/2 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.05...1.20	xVn	0.01	0.90	Pickup value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Trip delay time	60...300000	ms	10	60	Trip delay time
Operating curve type	5=ANSI DT 15=IEC DT 21=Inv. Curve A 22=Inv. Curve B 23=Programmable			5=ANSI DT	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 214: 27-1/2 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Disable / Enable
Num of pickup phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for trip activation
Minimum trip time	60...60000	ms	1	60	Minimum trip time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage block value	0.05...1.00	xVn	0.01	0.20	Low level blocking for undervoltage mode
Enable block value	0=False 1=True			1=True	Enable internal blocking
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.3.2.9 Monitored data

Table 215: 27-1/2 Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
27-1/2	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

4.3.2.10 Technical data

Table 216: 27 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: fn ±2Hz		
		±1.5% of the set value or ±0.002 x V_n		
Pickup time[1,2]		Minimum	Typical	Maximum
	V_{Fault} = 0.9 x set *Pickup value*	62 ms	64 ms	66 ms
Reset time		< 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 x f_n, where n = 2, 3, 4, 5,…		

1. *Pickup value* = 1.0 x V_n, Voltage before fault = 1.1 x V_n, f_n = 60 Hz, undervoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact
3. Minimum *Pickup value* = 0.50, *Pickup value* multiples in range of 0.90 to 0.20

4.3.3 Zero sequence overvoltage protection 59N

4.3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Zero sequence overvoltage protection	ROVPTOV	U0>	59N

4.3.3.2 Function block

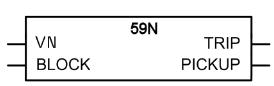


Figure 93: Function block

4.3.3.3 Functionality

The zero sequence overvoltage protection 59N is used in distribution networks where the zero sequence overvoltage can reach non-acceptable levels in, for example, high impedance grounding.

The function picks up when the zero sequence voltage exceeds the set limit. 59N 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.

4.3.3.4 Operation principle

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

The operation of residual overvoltage protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

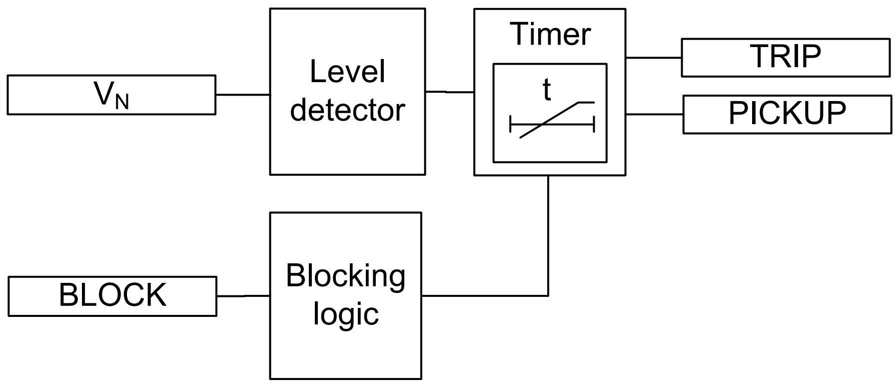


Figure 94: Functional module diagram. V_N represents the zero sequence voltage.

Level detector

The measured or calculated zero sequence voltage is compared with the set *Pickup value*. If the value exceeds the set *Pickup value*, the level detector sends an enable-signal to the timer.

Timer

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

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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

4.3.3.5 Application

59N is designed to be used for ground-fault protection in isolated neutral, resistance grounded or reactance grounded systems. In compensated networks, the pickup of the function can be used to control the switching device of the neutral resistor. The function can also be used for the back-up protection of feeders for busbar protection when a more dedicated busbar protection would not be justified.

In compensated and isolated neutral systems, the system neutral voltage, that is, the zero sequence voltage, increases in case of any fault connected to ground. Depending on the type of the fault and the fault resistance, the zero sequence voltage reaches different values. The highest zero sequence voltage, equal to the phase-to-ground voltage, is achieved for a single-phase ground fault. The zero sequence voltage increases approximately the same amount in the whole system and does not provide any guidance in finding the faulty component. Therefore, this function is often used as a back-up protection or as a release signal for the feeder ground-fault protection.

The protection can also be used for the ground-fault protection of generators and motors and for the unbalance protection of capacitor banks.

The zero sequence voltage can be calculated internally based on the measurement of the three-phase voltage. This voltage can also be measured by a single-phase voltage transformer, located between a transformer star point and ground, or by using an open-delta connection of three single-phase voltage transformers.

4.3.3.6 Signals

Table 217: 59N Input signals

Name	Type	Default	Description
VN	SIGNAL	0	Zero sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 218: 59N Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.3.3.7 Settings

Table 219: 59N Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...1.000	xVn	0.001	0.030	Pickup value
Trip delay time	40...300000	ms	1	40	Trip delay time

Table 220: 59N Non group settings

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

4.3.3.8 Monitored data

Table 221: 59N Monitored data

Name	Type	Values (Range)	Unit	Description
PICKUP_DUR	FLOAT32	0.00...100.00	%	Ratio of pickup time / trip time
59N	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

4.3.3.9 Technical data

Table 222: 59N Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x V_n		
Pickup time[1,2]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 x set *Pickup value*	29 ms	31 ms	32 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1. Zero sequence voltage before fault = 0.0 x V_n, f_n = 60 Hz, zero sequence 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

4.3.4 Positive sequence overvoltage protection 59PS

4.3.4.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Positive sequence overvoltage protection	PSPTOV	U1>	59PS

4.3.4.2 Function block

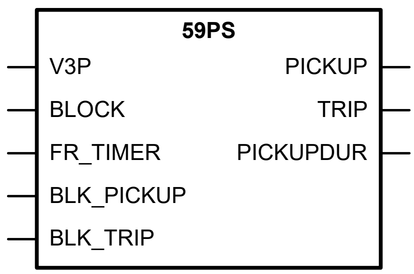


Figure 95: Function block

4.3.4.3 Functionality

The positive sequence voltage is constantly compared with the set value of positive sequence voltage and starts when the measured sequence voltage exceeds the *Pickup value*. If the overvoltage lasts the *Trip delay* time, the function gives the trip signal.

4.3.4.4 Operation principle

The 59PS function constantly monitors the magnitude of the positive sequence voltage. If and when the measured positive sequence voltage exceeds the *Pickup value* voltage, the PICKUP output gets activated. Should the overvoltage situation last the *Trip delay* time, the function trips through TRIP output.

The function includes *Relative hysteresis* setting in order to avoid oscillations of the PICKUP output when the measured positive sequence voltage value lies near the *Pickup value* voltage.

The delay of the heavy duty output relay is included in preset operate times (depends on the value of delay compensation).

The definite timer is allowed to run only if the input signal BLOCK is inactive. If the BLOCK signal is activated, the timer will be reset. Moreover the PICKUP and TRIP signals cannot be activated when the BLOCK signal is active.

When the output PICKUP is active, the percentage of delay time duration that has elapsed can be monitored through output PICKUPDUR of that sequence. It is possible to tune all the time delays provided in the function such that they provide delay equal to set delay within acceptable tolerance. Initialization input DLY_COM is used to provide compensation for delays caused in software and mechanical output relays. When FR_TIMER is active delay time counts are frozen, hence activation of FR_TIMER will have effect of increasing effective time delays by the time for which FR_TIMER is active.

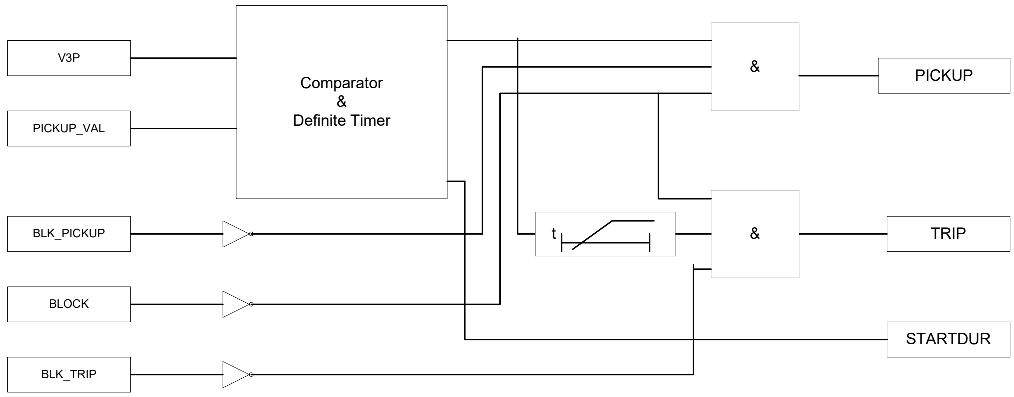


Figure 96: 59PS operation logic diagram

4.3.4.5 Application

Positive sequence overvoltage protection (59PS) is used to detect positive phase sequence overvoltage conditions. The 59PS function can be used in various applications as an alternative to ordinary three-phase overvoltage protection.

4.3.4.6 Signals

Table 223: 59PS input signals

Name	Type	Default	Description
V3P	REAL	0	Group signal for connecting needed analog voltage signals to the component
BLOCK	BOOL	FALSE	Block overall function by resetting timers (TRUE = blocked, FALSE = not blocked)
BLK_PICKUP	BOOL	FALSE	Block PICKUP output (TRUE = blocked, FALSE = not blocked)
BLK_TRIP	BOOL	FALSE	Block TRIP output (TRUE = blocked, FALSE = not blocked)
FR_TIMER	BOOL	FALSE	Freeze internal trip timer to the value at the time of activation. Value TRUE = freeze timer and FALSE = do not freeze timer.

Table 224: 59PS output signals

Name	Type	Description
TRIP	BOOL	TRIP signal for 59PS function
PICKUP	BOOL	PICKUP signal for 59PS logic
PICKUPDUR	REAL	PICKUP duration as percent of the total Trip delay time (ratio of elapsed time in pickup / Trip delay time)

4.3.4.7 Settings

Table 225: 59PS group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Relative hysteresis	1.0,,,100.0	%	0.1	2.0	Relative (percentage) hysteresis for operation
Pickup value	0.800...1.600	pu	0.001	1.100	59PS pickup value

Table 226: 59PS non-group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	0=Off 1=On			1=On	Operation Off/On
Reset delay	0...1200	ms	1	0	Reset delay time
Trip delay	0...1200	ms	1	0	Trip delay time

4.3.4.8 Technical data

Table 227: 59PS Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x V_n		
Pickup time[1,2]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 x set *Pickup value*	29 ms	31 ms	32 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Trip time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1. Zero sequence voltage before fault = 0.0 x V_n, f_n = 60 Hz, zero sequence 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

4.3.5 Negative sequence overvoltage protection 47

4.3.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative sequence overvoltage protection	NSPTOV	U2>	47

4.3.5.2 Function block

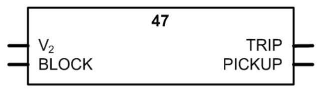


Figure 97: Function block

4.3.5.3 Functionality

The negative-sequence overvoltage protection 47 is used to detect negative-sequence overvoltage conditions. 47 is used for the protection of machines.

The function picks up when the negative-sequence voltage exceeds the set limit. 47 operates with the definite time (DT) characteristics.

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

4.3.5.4 Operation principle

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

The operation of negative sequence overvoltage protection can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

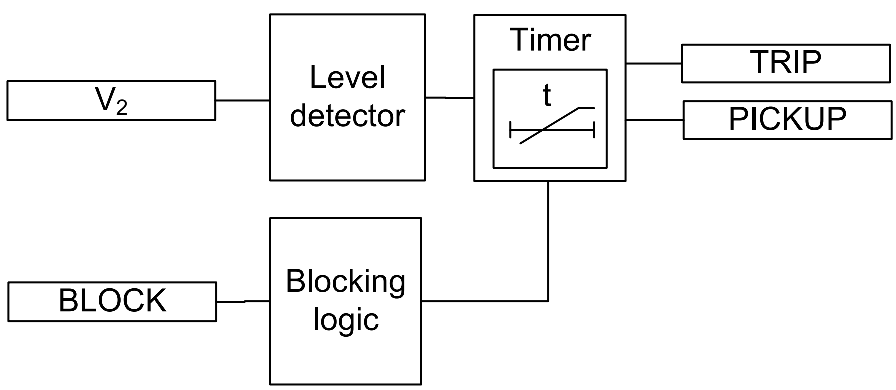


Figure 98: Functional module diagram. V_2 is used for representing negative phase sequence voltage.

Level detector

The calculated negative sequence voltage is compared with the set *Pickup value* setting. If the value exceeds the set *Pickup value*, the level detector enables the timer.

Timer

Once activated, the timer activates the PICKUP output. The time characteristic is according to DT. When the operation timer has reached the value set by *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 PICKUP output is deactivated.

The timer calculates the pickup duration (PICKUP_DUR) value which indicates the ratio of the pickup situation and the set trip time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking 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 relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

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

4.3.5.5 Application

A continuous or temporary voltage unbalance can appear in the network for various reasons. The voltage unbalance mainly occurs due to broken conductors or asymmetrical loads and is characterized by the appearance of a negative-sequence component of the voltage. In rotating machines, the voltage unbalance results in a current unbalance, which heats the rotors of the machines. The rotating machines, therefore, do not tolerate a continuous negative-sequence voltage higher than typically 1-2 percent x V_n.

The negative-sequence component current I_2, drawn by an asynchronous or a synchronous machine, is linearly proportional to the negative-sequence component voltage V_2. When V_2 is P% of V_n, I_2 is typically about 5 x P% x I_n.

The negative-sequence overcurrent 46 blocks are used to accomplish a selective protection against the voltage and current unbalance for each machine separately. Alternatively, the protection can be implemented with the 47 function, monitoring the voltage unbalance of the busbar.

If the machines have an unbalance protection of their own, the 47 operation can be applied as a backup protection or it can be used as an alarm. The latter can be applied when it is not required to trip loads tolerating voltage unbalance better than the rotating machines.

If there is a considerable degree of voltage unbalance in the network, the rotating machines should not be connected to the network at all. This logic can be implemented by inhibiting the closure of the circuit breaker if the 47 operation has 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 pickup value* is approximately 3 percent of V_n. A suitable value for the setting parameter *Trip delay time* depends on the application. If the 47 operation is used as a backup protection, the trip time should be set in accordance with the trip time of 46 used as the main protection. If the 47 operation is used as the main protection, the trip time should be approximately one second.

4.3.5.6 Signals

Table 228: 47 Input signals

Name	Type	Default	Description
V_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 229: 47 Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip
PICKUP	BOOLEAN	Pickup

4.3.5.7 Settings

Table 230: 47 Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pickup value	0.010...1.000	xVn	0.001	0.030	Pickup value
Trip delay time	40...120000	ms	1	40	Trip delay time

Table 231: 47 Non group settings

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

4.3.5.8 Monitored data

Table 232: 47 Monitored data

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

4.3.5.9 Technical data

Table 233: 47 Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: fn ±2Hz		
		±1.5% of the set value or ±0.002 × V_n		
Pickup time[1,2]		Minimum	Typical	Maximum
	V_{Fault} = 1.1 × set *Pickup value*	33 ms	35 ms	37 ms
	V_{Fault} = 2.0 × set *Pickup value*	24 ms	26 ms	28 ms
Reset time		< 40 ms		
Reset ratio		Typical 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 × V_n, f_n = 60 Hz, negative-sequence overvoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2. Includes the delay of the signal output contact

4.4 Frequency protection

4.4.1 Frequency protection 81O/81U, 81R

4.4.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency protection	FRPFRQ	f>/f<, df/dt	81O/81U, 81R

4.4.1.2 Function block

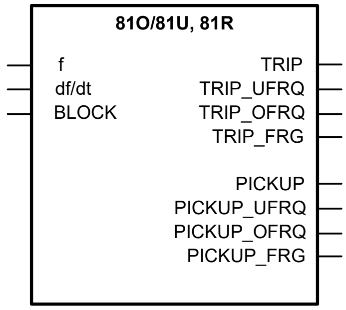


Figure 99: Function block

4.4.1.3 Functionality

The frequency protection functions (81O/81U, 81R) are 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.

4.4.1.4 Operation principle

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

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

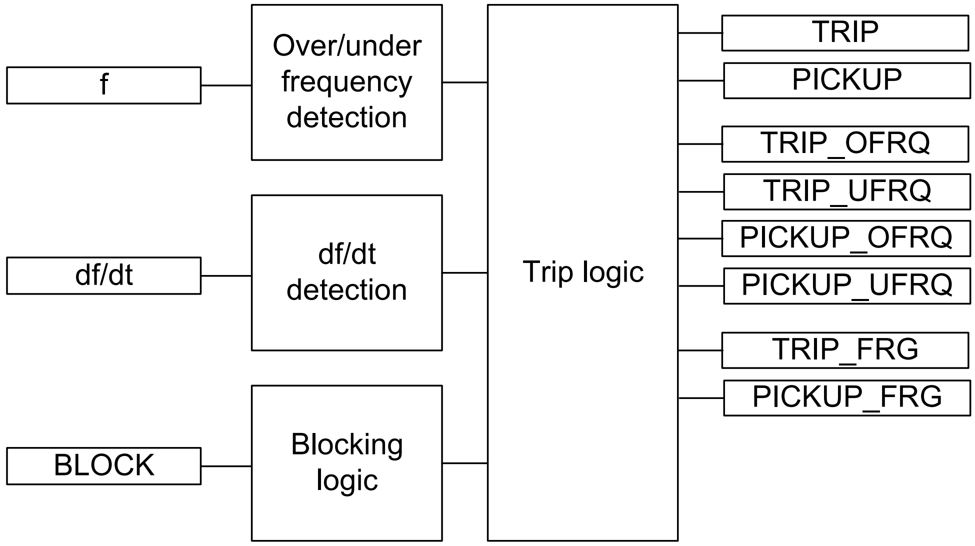


Figure 100: Functional module diagram

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 *Pickup 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 *Pickup 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 *Pickup value df/dt* value, the module reports the exceeding of the value to the operate logic module.

The relay does not accept the set value “0.00” for the Pickup value df/dt setting.

Operate logic

This module is used for combining different protection criteria based on the frequency and the frequency gradient measurement to achieve a more sophisticated behavior of the function. The criteria are selected with the *Operation mode* setting.

Table 234: 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.
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.

Operation mode	Description
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 (START_DUR) 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 235: 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 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 relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. 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

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.

4.4.1.6 Signals

Table 236: 81 Input signals

Name	Type	Default	Description
f	SIGNAL	0	Measured frequency
df/dt	SIGNAL	0	Rate of change of frequency
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 237: 81 Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
OPR_OFRQ	BOOLEAN	Operate signal for overfrequency
OPR_UFRQ	BOOLEAN	Operate signal for underfrequency
OPR_FRG	BOOLEAN	Operate signal for frequency gradient
START	BOOLEAN	Start
ST_OFRQ	BOOLEAN	Start signal for overfrequency
ST_UFRQ	BOOLEAN	Start signal for underfrequency
ST_FRG	BOOLEAN	Start signal for frequency gradient

4.4.1.7 Settings

Table 238: 81 Group settings

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>	0.900...1.200	xFn	0.001	1.050	Frequency start value overfrequency
Start value Freq<	0.800...1.100	xFn	0.001	0.950	Frequency start value underfrequency
Start value df/dt	-0.200...0.200	xFn /s	0.005	0.010	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 239: 81 Non group settings

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

4.4.1.8 Monitored Data

Table 240: 81 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

4.4.1.9 Technical data

Table 241: 81 Technical data

Characteristic		Value
Operation accuracy	f>/f<	±10 mHz
	df/dt	±100 mHz/s (in range |df/dt| < 5 Hz/s) ± 2.0% of the set value (in range 5 Hz/s < |df/dt| < 15 Hz/s)
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

4.4.2 Load shedding and restoration 81S

4.4.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Load shedding and restoration	LSHDPFRQ	UFLS/R	81S

4.4.2.2 Function block

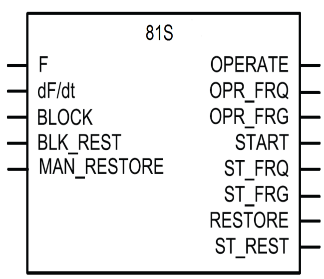


Figure 101: Function block

4.4.2.3 Functionality

The load shedding and restoration function 81S is capable of performing load shedding based on underfrequency and the rate of change of the frequency. The load that is shed during the frequency disturbance can be restored once the frequency has stabilized to the normal level.

The measured system frequency is compared to the set value to detect the underfrequency condition. The measured rate of change of frequency (df/dt) is compared to the set value to detect a high frequency reduction rate. The combination of the detected underfrequency and the high df/dt is used for the activation of the load shedding. There is a definite time delay between the detection of the underfrequency and high df/dt and the activation of 81S.

This time delay can be set and it is used to prevent unwanted load-shedding actions when the system frequency recovers to the normal level.

Throughout this document, “high df/dt” is used to mean “a high rate of change of the frequency in negative direction.”

Once the frequency has stabilized, 81S can restore the load that is shed during the frequency disturbance. The restoration is possible manually or automatically.

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

4.4.2.4 Operation principle

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

The operation of the load shedding and restoration function can be described using a module diagram. All the modules are explained in the next sections.

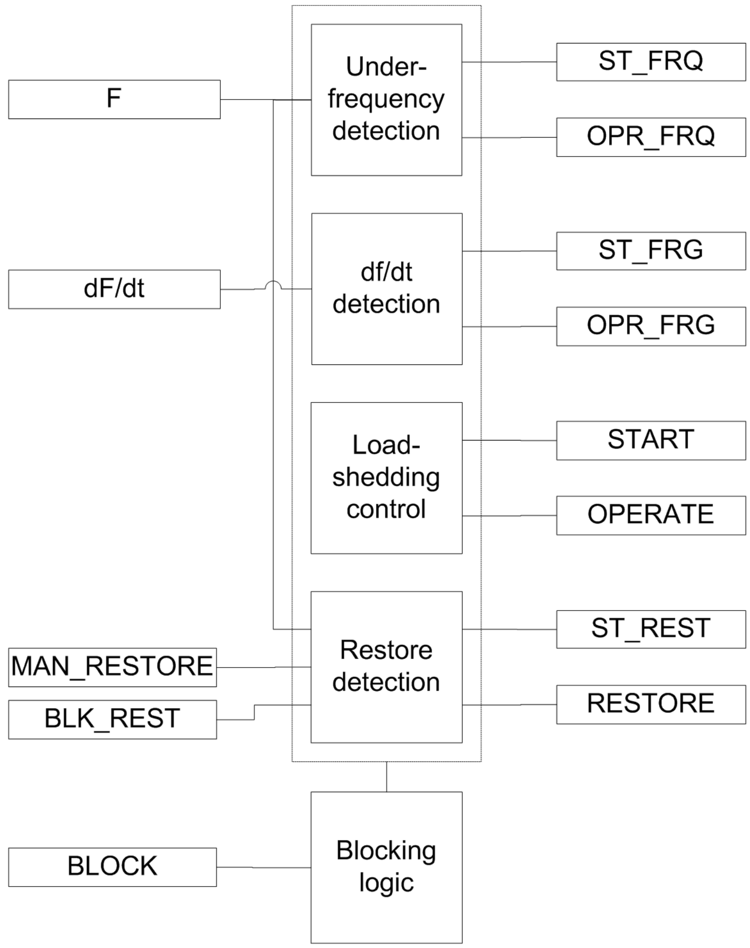


Figure 102: Functional module diagram

Underfrequency detection

The underfrequency detection measures the input frequency calculated from the voltage signal. An underfrequency is detected when the measured frequency drops below the set value of the *Start Value Freq* setting.

The underfrequency detection module includes a timer with the Definite Time (DT) characteristics. Upon detection of underfrequency, operation timer activates the ST_FRQ output. When the underfrequency timer has reached the value set by *Operate Tm Freq*, the OPR_FRQ output is activated if the underfrequency condition still persists. If the frequency becomes normal before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the timer resets and the ST_FRQ output is deactivated.

df/dt detection

The df/dt detection measures the input frequency calculated from the voltage signal and calculates its gradient. A high df/dt condition is detected by comparing the gradient to the

Start value df/dt setting. The df/dt detection is activated when the frequency gradient decreases at a faster rate than the set value of *Start value df/dt*.

The df/dt detection module includes a timer with the DT characteristics. Upon detection of df/dt, operation timer activates the ST_FRG output. When the timer has reached the value set by *Operate Tm df/dt*, the OPR_FRG output is activated if the df/dt condition still persists. If df/dt becomes normal before the module operates, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the ST_FRG output is deactivated.

Load-shedding control

The way of load shedding, that is, whether to operate based on underfrequency or high df/dt or both, is defined with the *Load shed mode* user setting. The valid operation modes for the *Load shed mode* settings are “Freq<“, “Freq< AND df/dt” and “Freq< OR df/dt”.

Once the selected operation mode conditions are satisfied, the START and OPERATE output signals are activated.

When the START output is active, the percentage of the elapsed delay time can be monitored through START_DUR which is available as monitored data.

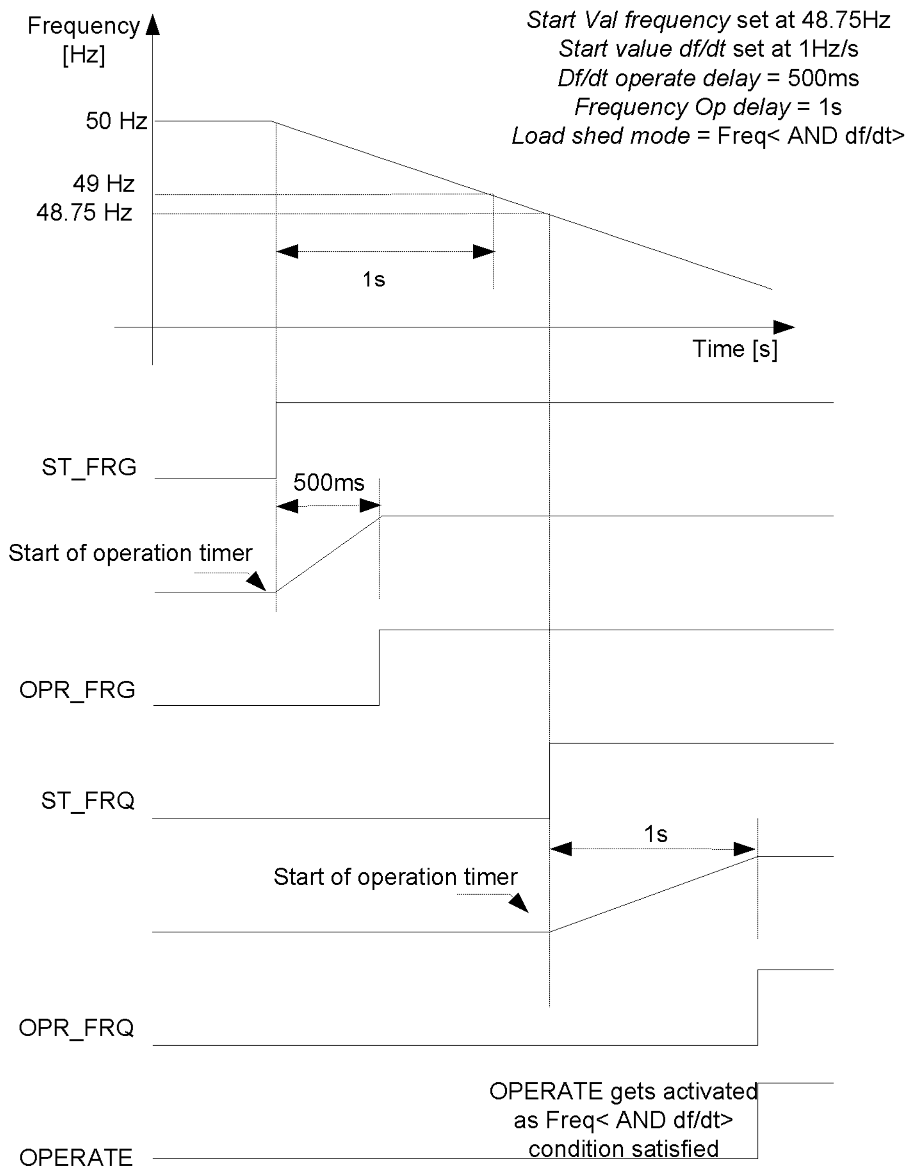


Figure 103: Load-shedding operation in the "Freq< AND df/dt>" mode when both Freq< and df/dt conditions are satisfied (Rated frequency=50 Hz)

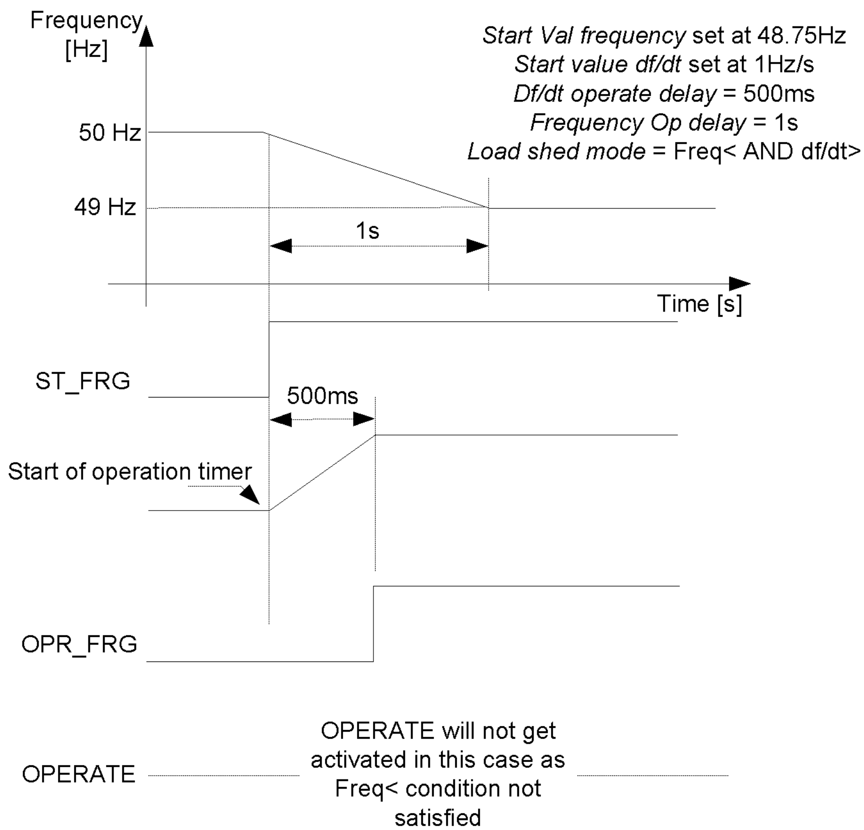


Figure 104: Load-shedding operation in the "Freq< AND df/dt>" mode when only the df/dt condition is satisfied (Rated frequency=50 Hz)

Restore detection

If after the activation of the `OPERATE` input the frequency recovers to a level above the *Restore start Val* setting, the `RESTORE` signal output is activated. The `RESTORE` output remains active for a 100 ms. The *Restore mode* setting is used to select the restoring mode to be "Disabled", "Auto" or "Manual".

Restoring mode	Description
Disabled	Load restoration is disabled.
Auto	In the "Auto" mode, input frequency is continuously compared to the *Restore start Val* setting. The restore detection module includes a timer with the DT characteristics. Upon detection of restoring, the operation timer activates the `ST_REST` output. When the timer has reached the value of the *Restore delay time* setting, the `RESTORE` output is activated if the restoring condition still persists. If the frequency drops below the *Restore start Val* before the `RESTORE` output is activated, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the `ST_REST` start output is deactivated.

Restoring mode	Description
Manual	In the “Manual” mode, a manual restoration is possible through the MAN_RESTORE input or via communication. The ST_REST output is activated if the MAN_RESTORE command is available and the frequency has exceeded the *Restore start Val* setting. The manual restoration includes a timer with the DT characteristics. When the timer has reached the set value of the *Restore delay time* setting, the RESTORE output is activated if the restoring condition still persists. If the frequency drops below the *Restore start Val* setting before the RESTORE output is activated, the reset timer is activated. If the reset timer reaches the value of the *Reset delay time* setting, the timer resets and the ST_REST start output is deactivated.

A condition can arise where the restoring operation needs to be canceled. Activating the BLK_REST input for the "Auto" or "Manual" modes cancels the restoring operation. In the “Manual” restoring mode, the cancellation happens even if MAN_RESTORE is present.

Once the RESTORE output command is cancelled, the reactivation of RESTORE is possible only after the reactivation of the OPERATE output, that is, when the next load-shedding operation is detected.

Blocking logic

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

The *Blocking mode* setting has three blocking methods. In the “Freeze timers” mode, the operate 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, OPR_FRQ and OPR_FRG outputs are not activated.

4.4.2.5 Application

An AC power system operates at a defined rated frequency. The nominal frequency in most systems in the world is 50 Hz or 60 Hz. The system operation is such that the operating frequency remains approximately at the nominal frequency value by a small margin. The safe margin of operation is usually less than ±0.5 Hz. The system frequency stability is one of the main concerns in the transmission and distribution network operation and control. To protect the frequency-sensitive electrical equipment in the network, departure from the allowed band for safe operation should be inhibited.

Any increase in the connected load requires an increase in the real power generation to maintain the system frequency. Frequency variations form whenever there are system conditions that result in an unbalance between the generation and load. The rate of change of the frequency represents the magnitude of the difference between the load and generation. A reduction in frequency and a negative rate of change of the frequency are observed when the load is greater than the generation, and an increase in the frequency along with a positive rate of change of the frequency are observed if the generation is greater than the load. The rate of change of the frequency is used for a faster decision of load shedding. In an underfrequency situation, the load shedding trips out the unimportant loads to stabilize the network. Thus, loads are normally prioritized so that the less important loads are shed before the important loads.

During the operation of some of the protective schemes or other system emergencies, the power system is divided into small islands. There is always a load - generation imbalance in such islands that leads to a deviation in the operating frequency from the nominal frequency. This off-nominal frequency operation is harmful to power system components like turbines and motors. Therefore, such situation must be prevented from continuing. The frequency-based load-shedding scheme should be applied to restore the operation of the system to normal frequency. This is achieved by quickly creating the load - generation balance by disconnecting the load.

As the formation of the system islands is not always predefined, several load-shedding relays are required to be deployed at various places near the load centers. A quick shedding of a large amount of load from one place can cause a significant disturbance in the system. The load-shedding scheme can be made most effective if the shedding of load feeders is distributed and discrete, that is, the loads are shed at various locations and in distinct steps until the system frequency reaches the acceptable limits.

Due to the action of load-shedding schemes, the system recovers from the disturbance and the operating frequency value recovers towards the nominal frequency. The load that was shed during the disturbance can be restored. The load-restoring operation should be done stepwise in such a way that it does not lead the system back to the emergency condition. This is done through an operator intervention or in case of remote location through an automatic load restoration function. The load restoration function also detects the system frequency and restores the load if the system frequency remains above the value of the set restoration frequency for a predefined duration.

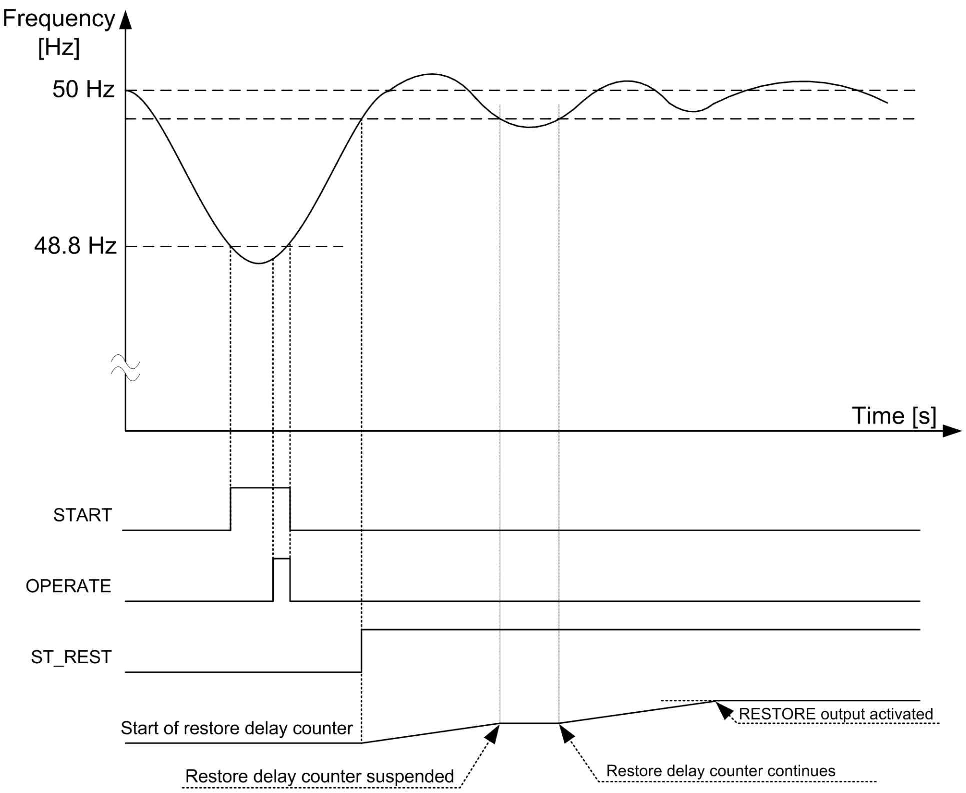


Figure 105: Operation of the load-shedding function

Power system protection by load shedding

The decision on the amount of load that is required to be shed is taken through the measurement of frequency and the rate of change of frequency (df/dt). At a single location, many steps of load shedding can be defined based on different criteria of the frequency and df/dt. Typically, the load shedding is performed in six or four steps with each shedding increasing the portion of load from five to twenty-five percent of full load within a few seconds. After every shedding, the system frequency is read back and further shedding actions are taken only if necessary. In order to take the effect of any transient, a sufficient time delay should be set.

The value of the setting has to be well below the lowest occurring normal frequency and well above the lowest acceptable frequency of the system. The setting level, the number of steps and the distance between two steps (in time or in frequency) depend on the characteristics of the power system under consideration. The size of the largest loss of generation compared to the size of the power system is a critical parameter. In large systems, the load shedding can be set at a high frequency level and the time delay is normally not critical. In small systems, the frequency start level has to be set at a low value and the time delay must be short.

If a moderate system operates at 50 Hz, an underfrequency should be set for different steps from 49.2 Hz to 47.5 Hz in steps of 0.3 – 0.4 Hz. The operating time for the underfrequency can be set from a few seconds to a few fractions of a second stepwise from a higher frequency value to a lower frequency value.

Table 242: Setting for a five-step underfrequency operation

Load-shedding steps	*Start value Freq* setting	*Operate Tm Freq* setting
1	0.984 x Fn (49.2 Hz)	45000 ms
2	0.978 x Fn (48.9 Hz)	30000 ms
3	0.968 x Fn (48.4 Hz)	15000 ms
4	0.958 x Fn (47.9 Hz)	5000ms
5	0.950 x Fn (47.5 Hz)	500 ms

The rate of change of frequency function is not instantaneous since the function needs time to supply a stable value. It is recommended to have a time delay long enough to take care of the signal noise.

Small industrial systems can experience the rate of change of frequency as large as 5 Hz/s due to a single event. Even large power systems can form small islands with a large imbalance between the load and generation when severe faults or combinations of faults are cleared. Up to 3 Hz/s has been experienced when a small island becomes isolated from a large system. For normal severe disturbances in large power systems, the rate of change of the frequency is much less, often just a fraction of 1.0 Hz/s.

Similarly, the setting for df/dt can be from 0.1 Hz/s to 1.2 Hz/s in steps of 0.1 Hz/s to 0.3 Hz/s for large distributed power networks, with the operating time varying from a few seconds to a few fractions of a second. Here, the operating time should be kept in minimum for the higher df/dt setting.

Table 243: Setting for a five-step df/dt< operation

Load-shedding steps	*Start value df/dt* setting	*Operate Tm df/dt* setting
1	-0.005 xFn /s (-0.25 Hz/s)	8000 ms
2	-0.010 x Fn /s (-0.50 Hz/s)	2000 ms
3	-0.015 x Fn /s (-0.75 Hz/s)	1000 ms
4	-0.020 x Fn /s (-1.00 Hz/s)	500 ms
5	-0.025 x Fn /s (-1.25 Hz/s)	250 ms

Once the frequency has stabilized, the shed load can be restored. The restoring operation should be done stepwise, taking care that it does not lead the system back to the emergency condition.

Table 244: Setting for a five-step restoring operation

Load-shedding steps	*Restoring start Val* setting	*Restore delay time* setting
1	0.990 · Fn (49.5 Hz)	200000 ms
2	0.990 · Fn (49.5 Hz)	160000 ms
3	0.990 · Fn (49.5 Hz)	100000 ms
4	0.990 · Fn (49.5 Hz)	50000 ms
5	0.990 · Fn (49.5 Hz)	10000 ms

4.4.2.6 Signals

Table 245: 81S input signals

Name	Type	Default	Description
f	SIGNAL	0	Measured frequency
df/dt	SIGNAL	0	Rate of change of frequency
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
BLK_REST	BOOLEAN	0=False	Block restore
MAN_RESTORE	BOOLEAN	0=False	Manual restore signal

Table 246: 81S output signals

Name	Type	Description
OPERATE	BOOLEAN	Operation of load shedding
OPR_FRQ	BOOLEAN	Operate signal for under frequency
OPR_FRG	BOOLEAN	Operate signal for high df/dt
START	BOOLEAN	Start
ST_FRQ	BOOLEAN	Pick-Up signal for under frequency detection
ST_FRG	BOOLEAN	Pick-Up signal for high df/dt detection
RESTORE	BOOLEAN	Restore signal for load restoring purposes
ST_REST	BOOLEAN	Restore frequency attained and restore timer started

4.4.2.7 Settings

Table 247: 81S group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Load shed mode	1=Freq< 6=Freq< OR df/dt 8=Freq< AND df/dt			1=Freq<	Set the operation mode for load shedding function
Restore mode	1=Disabled 2=Auto 3=Manual			1=Disabled	Mode of operation of restore functionality
Start value Freq	0.800...1.200	xFn	0.001	0.975	Frequency setting/start value
Start value df/dt	-0.200...-0.005	xFn /s	0.005	-0.010	Setting of frequency gradient for df/dt detection
Operate Tm Freq	80...200000	ms	10	200	Time delay to operate for under frequency stage
Operate Tm df/dt	120...200000	ms	10	200	Time delay to operate for df/dt stage
Restore start Val	0.800...1.200	xFn	0.001	0.998	Restore frequency setting value
Restore delay time	80...200000	ms	10	300	Time delay to restore

Table 248: 81S non-group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	50	Time delay after which the definite timers will reset

4.4.2.8 Monitored data

Table 249: 81S monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Start duration
LSHDPFRQ	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.2.9 Technical data

Table 250: 81S technical data

Characteristic		Value
Operation accuracy	f<	±10 mHz
	df/dt	±100 mHz/s (in range |df/dt| < 5 Hz/s) ± 2.0% of the set value (in range 5 Hz/s < |df/dt| < 15 Hz/s)
Start time	f<	< 80 ms
	df/dt	< 120 ms
Reset time		< 150 ms
Operate time accuracy		±1.0% of the set value or ±30 ms

4.5 Other protection functions available in RER620

4.5.1 Circuit breaker failure protection 50BFT

4.5.1.1 Identification

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

4.5.1.2 Function block

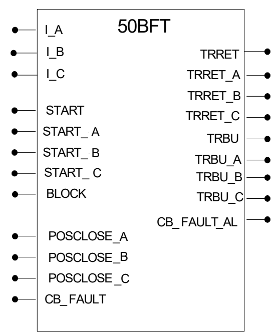


Figure 106: Function block

4.5.1.3 Functionality

The breaker failure function 50BFT is activated by trip commands from other protection functions. The commands are either internal commands to the terminal or external commands through binary inputs. The pickup or start input command can be single phase or common for all three phases depending on the choice whether single phase or three phase function is chosen. 50BFT includes a single or all three phase conditional or unconditional re-trip function, and also back-up trip function.

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

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

4.5.1.4 Operation principle

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

The operation of breaker failure protection can be described by using a module diagram in the figure below, typically for Phase A, when single phase operation mode is selected. All the blocks in the diagram are explained in the next sections. Also further information on retrip and back-up trip logics is given in sub-module diagrams.

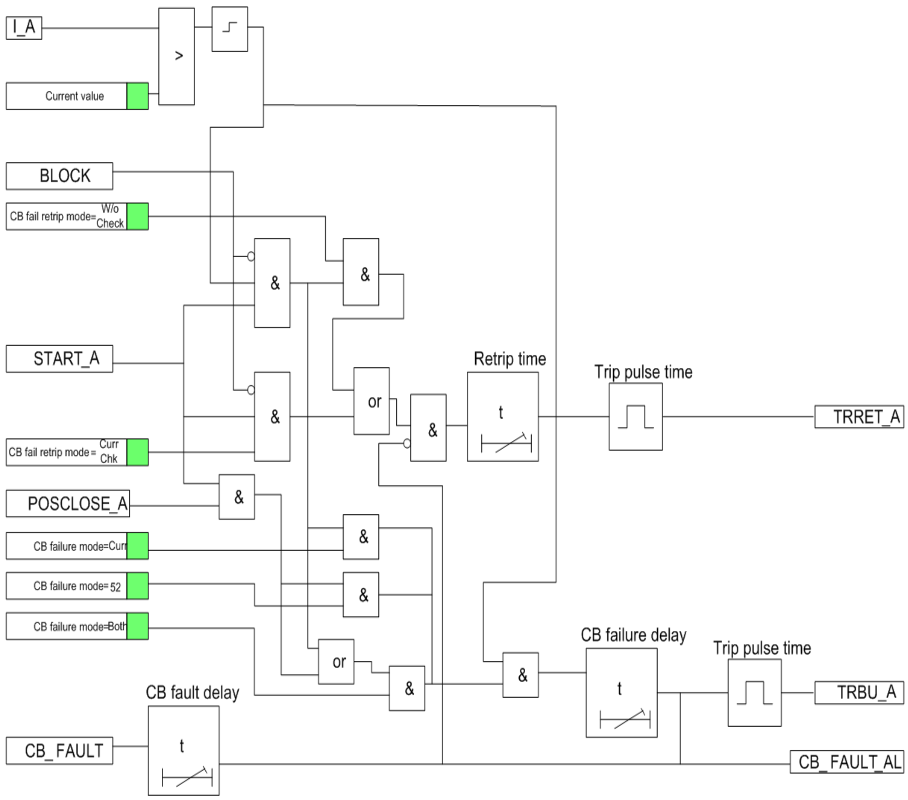


Figure 107: Functional module diagram, typical for Phase A when Single Phase Operation mode is selected

Level detector *Current Value*

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

When mode is selected for 3phase operation, the same setting *Current Value* is also used to initiate 3 pole breaker fail trip initiation whenever the input START gets an initiation gets energized. In this case the highest of the three phase currents are used to compare against the set *Current Value* setting (See Figure below).

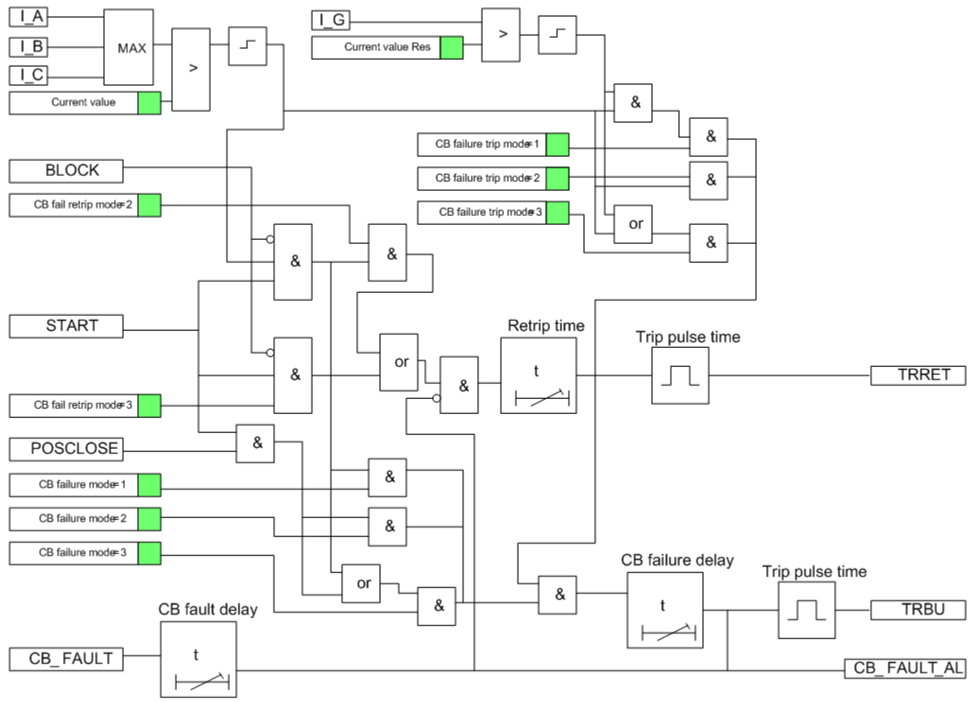


Figure 108: Functional module diagram, when operation mode is selected as three phase with three phase breaker failure function

Level detector *Current Value Res*

When operation mode is selected as three phase and when the input START is energized, the comparator, comparing the measured ground current or residual current with the set *Current value Res* is effective. When three phase mode is chosen, the input POSCLOSE is internally derived as AND combination of POSCLOSE_A, POSCLOSE_B and POSCLOSE_C inputs to the logic. When three pole tripping device is involved, the breaker close position can be looped to all the three inputs.

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

Retrip logic

The operation of the retrip logic can be described by using a module diagram, for three phase operation:

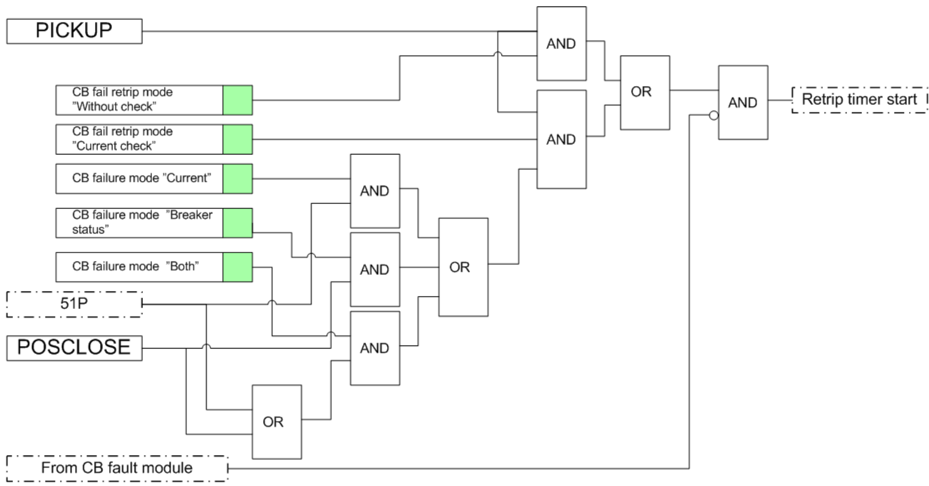


Figure 109: *Retrip logic internal design*

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

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

Back-up trip logic

The operation of the back-up trip logic can be described by using a module diagram when three phase operation mode is selected:

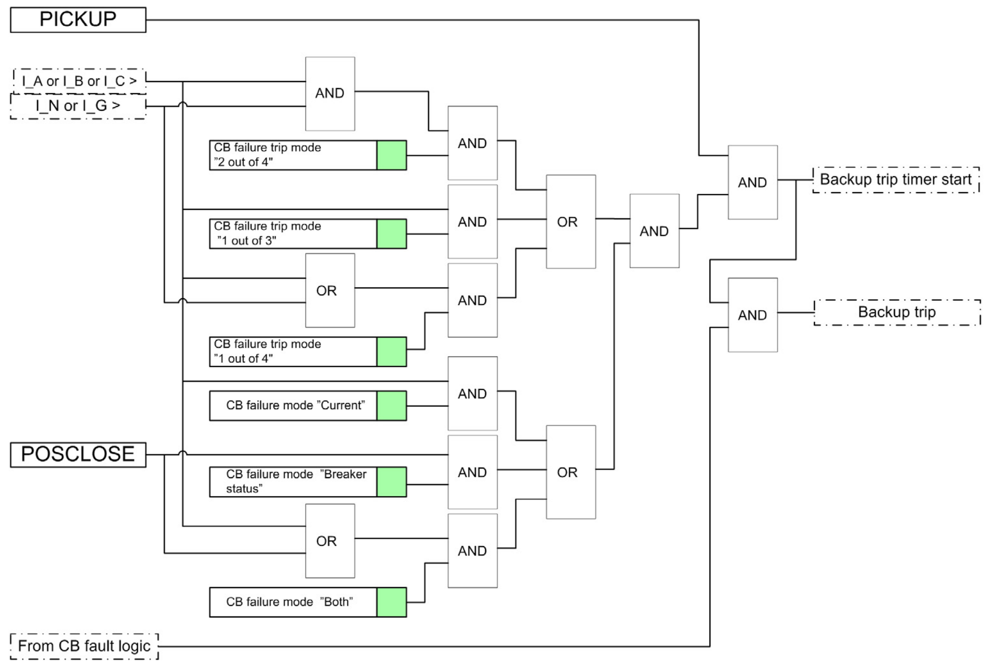


Figure 110: *Back-up trip logic internal design*

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

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

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

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

Timer 1

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

Timer 2

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

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

$$CBfailuredelay \geq Retriptime + t_{cbopen} + t_{BFP\_reset} + t_{margin}$$

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

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

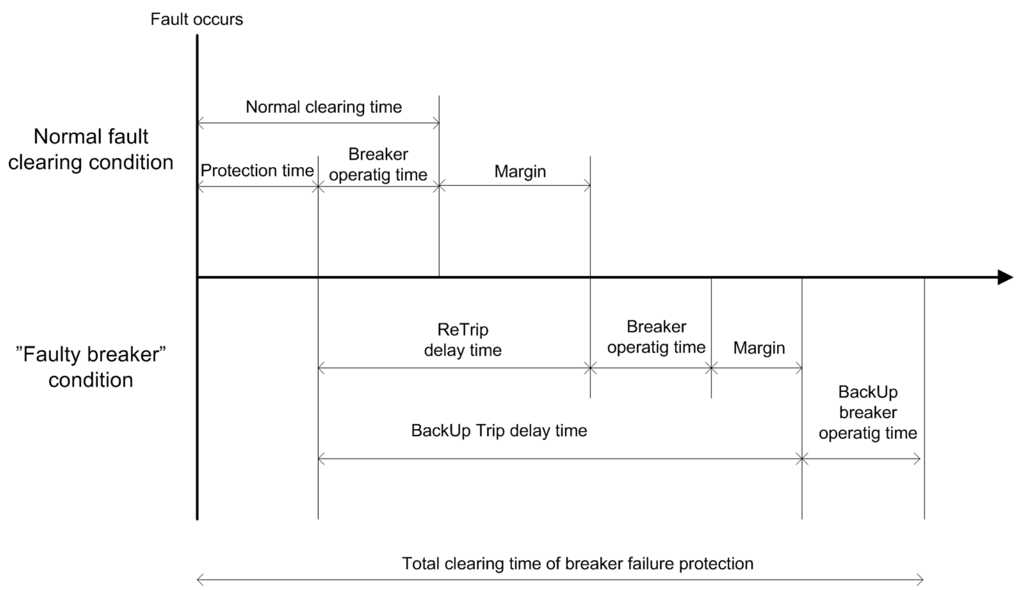


Figure 111: Time line of breaker failure protection

Timer 3

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

4.5.1.5 Application

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

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

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

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

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

The retrip timer is initiated after the pickup input is set to true. When the pre-defined time setting is exceeded, 50BFT 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 50BFT 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.

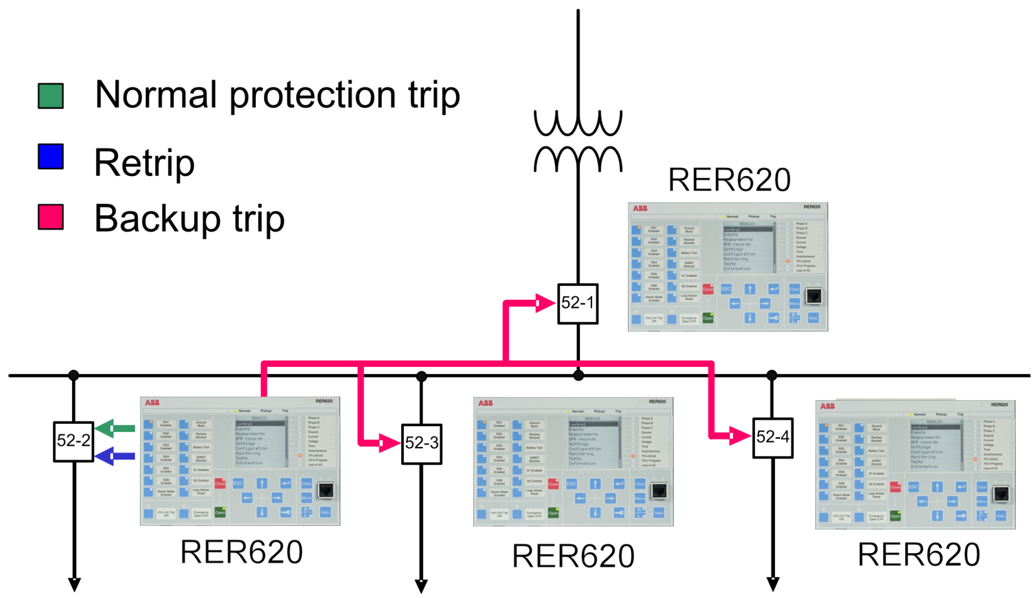


Figure 112: Typical breaker failure protection scheme in distribution substations

4.5.1.6 Signals

Table 251: 50BFT Input signals

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

Table 252: 50BFT Output signals

Name	Type	Description
CB_FAULT_AL	BOOLEAN	Delayed CB failure alarm
TRBU	BOOLEAN	Backup trip
TRBU_A	BOOLEAN	Phase A Backup trip
TRBU_B	BOOLEAN	Phase B Backup trip
TRBU_C	BOOLEAN	Phase C Backup trip
TRRET	BOOLEAN	Retrip
TRRET_A	BOOLEAN	Phase A Retrip
TRRET_B	BOOLEAN	Phase B Retrip

Name	Type	Description
TRRET_C	BOOLEAN	Phase C Retrip

4.5.1.7 Settings

Table 253: 50BFT Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Off / On
Current value	0.05...1.00	xIn	0.05	0.30	Operating phase current
Current value Gnd	0.05...1.00	xIn	0.05	0.30	Operating ground current
CB failure trip mode	1=2 out of 4 2=1 out of 3 3=1 out of 4			2=1 out of 3	Backup trip current check mode
CB failure mode	1=Current 2=Breaker status 3=Both			3=Both	Operating mode of function
CB fail retrip mode	1=Disabled 2=Without Check 3=Current check			3=Current Check	Operating mode of retrip logic
Retrip time	0...60000	ms	10	300	Delay timer for retrip
CB failure delay	0...60000	ms	10	1000	Delay timer for backup trip
CB fault delay	0...60000	ms	10	5000	Circuit breaker faulty delay
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Phase current measurement mode of function
Trip pulse time	0...60000	ms	10	150	Pulse length of retrip and backup trip outputs

4.5.1.8 Monitored data

Table 254: 50BFT Monitored data

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

4.5.1.9 Technical data

Table 255: 50BFT Technical data

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

4.5.2 Single Phase Circuit breaker close failure protection 50BFC

4.5.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker close failure protection	SCCBRBCF	SCCBRBCF	50BFC

4.5.2.2 Function block

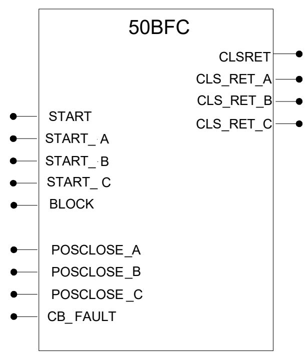


Figure 113: Function block

4.5.2.3 Functionality

The breaker close failure function 50BFC is activated by close commands from either internal auto reclose commands or external commands through START inputs. The pickup or start input command can be single phase or common for all three phases depending on the choice whether single phase or three phase breaker operation mode is chosen. 50BFC includes a single or all three phase unconditional re-close function.

The function has a timer for attempting automatically a re-close timer for the repeated closing of the intended breaker. A minimum close pulse length can be set independently for the output.

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

4.5.2.4 Operation principle

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

The operation of breaker close failure protection can be described by using a module diagram, as shown in the top portion of the logic diagram shown in the figure next page. The signal inputs POS_CLOSE_A, START_A and BLOCK inputs are processed in the Start logic block. Any attempt to close the A pole of the breaker, as decided by the input START_A input going high generates command to try reclosing the breaker after the set close delay time, for a duration of close pule time, set in the unit. Alarm generation on unsuccessful attempt can be done external to this logic in the unit.

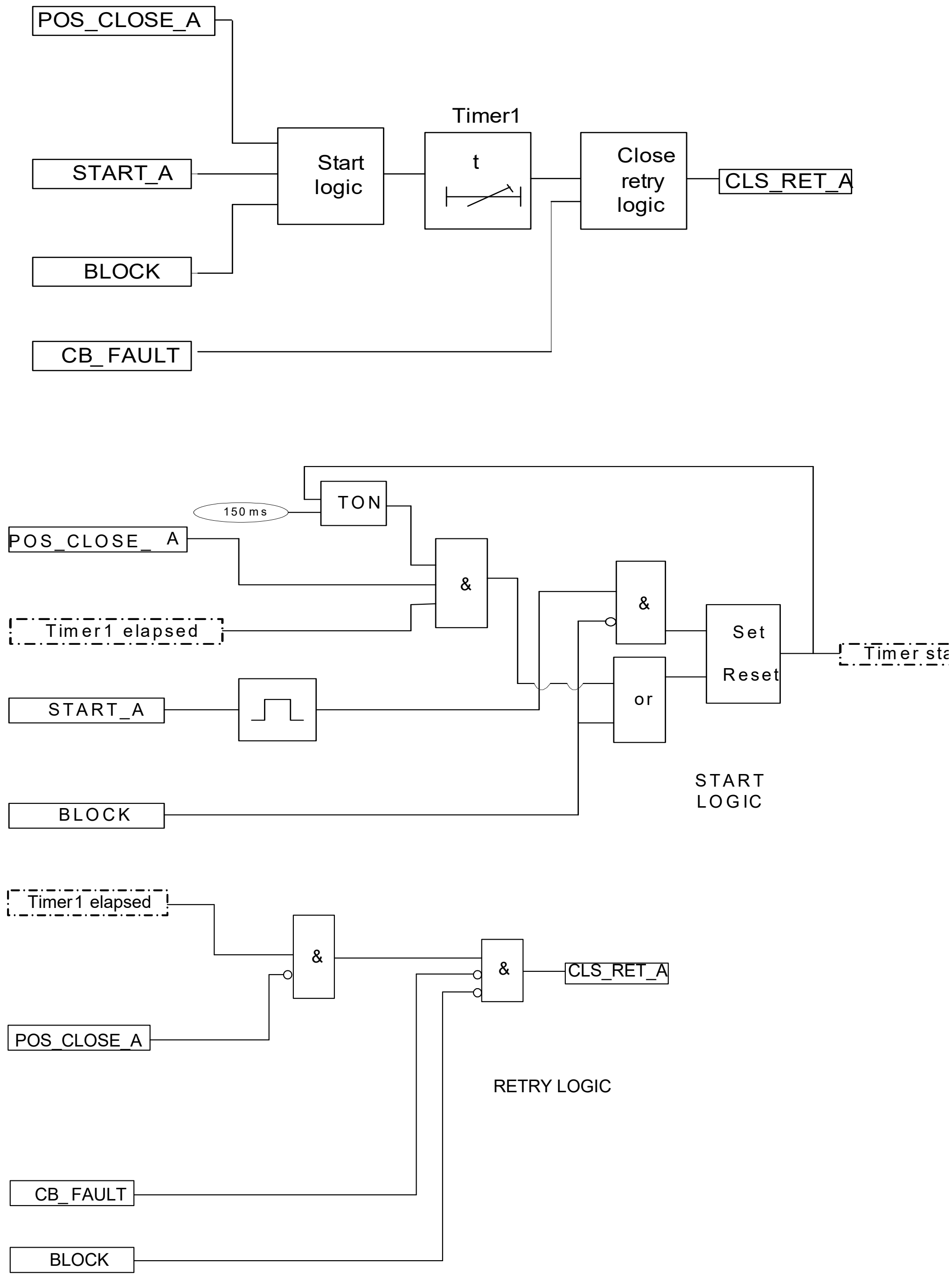


Figure 114: Functional module diagram, typical for Phase A, when single phase operation mode is selected

The following figure is applicable when 3 phase operation mode is selected in the unit. The signal input POSCLOSE is typically the status input of a three pole breaker / recloser. In case there are separate pole operating mechanisms, the input is OR combination of all three phase inputs either through parallel connection of 52a inputs wired to a binary input or through a logic.

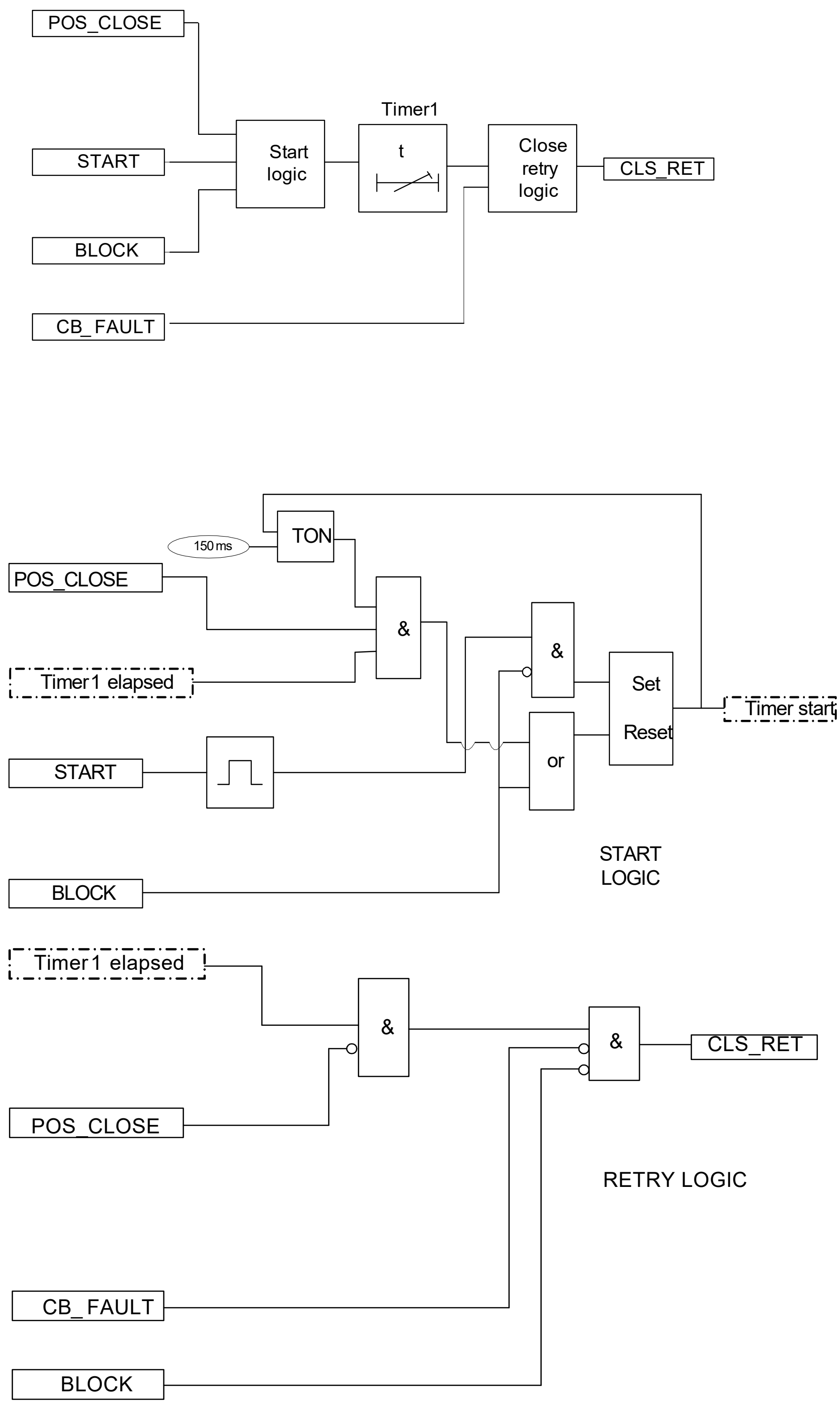


Figure 115: Functional module diagram, for three phase breaker close failure function when three phase operation mode is selected

4.5.2.5 Signals

Table 256: 50BFC Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block BFC operation
START_A	BOOLEAN	0=False	Phase A BFC close command
START_B	BOOLEAN	0=False	Phase B BFC pickup command
START_C	BOOLEAN	0=False	Phase C BFC pickup command
POSCLOSE_A	BOOLEAN	0=False	CB Phase A in closed position
POSCLOSE_B	BOOLEAN	0=False	CB Phase B in closed position
POSCLOSE_C	BOOLEAN	0=False	CB Phase C in closed position
CB_FAULT	BOOLEAN	0=False	CB faulty and unable to close

Table 257: 50BFC Output signals

Name	Type	Description
CLS_RET	BOOLEAN	CB Close
CLS_RET_A	BOOLEAN	CB Phase A Close
CLS_RET_B	BOOLEAN	CB Phase B Close
CLS_RET_C	BOOLEAN	CB Phase C Close

4.5.2.6 Settings

Table 258: 50BFC Non group settings RA01

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			5=Disable	Operation Off / On
Close delay time	0...60000	ms	10	300	Delay timer for reclose attempt
Close pulse time	0...60000	ms	10	150	Pulse length of reclose outputs

Table 259: 50BFC Non group settings RA02

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Close delay time	0...60000	ms	10	2000	Delay timer for reclose attempt
Close pulse time	0...60000	ms	10	150	Pulse length of reclose outputs

4.5.2.7 Monitored data

Table 260: 50BFC Monitored data

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

4.5.2.8 Technical data

Table 261: 50BFC Technical data

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

4.5.3 High impedance fault detector HIZ

4.5.3.1 Identification

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

4.5.3.2 Function block symbol

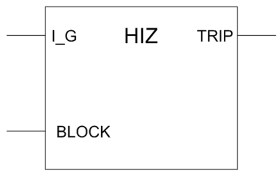


Figure 116: Function block symbol

4.5.3.3 Functionality

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

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

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

4.5.3.4 Principle of operation

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

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

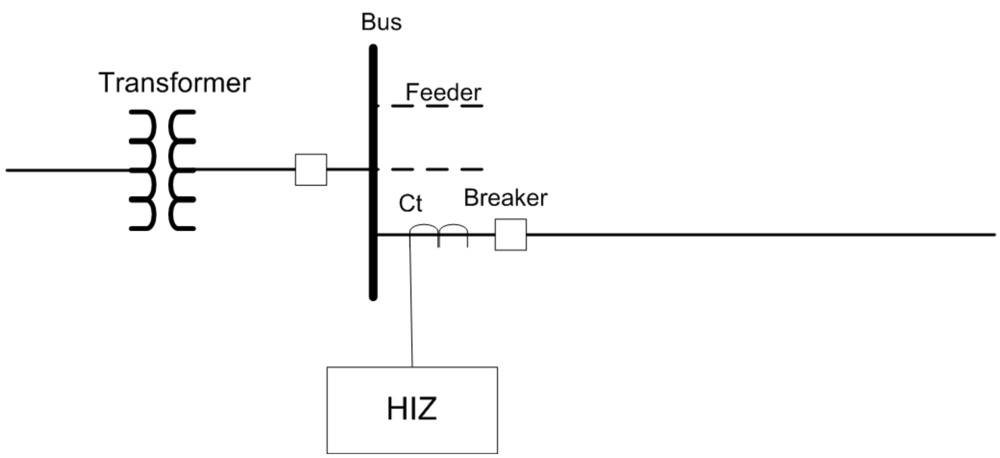


Figure 117: Electrical power system equipped with HIZ

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

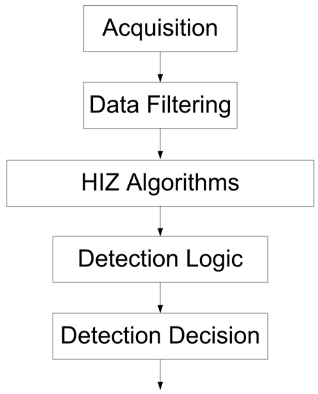


Figure 118: Block diagram of HIZ

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

Figure 119: Validation of HIZ on gravel

Figure 120: Validation of HIZ on concrete

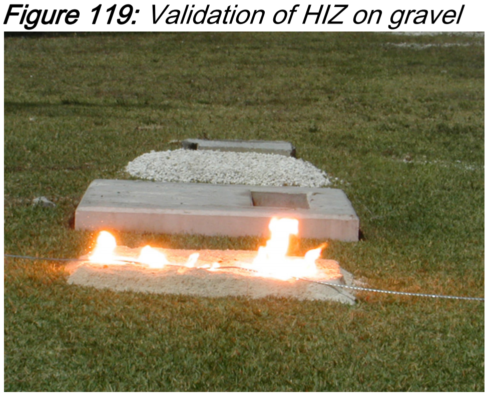


Figure 121: Validation of HIZ on sand

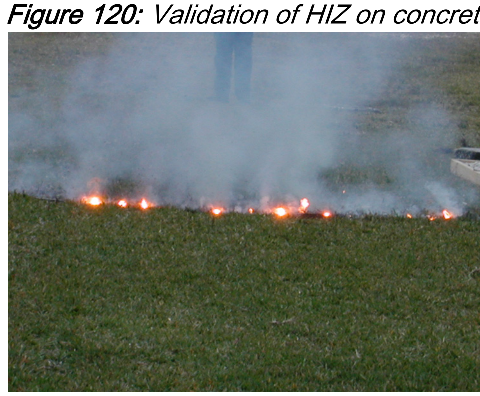


Figure 122: Validation of HIZ on grass

4.5.3.5 Application

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

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

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

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

4.5.3.6 Signals

Table 262: HIZ Input signals

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

Table 263: HIZ Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip

4.5.3.7 Settings

Table 264: HIZ Group settings

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

Table 265: HIZ Non group settings

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

4.5.3.8 Monitored data

Table 266: HIZ Monitored data

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

4.5.4 Fault locator FLOC

4.5.4.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fault locator	DRFLO	FLO	FLO

4.5.4.2 Function block

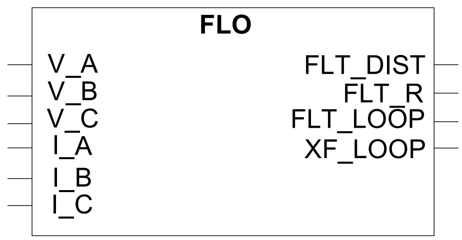


Figure 123: Function block

4.5.4.3 Functionality

The fault locator function performs the estimation of apparent distance to fault and fault resistance. The calculation is performed by comparing the pre-fault current and voltage phasor by fault current and voltage phasor along with line parameters.

The fault loop is determined and the respective voltage and current phasor are selected for the fault location algorithm. The pre fault current and voltage phasor are used to calculate the pre fault load impedance and fault current and voltage phasor are used to calculate the apparent impedance during the fault. The load impedance, apparent impedance and line parameters are used to estimate the fault resistance and distance to fault.

4.5.4.4 Operation principle

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

The operation of FLO can be described by using a module diagram (see Figure 124). All the modules in the diagram are explained in the next sections.

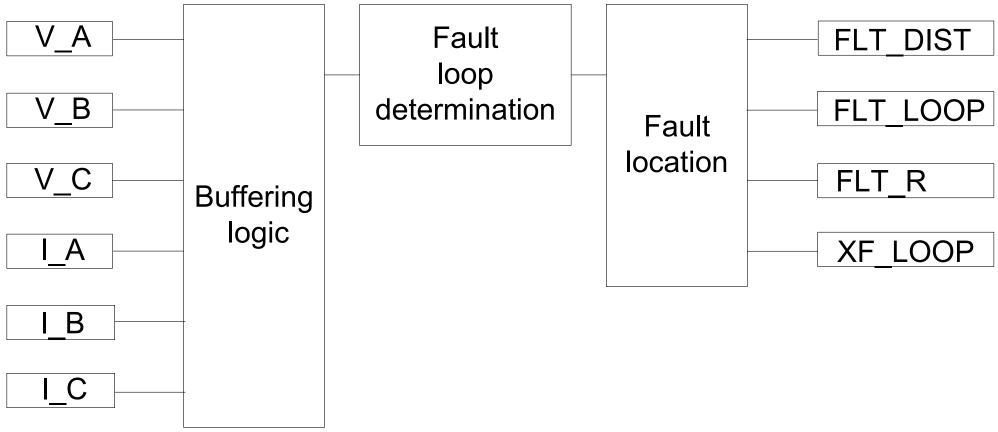


Figure 124: Functional module diagram

Buffering logic

This module buffers the three phase voltage and current phasor input values (DFT values of V_A, V_B, V_C, I_A, I_B, I_C). Once the phase current magnitude is more than the *Phase Level* setting the pre-fault buffer will freeze and updating of fault buffer will be started. The fault buffer will freeze once the buffer is updated fully. The fault location algorithm will be started only if Relay Trip signal is detected.

Fault loop determination

Any fault can be categorized as either a phase to phase fault or a phase to ground fault.

The fault loop determination algorithm determines whether the fault is a phase to ground fault or phase to phase fault by comparing the phase currents with zero sequence current.

This module determines the fault loop from pre-fault and fault phasor stored in the respective buffers. The fault typing is the procedure to identify the type of fault and therefore the respective voltage and current phasor can be selected from the pre-fault and fault buffers, for the fault location algorithm.

Once the fault has been classified as either a phase to ground or phase to phase fault, then the specific fault loop is determined by comparing all phase currents with the setting *Phase Level*. Fault loop determination is done in accordance with Table 267.

Table 267: Fault identification

Fault in phase A	Fault in phase B	Fault in phase C	Fault in ground (Io)	FLTLOOP	FLTLOOP
1	0	0	1	AG Fault	1
0	1	0	1	BG Fault	2
0	0	1	1	CG Fault	3
1	1	0	1	AB Fault	4
0	1	1	1	BC Fault	5
1	0	1	1	CA Fault	6
1	1	1	1	ABC Fault	7
1	1	0	0	ABG Fault	-1
0	1	1	0	BCG Fault	-2
1	0	1	0	CAB Fault	-3
1	1	1	0	ABCG Fault	-4
0	0	0	0	No Fault	0

Once the specific fault type is determined, the respective fault loop voltage and current phasor are taken for fault location algorithm.

If the fault is any single phase to ground fault, then the respective phase current should be ground compensated.

The procedure for the ground compensation is given below,

For ground fault cases, the current measured at the relay is ground compensated by employing the following formula:

$$I_{rly}^{*} = I_{rly} + k * I_0 * (ZL_{zero} - ZL_{pos}) / ZL_{pos}$$

Equation (37)

where

$$I_0 = (I\_A + I\_B + I\_C)/3$$

Equation (38)

k = 1.0 (scaling factor)

ZL_{pos} and ZL_{zero} refer to positive and zero sequence line impedances.

$ZL_{pos} = RL_{pos} + j*XL_{pos}$

$ZL_{zero} = RL_{zero} + j*XL_{zero}$

RL_{pos} = *PosSeqR* * *LinLen*

XL_{pos} = *PosSeqX* * *LinLen*

RL_{zero} = *ZeroSeqR* * *LinLen*

XL_{zero} = *ZeroSeqX* * *LinLen*

I_{rly}^{*} = Ground compensated phase current

I_{rly} = Non-compensated phase current

R1 is positive sequence line resistance in ohm/ (miles or kms) and is provided as a setting

X1 is positive sequence line reactance in ohm/ (miles or kms) and is provided as a setting

R0 is zero sequence line resistance in ohm/ (miles or kms) and is provided as a setting

X0 is zero sequence line reactance in ohm/ (miles or kms) and is provided as a setting

Line Length is the length of the line in the units of kilometers (Km) or miles and is provided as a setting.

If *R1*, *X1*, *R0*, *X0* are given in ohm/mile then the length of the line *Line Length* should be given in the unit of miles

If *R1*, *X1*, *R0*, *X0* are given in ohm/Km then the length of the line *Line Length* should be given in the unit of Km's.

Table 268 describes what will be the voltage phasor and current phasor under different fault types.

Table 268: Relay voltage and current phasor identification

FLTLOOP	Current phasor	Voltage phasor
AG Fault	I_A*	V_A
BG Fault	I_B*	V_B
CG Fault	I_C*	V_C
ABG Fault	(I_A - I_B)	(V_A - V_B)
BCG Fault	(I_B - I_C)	(V_B - V_C)
CAG Fault	(I_C - I_A)	(V_C - V_A)
ABCG Fault	I_A	V_A
AB Fault	(I_A - I_B)	(V_A - V_B)
BC Fault	(I_B - I_C)	(V_B - V_C)
CA Fault	(I_C - I_A)	(V_C - V_A)
ABC Fault	I_A	V_A

* indicates the respective current is ground compensated

Fault location

This module calculates the distance to fault and fault resistance from the voltage phasor and current phasor selected based on type of the fault (see Table 268).

The algorithm uses the fundamental frequency phasor voltages and currents measured at the relay terminal before and during the fault.

The algorithm basically is an iterative technique, performs a comparison of the pre fault load impedance and apparent impedance during the fault, to estimate the distance to fault.

Estimated values of fault resistance, pre fault load impedance and line impedance are then modified using the correction factors. And the corrected values are used to estimate the final FLT_DIST and FLT_R.

During the auto-re-closure sequences the fault location is done with initial fault conditions.

4.5.4.5 Application

Electrical power system has grown rapidly over the last few decades. This resulted in a large increase of the number of lines in operation and their total length. These lines experience faults which are caused by storms, lightning, snow, freezing rain, insulation breakdown and short circuits caused by birds and other external objects. In most cases, electrical faults manifest in mechanical damage, which must be repaired before returning the line to service. The restoration can be expedited if the location of the fault is either known or can be expedited with reasonable accuracy.

Fault locators provide estimate for both sustained and transient faults. Generally transient faults cause minor damage that is not easily visible on inspection. Fault locators help identify those locations for early repairs to prevent recurrence and consequent major damage.

The fault location algorithm is most applicable for radial feeder. The algorithm is based on the system model shown in Figure 125. The algorithm was designed to be used on a homogeneous radial distribution line. Therefore the unit is not intended to be used on a distribution line with many different types of conductors because the algorithm will not be as accurate. Fault locator algorithm may not be accurate for switch on to fault condition.

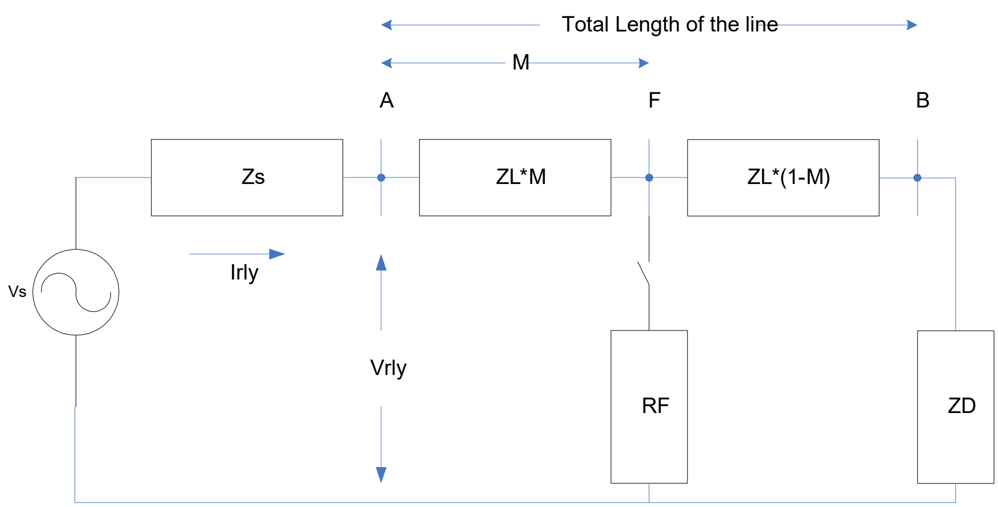


Figure 125: System model considered for fault location

Where,

Vs = Source Voltage

Vrly = Voltage at the relay location

Irly = Current in the transmission line at the relay location

Zs = Source impedance

ZL = Transmission line impedance in ohm/unit length

ZD = Load impedance

RF = Fault resistance

M = Distance to point of fault from relay location

4.5.4.6 Signals

Table 269: FLO input signals

Name	Type	Default	Description
V_A	SIGNAL	0	Phase A Voltage
V_B	SIGNAL	0	Phase B Voltage
V_C	SIGNAL	0	Phase C Voltage
I_A	SIGNAL	0	Phase A Current
I_B	SIGNAL	0	Phase B Current
I_C	SIGNAL	0	Phase C Current

4.5.4.7 Settings

Table 270: FLO group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	ON/OFF			ON	Operation
Line Length	0.00…300.00	Miles/Kms		100.00	Length of the transmission or distribution line in miles
R1	0.000...20.000	Ohm/(Mile or Km)		1.000	Positive sequence resistance of line in primary Ohm/(Mile or Km)
X1	0.000...30.000	Ohm/(Mile or Km)		2.000	Positive sequence reactance of line in primary Ohm/(Mile or Km)
R0	0.000...20.000	Ohm/(Mile or Km)		0.010	Zero sequence resistance of line in primary Ohm/(Mile or Km)
X0	0.000...30.000	Ohm/(Mile or Km)		1.000	Zero sequence reactance of line in primary Ohm/(Mile or Km)
Phase Level	0.00...40.00	%In		0.10	Threshold magnitude of phase current in the per-unit of primary rated current

4.5.4.8 Monitored data

Table 271: FLO monitored data

Name	Type	Description
FLT_DIST	FLOAT32	Estimated distance to fault in Miles or Kms depending on Line parameter units
FLT_R	FLOAT32	Estimated fault resistance in ohms
XF_LOOP	FLOAT32	Estimated reactance in the fault loop in ohms
FLT_LOOP	-1=ABG Fault -2=BCG Fault -3=CAG Fault -4=ABCG Fault 0=No Fault 1=AG Fault 2=BG Fault 3=CG Fault 4=AB Fault 5=BC Fault 6=CA Fault 7=ABC Fault	Fault loop

4.5.5 Directional positive sequence power protection 32P

The directional positive sequence power protection (32P) function detects power direction for phase directional power. Release signal is given if the angle difference polarizing and operating quantity is in predefined direction (forward or reverse direction). The release signal is given with definite time delay.

4.5.5.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional positive sequence power protection	DPSRDIR	P>->	32P

4.5.5.2 Function block

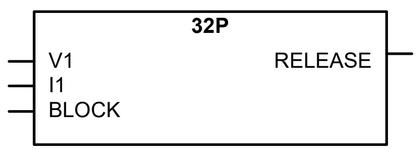


Figure 126: Function block

4.5.5.3 Functionality

The directional positive sequence power protection (32P) function is used to detect positive sequence power direction. The output of the function is used for blocking or releasing other functions in protection scheme.

This function contains a blocking functionality which blocks function output and resets the timer.

4.5.5.4 Operation principle

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

The operation of 32P can be described by using a module diagram (see Figure 127). All the modules in the diagram are explained in the next sections.

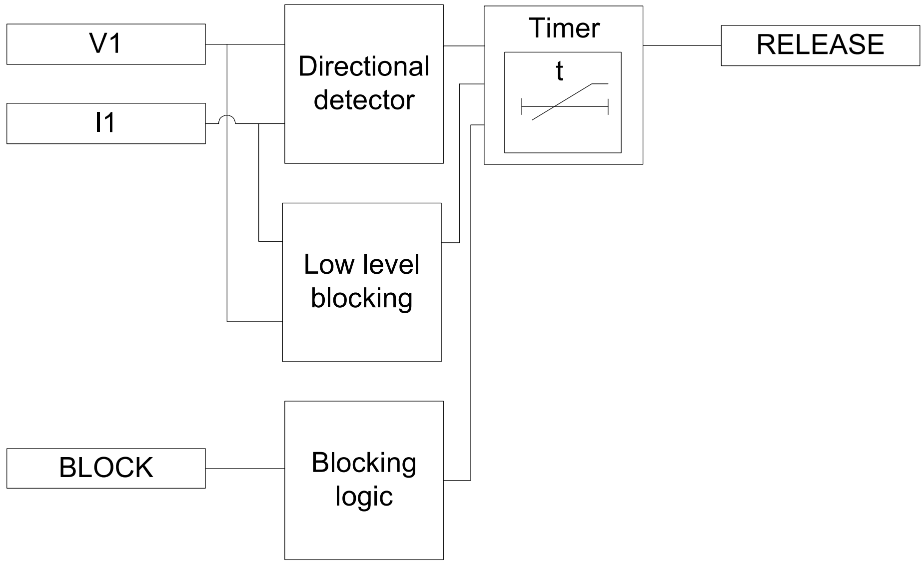


Figure 127: Functional module diagram

Directional detector

The Directional detector module compares the angle of positive sequence current (I_1) to the angle of positive sequence voltage (V_1). Using the positive sequence voltage angle as the reference the positive sequence current angle is compared to the *Characteristic angle* setting. If the angular difference is within the operating sector selected by the *Directional mode* setting, then enable signal is sent to the Timer.

The operating sector is defined by the setting *Min forward angle*, *Max forward angle*, *Min reverse angle*, and *Max reverse angle* (see Figure 128). The user selectable options for *Directional mode* settings are “Forward” and “Reverse”

The sector limits are always given as positive degree values.

The *Characteristic angle* is also known as Relay Characteristic Angle (RCA), Relay Base Angle or Maximum Torque Line.

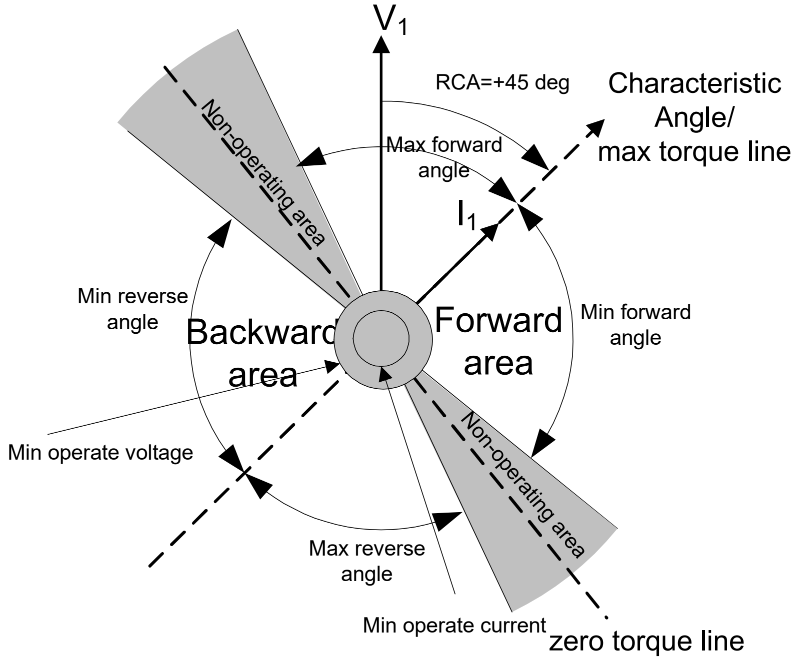


Figure 128: Configurable directional settings

Low level blocking

For reliable operation, signals levels should be greater than minimum level. If they are not greater than minimum level, Timer is blocked. If the amplitude of the positive sequence current amplitude is greater than *Min Trip Current* value and positive sequence voltage amplitude is greater than *Min operate voltage* value then enable signal is sent to the Timer.

Timer

Once activated the internal operate timer is started. The timer characteristic is according to Definite Time (DT). When the Timer has reached the value of *Release delay time*, the RELEASE output is activated. If a drop-off situation happens, that is if operating current moves outside operating sector or signal amplitudes becomes below the minimum level before *Release delay time* is exceeded, the timer reset state is activated. If drop off continues for more than *Reset delay time* the Timer is deactivated.

Blocking logic

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates RELEASE output and resets the Timer.

4.5.5.5 Application

The 32P function improves the possibility to obtain selective function of the overcurrent protection in meshed networks. The 32P function is used to block or release other overcurrent protection functions.

4.5.5.6 Signals

Table 272: 32P input signals

Name	Type	Default	Description
V1	REAL	0.0	Positive sequence voltage
I1	REAL	0.0	Positive sequence current
BLOCK	BOOL	FALSE	Block signal for all binary outputs

Table 273: 32P measured values

Name	Type	Default	Description
I1_AMPL	REAL	0.0	Positive sequence current amplitude
I1_ANGL	REAL	0.0	Positive sequence current phase angle
V1_AMPL	REAL	0.0	Positive sequence voltage amplitude
V1_ANGL	REAL	0.0	Positive sequence voltage phase angle
BLOCK	BOOL	FALSE	Block signal for all binary outputs

Table 274: 32P output signals

Name	Type	Description
RELEASE	BOOL	Release signal if directional criteria is satisfied

4.5.5.7 Settings

Table 275: 32P group settings

Name	Values (Range)	Unit	Step	Default	Description
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward,	Power direction forward or reverse direction
Max forward angle	0 …90	Deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0 …90	Deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0…90	Deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0 …90	Deg	1	88	Minimum phase angle in reverse direction
Characteristic angle	-179…180	Deg	1	60	Characteristic angle
Release delay time	0...1000	ms	1	10	Release delay time for the directional criteria

Table 276: 32P non-group settings

Name	Values (Range)	Unit	Step	Default	Description
Operation	0=Off 1=On			1=ON	Operation Off / On
Reset delay time	0…60000	ms	1	20	Reset delay time
Min operate voltage	0.01…1.00	pu	0.01	0.3	Minimum operating voltage
Min operate current	0.005…1.00	pu	0.001	0.1	Minimum operating current

4.5.5.8 Monitored data

Table 277: 32P Monitored data

Name	Type	Values (Range)	Unit	Description
DIRECTION	ENUM	0=unknown 1=forward 2=backward		Direction information
ANGLE_RCA	REAL			Angle between operating angle and characteristic angle

4.5.5.9 Technical data

Table 278: 32P Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency measured: fn ±2Hz
	±1.5% of the current or ±0.01A ±1.5% of the voltage or ±1V ±3.0% of the characteristic angle or ±4 Deg

4.5.6 Directional negative/zero sequence power protection 32N

Directional negative/zero sequence power protection (32N) is used to detect the direction of negative sequence power or residual power.

Release signal is given if the angle difference between polarizing and operating quantity is in predefined direction (forward or reverse direction). The release signal is given with a definite time delay.

4.5.6.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional negative/zero sequence power protection	DNZSRDIR	Q>->	32N

4.5.6.2 Function block

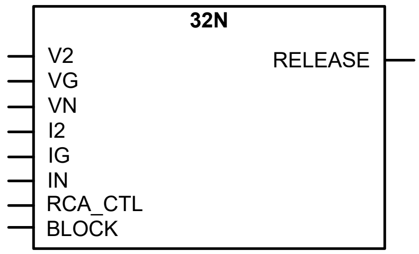


Figure 129: Function block

4.5.6.3 Functionality

Directional negative/zero sequence power protection (32N) is used to detect negative or residual power direction. The output of the function is used for blocking or releasing other functions in protection scheme.

In negative sequence voltage selection, if the angle difference between negative sequence voltage and negative sequence current is in predefined direction (either in forward or reverse direction), 32N gives release signal after a definite time delay.

In residual voltage selection, if the angle difference between residual voltage and residual current is in predefined direction (either in forward or reverse direction), 32N gives release signal after a definite time delay.

This function contains a blocking functionality which blocks the function output and resets the timer.

4.5.6.4 Operation principle

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

The operation of 32N can be described by using a module diagram (see Figure 130). All the modules in the diagram are explained in the next sections.

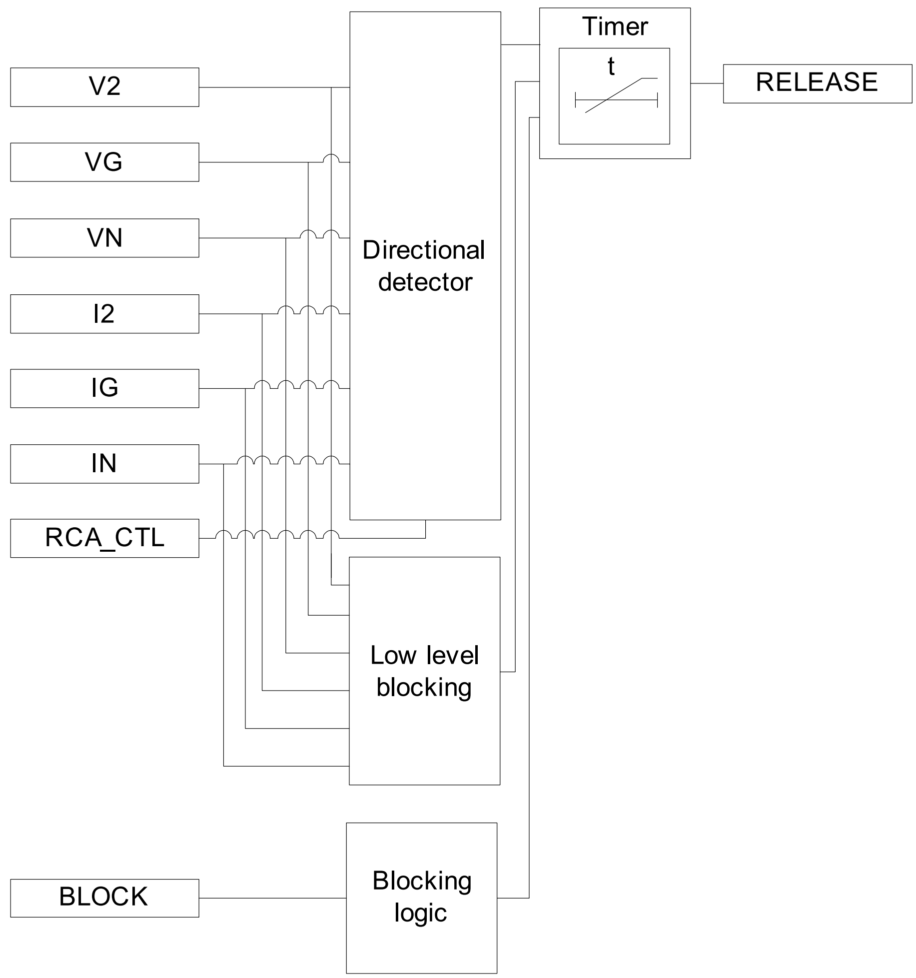


Figure 130: Functional module diagram

Directional detector

When “Neg. seq. volt.” selection is made using *Pol signal Sel*, the directional detector module compares angle of negative sequence current (I_2) to the negative sequence voltage ($-V_2$). Using the negative sequence voltage angle as the reference the negative sequence current angle is compared to the *Characteristic angle*. If the angle difference is within the operating sector selected by *Direction mode* setting then enable signal is sent to the Timer.

The value of *Characteristic angle* should be chosen in such way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the backward zone.

The operating sector is defined by the settings *Max forward angle*, *Max reverse angle*, *Min forward angle* and *Min reverse angle* (see Figure 131). User selectable options for *Directional mode* are “Forward” and “Reverse”.

The *Characteristic angle* is also known as Relay Characteristic Angle (RCA), Relay Base Angle or Maximum Torque Line.

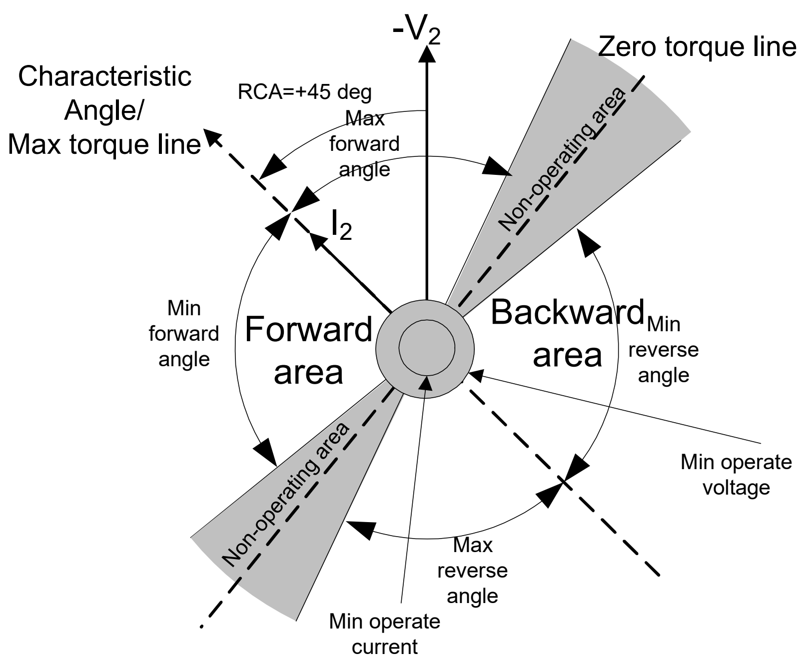


Figure 131: Configurable directional setting when "Neg. seq. volt." selection is made using Pol signal Sel

When "Measured V_G" or "Calculated V_N" voltage selection is made using *Pol signal Sel* setting, the Directional detector module compares the angle of the residual current to the residual voltage. Using the residual voltage as reference the residual current angle is compared to the *Characteristic angle* setting. If the angle difference is within the operating sector selected by *Directional mode* setting, then enable signal is sent to the Timer.

The "Measured IG" or "Calculated IN" (residual current) can be selected using *Io signal Sel* setting.

The "Measured VG", "Calculated VN" (residual voltage) can be selected using *Pol signal Sel* setting.

The polarizing quantity (residual voltage) is inverted because of switched voltage measurement cables, the correction can be done by setting the *Pol reversal* setting to "True" which rotates polarizing quantity by 180 degrees.

The operating sector is defined by the settings *Max forward angle*, *Max reverse angle*, *Min forward angle*, and *Min reverse angle* (see Figure 131). User selectable options for *Directional mode* are "Forward" and "Reverse".

The directional characteristic for measured or calculated residual power is same.

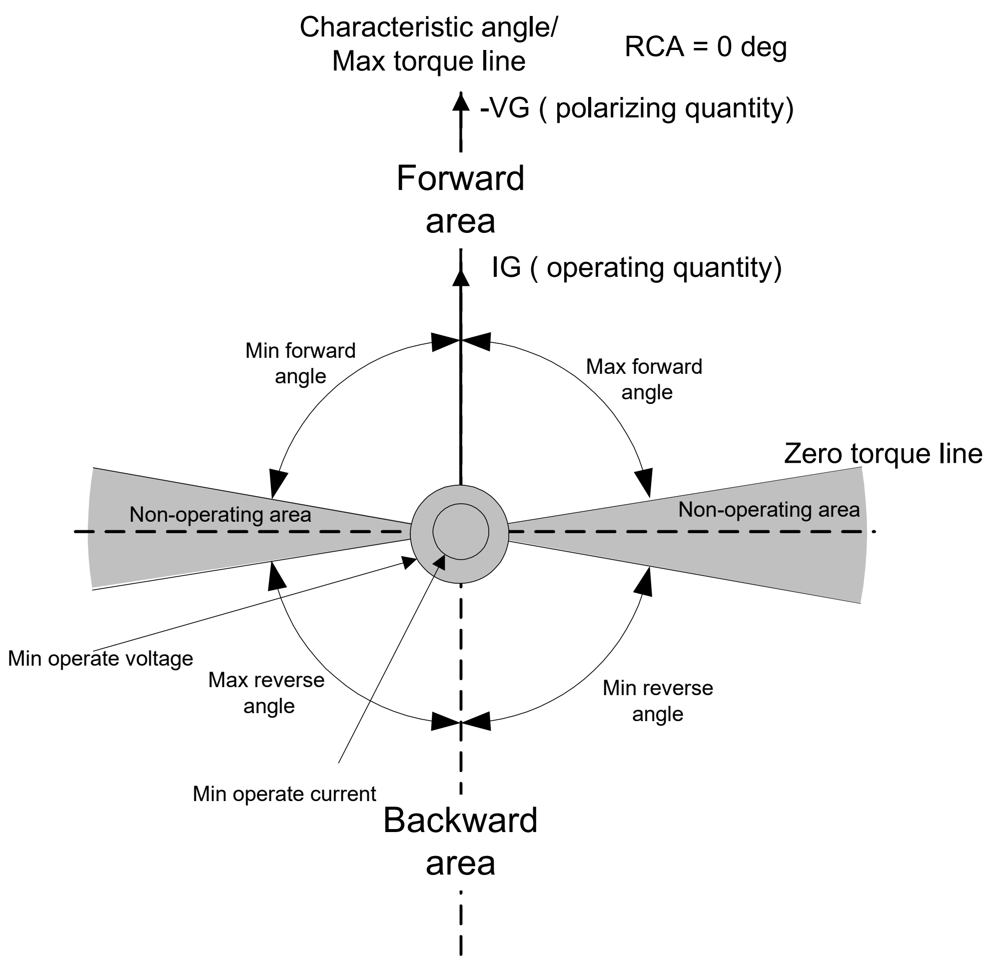


Figure 132: Configurable directional setting for "Measured V_G" or "Calculated V_N" (residual voltage) using Pol signal Sel setting

The *Characteristic angle* setting is done based on method of grounding employed in the network. For example in case of isolated network the *Characteristic angle* is set equal to -90˚, in case of compensated network the *Characteristic angle* is set equal to 0˚ and 60˚ for solidly grounded systems. In general *Characteristic angle* is selected so that it matches close to the expected fault angle value, which results into maximum sensitivity. The *Characteristic angle* can be set anywhere between -179˚ to +180˚. Figure 133 and Figure 134 show examples of the operating area with RCA set to +60˚ and -90˚, respectively.

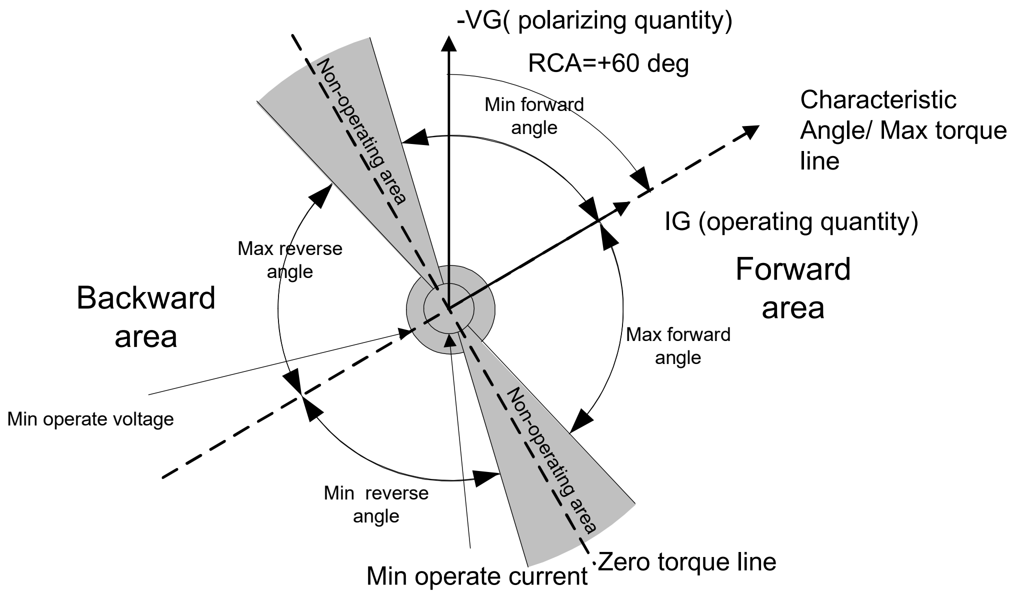


Figure 133: Configurable directional characteristics (RCA =+60˚) for a solidly earthed network

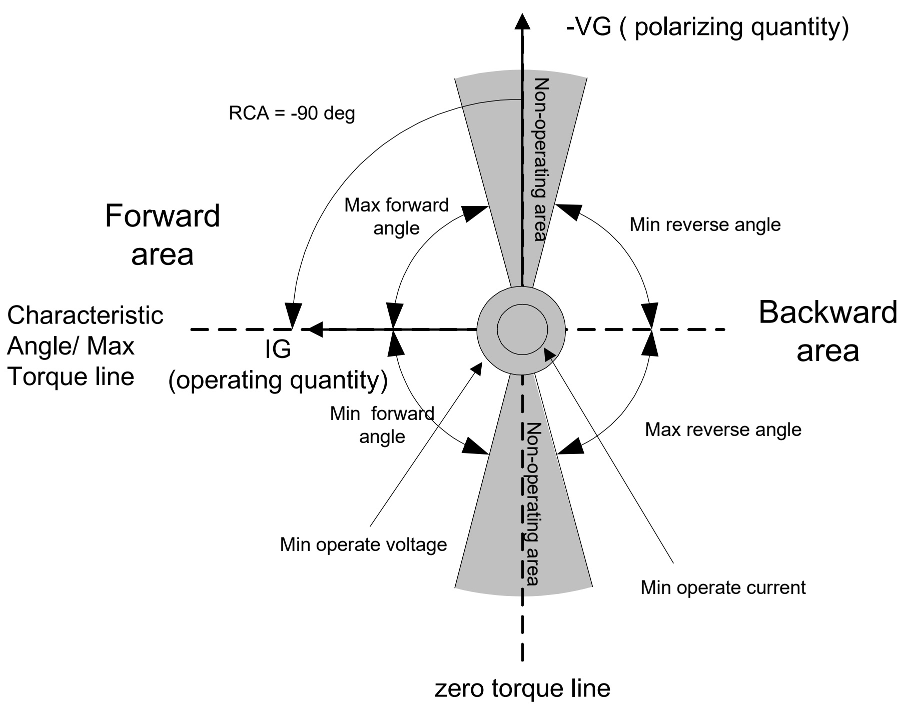


Figure 134: Configurable directional characteristics (RCA = -90 ˚) for an isolated network

The *Characteristic angle* should be set to a positive value if the operating signal, IG or IN lags the polarizing quantity –VG or –VN, respectively, and a negative value if operating signal IG or IN leads the polarizing quantity –VG or –VN, respectively.

Table 279: Recommended Characteristic angle setting for different network

Type of network	Characteristic angle recommended
Compensated network	0 ˚
Solidly earthed network	+60 ˚
Isolated network	-90 ˚

The *Characteristic angle* setting is adjusted to the operation according to the method of neutral point earthing so that in an isolated network the *Characteristic angle* = -90° and in a compensated network = 0°. In addition, the *Characteristic angle* can be changed via the control signal RCA_CTL, in which case the alternatives are -90° and 0°. The operation of the RCA_CTL depends on the *Characteristic angle* setting.

The Peterson 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* accordingly. This is done with an auxiliary input in the relay which receives a signal from an auxiliary switch of the disconnector of the Peterson coil in compensated networks or of the earthing resistor in earthed network as a result the *Characteristic angle* is set automatically to suit the earthing method. The table below shows the *Characteristic angle* control for RCA_CTL condition.

Table 280: Characteristic angle control for RCA_CTL condition

Characteristic angle Setting	RCA_CTL=FALSE	RCA_CTL=TRUE
-90°	*Characteristic angle* = -90°	*Characteristic angle* = 0°.
0°.	*Characteristic angle* = 0°.	*Characteristic angle* = -90°

Low level blocking

For reliable operation, signals levels should be greater than minimum level. If they are not greater than minimum level, Timer is blocked.

In “Neg. seq. volt.” polarization selection using *Pol signal Sel*, if the amplitude of the negative sequence current is greater than *Min operate current* value and negative sequence voltage amplitude is greater than *Min operate voltage* value then enable signal is sent to the Timer.

In “Measured VG” or “Calculated VN” polarization selection using *Pol signal Sel*, if the amplitude of the residual current is greater than the *Min operate current* value and residual voltage amplitude is greater than the *Min operate voltage* value then enable signal is sent to the Timer.

Timer

Once activated the internal operate timer is started. The timer characteristic is according to Definite Time (DT). When the Timer has reached the value of *Release delay time*, the RELEASE output is activated. If a drop-off situation happens, that is, if operating current moves out of the operating sector or signal amplitudes become below the minimum levels, before the *Release delay time* is exceeded, the timer reset state is activated. If drop off continues for more than *Reset delay time* the Timer is deactivated.

Blocking logic

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates RELEASE output and resets the Timer.

4.5.6.5 Application

The directional negative/zero sequence power protection (32N) function improves the possibility to obtain selective function of the over-current protection in meshed networks. The 32N function is used to block or release other over current protection function.

4.5.6.6 Signals

Table 281: 32N input signals

Name	Type	Default	Description
V2	REAL	0.0	Negative sequence voltage
VG	REAL	0.0	Measured residual voltage or Ground voltage
VN	REAL	0.0	Calculated residual voltage or Neutral voltage
I2	REAL	0.0	Negative sequence current
IG	REAL	0.0	Measured residual current or Ground current
IN	REAL	0.0	Calculated residual current or Neutral current
RCA_CTL	BOOL	FALSE	Relay characteristic angle control
BLOCK	BOOL	FALSE	Block signal for all binary outputs

Table 282: 32N measured values

Name	Type	Default	Description
IG_AMPL	REAL	0.0	Measured residual current or Ground current amplitude
IG_ANGL	REAL	0.0	Measured residual current or Ground current phase angle
IN_AMPL	REAL	0.0	Calculated residual current or Neutral current amplitude
IN_ANGL	REAL	0.0	Calculated residual current or Neutral current phase angle
VG_AMPL	REAL	0.0	Measured residual voltage or Ground voltage amplitude
VG_ANGL	REAL	0.0	Measured residual voltage or Ground voltage phase angle
VN_AMPL	REAL	0.0	Calculated residual voltage or Neutral voltage amplitude
VN_ANGL	REAL	0.0	Calculated residual voltage or Neutral voltage phase angle
I2_AMPL	REAL	0.0	Negative sequence current amplitude
I2_ANGL	REAL	0.0	Negative sequence current phase angle
V2_AMPL	REAL	0.0	Negative sequence voltage amplitude
V2_ANGL	REAL	0.0	Negative sequence voltage phase angle
BLOCK	BOOL	FALSE	Block signal for all binary outputs
RCA_CTL	BOOL	FALSE	Relay characteristic angle control

Table 283: 32N output signals

Name	Type	Description
RELEASE	BOOL	Release signal if directionality criteria is satisfied

4.5.6.7 Settings

Table 284: 32N group settings

Name	Values (Range)	Step	Unit	Default	Description
Directional mode	1=Non-directional 2=Forward 3=Reverse	1	-	2=Forward	Directional mode of operation
Max forward angle	0…180	1	Deg	88	Maximum phase angle in forward direction
Max reverse angle	0…180	1	Deg	88	Maximum phase angle in reverse direction
Min forward angle	0…180	1	Deg	88	Minimum phase angle in forward direction
Min reverse angle	0…180	1	Deg	88	Minimum phase angle in reverse direction
Characteristic angle	-179…180	1	Deg	60	Characteristic angle
Release delay time	0…1000	1	ms	10	Release delay time

Table 285: 32N non-group setting

Name	Values (Range)	Step	Unit	Default	Description
Operation	0=Off 1=On			1=ON	Operation Off / On
Reset delay time	0…60000	1	ms	20	Reset delay time
Pol reversal	0=False 1=True			1=True	Rotate polarizing quantity
Min operate voltage	0.01…1.00	0.01	pu	0.3	Minimum operating current
Min operate current	0.01…1.00	0.01	pu	0.1	Minimum operating voltage
Io signal Sel	1=Measured IG 2=Calculated IG			1=Measured IG	Selection used for Io signal
Pol signal Sel	1=Measured VG 2=Calculated VN 3=Neg. seq volt			1=Measured VG	Selection for used polarization signal

4.5.6.8 Monitored data

Table 286: 32N Monitored data

Name	Type	Values (Range)	Unit	Description
DIRECTION	ENUM	0=unknown 1=forward 2=backward		Direction information
ANGLE_RCA	REAL			Angle between operating angle and characteristic angle

4.5.6.9 Technical data

Table 287: 32N Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency measured: fn ±2Hz
	±1.5% of the current or ±0.01A ±1.5% of the voltage or ±1V ±3.0% of the characteristic angle or ±4 Deg

Section 5 Control functions

5.1 Circuit breaker control 52

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single-phase circuit breaker control	SCBXCBR	I<->0 CB	52

5.1.2 Function block

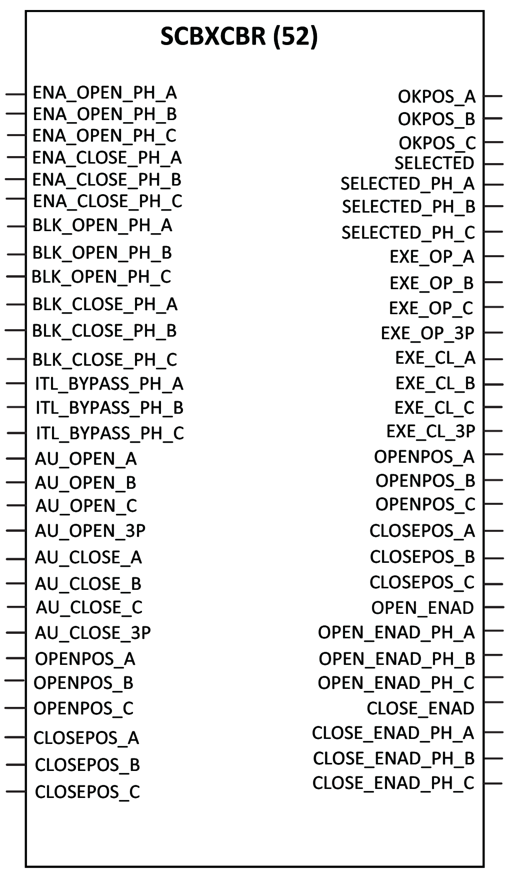


Figure 135: Function block

5.1.3 Functionality

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

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

5.1.4 Operation principle

Status indication and validity check

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

Table 288: Status indication

Status (POSITION)	OPENPOS_x	CLOSEPOS_x	OKPOS_x
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

Blocking

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

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

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

The ITL_BYPASS_PH_x input is used if the interlocking functionality needs to be bypassed. When INT_BYPASS is TRUE, the circuit breaker control for the respective phase is made possible by discarding the ENA_OPEN_PH_x and ENA_CLOSE_PH_x input states. However, the BLK_OPEN_PH_x and BLK_CLOSE_PH_x input signals are not bypassed with the interlocking bypass functionality since they always have higher priority.

Open and close operations

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

Open and close pulse widths

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

Control methods

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

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

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

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

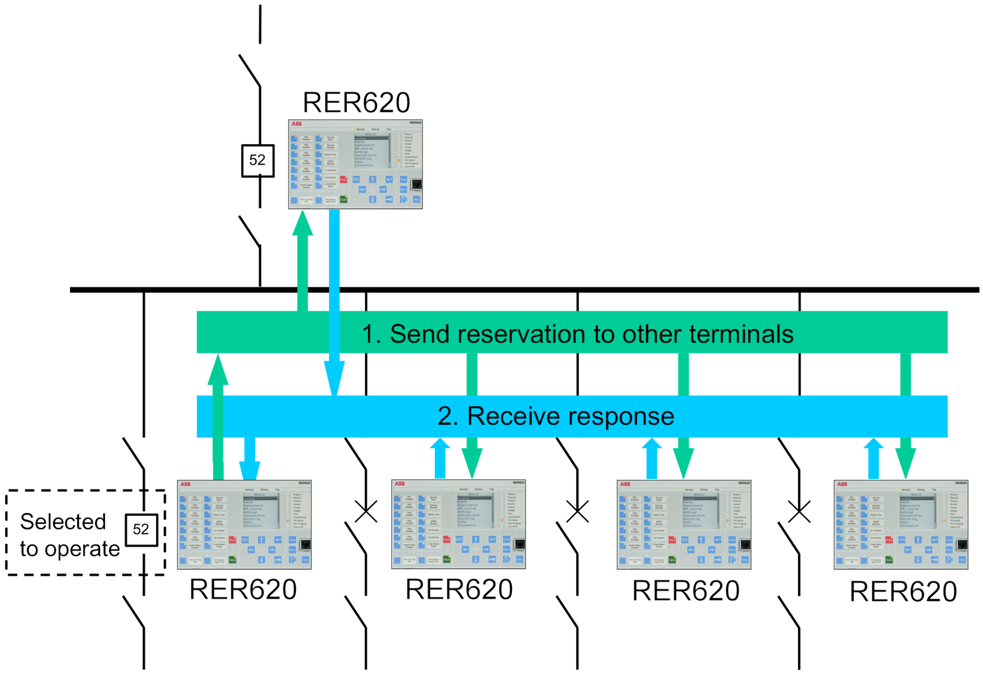


Figure 136: Control procedure in SBO method

5.1.5 Application

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

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

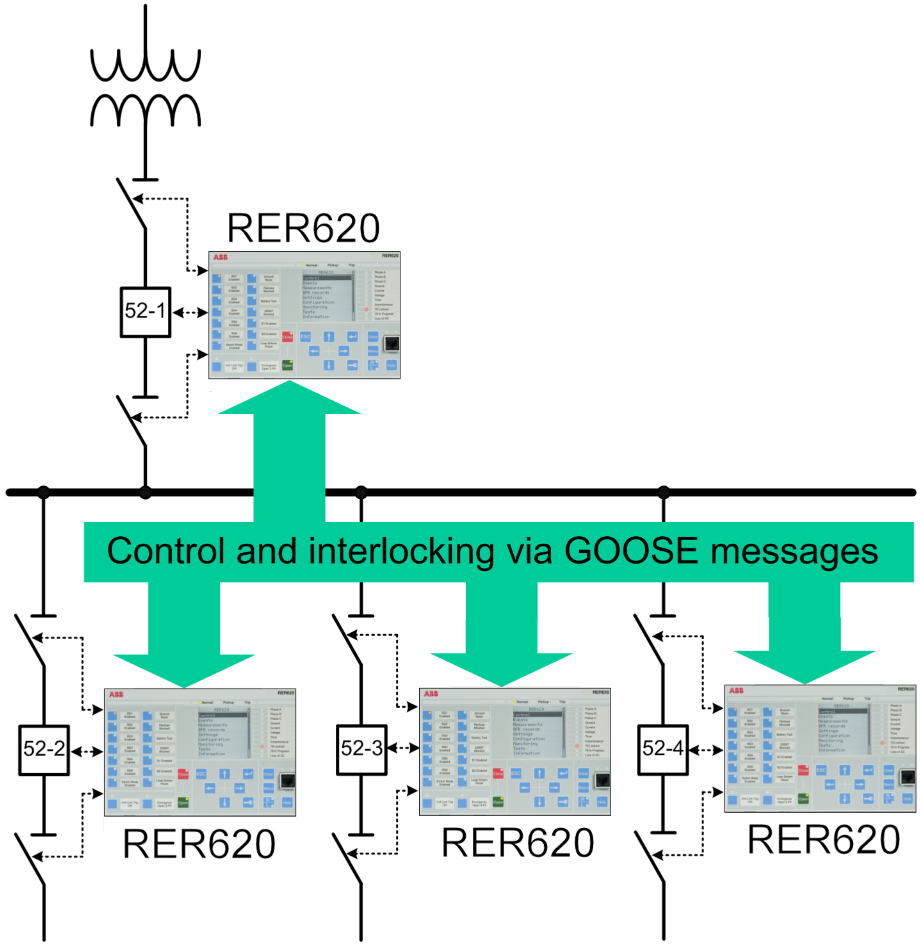


Figure 137: Status indication based interlocking via GOOSE messaging

5.1.6 Signals

Table 289: 52 Input signals

Name	Type	Default	Description
ENA_OPEN	BOOLEAN	1=True	Enables opening
ENA_CLOSE	BOOLEAN	1=True	Enables closing
BLK_OPEN	BOOLEAN	0=False	Blocks opening
BLK_CLOSE	BOOLEAN	0=False	Blocks opening
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE
AU_OPEN_3P	BOOLEAN	0=False	Input signal used to open the breaker[1]
AU_CLOSE_3P	BOOLEAN	0=False	Input signal used to close the breaker
ENA_OPEN_PH_A	BOOLEAN	1=True	Enables opening phase A
ENA_OPEN_PH_B	BOOLEAN	1=True	Enables opening phase B
ENA_OPEN_PH_C	BOOLEAN	1=True	Enables opening phase C
ENA_CLOSE_PH_A	BOOLEAN	1=True	Enables closing phase A
ENA_CLOSE_PH_B	BOOLEAN	1=True	Enables closing phase B
ENA_CLOSE_PH_C	BOOLEAN	1=True	Enables closing phase C
BLK_OPEN_PH_A	BOOLEAN	0=False	Blocks opening phase A
BLK_OPEN_PH_B	BOOLEAN	0=False	Blocks opening phase B
BLK_OPEN_PH_C	BOOLEAN	0=False	Blocks opening phase C
BLK_CLOSE_PH_A	BOOLEAN	0=False	Blocks closing phase A
BLK_CLOSE_PH_B	BOOLEAN	0=False	Blocks closing phase B
BLK_CLOSE_PH_C	BOOLEAN	0=False	Blocks closing phase C
ITL_BYPASS_PH_A	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE of phase A interlocking when TRUE
ITL_BYPASS_PH_B	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE of phase B interlocking when TRUE
ITL_BYPASS_PH_C	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE of phase AC interlocking when TRUE
OPENPOS_A	BOOLEAN	0=False	Signal for open position ph A apparatus from I/O[1]
OPENPOS_B	BOOLEAN	0=False	Signal for open position ph B apparatus from I/O[1]
OPENPOS_C	BOOLEAN	0=False	Signal for open position ph C apparatus from I/O[1]
CLOSEPOS_A	BOOLEAN	0=False	Signal for close position ph A apparatus from I/O[1]
CLOSEPOS_B	BOOLEAN	0=False	Signal for close position ph B apparatus from I/O[1]
CLOSEPOS_C	BOOLEAN	0=False	Signal for close position ph C apparatus from I/O[1]
AU_OPEN_A	BOOLEAN	0=False	Input signal used to open breaker ph A[1]
AU_OPEN_B	BOOLEAN	0=False	Input signal used to open breaker ph B[1]
AU_OPEN_C	BOOLEAN	0=False	Input signal used to open breaker ph C[1]
AU_CLOSE_A	BOOLEAN	0=False	Input signal used to close breaker ph A[1]
AU_CLOSE_B	BOOLEAN	0=False	Input signal used to close breaker ph B[1]
AU_CLOSE_C	BOOLEAN	0=False	Input signal used to close breaker ph C[1]

1. Not available for monitoring

Table 290: 52 Output signals

Name	Type	Description
SELECTED	BOOLEAN	Object selected
EXE_OP_3P	BOOLEAN	Executes the command for open direction
EXE_CL_3P	BOOLEAN	Executes the command for close direction
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
SELECTED_PH_A	BOOLEAN	Phase A object selected
SELECTED_PH_B	BOOLEAN	Phase B object selected
SELECTED_PH_C	BOOLEAN	Phase C object selected
EXE_OP_A	BOOLEAN	Executes the command for phase A open direction
EXE_OP_B	BOOLEAN	Executes the command for phase B open direction
EXE_OP_C	BOOLEAN	Executes the command for phase C open direction
EXE_CL_A	BOOLEAN	Executes the command for phase A close direction
EXE_CL_B	BOOLEAN	Executes the command for phase B close direction
EXE_CL_C	BOOLEAN	Executes the command for phase C close direction
OPENPOS_A	BOOLEAN	Apparatus phase A open position
OPENPOS_B	BOOLEAN	Apparatus phase B open position
OPENPOS_C	BOOLEAN	Apparatus phase C open position
CLOSEPOS_A	BOOLEAN	Apparatus phase A close position
CLOSEPOS_B	BOOLEAN	Apparatus phase B close position
CLOSEPOS_C	BOOLEAN	Apparatus phase C close position
OKPOS_A	BOOLEAN	Apparatus phase A position is ok
OKPOS_B	BOOLEAN	Apparatus phase B position is ok
OKPOS_C	BOOLEAN	Apparatus phase C position is ok
OPEN_ENAD_PH_A	BOOLEAN	Opening phase A is enabled based on input status
OPEN_ENAD_PH_B	BOOLEAN	Opening phase B is enabled based on input status
OPEN_ENAD_PH_C	BOOLEAN	Opening phase C is enabled based on input status
CLOSE_ENAD_PH_A	BOOLEAN	Closing phase A is enabled based on input status
CLOSE_ENAD_PH_B	BOOLEAN	Closing phase B is enabled based on input status
CLOSE_ENAD_PH_C	BOOLEAN	Closing phase C is enabled based on input status

5.1.7 Settings

Table 291: 52 Non group settings

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

5.1.8 Monitored data

Table 292: 52 Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication
PHASE_A	DbPos	0=Intermediate 1=open 2=closed 3=faulty		Apparatus phase A Position indication
PHASE_B	DbPos	0=Intermediate 1=open 2=closed 3=faulty		Apparatus phase B Position indication
PHASE_C	DbPos	0=Intermediate 1=open 2=closed 3=faulty		Apparatus phase C Position indication

5.2 Autoreclosing 79

The RER620 single-phase tripping and reclosing option is advantageous for use on many electric utility distribution systems, including rural, residential and some commercial loads. It supports both conventional three phase auto-reclosing and single phase auto-reclosing.

It provides a control capability function of the recloser to trip and/or lockout whenever there is a fault on one-phase, two-phases or three-phases. This feature allows an electric utility to prevent unnecessary three-phase interruptions and outages of their distribution network where a majority of outages can be attributed to single-phase transient type faults thereby improving the overall power system reliability and quantity of power delivered to customers on the distribution feeder.

The operation of the autoreclosing function can be described by using a module diagram.

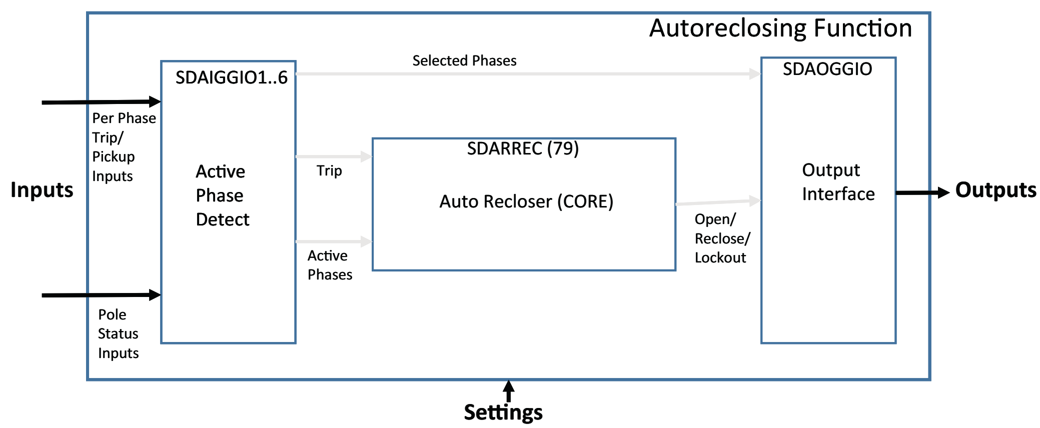


Figure 138: Conceptual auto-reclosing function diagram

The full Autorecloser functionality consists of 3 sections or parts.

The first part of the function consists of SDAIGGIO function blocks determines which phase(s), if any, are to be tripped. This determination is based on the condition of each phase (whether tripped, only picked up or already open).

The second part of the function SDARREC block invokes the core autorecloser function, which determines whether / when to reclose / lockout etc.

The third part of the function consist of SDAOGGIO block distributes the autorecloser outputs to the phases currently active, as determined by the first part of the function.

The connections between these functions (shown as passive lines) are internal and not visible in the application configuration.

Inputs to the function consist of per phase trip / pickup signals from various protection functions, and the states of all poles, if any of them is / are open. Outputs from the function consist of per phase breaker open / close commands, and lockout signals.

Input and output function blocks are basically support function blocks. Though these functions are instantiated independently, they don't have their own settings. The core autorecloser function which is called SDARREC and all the parameter settings to the overall functionality are updated only in this function block. This is the reason the overall Autorecloser (AR) functionality is called with the same name.

5.2.1 Identification

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

5.2.2 Function block

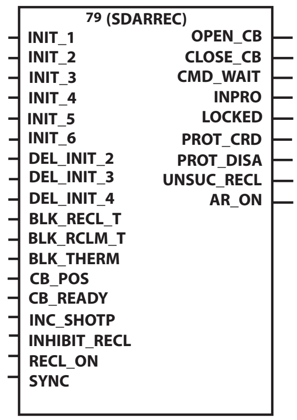


Figure 139: SDARREC 79 core function block

5.2.2.1 Supporting function blocks

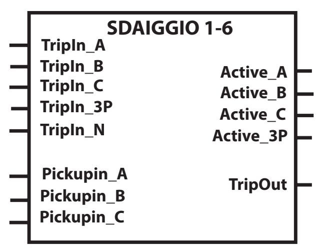


Figure 140: SDAIGGIO function blocks (1…6)

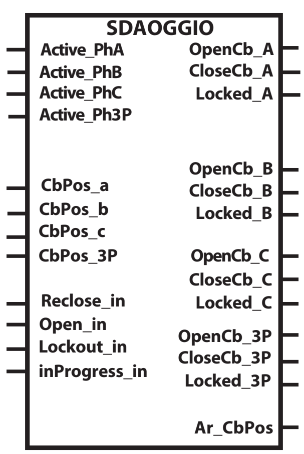


Figure 141: SDAOGGIO Function Block

5.2.3 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.

In a distribution network, bulk of the load is single phase / independent. It is therefore not necessary to de-energize all three phases for a single phase fault. The single phase auto-reclose function SDARREC can be used for auto-reclosing together with any circuit breaker that has the characteristics required for single phase auto-reclosing. For multi-phase asymmetrical faults, the trip should occur on the tripped as well as the picked up phases.

The function provides five programmable auto-reclose shots which can perform one to five successive auto-reclosings of desired type and duration, for instance one high-speed and one delayed auto-reclosing.

The SDARREC allows single phase operations, where the number of poles operating together can be one, two or three, depending on fault conditions. Once a fault occurs, the "Active Phase Detection" function determines which phases are to be active for the next reclose shot.

The autorecloser function used by the SDARREC receives equivalent “TRIP”, “PoleStatus”, etc. signals that are formed by integrating individual phase signals from the active phases. It performs its logic and generates equivalent OPEN / RECLOSE / LOCKOUT etc. signals. Subsequent logic then routes these signals to the appropriate, “active” phase outputs.

5.2.3.1 Single phase tripping

The single phase tripping function is controlled by the settings SinglePhaseMode and Shot Mode 1...5. The SinglePhaseMode setting can have three values, OPUP, OOAP and APAT.

The value OPUP stands for “Only Picked Up Phases”. With this value, the SDARREC will trip the tripped and picked up phases. Unfaulted phase(s) will stay closed.

The value OOAP stands for “One Or All Phases”. With this value, the SDARREC will trip the tripped and picked up phases as in the OPUP mode. Additionally, it will also look at whether only one phase is going to be left closed as a result of the OPUP logic. If so, it will trip the remaining phase as well.

The value APAT stands for “All Poles All the Time”, and effectively disables the single phase mode. All the poles are operated always.

In addition, the Shot Mode settings can override the SinglePhaseMode setting for each specific reclose shot, and on a per autorecloser input basis. These settings values can be either 0 or 1. When the value is 0, the SinglePhaseMode setting determines the number of phases opening. When the value is 1, all three poles will open, regardless of the SinglePhaseMode setting.

5.2.3.2 Protection signal definition

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

Table 293: Control line setting definition

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

prot = protection signal
other = non-protection signal

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

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

It is emphasized that the three phases of the same protection function should be fed to the same INIT input to the autorecloser.

5.2.4 Operation principle

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

Setting the *Operation* setting to “Off” will prevent tripping by any protection function!

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.

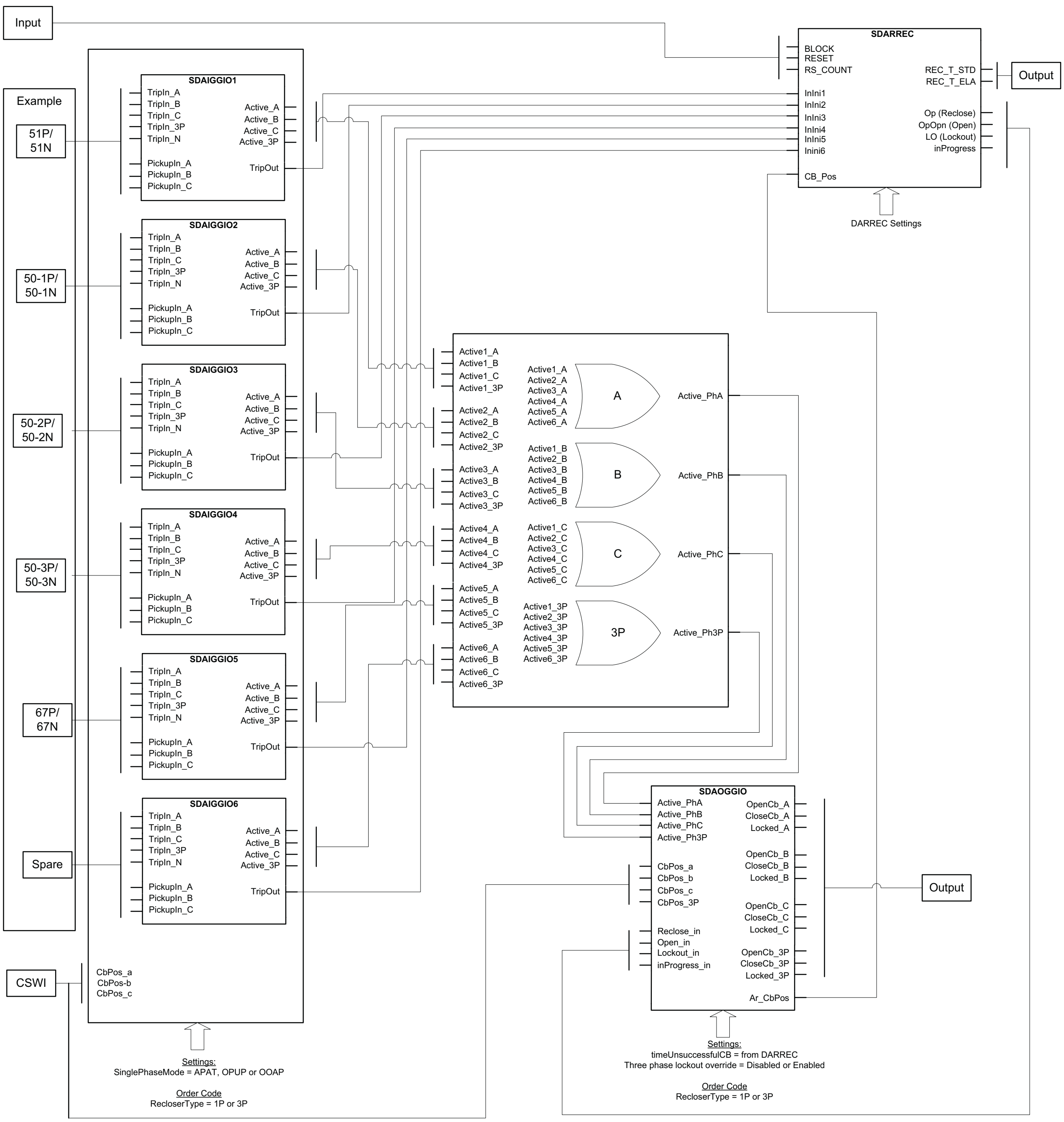


Figure 142: Logical overview diagram with internal connections in overall Autoreclosing functionality

The logical diagram showing internal connections between SDAIGGIO input blocks, SDARREC Core block and SDAOGGIO output block is shown in Figure 142.

The 3 sections of overall Autorecloser functionality explained below.

5.2.4.1 Active Phases Determination with SDAIGGIO Blocks

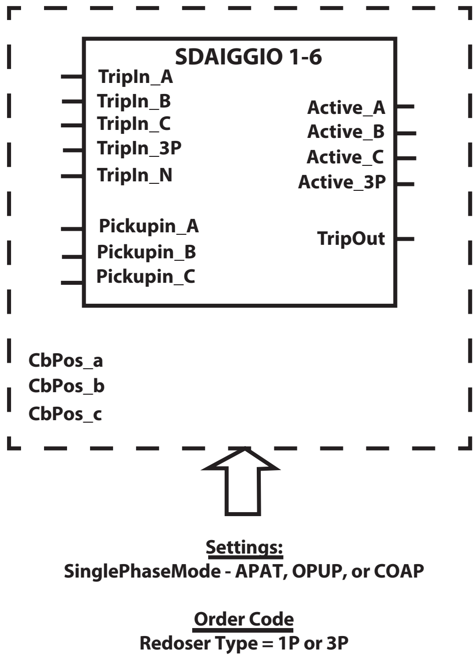


Figure 143: SDAIGGIO function block

The input section, consists of 6 modular supporting functional blocks called SDAIGGIO1..6, collates various signal phase trip / pickup signals from different single phase protection functions. It uses the logic described below to determine which phases are to be activated for this reclose cycle, and tailors its outputs to be fed to the autorecloser / output functions.

SDAIGGIO 1 ..6

A functional block diagram is shown in Figure 143. It shows one SDAIGGIO block for autorecloser function input. There are six such blocks altogether. They are not independent function blocks and they are instantiated as part of overall autoreclosing functionality.

The Autoreclosing function allows a picked up / unfaulted phase to trip along with the faulted phase. The picked up phase is tripped, as it is presumed to be a part of the same multi-phase fault, though with a lower fault current. An unfaulted phase may also be tripped in case it is not advisable for only one phase to remain energized after the breaker opens.

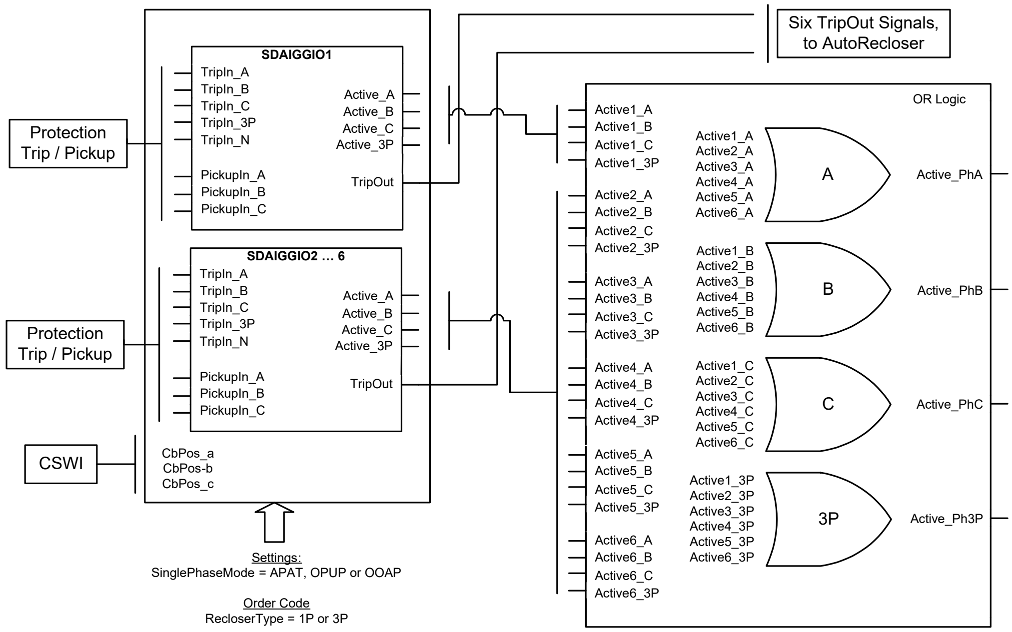


Figure 144: Active phase determination

This feature is implemented by the SDAIGGIO block. It accepts trip / pickup signals from a protection function and determines (based on settings) which phases are to be tripped. It then generates one TRIP output, along with which phases are active.

The SDAIGGIO feature consists of the following three modes:

OPUP: (Only Picked Up Phases)

- For a phase fault, once a phase protection function generates a trip command, the other phases are examined for a picked up state. If another phase is in a "picked up" state, that phase is also issued a trip command.
- For a neutral fault, all the picked up phases are tripped. If no phase is picked up, then all phases are tripped. The neutral picked up signal is not used.
- Reclose operations are synchronized between poles.

OOAP: (One Or All Phases)

- In this case, the trip decision is made in steps:
- First, the OPUP mode is used to determine which phase(s) will be tripped.
- Second, the state of poles is considered. A pole may already be open due to an earlier trip (operate) / lockout or a manual / scada operation.
- If the decision in the first step will leave exactly one phase in a CLOSED state, then that phase is also issued a trip command.
- As an example, consider the following sequence:
- “A” phase sees a fault; “B” and “C” were not picked up. Only the “A” phase is tripped, and locks out after the reclose cycle.

- Later, after “A” phase locks out, but before it is restored, “B” phase sees a fault, and “C” is not picked up. Using the OPUP logic, only the “B” phase would have been tripped. However, this would leave only the “C” phase CLOSED. In the OOAP mode, the “C” phase will also be tripped, though it does not have a fault.
- Reclose operations are synchronized between poles.

APAT: (All Poles All the Time)

- In this case, the single phase function is disabled. The recloser operates as a three phase recloser. However, we still have three actuators and three position sensors for the three poles, so the controls must operate independently. However, for any fault, the trip, reclose, lockout signals are issued to all three phases.

SDARREC “OR” logic function

The SDARREC has six SDAIGGIO functions. Each will operate independent of the others. The “OR” logic function combines the “Active Phase” outputs from the six SDAIGGIO blocks and generates one set of combined “Active Phase” outputs for use by the output SDAOGGIO function. Its functional block is as shown in Figure 144 above. . This entire "OR" logic along with output channels of SDAGGIO blocks connected to SDARREC function block through fixed internal connections which are not visible in the application configuration.

5.2.4.2 Autorecloser function (Core)

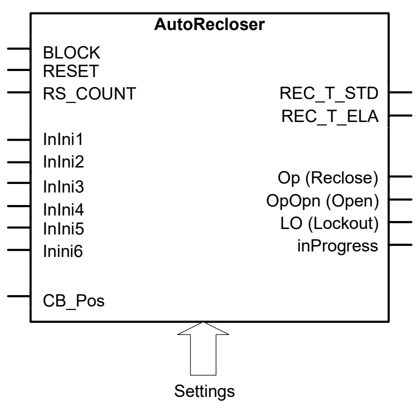


Figure 145: Autorecloser (core) function block

The autorecloser function accepts "TRIP" signals from the input functions and generates the appropriate reclose / open / lockout signals, for use by the output function. The operation of the auto-reclose function can be described by using a module diagram (Figure 146). All the blocks in the diagram are explained in the next sections.

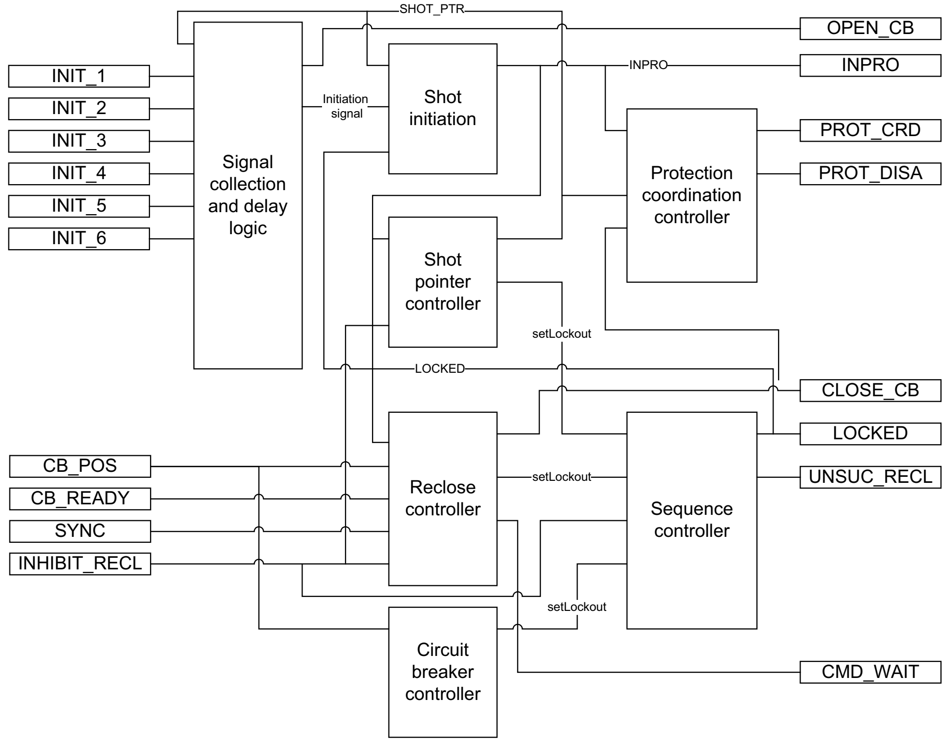


Figure 146: Autorecloser functional module diagram

Signal collection

When the protection trips, the initiation of autoreclose shots is in most applications executed with the `INIT_1...6` inputs.

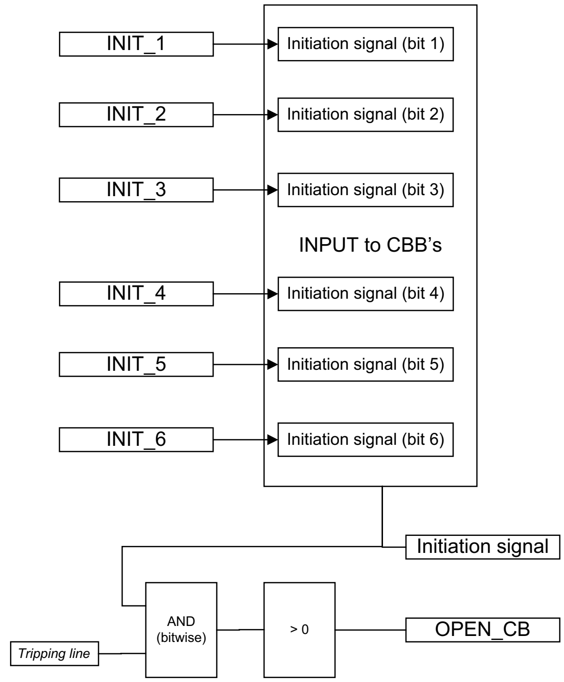


Figure 147: Initiation input signals

In total, the AR function contains six separate initiation lines used for the initiation or blocking of the auto-reclose shots.

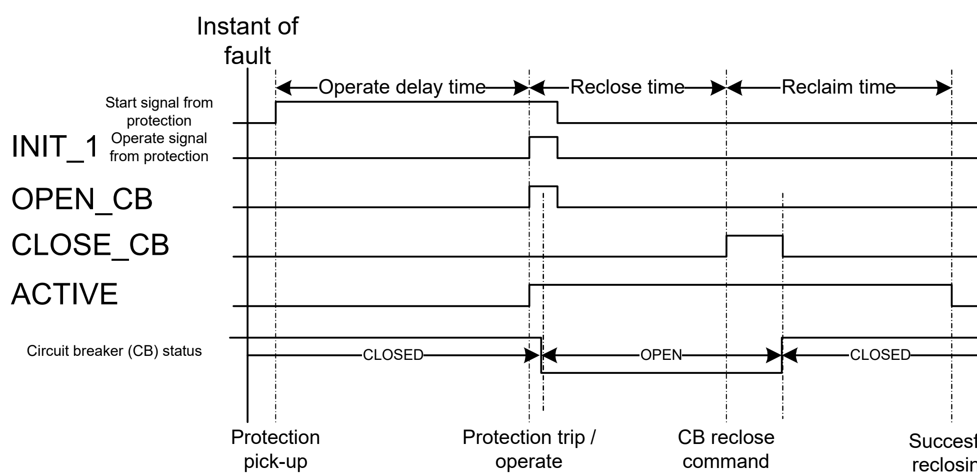


Figure 148: Signal scheme of auto-reclose operation initiated with protection operate signal

The auto-reclose shot is initiated with a trip signal of the protection function. The auto-reclose starts when the protection operate delay time elapses. Normally, all trip and start signals are used to initiate an auto-reclose shot and trip the circuit breaker. If any of the input signals 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.

Shot initiation

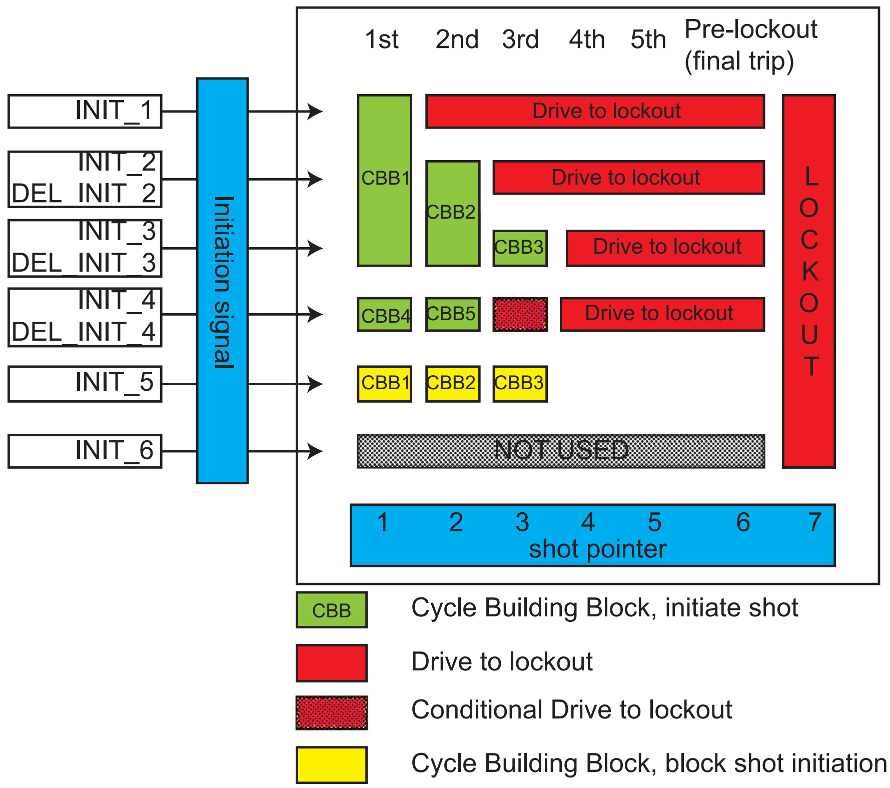


Figure 149: Example of an autoreclose program with a reclose scheme matrix

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

The settings related to CBB configuration are:

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

The reclose time defines the open and dead times, that is, the time between the `OPEN_CB` and the `CLOSE_CB` commands. The *Init signals CBBx* setting defines the initiation signals. The *Blk signals CBBx* setting defines the blocking signals that are related to the

CBB (rows in the matrix). The *Shot number CBB1…CBB7* setting defines which shot is related to the CBB (columns in the matrix). For example, CBB1 settings are:

- *First reclose time* = 1.0s
- *Init signals CBB1* = 7 (three lowest bits: 000111 = 7)
- *Blk signals CBB1* = 16 (the fifth bit: 010000 = 16)
- *Shot number CBB1* = 1

CBB2 settings are:

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

CBB3 settings are:

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

CBB4 settings are:

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

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

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

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

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

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

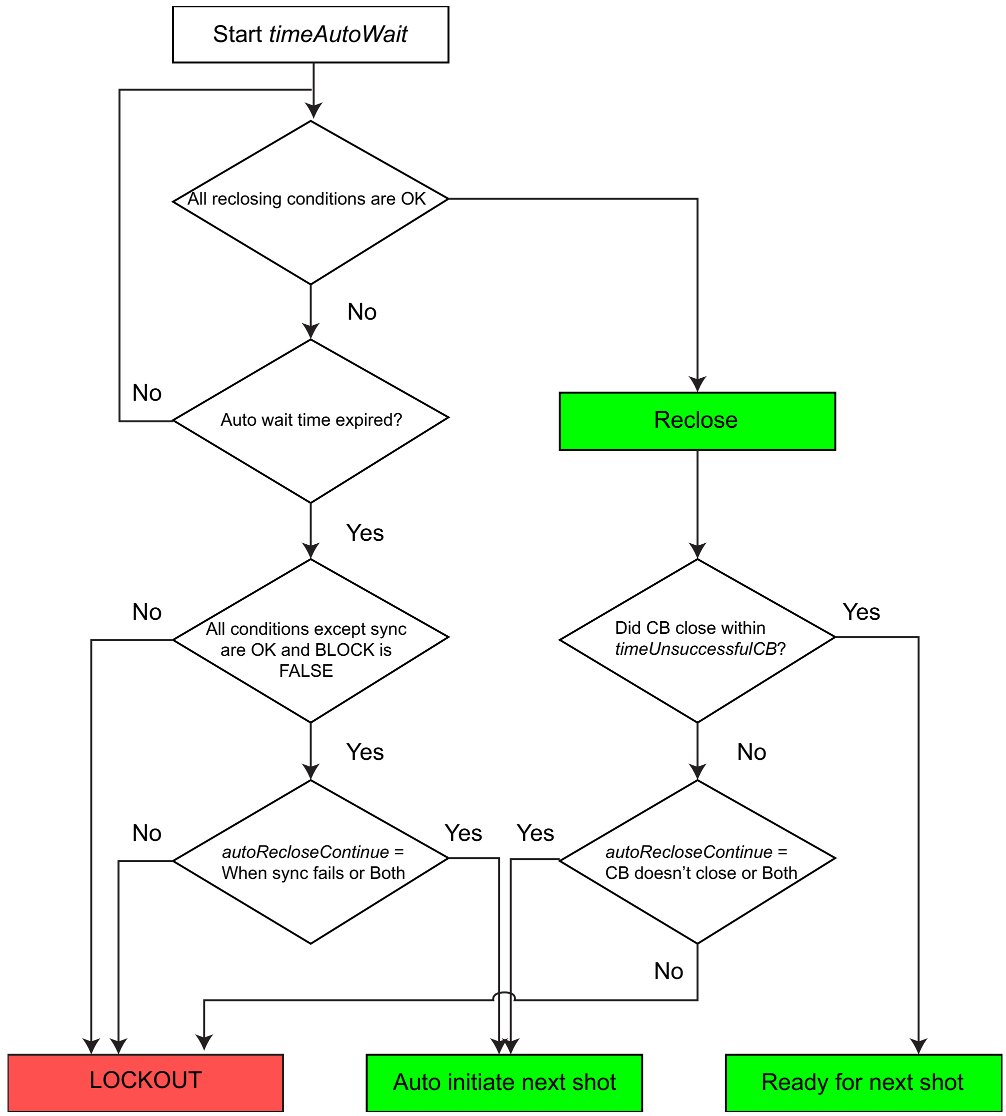


Figure 150: Logic diagram of auto-initiation sequence detection

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.

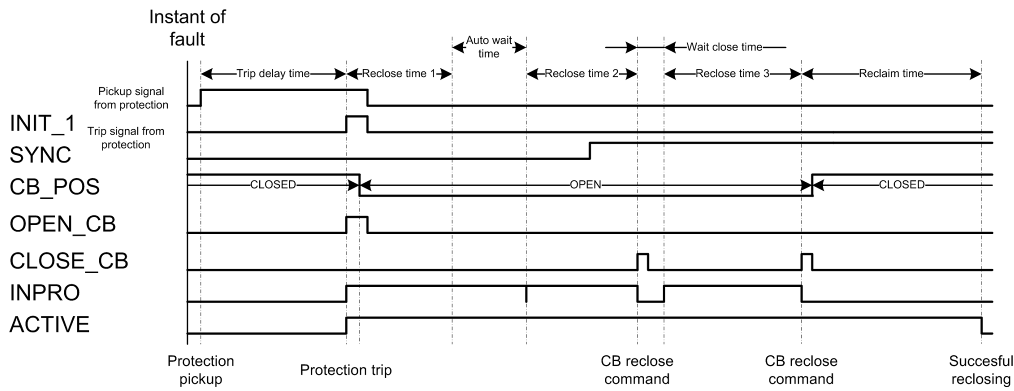


Figure 151: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

Shot initiation and shot sequencing Possibilities

The autoreclose function is initiated after the protection has detected a fault, issued a trip and opened the breaker. One input is enough for initiating the function.

The function consists of six individual initiation lines `INIT_1, INIT_2... INIT 6`. The user can use as many of the initiation lines as required. Using only one line makes setting easier, whereas by using multiple lines, higher functionality can be achieved. Basically, there are no differences between the initiation lines.

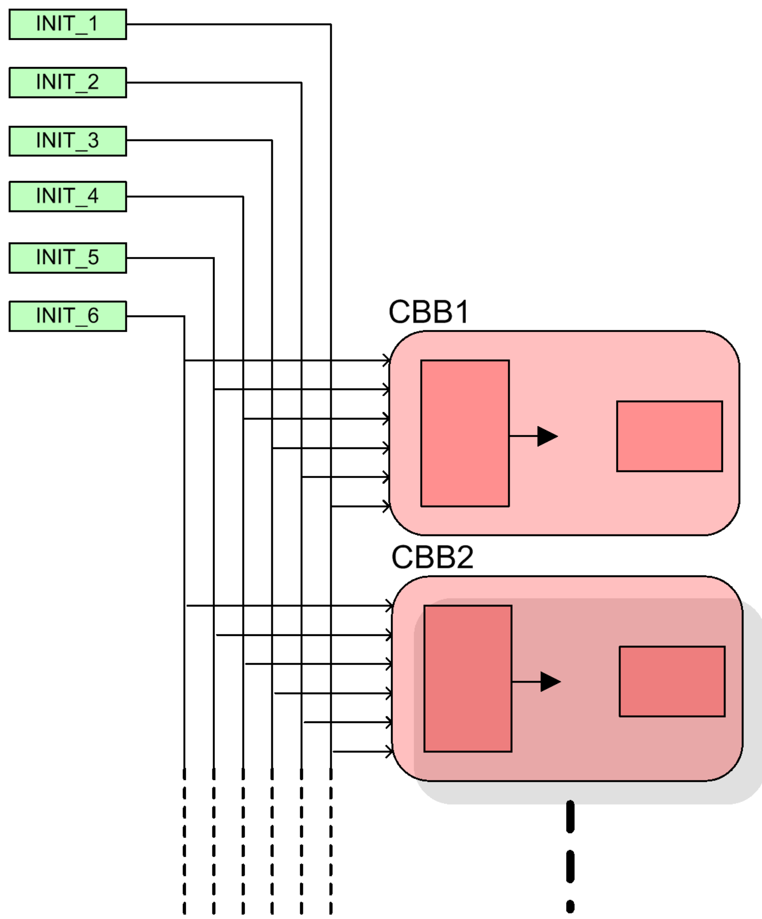


Figure 152: Simplified CBB initiation diagram

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

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

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

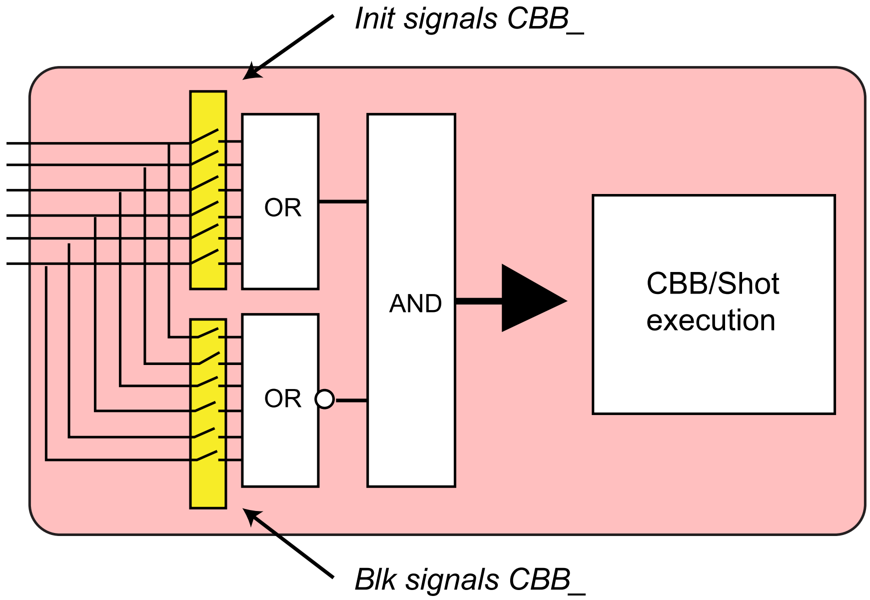


Figure 153: Simplified CBB diagram

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

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

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

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

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

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

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

- Only such CBBs that are set for the next shot in the sequence can be accepted for execution. For example, if the next shot in the sequence should be shot 2, a request from CBB set for shot 3 is rejected.
- Any CBB that is set for the next shot or any of the following shots can be accepted for execution. For example, if the next shot in the sequence should be shot 2, also CBBs that are set for shots 3, 4 and 5 are accepted. In other words, shot 2 can be ignored.

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

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

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.

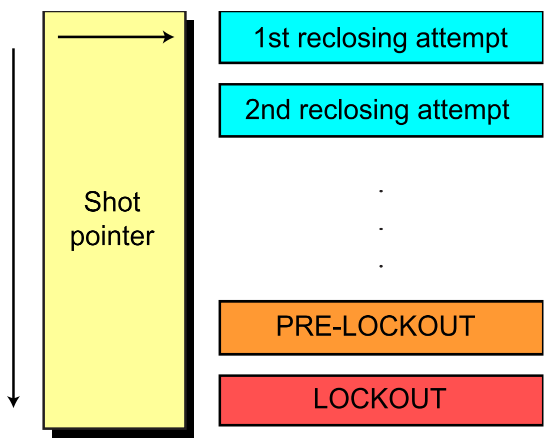


Figure 154: Shot pointer function

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:

- 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.

Reclose controller

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

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

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

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

The synchronism requirement for the CBBs can be defined with the *Synchronization set* setting, which is a bit mask. The lowest bit in the *Synchronization 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.

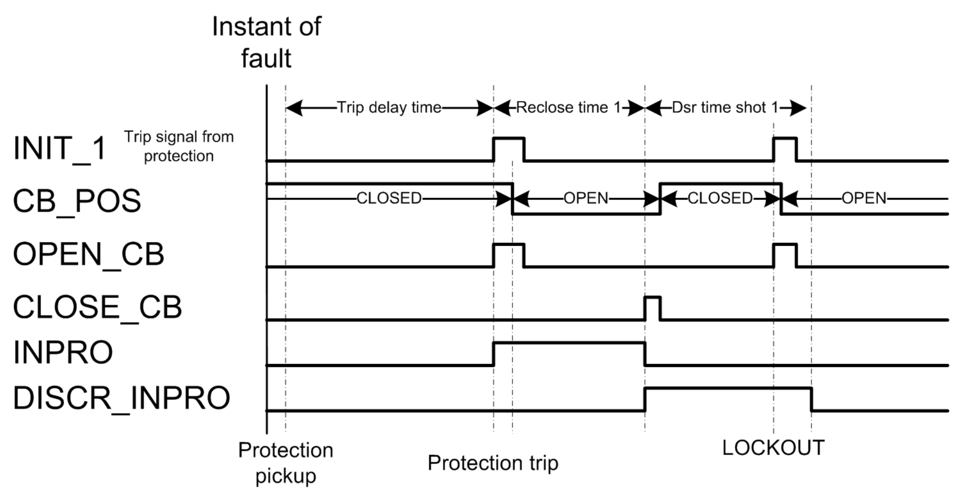


Figure 155: Initiation during discrimination time - AR function goes to lockout

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

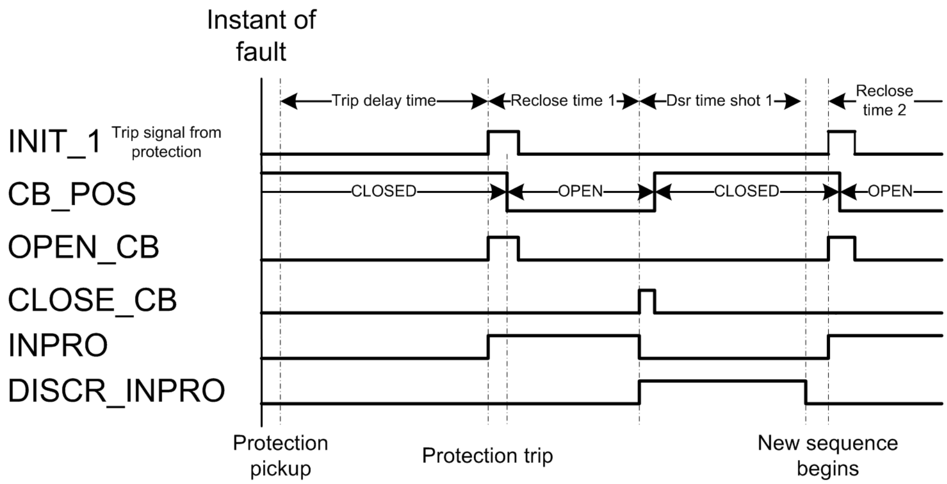


Figure 156: Initiation after elapsed discrimination time - new shot begins

Sequence controller

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

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

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

The AR function can go to lockout for many reasons:

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

- The circuit breaker is closed manually during an autoreclose sequence and the manual close mode is FALSE.

Protection coordination controller

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

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

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

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

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

- "no condition": the PROT_CRD output is controlled only with the *Protection crd limit* setting
- "AR inoperative": the PROT_CRD output is active, if the AR function is disabled or in the lockout state, or if the INHIBIT_RECL input is active
- "CB close manual": the PROT_CRD output is active for the reclaim time if the circuit breaker has been manually closed, that is, the AR function has not issued a close command
- "AR inop, CB man": both the modes "AR inoperative" and "CB close manual" are effective
- "always": the PROT_CRD output is constantly active

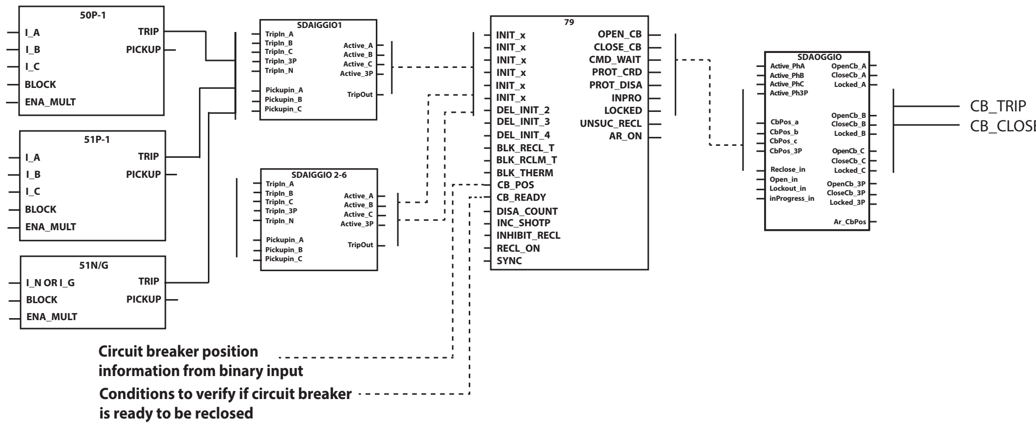


Figure 157: Configuration example of using the `PROT_CRD` *output for protection blocking*

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

Circuit breaker controller

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

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

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

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

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

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

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

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

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

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

The frequent-operation counter has three settings:

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

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

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

5.2.4.3 Output Interface with SDAOGGIO Block

This consists of the function block SDAOGGIO, shown in Figure 158 below.

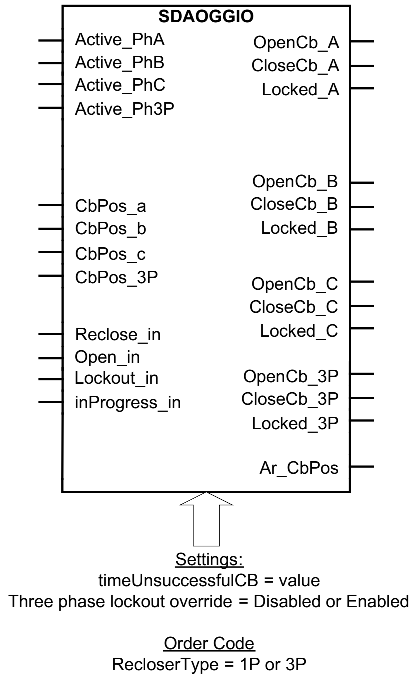


Figure 158: SDAOGGIO Function Block

This module combines the outputs from the AutoRecloser function and the “Active Phase Detect” function to route the TRIP / RECLOSE / LOCKOUT signals to the phases that are active for the reclose cycle in progress currently.

The autorecloser function requires a single “Pole Status” signal for its internal needs. However, the SDARREC function can allow operations on more than one phase at a time. Two or three phases can be active at the same time.

When more than one pole is active, the SDAOGGIO will generate an equivalent “pole status” signal for the AutoReclose function. Although all the TRIP / RECLOSE commands are issued simultaneously, one pole may operate with a delay compared to the other(s). In such cases, the SDAOGGIO will wait for all the active poles to complete their transition before generating a valid status to be used by the AutoRecloser function.

5.2.5 Zone sequence coordination

Zone sequence 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.

5.2.6 Counters

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

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

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

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

5.2.7 Application

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

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

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

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

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

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

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

Table 294: Important definitions related to autoreclosing

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

5.2.7.1 Single Phase Tripping

The RER620 single-phase tripping and reclosing option is advantageous for use on many electric utility distribution systems, including rural, residential and some commercial loads. It provides a control capability function of the recloser to trip and/or lockout whenever there is a fault on one-phase, two-phases or three-phases. This feature allows an electric utility to prevent unnecessary three-phase interruptions and outages of their distribution network where a majority of outages can be attributed to single-phase transient type faults thereby improving the overall power system reliability and quantity of power delivered to customers on the distribution feeder.

Overview of the features in single-phase tripping

As an example of single-phase operation of an RER620 with a recloser, imagine that the recloser is protecting a rural three-phase line. Suppose that a fault occurs on A-phase, where the fault is permanent and there is no fuse between the recloser and the fault. A conventional three-phase recloser will trip for two instantaneous operations followed by two time-delayed operations. The single-phase fault on A-phase will cause all customers downstream to experience three interruptions of power and an outage until the fault is repaired, cleared and the recloser restored to normal operation. The RER620 with single-phase tripping can operate the recloser for the same single-phase fault on A-phase as a single-pole trip, reclose and lockout. This provides a significant advantage to 67% of the customers downstream of the fault since their power is not interrupted. The operation of single-phase operation will trip for two instantaneous operations, two time-delayed operation and lockout on the A-phase pole. Since the fault is a permanent single-phase-to-ground fault, (e.g. A-N), the load connected to A-phase will experience an outage but the other two phases (e.g. B-phase and C-phase) will not experience any interruption of power and will stay energized.

The single phase tripping option is designed to be extremely flexible in order to meet the most demanding requirements. Listed below are brief descriptions of the features for single-phase and three-phase tripping operation:

RER620s supplied with the single phase tripping option consist of the same hardware (front panel and modules) as the standard three phase units. Settings for single phase tripping RER620s, however, vary from the three phase units. With this option, you must select whether you want to use the single phase tripping option or not in SDARREC Settings. In three-phase tripping mode, the RER620 operates in the same manner as a unit without the single-phase tripping option. Single-phase tripping is disabled. Three-phase tripping is enabled.

In single-phase tripping mode, the phase that detects fault current (e.g., current above the pickup threshold level) will initiate the recloser respective pole to trip open. In this mode, for each protection group, the user may choose one of three modes of operation for single-phase tripping: APAT (All Poles All the Time), OPUP (Only Picked Up Phases) and OOAP (One Or All Phases).

Conditions on Single Phase Tripping

- When there is a single-phase fault and there is another phase that becomes involved, the additional phase will immediately time out and trip on the curve associated with the step that the other phase has tripped on last. However, all tripped phases will reclose in tandem.
- When a single phase has locked out, the reset timer will count down from its set value in the recloser settings. If another phase becomes involved before the reset time expires, that phase will operate one shot to lockout. If, alternatively, the reset timer has expired, the additional involved phase will go through the full sequence of programmed operations.
- In single-phase tripping, the phase fault current must be greater than the phase element pickup for the single-phase trip to occur. If the fault current is above the neutral setting, but below the phase setting, a three-phase trip will occur.
- In the case where both the phase and ground element pick up (all phases must be closed for neutral pickup), the trip time for the involved phases will be based on the faster of the phase trip or the ground setting.
- After a single phase trip or lockout operation, all ground tripping is de-energized. This prevents nuisance tripping of adjacent phases afterwards, due to load imbalance.

OPUP Mode - Only Picked Up Phases

If OPUP is selected, any respective phase that detects fault current by the RER620 is actuated to open the respective pole of the recloser. The option for OPUP also allows each pole on the recloser to open independently if the RER620 detects fault current on any of the other two phases.

For example, suppose that a fault is detected on phase B. The RER620 will sense this pickup and initiate a binary output signal from the RER620 to the recloser, the recloser will trip open phase B and await timing from the RER620 for subsequent reclose or lockout. Now suppose that during the pickup and subsequent trip of phase B, the RER620 senses another fault on phase A. The RER620 will detect that fault and initiate a binary output signal from the RER620 to the recloser for pole A, the recloser will trip open phase A and then await timing from the RER620 for reclose or lockout. Comparable sequences may occur and operation of the RER620 will continue to operate for phase C or any combination of phase(s) caused by excessive load or fault current.

OOAP Mode - One Or All Phases

In this mode, if a single-phase fault is detected or picked up on one pole, a single-phase trip will occur as in the case of OPUP mode. However, if a combination of two or three phases pickup or detect a fault, then the RER620 will initiate a binary trip output to the recloser for all three poles to trip.

For example, consider a situation where the distribution load has motors connected onto the distribution line. If a single-phase fault occurred on any phase of the line, the RER620 should initiate a trip of all three phases, OOAP, to prevent the three-phase motors from single phasing. A three-phase motor may continue to run with the loss of a single-phase, but it will overheat. In addition, a stopped three-phase motor that is attempting to start with the loss of a single-phase will cause overheating in the motor. For this application, a distribution line with three-phase motors should implement OOAP on single-phase faults.

Some common examples:

- The recloser is set to trip on a single-phase fault in single-phase fashion, but lockout in three-phase fashion (OOAP). A fault is detected and the recloser trips open on one phase and will lockout on all three phases if the fault detected is a permanent fault.
- The recloser is set to trip on a single-phase fault (OOAP). A two-phase fault is detected and the recloser trips open on all three-phases and will lockout on all three phases if the fault detected is a permanent fault.

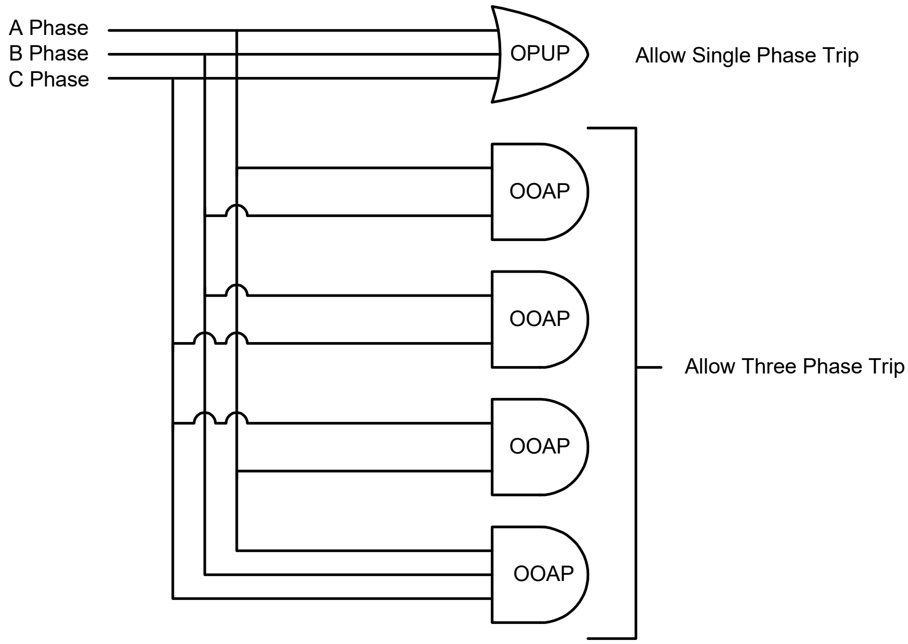


Figure 159: OOAP mode logic

Summary of Single-Phase Tripping

The following diagrams illustrates overall logical diagram, the state of different poles for different faults, based on the settings in use.

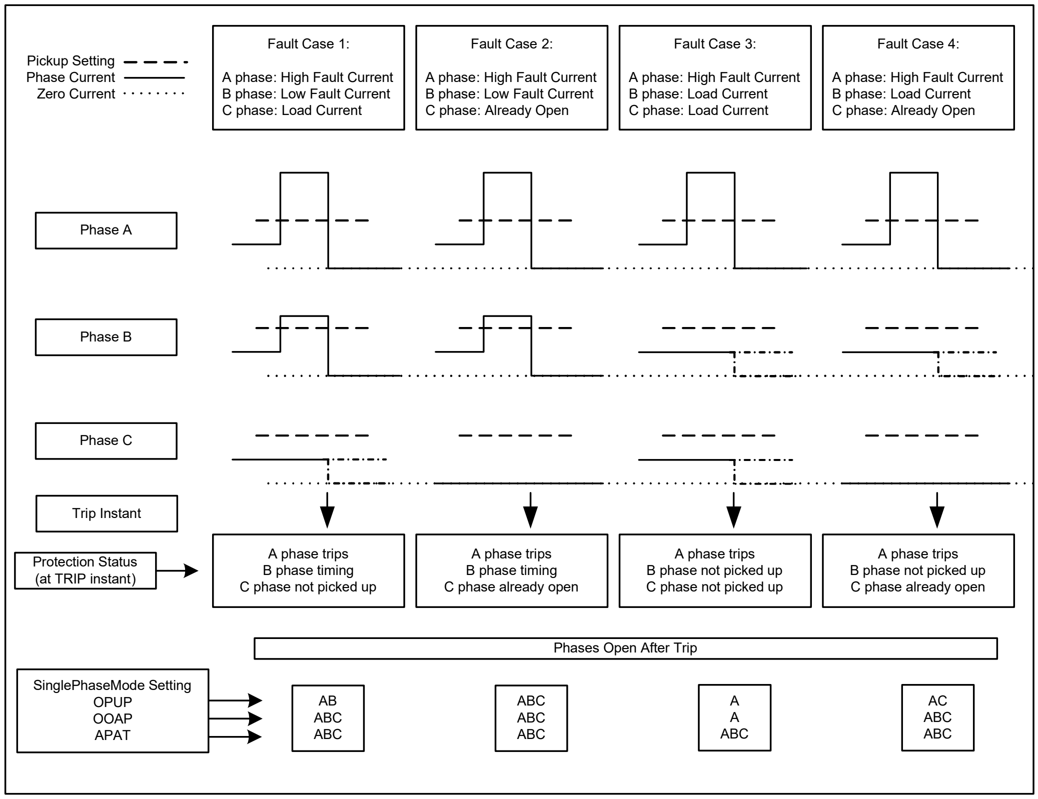


Figure 160: Summary of single-phase tripping

5.2.8 Configuration examples

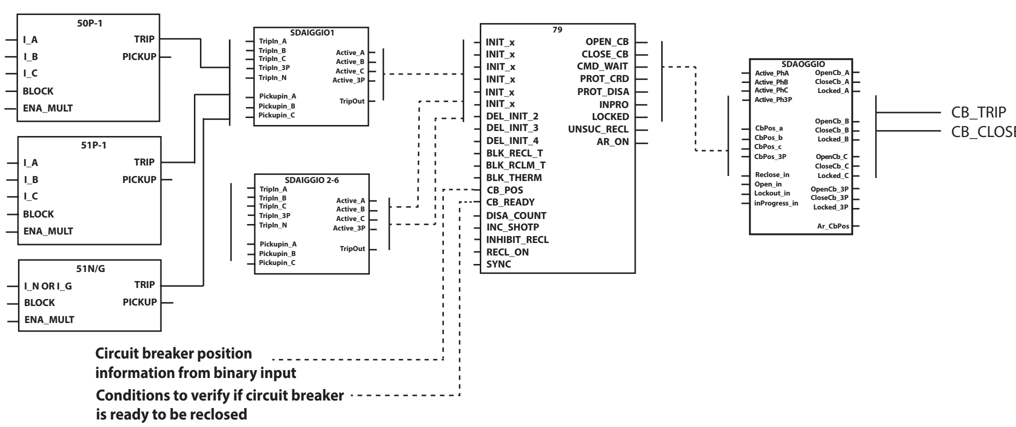


Figure 161: Example connection between protection and autoreclose functions in relay configuration

It is possible to create several sequences for a configuration.

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

Example 1

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

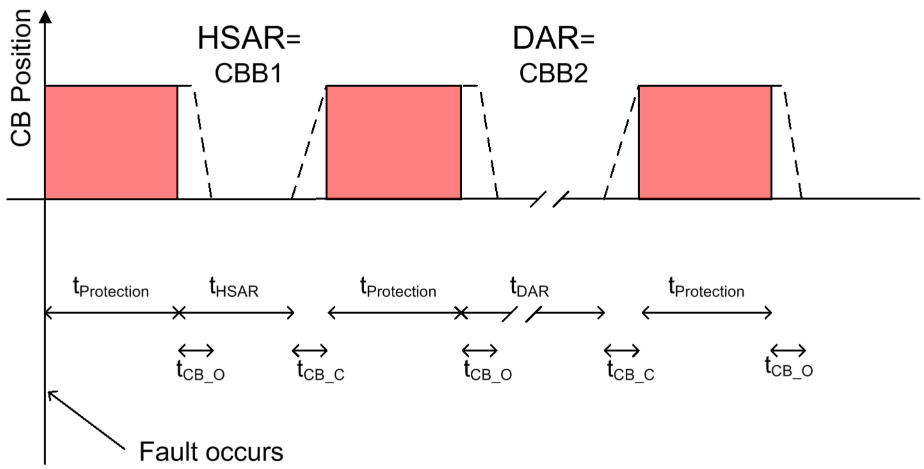


Figure 162: Autoreclose sequence with two shots

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

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

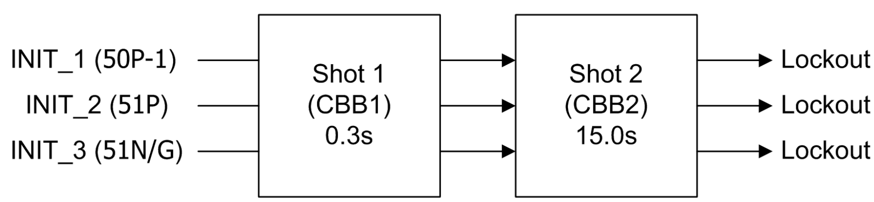


Figure 163: Two shots with three initiation lines

Table 295: Settings for configuration example 1

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

Example 2

There are two separate sequences implemented with three shots. Shot 1 is implemented by CBB1 and it is initiated with the high stage of the overcurrent protection (50P-1). Shot 1 is set as a high-speed autoreclosing with a short time delay. Shot 2 is implemented with CBB2 and meant to be the first shot of the autoreclose sequence initiated by the low stage of the overcurrent protection (51P) and the low stage of the non-directional ground-fault protection (51N/G). It has the same reclose time in both situations. It is set as a high-speed autoreclosing for corresponding faults. The third shot, which is the second shot in the autoreclose sequence initiated by 51P or 51N/G, is set as a delayed autoreclosing and executed after an unsuccessful high-speed autoreclosing of a corresponding sequence.

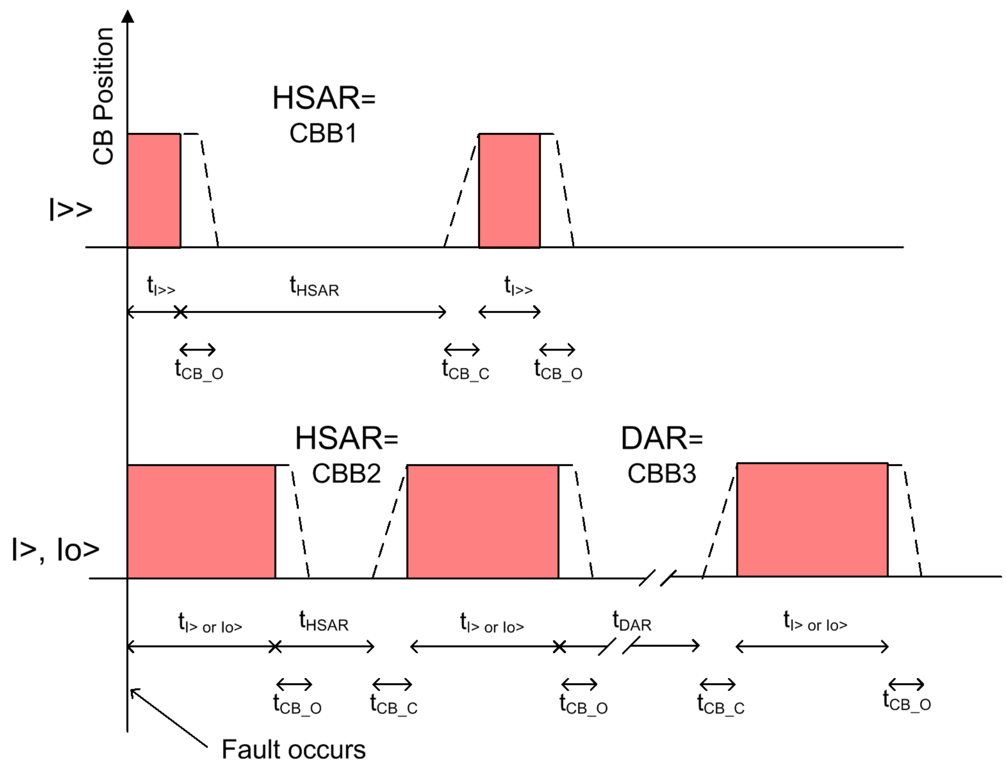


Figure 164: Autoreclose sequence with two shots with different shot settings according to initiation signal

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

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

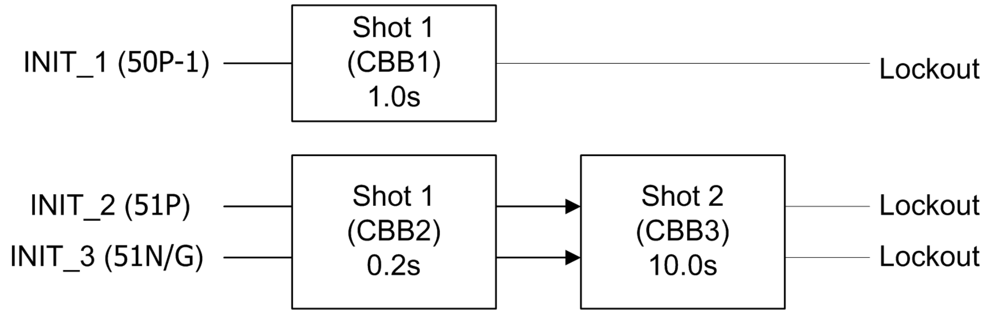


Figure 165: Three shots with three initiation lines

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

Table 296: Settings for configuration example 2

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	1 (line 1)
First reclose time	1.0s (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

5.2.9 Signals

Table 297: 79 input signals

Name	Type	Default	Description
TRIP_1A	Binary	0=False	AR initialization / trip signal, input 1, phase A
TRIP_1B	Binary	0=False	AR initialization / trip signal, input 1, phase B
TRIP_1C	Binary	0=False	AR initialization / trip signal, input 1, phase C
TRIP_1_3P	Binary	0=False	AR initialization / trip signal, input 1, three phase
TRIP_1N	Binary	0=False	AR initialization / trip signal, input 1, neutral
PICKUP_1A	Binary	0=False	AR start / pickup signal, input 1, phase A
PICKUP_1B	Binary	0=False	AR start / pickup signal, input 1, phase B
PICKUP_1C	Binary	0=False	AR start / pickup signal, input 1, phase C
TRIP_2A	Binary	0=False	AR initialization / trip signal, input 2, phase A
TRIP_2B	Binary	0=False	AR initialization / trip signal, input 2, phase B
TRIP_2C	Binary	0=False	AR initialization / trip signal, input 2, phase C
TRIP_2_3P	Binary	0=False	AR initialization / trip signal, input 2, three phase
TRIP_2N	Binary	0=False	AR initialization / trip signal, input 2, neutral
PICKUP_2A	Binary	0=False	AR start / pickup signal, input 2, phase A
PICKUP_2B	Binary	0=False	AR start / pickup signal, input 2, phase B
PICKUP_2C	Binary	0=False	AR start / pickup signal, input 2, phase C
TRIP_3A	Binary	0=False	AR initialization / trip signal, input 3, phase A
TRIP_3B	Binary	0=False	AR initialization / trip signal, input 3, phase B
TRIP_3C	Binary	0=False	AR initialization / trip signal, input 3, phase C
TRIP_3_3P	Binary	0=False	AR initialization / trip signal, input 3, three phase
TRIP_3N	Binary	0=False	AR initialization / trip signal, input 3, neutral
PICKUP_3A	Binary	0=False	AR start / pickup signal, input 3, phase A
PICKUP_3B	Binary	0=False	AR start / pickup signal, input 3, phase B
PICKUP_3C	Binary	0=False	AR start / pickup signal, input 3, phase C
TRIP_4A	Binary	0=False	AR initialization / trip signal, input 4, phase A
TRIP_4B	Binary	0=False	AR initialization / trip signal, input 4, phase B
TRIP_4C	Binary	0=False	AR initialization / trip signal, input 4, phase C
TRIP_4_3P	Binary	0=False	AR initialization / trip signal, input 4, three phase
TRIP_4N	Binary	0=False	AR initialization / trip signal, input 4, neutral
PICKUP_4A	Binary	0=False	AR start / pickup signal, input 4, phase A
PICKUP_4B	Binary	0=False	AR start / pickup signal, input 4, phase B
PICKUP_4C	Binary	0=False	AR start / pickup signal, input 4, phase C
TRIP_5A	Binary	0=False	AR initialization / trip signal, input 5, phase A
TRIP_5B	Binary	0=False	AR initialization / trip signal, input 5, phase B
TRIP_5C	Binary	0=False	AR initialization / trip signal, input 5, phase C
TRIP_5_3P	Binary	0=False	AR initialization / trip signal, input 5, three phase
TRIP_5N	Binary	0=False	AR initialization / trip signal, input 5, neutral
PICKUP_5A	Binary	0=False	AR start / pickup signal, input 5, phase A

Name	Type	Default	Description
PICKUP_5B	Binary	0=False	AR start / pickup signal, input 5, phase B
PICKUP_5C	Binary	0=False	AR start / pickup signal, input 5, phase C
TRIP_6A	Binary	0=False	AR initialization / trip signal, input 6, phase A
TRIP_6B	Binary	0=False	AR initialization / trip signal, input 6, phase B
TRIP_6C	Binary	0=False	AR initialization / trip signal, input 6, phase C
TRIP_6_3P	Binary	0=False	AR initialization / trip signal, input 6, three phase
TRIP_6N	Binary	0=False	AR initialization / trip signal, input 6, neutral
PICKUP_6A	Binary	0=False	AR start / pickup signal, input 6, phase A
PICKUP_6B	Binary	0=False	AR start / pickup signal, input 6, phase B
PICKUP_6C	Binary	0=False	AR start / pickup signal, input 6, phase C
CB_POS_A	Binary	0=False	Circuit breaker position signal, phase A
CB_POS_B	Binary	0=False	Circuit breaker position signal, phase B
CB_POS_C	Binary	0=False	Circuit breaker position signal, phase C
CB_POS_3P	Binary	0=False	Circuit breaker position signal, three phase
BLK_RECL_T	Binary	0=False	Blocks and resets reclose time
BLK_RCLM_T	Binary	0=False	Blocks and resets reclaim time
BLK_THERM	Binary	0=False	Blocking signal from thermal overload protection
INC_SHOTP	Binary	0=False	Sequence control signal
INHIBIT_RECL	Binary	0=False	Interrupts and inhibits reclosing sequence
RECL_ON	Binary	0=False	Level sensitive signal for allowing (high) / not allowing reclosing
SYNC	Binary	0=False	Synch-check signal

Table 298: 79 output signals

Name	Type	Description
OPEN_CB_A	Binary	Open command to Circuit Breaker, phase A
CLOSE_CB_A	Binary	(Re)close command to Circuit Breaker, phase A
LOCKED_A	Binary	Locked out, phase A
OPEN_CB_B	Binary	Open command to Circuit Breaker, phase B
CLOSE_CB_B	Binary	(Re)close command to Circuit Breaker, phase B
LOCKED_B	Binary	Locked out, phase B
OPEN_CB_C	Binary	Open command to Circuit Breaker, phase C
CLOSE_CB_C	Binary	(Re)close command to Circuit Breaker, phase C
LOCKED_C	Binary	Locked out, phase C
OPEN_CB_3P	Binary	Open command to Circuit Breaker, three phase
CLOSE_CB_3P	Binary	(Re)close command to Circuit Breaker, three phase
LOCKED_3P	Binary	Locked out, three phase
CMD_WAIT	Binary	Wait for master command
INPRO	Binary	Reclosing shot in progress, activated during reclose time
PROT_CRD	Binary	Protection coordination signal
UNSUC_RECL	Binary	reclosing sequence unsuccessful
AR_ON	Binary	status ON / OFF
READY	Binary	ready for new sequence

5.2.10 Settings

Table 299: 79 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=On 5=Off			5=On	Operation mode Off/On. Setting this setting to “Off” will prevent tripping by any protection function!
Reclosing operation	1=Off 2=External Ctl 3=On			1=On	Reclosing operation (Off, External Ctl / On)
Single phase mode	1=APAT 2=OPUP 3=OOAP			1=APAT	Mode of operation for the autorecloser in single-phase mode
Shot mode 1	0...63			0	Defines 1P or 3P operation mode per input for first reclose shot
Shot mode 2	0...63			0	Defines 1P or 3P operation mode per input for second reclose shot
Shot mode 3	0...63			0	Defines 1P or 3P operation mode per input for third reclose shot
Shot mode 4	0...63			0	Defines 1P or 3P operation mode per input for fourth reclose shot
Shot mode 5	0...63			0	Defines 1P or 3P operation mode per input for fifth reclose shot
Enable three-phase lockout override	1=Disable 2=Enable			1=Disable	If enabled, performs a three-phase trip and lockout on the last shot
Reclaim time	0.1...1800.0	s	0.1	10.0	Reclaim time
First reclose time	0.0...300.0	s	0.1	0.5	Reclose time for CBB1
Second reclose time	0.0...300.0	s	0.1	0.5	Reclose time for CBB2
Third reclose time	0.0...300.0	s	0.1	1.5	Reclose time for CBB3
Fourth reclose time	0.0...300.0	s	0.1	4.5	Reclose time for CBB4
Fifth reclose time	0.0...300.0	s	0.1	5.0	Reclose time for CBB5
Sixth reclose time	0.0...300.0	s	0.1	5.0	Reclose time for CBB6
Seventh reclose time	0.0...300.0	s	0.1	5.0	Reclose time for CBB7
Manual close mode	0=False 1=True			0=False	Manual close mode
Wait close time	0.05...10.00	s	0.01	0.25	Allowed CB closing time after reclose command
Max wait time	0.1...1800.0	s	0.1	10.0	Maximum wait time for BLK_RECL_T reclease (from master)
Max trip time	0.1...10.0	s	0.1	10.0	Maximum wait time for protection signal deactivation
CB close pulse time	0.01...10.00	s	0.01	0.2	Close pulse time
Max thm block time	0.1...1800.0	s	0.1	10.0	Maximum wait time for thermal blocking deactivation
Cut-out time	0.1...1800.0	s	0.1	10.0	Protection coordination signal cut-out time
Dsr time shot 1	0.00...10.00	s	0.01	0.00	Discrimination time for first reclosing
Dsr time shot 2	0.00...10.00	s	0.01	0.00	Discrimination time for second reclosing
Dsr time shot 3	0.00...10.00	s	0.01	0.00	Discrimination time for third reclosing
Dsr time shot 4	0.00...10.00	s	0.01	0.00	Discrimination time for fourth reclosing
Terminal priority	1=None 2=Low (follower) 3=High (master)			1=None	Terminal priority

Parameter	Values (Range)	Unit	Step	Default	Description
Synchronization set	0...127			0	Configures synchrony check for CBB
Auto wait time	0.00...60.00	s	0.01	2.00	Maximum wait time for reclosing condition fulfilling
Auto lockout reset	0=False 1=True			1=True	Automatic lockout reset
Protection crd limit	1...5			3	Protection coordination shot limit
Protection crd mode	1=No condition 2=AR inoperative 3=CB close manual 4=AR inop, CB man 5=Always			1=No condition	Protection coordination mode
Auto initiation cnd	1=Not allowed 2=When sync fails 3=CB doesn't close 4=Both			2=When sync fails	Auto initiation condition
Tripping line	0...63			63	Defines INIT inputs which cause CMD_OPEN activation
Control line	0...63			63	Defines INIT inputs which are protection signals
Allow shot jump	0=False 1=True			1=True	Allows shot jumping
CB closed Pos status	0=False 1=True			1=False	Status (TRUE or FALSE) meaning closed CB in input CB_POS
Fourth delay in SOTF	0=False 1=True			0=False	Sets fourth delay into use for all DEL_INIT signals during SOTF
Init signals CBB1	0...63			3	Sets INIT inputs which initiate CBB1
Init signals CBB2	0...63			3	Sets INIT inputs which initiate CBB2
Init signals CBB3	0...63			3	Sets INIT inputs which initiate CBB3
Init signals CBB4	0...63			3	Sets INIT inputs which initiate CBB4
Init signals CBB5	0...63			0	Sets INIT inputs which initiate CBB5
Init signals CBB6	0...63			0	Sets INIT inputs which initiate CBB6
Init signals CBB7	0...63			0	Sets INIT inputs which initiate CBB7
Blk signals CBB1	0...63			60	Sets INIT inputs which block CBB1
Blk signals CBB2	0...63			60	Sets INIT inputs which block CBB2
Blk signals CBB3	0...63			60	Sets INIT inputs which block CBB3
Blk signals CBB4	0...63			60	Sets INIT inputs which block CBB4
Blk signals CBB5	0...63			0	Sets INIT inputs which block CBB5
Blk signals CBB6	0...63			0	Sets INIT inputs which block CBB6
Blk signals CBB7	0...63			0	Sets INIT inputs which block CBB7
Shot number CBB1	0...5			0	Sets CBB1 shot number
Shot number CBB2	0...5			0	Sets CBB2 shot number
Shot number CBB3	0...5			0	Sets CBB3 shot number
Shot number CBB4	0...5			0	Sets CBB4 shot number
Shot number CBB5	0...5			0	Sets CBB5 shot number
Shot number CBB6	0...5			0	Sets CBB6 shot number

Parameter	Values (Range)	Unit	Step	Default	Description
Shot number CBB7	0...5			0	Sets CBB7 shot number
Frq Op counter limit	0...250			0	Frequent operation counter lockout limit
Frq Op time	1...250	min		1	Frequent operation counter time
Frq Op recovery time	1...250	min		1	Frequent operation counter recovery time
Auto init	0...63			0	Defines INIT lines that are activated at auto initiation

5.2.11 Monitored data

Table 300: SDAIGGIO monitored outputs

Name	Type	Values (Range)	Unit	Description
ACTIVE_1A	Binary	0=False 1=True		Phase A protection active for input 1
ACTIVE_1B	Binary	0=False 1=True		Phase B protection active for input 1
ACTIVE_1C	Binary	0=False 1=True		Phase C protection active for input 1
ACTIVE_1_3P	Binary	0=False 1=True		Three phase protection active for input 1
TRIPOUT_1	Binary	0=False 1=True		Protection trip active for input 1
ACTIVE_2A	Binary	0=False 1=True		Phase A protection active for input 2
ACTIVE_2B	Binary	0=False 1=True		Phase B protection active for input 2
ACTIVE_2C	Binary	0=False 1=True		Phase C protection active for input 2
ACTIVE_2_3P	Binary	0=False 1=True		Three phase protection active for input 2
TRIPOUT_2	Binary	0=False 1=True		Protection trip active for input 2
ACTIVE_3A	Binary	0=False 1=True		Phase A protection active for input 3
ACTIVE_3B	Binary	0=False 1=True		Phase B protection active for input 3
ACTIVE_3C	Binary	0=False 1=True		Phase C protection active for input 3
ACTIVE_3_3P	Binary	0=False 1=True		Three phase protection active for input 3
TRIPOUT_3	Binary	0=False 1=True		Protection trip active for input 3
ACTIVE_4A	Binary	0=False 1=True		Phase A protection active for input 4
ACTIVE_4B	Binary	0=False 1=True		Phase B protection active for input 4
ACTIVE_4C	Binary	0=False 1=True		Phase C protection active for input 4
ACTIVE_4_3P	Binary	0=False 1=True		Three phase protection active for input 4
TRIPOUT_4	Binary	0=False 1=True		Protection trip active for input 4
ACTIVE_5A	Binary	0=False 1=True		Phase A protection active for input 5
ACTIVE_5B	Binary	0=False 1=True		Phase B protection active for input 5
ACTIVE_5C	Binary	0=False 1=True		Phase C protection active for input 5
ACTIVE_5_3P	Binary	0=False 1=True		Three phase protection active for input 5

Name	Type	Values (Range)	Unit	Description
TRIPOUT_5	Binary	0=False 1=True		Protection trip active for input 5
ACTIVE_6A	Binary	0=False 1=True		Phase A protection active for input 6
ACTIVE_6B	Binary	0=False 1=True		Phase B protection active for input 6
ACTIVE_6C	Binary	0=False 1=True		Phase C protection active for input 6
ACTIVE_6_3P	Binary	0=False 1=True		Three phase protection active for input 6
TRIPOUT_6	Binary	0=False 1=True		Protection trip active for input 6

Table 301: SDAOGGIO monitored inputs

Name	Type	Values (Range)	Unit	Description
ACTIVE_PH_A	Binary	0=False 1=True		Phase A protection is active for trip
ACTIVE_PH_B	Binary	0=False 1=True		Phase B protection is active for trip
ACTIVE_PH_C	Binary	0=False 1=True		Phase C protection is active for trip
ACTIVE_PH_3P	Binary	0=False 1=True		Three phase protection is active for trip
RECLOSE_IN	Binary	0=False 1=True		Reclose command active
OPEN_IN	Binary	0=False 1=True		Open command active
LOCKOUT_IN	Binary	0=False 1=True		Lockout command active
INPROGRESS_IN	Binary	0=False 1=True		Reclose sequence in progress
CB_POS_A				Circuit breaker position signal, phase A
CB_POS_B				Circuit breaker position signal, phase B
CB_POS_C				Circuit breaker position signal, phaseC
CB_POS_P				Circuit breaker position signal, three phase

Table 302: 79 monitored data

Name	Type	Values (Range)	Unit	Description
FRQ_OPR_CNT	INT32	0...2147483647		Frequent operation counter
FRQOP_CNT_AL	Binary	0=False 1=True		Frequent operation counter alarm
STATUS	Enum	-2=Unsuccessful -1=Not defined 1=Ready 2=In progress 3=Successful		Auto reclosing status
ACTIVE	Binary	0=False 1=True		Reclosing sequence active
INPRO_1	Binary	0=False 1=True		First reclosing in progress
INPRO_2	Binary	0=False 1=True		Second reclosing in progress
INPRO_3	Binary	0=False 1=True		Third reclosing in progress
INPRO_4	Binary	0=False 1=True		Fourth reclosing in progress
INPRO_5	Binary	0=False 1=True		Fifth reclosing in progress
DISCR_IN_PRO	Binary	0=False 1=True		Discrimination time in progress
CUTOUT_INPRO	Binary	0=False 1=True		Cut-out time in progress
SUC_RECL	Binary	0=False 1=True		Reclosing sequence successful
UNSUC_CB	Binary	0=False 1=True		Circuit breaker closing unsuccessful
CNT_SHOT1	INT32	0...2147483647		Resetable operation counter, shot 1
CNT_SHOT2	INT32	0...2147483647		Resetable operation counter, shot 2
CNT_SHOT3	INT32	0...2147483647		Resetable operation counter, shot 3
CNT_SHOT4	INT32	0...2147483647		Resetable operation counter, shot 4
CNT_SHOT5	INT32	0...2147483647		Resetable operation counter, shot 5
COUNTER	INT32	0...2147483647		Resetable operation counter, all shots
SHOT_PTR	INT32	0...6		Shot pointer value
MAN_CB_CL	Binary	0=False 1=True		Circuit breaker closed manually
SOTF	Binary	0=False 1=True		Switch-onto-fault
REC_T_STD	Binary	0=False 1=True		Reclaim time started
REC_T_ELA	Binary	0=False 1=True		Reclaim time elapsed
DISA_COUNT				Disable signal for counters

5.2.12 Technical data

Table 303: 79 Technical data

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

5.3 Synch-check/voltage check 25

5.3.1 Identification

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

5.3.2 Function block

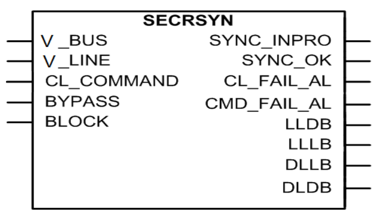


Figure 166: Function block

5.3.3 Functionality

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

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

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

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

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

The energizing check function measures the bus and line voltages and compares them to both high and low threshold detectors. The output is given only when the actual measured quantities match the set conditions.

The synch-check function in the continuous mode measures the conditions across the circuit breaker from separate power system parts and compares them to the set limits. When all the measured quantities are within their set limits simultaneously, that is, the systems are in synchronism, the output for allowing or executing the circuit breaker closing is activated.

The synch-check function in the command mode measures the conditions across the circuit breaker and also determines the angle change occurring during the closing delay of the circuit breaker from the measured slip frequency. The output is given only when all the measured conditions are within their set limits simultaneously. The issue of the output is timed to give closure at the optimal delay of the circuit breaker and the closing circuit.

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

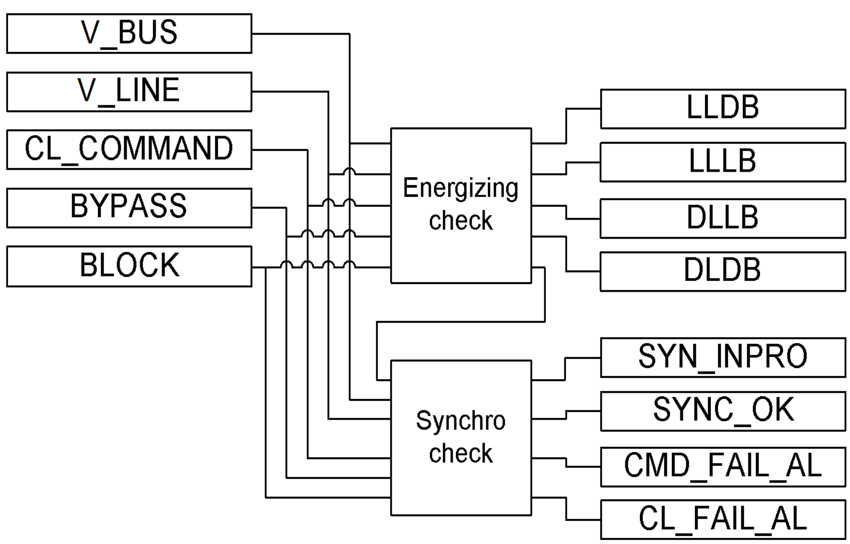


Figure 167: Functional module diagram

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

Energizing check

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

Table 304: Live dead mode of operation under which switching can be carried out

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

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

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

In synch-check function the two voltage inputs are referred to as Bus and Line while in RER620 the inputs are referred to as Source-1 and Source-2. Unless otherwise indicated consider Source-1 as Bus and Source-2 as Line side. For example if Source 2 voltage goes below the ‘dead’ threshold setting, the same will be considered as Line Dead as TRUE by synchro-check function. If Source 2 voltage goes above ‘live’ threshold, the Live Line will be TRUE

Synch-check

The synch-check function measures the difference between the line voltage and bus voltage. The function permits the closing of the circuit breaker when the following conditions are simultaneously fulfilled.

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

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

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

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

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

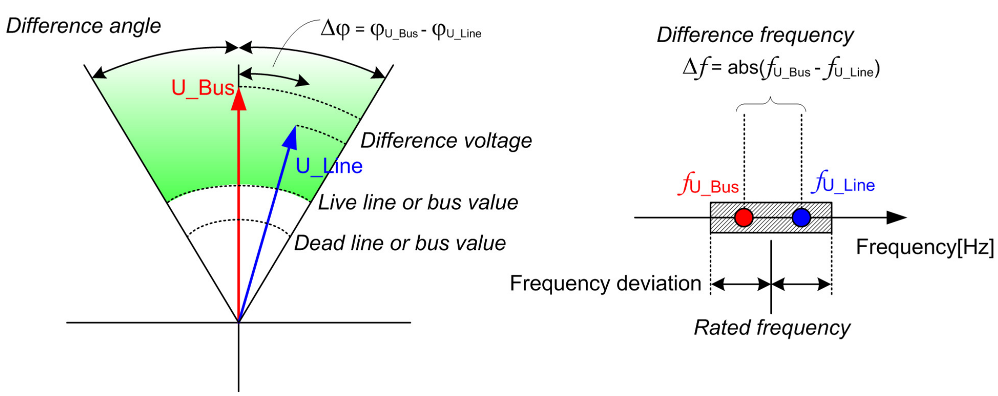


Figure 168: Conditions to be fulfilled when detecting synchronism between systems

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

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

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

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

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

Continuous mode

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

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

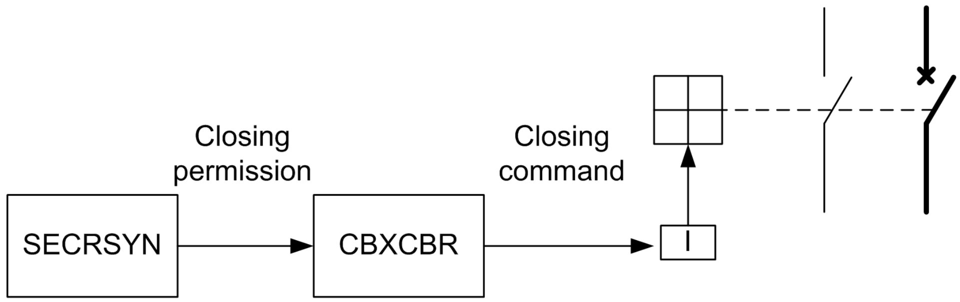


Figure 169: A simplified block diagram of the synch-check function in the continuous mode operation

Command mode

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

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

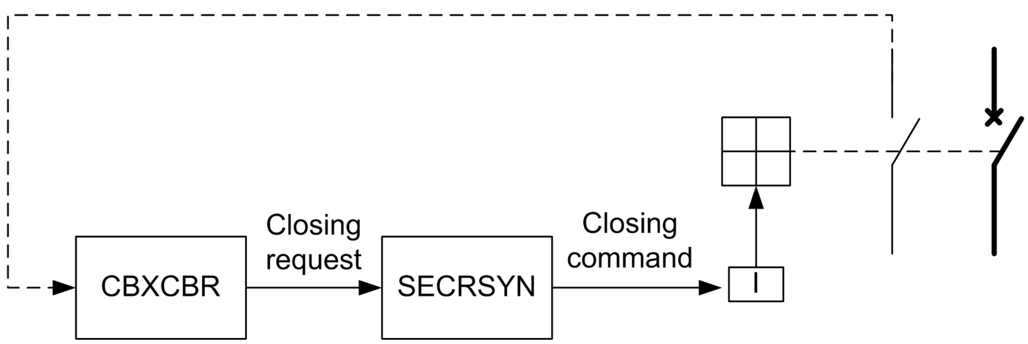


Figure 170: A simplified block diagram of the synch-check function in the command mode operation

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

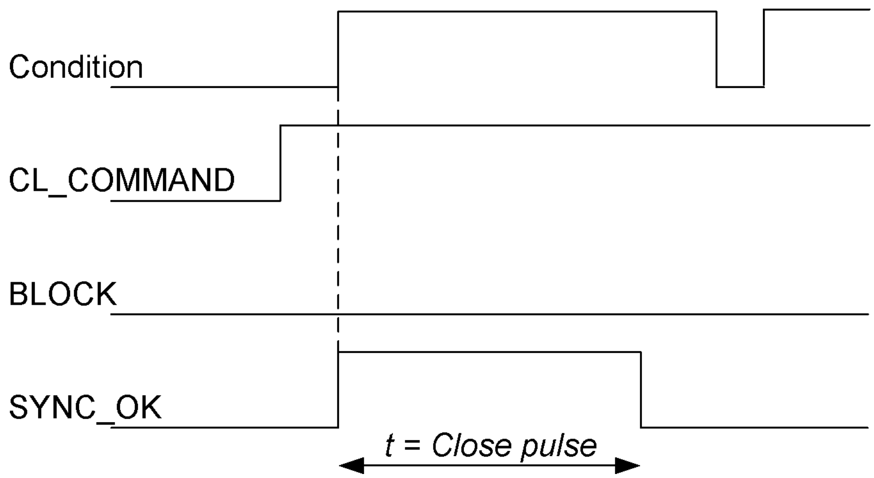


Figure 171: Determination of the pulse length of the closing signal

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

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

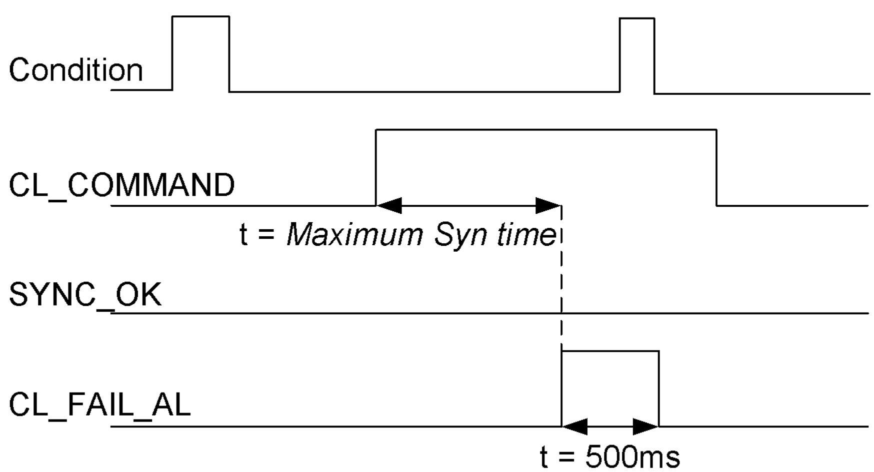


Figure 172: Determination of the checking time for closing

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

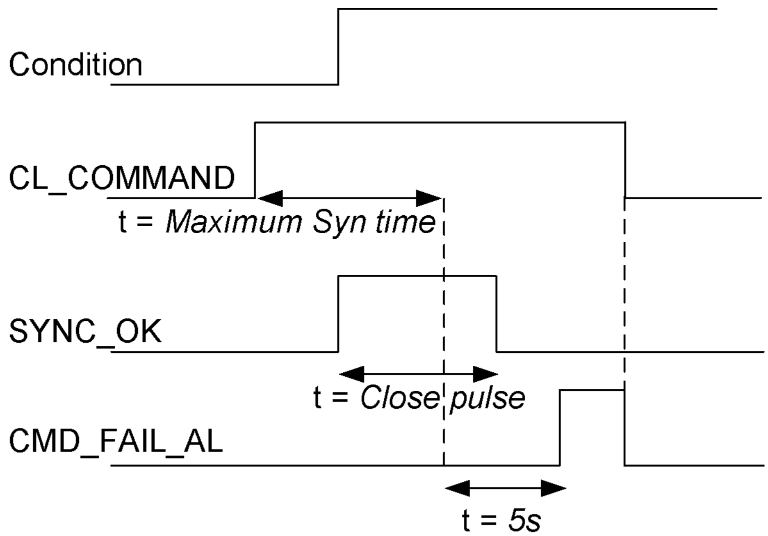


Figure 173: Determination of the alarm limit for a still-active command signal

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

Bypass mode

SECRSYN can be set into bypass mode by setting the parameters *Synch check mode* and *Energizing check mode* to *"*Off*"* or alternatively, by activating the `BYPASS` input.

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

Voltage angle difference adjustment

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

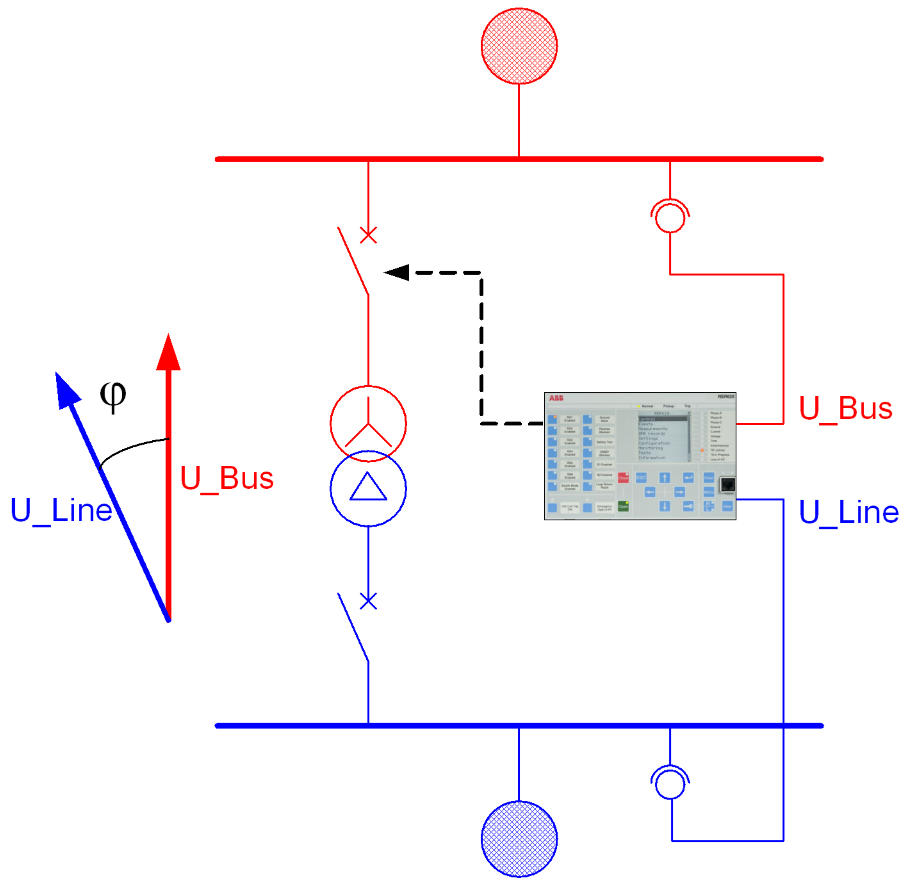


Figure 174: Angle difference when power transformer is in sychro-check zone

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

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

5.3.5 Application

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

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

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

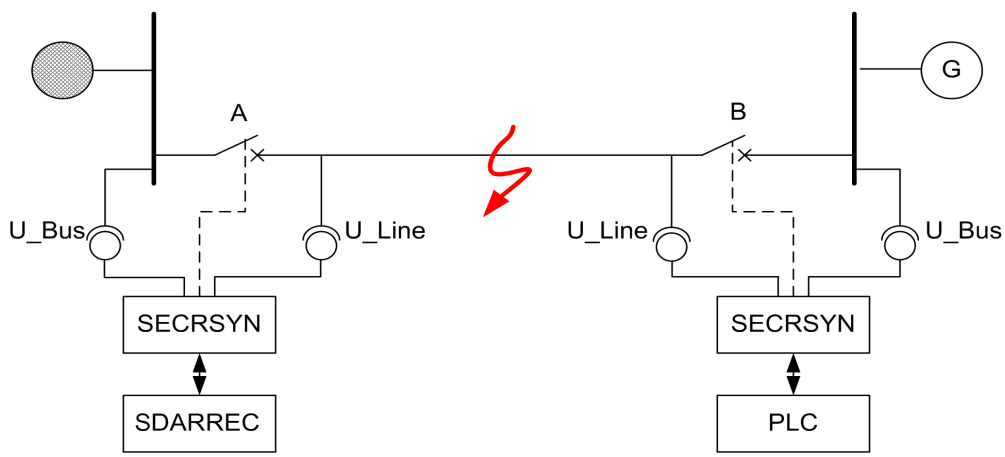


Figure 175: Synch-check function SECRSYN checking energizing conditions and synchronism

Connections

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

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

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

Figure 176 shows an example where the synch-check is used for the circuit breaker closing between a busbar and a line. The phase-to-phase voltages are measured from the busbar and also one phase-to-phase voltage from the line is measured.

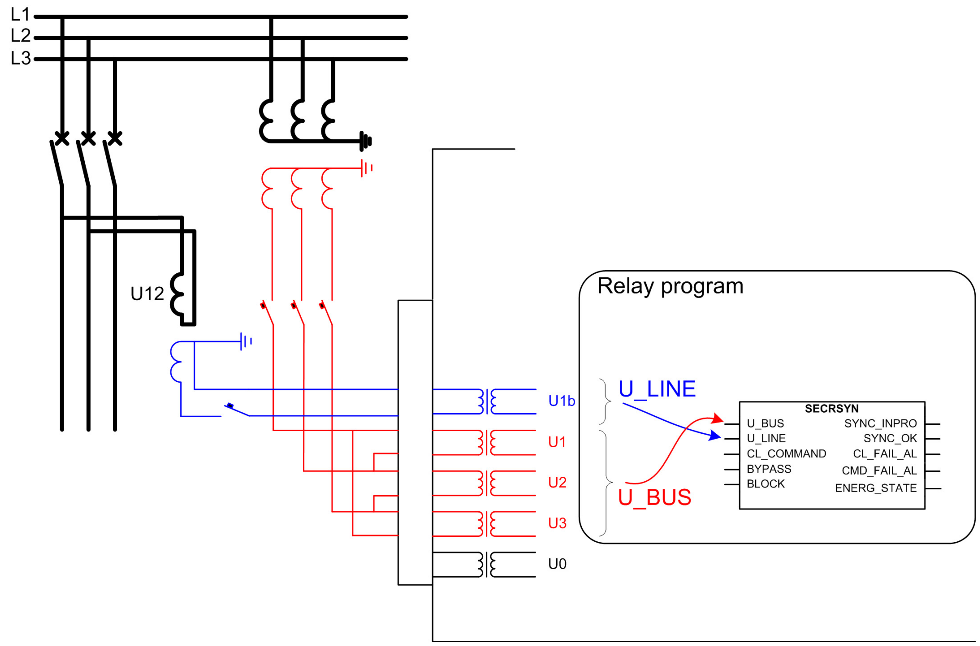


Figure 176: Connection of voltages for the relay and signals used in synch-check

5.3.6 Signals

Table 305: 25 input signals

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

Table 306: 25 output signals

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

5.3.7 Settings

Table 307: 25 group settings

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

Table 308: 25 non-group settings

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

5.3.8 Monitored data

Table 309: 25 monitored data

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

5.3.9 Technical data

Table 310: 25 technical data

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

5.4 Loop control (DLCM)

5.4.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loop control	DLCM	DLCM	DLCM

5.4.2 Function block

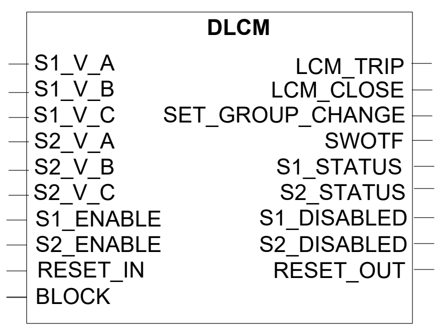


Figure 177: Function block

5.4.3 Functionality

The loop control functionality enables proper switching of recloser in order to sectionalize the faulted section from the distribution system. The function can be operated in three modes, based on the type of the recloser in the loop control scheme. The full scheme of loop control typically consists of three types of recloser used in the loop control system design. They are sectionalizer recloser, mid-point recloser and tie-point recloser. The functionality of loop control function in different modes is clearly explained in the next sections of the document.

A recloser loop control scheme typically utilizes a predetermined RER620 controlled reclosers installed in series between two substation feeder circuits. This provides isolation of any faulted section within a given distribution circuit while re-establishing service to all customers unaffected by the faulted section within a relatively short period. Loop control schemes are typically located at or near key customers at various locations throughout the distribution system, or where reliability on particular circuits is particularly poor.

There are three common configurations that the loop control can be configured. These are defined by the number of reclosers in a loop and their respective types. The three- and five recloser systems are basic arrangements; the four-recloser topology is a hybrid of the three- and five-recloser topology.

The distribution one-line diagram in Figure 178 represents a typical full implementation of a loop system.

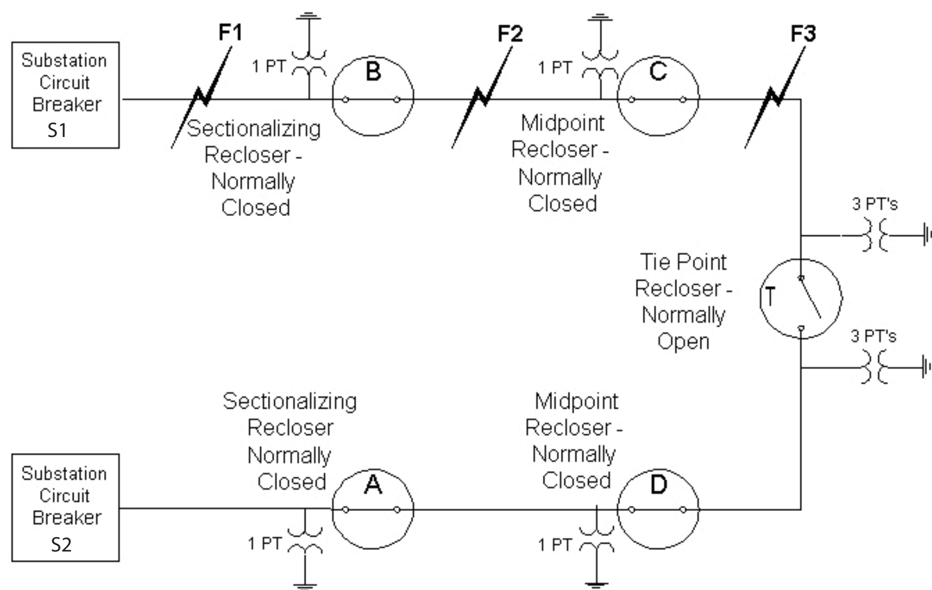


Figure 178: 5-Recloser loop control system

A typical full implementation of a loop system consists of 3 type of reclosers:

- Sectionalizing reclosers
- Midpoint reclosers
- TiePoint recloser

An explanation of the function of each of these reclosers types is given in the section below.

5.4.3.1 Sectionalizing Recloser

The Sectionalizing recloser is a normally closed recloser that opens in response to a downstream fault condition or to a loss of phase voltage from an upstream circuit. The sectionalizer is typically the first protective device on the distribution line outside the substation. Various settings determine the Sectionalizing recloser's sensitivity to both current and voltage conditions. By design, for permanent faults between the substation and the Sectionalizing recloser, the Sectionalizing recloser will open after a program delay to set up for the back feeding from the alternate source. This timer is set to expire prior to the Midpoint and Tiepoint timers.

5.4.3.2 Midpoint Recloser

The Midpoint recloser also is normally closed. Unlike the Sectionalizing recloser, however, it does not open in response to phase voltage loss. Instead, it supports loop control by automatically altering the RER620 settings in accordance with changing voltage conditions. Specifically, upon the expiration of it's under voltage timer, it will switch to a new setting group to prepare for a back feed condition and for a period will go into non-reclose mode. The reason for the nonreclose is that in the event the fault is between the Sectionalizing unit and the Midpoint, it would be undesirable to have the recloser sequence through multiple operations. Though the reclose blocked condition will change to normal after a programmed amount of time, the control will stay in New Settings Group until the loop scheme is reset.

5.4.3.3 Tiepoint Recloser

The Tiepoint recloser, unlike the Sectionalizing and Midpoint recloser is normally open. It closes in response to a loss of all phase voltages from one source if the other source phase voltages are live. Once closed, the Tiepoint breaker will trip automatically if a downstream overcurrent condition exists and is not isolated by the midpoint recloser first. The Tiepoint recloser can be set to employ different fault thresholds depending on which side of the loop it is supplying, i.e., which side is downstream. After the close operation, it also is set to go into non-reclose mode for a period of time in the event the fault is between the Midpoint and Tiepoint. If the control changed to New Settings Group for the close operation, it will remain in that setting group until the Recloser is opened and the loop scheme is reset.

5.4.4 Operation principle

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

The operation of DLCM can be described by using a module diagram (see Figure 179). All the modules in the diagram are explained in the next sections.

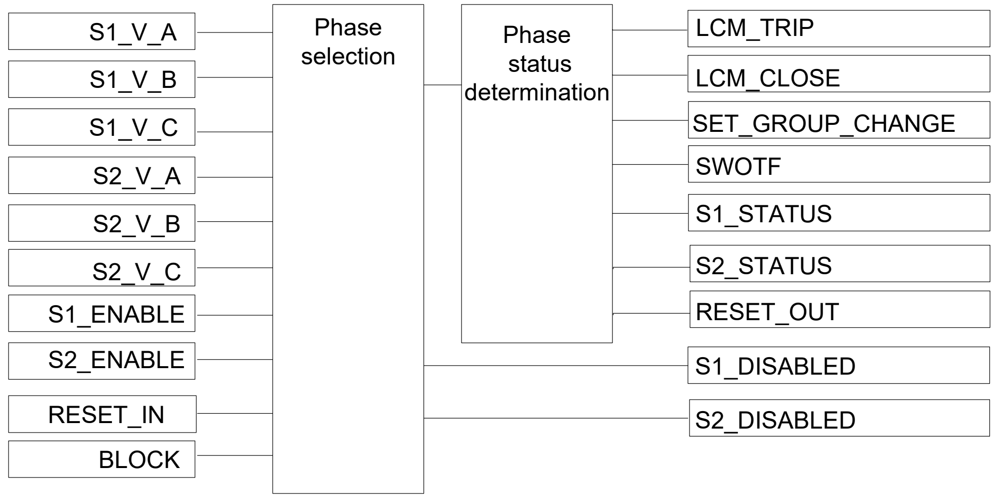


Figure 179: Functional module diagram

Phase selection

The identification of source and phases for which, phase status has to be determined is done in the phase selection.

A source is a substation feeder with breaker and ancillary equipment. The substation source is not normally included in the loop scheme logic system, it is only intended to supply the power for the loop control system down the feeder. All loop control systems assume two sources of supply. These sources may be supplied by the same or different distribution substation feeders, with different feeders permitting a higher level of service during some fault conditions. The selection of these substations it is recommended that the following be considered:

- Both sources supply power of the same phase rotation
- The voltage level of each source are similar
- The capacity of the each source/feeder (transformers, protective devices, regulators, wire, etc. are capable of picking up load of the feeder to be added by a loop operation (normally to the Sectionalizing recloser on the other source).

The phase selection is done based on the below listed settings.

- Line side src
- Vt config line
- Vt line phase
- Vt line enable
- Vt config load
- Vt load phase
- Vt load enable

Basically the recloser consists of two bus voltages as S1 and S2. This is clearly depicted in Figure 180.

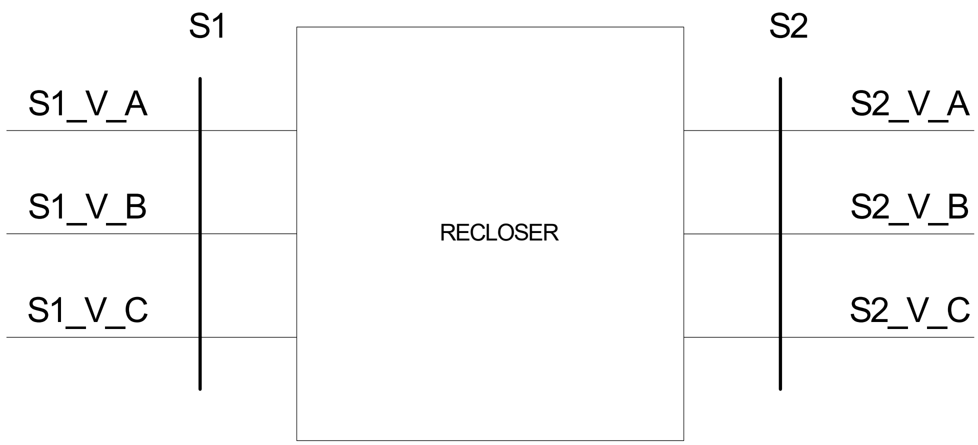


Figure 180: Depiction of recloser with sources

Independent of type of recloser in loop control scheme, i.e., either recloser is sectionalizing, mid-point or tie-point, the sources and phases will be similar to Figure 180.

The phase selection for the three modes is explained below.

The loop control is operated in 4 modes as “Sectionalize”, “Mid-point”, “Tie-point” or “Disabled” in *LCM Mode* setting.

The *Line side src* setting can be selected as “S1” or “S2” to select the respective source as line side source. If the power is flowing from S1 to S2 then the *Line side src* is selected as “S1” and vice versa. This is explained pictorially in Figure 181.

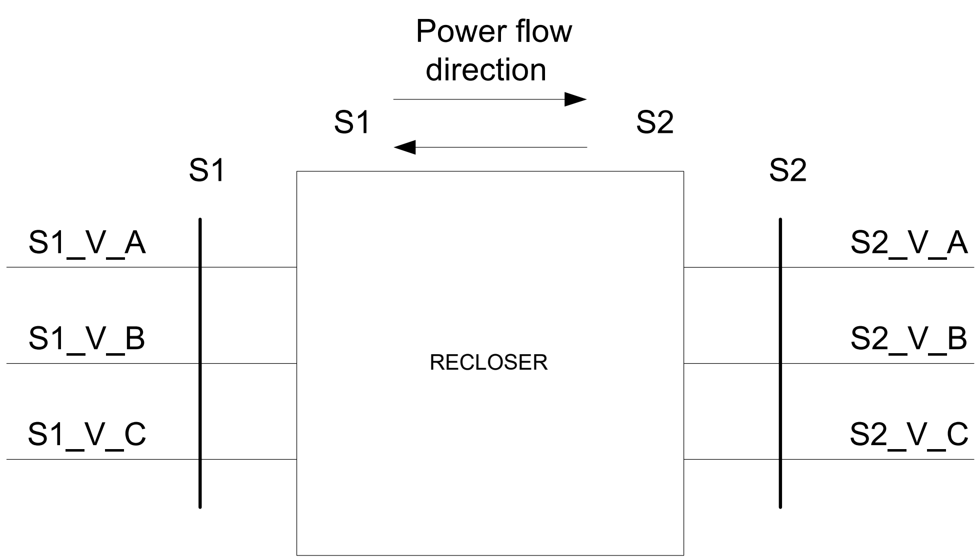


Figure 181: Explanation of line side source

Once the line side source is selected the phases of the respective source is identified by giving the number of voltage transformers connected to the respective source.

In case of sectionalizer mode, the *Vt config line* setting is selected with number of voltage transformers connected. If the *Vt config line* is “1” or “2”,the *Vt line phase* setting is selected as the phase to which the voltage transformers is connected. The *Vt line enable* should be TRUE to consider the settings *Vt config line* and *Vt line phase*. Table 311 clearly explains the phases selected with different possible selection of appropriate settings in Sectionalizing recloser modes.

In case of mid-point mode, the numbers of voltage transformers connected can be either 1 or 3. So the *Vt config line* can be either “1” or “3”. The phase selection is similar as in sectionalizer mode but *Vt config line* cannot be “2”.

In case of tie-point mode the 3 phases of both sources are considered. Hence in tie-point mode the *Vt config line* and *Vt config load* settings should be selected as “3” and *Vt line enable* and *Vt load enable* should be selected as ‘TRUE”. That is tie-point recloser should always have 3 voltage transformers connected to each source.

In case of disabled mode no phase is considered.

Table 311: Selection of phases in Sectionalizing recloser mode

Line side src	*Vt config line*	*Vt line phase*	*Vt line enable*	Phases Selected
S1	3	Not valid	TRUE	S1_V_A S1_V_B S1_V_C
S1	1	PhA	TRUE	S1_V_A
S1	1	PhB	TRUE	S1_V_B
S1	1	PhC	TRUE	S1_V_C
S1	2	PhA	TRUE	S1_V_A S1_V_B
S1	2	PhB	TRUE	S1_V_B S1_V_C
S1	2	PhC	TRUE	S1_V_C S1_V_A
S2	3	Not valid	TRUE	S2_V_A S2_V_B S2_V_C
S2	1	PhA	TRUE	S2_V_A
S2	1	PhB	TRUE	S2_V_B
S2	1	PhC	TRUE	S2_V_C
S2	2	PhA	TRUE	S2_V_A S2_V_B
S2	2	PhB	TRUE	S2_V_B S2_V_C
S2	2	PhC	TRUE	S2_V_C S2_V_A

The outputs S1_DISABLED and S2_DISABLED indicate whether the respective source is enabled or disabled. The output will be TRUE if respective source is disabled.

The condition for any source to be enabled in sectionalizer or midpoint modes is the respective source should be selected as Line side source and Vt line enable should be “TRUE” and the respective source enable input should be triggered with a positive pulse.

The condition for any source to be enabled in tie-point mode is to set the settings Vt line enable and Vt load enable as TRUE and the respective source enable inputs should be triggered with a positive pulse.

The source enable inputs S1_ENABLE and S2_ENABLE are pulse triggered inputs. This is true if the present status of source is enabled. By applying a positive pulse to the respective inputs the respective source will be disabled and vice versa.

Phase status determination

Phase status determination module determines the status of phases selected. The status of phase can be live or dead or neither live nor dead based on the level of the respective phase voltages.

The phase status logic compares the measured value of the respective phase voltage with Live bus threshold and Dead bus threshold settings. If the measured voltage is greater than Live bus threshold for a time of Live bus time then the respective phase is declared as live bus. If the measured voltage is less than Dead bus threshold for a time of Dead bus time then respective phase is declared as dead bus. If the measured voltage exceeds the Dead bus threshold for a time less than Volt regain time then it is ignored by the function and dead bus timer will be continuous during this time. If the voltage is restored for the Volt regain time or longer, the dead bus timer is cleared and the status will change to either live bus or neither live nor dead based on the voltage level. The phase is declared as neither live nor dead if the phase voltage is above the Dead bus threshold and below the Live bus threshold.

In sectionalizing mode, if *Vt config line* is “3” and the setting *Sect3POpMode* is selected as “Any phase” then any of the 3 phases should be declared as dead to activate the LCM_TRIP. If *Sect3POpMode* is selected as “Three phase” then all of the 3 phases should be declared as dead to activate the LCM_TRIP. If *Vt config line* is “1” then the respective phase selected in *Vt line phase* setting should be declared as dead to activate the LCM_TRIP.

In midpoint mode, the SET_GROUP_CHANGE is activated and SWOTF output is activated for a time of SWOTF time setting if the status of the phases selected is dead and if *En set grp chg* setting is TRUE.

In tie point mode, the LCM_CLOSE is activated and also the SWOTF output is activated for a time of SWOTF time setting, if the status of the 3 phases of one source is live and the status of 3 phases of the other source is dead. And also the SET_GROUP_CHANGE is activated, if source selected as line side is dead and if *En set grp chg* setting is TRUE.

The S1_STATUS and S2_STATUS outputs, provides the status of the respective bus. If the output is activated, it indicates the respective source is dead and vice versa.

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates all outputs and resets internal timers.

Reset Logic

The loop control function is provided with reset logic for safety reasons. The reset logic is explained for each of the loop control modes in the next few paragraphs.

In the sectionalizer and midpoint mode, if the setting Reset on power up is set as "TRUE", then after any re-initialization activity in the relay like power off-and-on, software reset, committing to a setting change etc., the loop control will be in reset or active state and RESET_OUT output will be FALSE. If the setting Reset on power up is set as "FALSE", then after any re-initialization activity in the relay, the loop control will be in non-reset or in-active state and RESET_OUT output will be TRUE. In the later case, to arm the loop control, RESET_IN input is triggered with a positive pulse. The loop control goes into non–reset state if LCM_TRIP output is activated in sectionalizer mode or SET_GROUP_CHANGE output is activated in mid-point mode. After restoring the line, the loop control is reset by providing a positive pulse through RESET_IN input.

In the tie-point mode, after the power on and power off of relay, the loop control will always go into non–reset mode due to safety reasons. The loop control can be moved to active state by providing a positive pulse at RESET_IN input. The loop control goes into non–reset state if LCM_CLOSE output is activated. After restoring the line, the loop control is reset by providing a positive pulse through RESET_IN input.

The RESET_OUT indicates whether the loop control is in reset or non-reset state. If RESET_OUT is TRUE it indicated the loop control is in non reset state and vice versa.

Table 312: Reset Logic

DLCM setting	DLCM state before re-initialization of relay	DLCM function state after re-Initialization of relay		
		Sectionalizing mode	Midpoint mode	Tie point mode
“Reset on power up” =TRUE	NOT RESET	DLCM function is reset/armed/activated & “RESET_OUT” output is FALSE. This is irrespective of the previous state before Re-initialization.	DLCM function is reset/armed/activated & “RESET_OUT” output is FALSE. This is irrespective of the previous state before Re-initialization.	DLCM function is always non-reset/in-active and “RESET_OUT” output will be TRUE for safety reasons. To activate the function, RESET_IN input is triggered with a positive pulse or through LHMI “Loop Scheme Reset” button
	RESET			
“Reset on power up” =FALSE	NOT RESET	DLCM function is non-reset/in-active and “RESET_OUT” output will be TRUE. To activate the function, RESET_IN input is triggered with a positive pulse or through LHMI “Loop Scheme Reset” button	DLCM function is non-reset/in-active and “RESET_OUT” output will be TRUE. To activate the function, RESET_IN input is triggered with a positive pulse or through LHMI “Loop Scheme Reset” button	DLCM function is always non-reset/in-active and “RESET_OUT” output will be TRUE for safety reasons. To activate the function, RESET_IN input is triggered with a positive pulse or through LHMI “Loop Scheme Reset” button -
	RESET			

The sectionalizing reset setting provides automation on the reset logic in sectionalizing mode. If sectionalizing reset is TRUE then if the loop control is in non reset mode and if the bus voltage is above live bus threshold for live bus time then the loop control will go into reset mode automatically. This feature is only applicable in sectionalizing recloser mode.

5.4.5 Application

The loop control scheme is implemented to improve the circuit reliability and to provide more effective system operation. The loop control function is used in implementing the loop control schemes.

In general, loop control scheme is implemented in three different configurations. These are defined by the number of reclosers in a loop and their respective types. They are five recloser, three recloser and four recloser configurations. The three- and five recloser systems are basic arrangements; the four-recloser topology is a hybrid of the three- and five-recloser topology.

5.4.5.1 Three-Recloser Loop Control

The three-recloser system bridges two sources with a normally open TiePoint recloser. Between each source and the TiePoint is a normally closed sectionalizing recloser. There are two fault scenarios to consider in the three-recloser system. In one scenario, a line fault occurs between a source and its Sectionalizing recloser. The second scenario involves a line fault between the Sectionalizing and TiePoint recloser

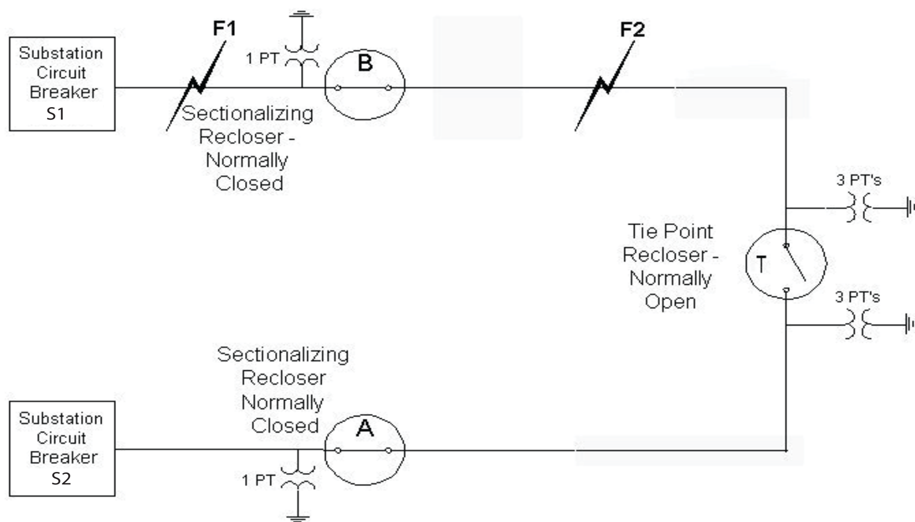


Figure 182: 3-Recloser Loop Control

3-Recloser Fault 1 Scenario

In a 3-recloser loop control scheme, Figure 182, if there is a permanent fault between the S1 circuit breaker and the sectionalizing recloser B at F1, the S1 circuit breaker will recognize the fault and go through its reclosing shots to lockout (for illustration purposes we will assume 3 operations to lockout for all devices). Recloser B will recognize a loss of voltage after the first circuit breaker operation, and if the voltage does not return to greater than live bus threshold value level for the livebus timer setting, it will automatically trip after t1 seconds, per Figure 183, isolating the faulted zone on the source side of the recloser. The tie-point recloser T at the same instant will recognize a loss of 3-phase voltage on the S1 side of its recloser PTs. After a delay time of t2 seconds from the initial fault at S1 the tie-point recloser T will close. This establishes service from S2, recloser A and through the tie-point recloser T to the faulted sectionalizing recloser B. Figure 183 and Table 313 summarize the events.

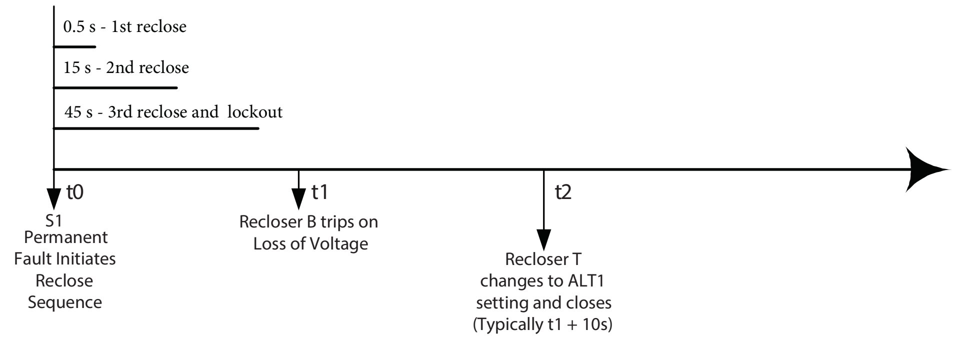


Figure 183: 3-Recloser Fault 1 Sequence of Events

Table 313: 3-Recloser Fault 1 Sequence of Events

Time	Event or Conditon
t0	Permanent line fault F1 occurs between source and Sectionalizing recloser. Source circuit breaker trips and locks out causing loss of voltage at the Sectionalizing and TiePoint reclosers.
t1	Sectionalizing recloser declares phases dead, initiates loop control sequence, trips and locks out the breaker.
t2	TiePoint recloser declares phases dead, initiates loop control sequence, changes to Alternate 1 settings and closes. Providing service up to the Load Side of Sectionalizer B.

3-Recloser Fault 2 Scenario

If a permanent fault occurred at location F2, Figure 182, the following sequence occurs; recloser

B proceeds through its reclosing sequence of overcurrent protection, which is the primary protection activity for the RER620. Upon tripping of recloser B, recloser T senses loss of voltage and after its time delay of t1 seconds, closes onto the permanent fault. Since this fault is permanent and recloser T has closed into the fault, recloser T goes directly to lockout by design. The unfaulted portion of the distribution feeder circuit between S1 to recloser B remains in service, as does S2 to recloser T. Figure 184 and Figure 314 summarize the sequence of events.

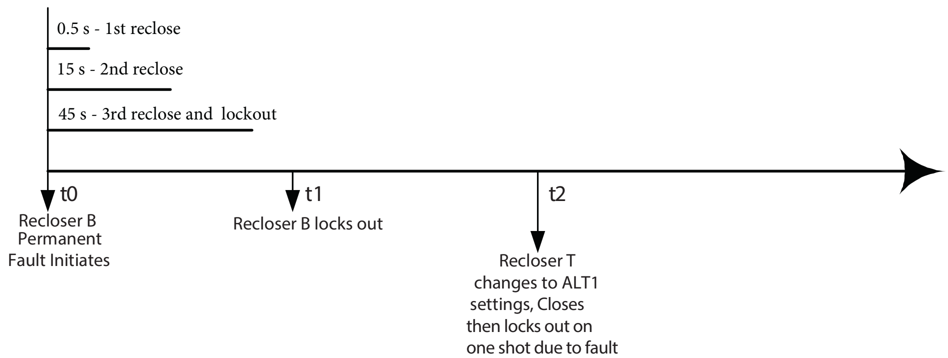


Figure 184: 3-Recloser Fault 2 Sequence of Events

Table 314: 3-Recloser Fault 2 Sequence of Events

Time	Event or Conditon
t0	Permanent fault occurs between Sectionalizing and TiePoint reclosers.
t1	Sectionalizing recloser trips and locks out causing loss of voltage at the TiePoint recloser..
t2	TiePoint recloser declares phases dead, initiates loop control sequence and closes its breaker.
t3	TiePoint recloser senses line fault, trips and locks out.

Loop Schemes can be setup as one-way or two-way systems. One-way systems allow the tiepoint recloser close when voltage is lost on one side but not the other. This may be necessary for situations where the one feeder cannot support additional load but can be picked up by the other feeder. Two-way schemes are more common, and are set to pick up load in either direction. For two-way schemes, there may be a need for an alternate protection setting group change for proper coordination. This can be done automatically based on programmed settings.

5.4.5.2 Five-Recloser Loop Control

The five-recloser system is similar to the three-recloser system except that a normally closed Midpoint recloser divides the segments between the TiePoint recloser and each Sectionalizing recloser. Figure 185 shows the relative location of midpoint reclosers. The Mid-point recloser differs from Sectionalizing and TiePoint reclosers in that it does not initiate breaker operations (trip or close) based on phase voltages. Instead, it alters the RER620's response to overcurrent conditions. Upon a loss of voltage (below dead bus threshold voltage level) and after the programmed Dead bus time, the Midpoint RER620 will activate have two additional outputs, which include:

- Switch-on-to-fault (SWOTF)
- SET_GROUP_CHANGE

If the status of phases selected is dead, the SET_GROUP_CHANGE is activated if "En Set Grp chg" setting is TRUE and SWOTF output is activated for time of SWOTF time setting preventing the recloser from reclosing back into an anticipated fault for a back feed condition (after the tie-point closes).

Once the SWOTF timer expires, the unit goes into normal reclosing mode to allow isolation of any subsequent temporary faults.

Note that the Tie-point loop control mode also enables SWOTF output for a time of SWOTF time setting if the status of the 3 phases of one source is live and the status of 3 phases of the other source is dead. And also the SET_GROUP_CHANGE is activated, if source selected as line side is dead and if "En set grp chg" setting is TRUE.

SET_GROUP_CHANGE settings refer to alternate current thresholds used by the RER620 in recognizing overcurrent conditions. This is important in the Midpoint and TiePoint reclosers because their loads and protective settings may vary depending on which source is supplying the power. The user can optionally program both the Midpoint and TiePoint reclosers to switch to another group settings when initiating loop control sequences.

Because of the additional reclosers in a five-recloser system, there are three potential fault locations on each side of the TiePoint:

- Between source and Sectionalizing recloser
- Between Sectionalizing and Midpoint reclosers
- Between Midpoint and TiePoint reclosers

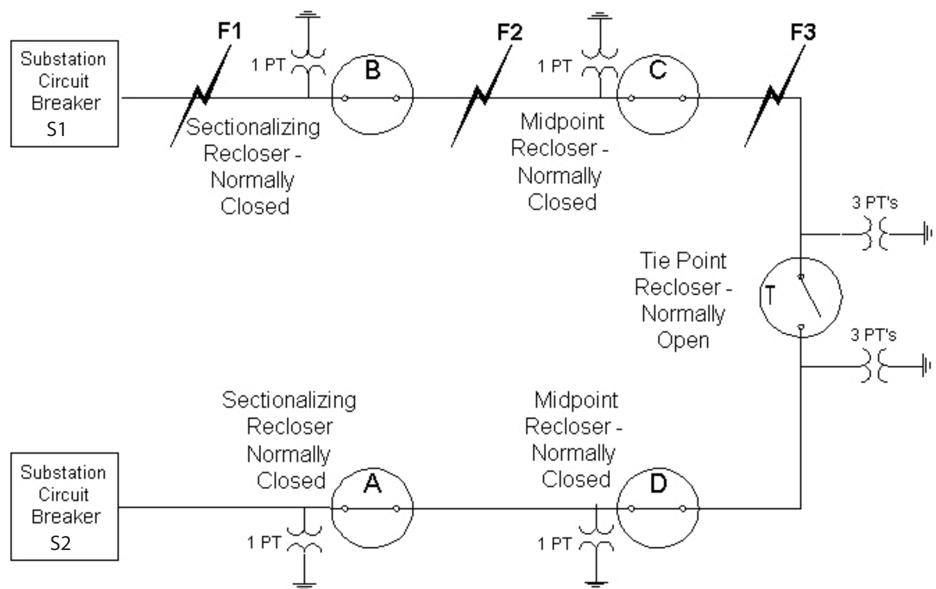


Figure 185: 5-Recloser Loop Control

5-Recloser Fault 1 Scenario

In a 5-recloser loop control scheme, Figure 185, if there is a permanent fault between the S1 circuit breaker and the sectionalizing recloser B at F1, the S1 circuit breaker will recognize the fault and go through its reclosing shots to lockout (for illustration purposes we will assume 3 operations to lockout for all devices). Recloser B will recognize a loss of voltage after the first circuit breaker operation, and if the voltage does not return for the livebus timer setting, it will automatically trip after t1 seconds (see Figure 186), isolating the faulted zone on the source side of the recloser.

The Midpoint recloser C senses the same loss of voltage, and if the voltage does not return for the livebus timer setting will request the RER620 to start its SWOTF timer and, if programmed, to use new changed group settings after t2 seconds (typically set around 10 seconds after the Sectionalizer is set to lockout).

The tie-point recloser T at the same instant will recognize a loss of 3-phase voltage on the S1 side of its recloser PTs. After a delay time of t3 seconds from the initial fault at S1 the tie-point recloser T will close, and if programmed, switch to New Group settings. This establishes service from S2, recloser A and through the tie-point recloser T to the faulted sectionalizing recloser B. The TiePoint recloser is typically set to declare its phase voltages dead sometime after the Midpoint recloser has started its SWOTF timer and before the SWOTF timer expires.

The unfaulted portion of the distribution feeder circuit between recloser B and recloser T is picked back up. Figure 186 and Table 315 summarize the events.

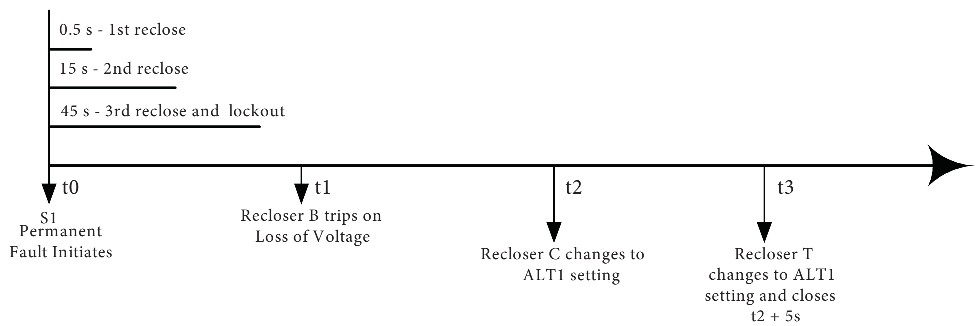


Figure 186: 5-Recloser Fault 1 scenario Sequence of Events

Table 315: 5-Recloser Fault 1 scenario Sequence of Events

Time	Event or Conditon
t0	Permanent line fault occurs Source breaker trips and locks out causing loss of voltage at the Sectionalizing, Midpoint and TiePoint reclosers.
t1	Sectionalizing recloser declares phases dead, initiates loop control sequence, trips and locks out its breaker.
t2	Midpoint recloser declares phases dead, initiates loop control sequence, starts SWOTF timer and requests ALT thresholds (per settings)
t3	TiePoint recloser declares phases dead, initiates loop control sequence and closes its breaker. May request ALT thresholds (per settings) before closing breaker.

5-Recloser Fault 2 Scenario

In a 5-recloser loop control scheme, Figure 182, if there is a permanent fault between the sectionalizing recloser B and the midpoint recloser C at F2, recloser B will recognize the fault and go through its reclosing shots to lockout (assuming proper coordination with the circuit breaker at Source 1). Recloser C will recognize a loss of voltage after the first recloser B operation, and if the voltage does not return for the livebus timer setting, will request the RER620 to start its SWOTF timer and, if programmed, to use New Group Settings after t2 seconds (typically set around 10 seconds after the Sectionalizer is set to trip). See Figure 187 the tie-point recloser T at the same instant will recognize a loss of 3-phase voltage on the S1 side of its recloser PTs. After a delay time of t3 seconds from the initial fault at S1 the tie-point recloser T will close, and if programmed, switch to New Group Settings. Since the fault is permanent, fault current will flow from the alternate source. With proper coordination in this direction, the mid-point recloser will trip on overcurrent (one shot due to its SWOTF mode), isolating the faulted section between Recloser B and C. This establishes service from S2 to Recloser C. The TiePoint recloser is typically set to declare its phase voltages dead sometime after the Midpoint recloser has started its SWOTF timer and before the SWOTF timer expires. The unfaulted portion of the distribution feeder circuit from S2 to recloser B never loses service, and from Recloser C to the tie-point recloser the load is picked back up. Figure 187 and Table 316 summarize the events.

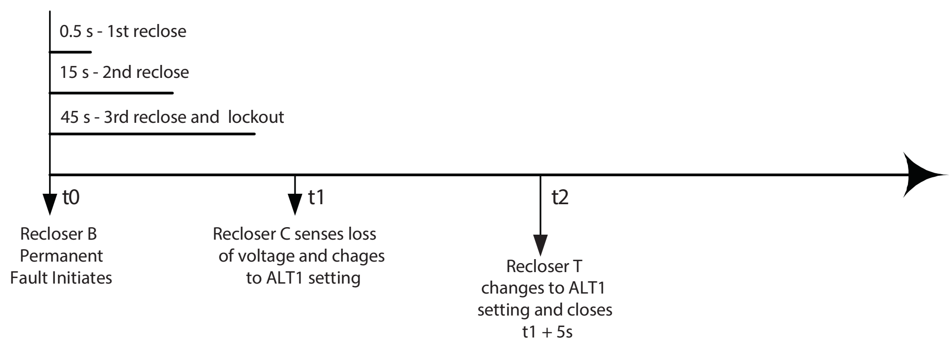


Figure 187: 5-Reclosre Fault 2 scenario Sequence of Events

Table 316: 5-Reclosre Fault 2 scenario Sequence of Events

Time	Event or Conditon
t0	Permanent line fault occurs. Sectionalizing recloser trips and locks out causing loss of voltage at the Midpoint and TiePoint reclosers.
t1	Midpoint recloser declares phases dead, initiates loop control sequence, starts SWOTF timer. May request ALT thresholds (per settings).
t2	TiePoint recloser declares phases dead, initiates loop control sequence and closes its breaker. May request ALT thresholds (per settings) before closing breaker.

5-Recloser Fault 3 Scenario

If a permanent fault occurred at location F3, Figure 186, the following sequence occurs; recloser C proceeds through its reclosing sequence of overcurrent protection (assume 3 operations to lockout). Upon tripping of recloser C, recloser T senses loss of voltage and after its time delay of t1 seconds, closes onto the permanent fault. Since this fault is permanent and recloser T has closed into the fault, recloser T does not go through the same recloser sequence as recloser C just went through, recloser T goes directly to lockout. The unfaulted portion of the distribution feeder circuit between S1 to recloser C remains in service, as does S2 to recloser T. Figure 188 and Table 317 summarize the sequence of events.

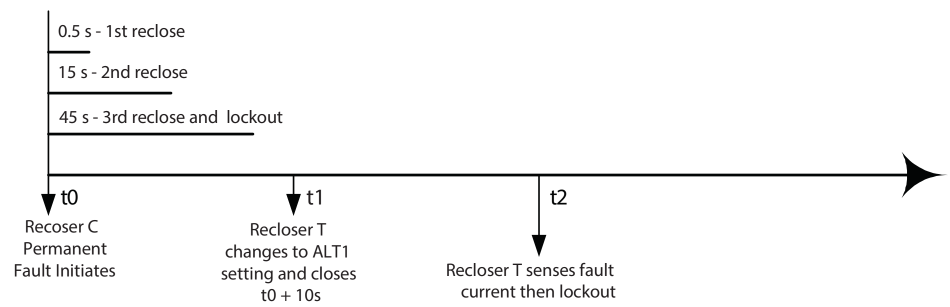


Figure 188: 5-Reclosre Fault 3 scenario Sequence of Events

Table 317: 5-Reclosre Fault 3 scenario Sequence of Events

Time	Event or Conditon
t0	Permanent line fault occurs. Midpoint recloser trips and locks out causing loss of voltage at the TiePoint reclosers.
t1	TiePoint recloser declares phases dead, initiates loop control sequence, and closes its breaker. May request ALT thresholds (per settings) before closing breaker.
t2	TiePoint breaker trips and locks out.

5.4.5.3 Four-Recloser System Operation

A four-recloser system is a hybrid of the three- and five-recloser systems. Between one source and the TiePoint, recloser is a Sectionalizing recloser and a Midpoint recloser. Only a Sectionalizing recloser appears between the other source and the TiePoint. The Sectionalizer and Midpoint from one source of the TiePoint is configured like reclosers in a five-recloser system. The other Sectionalizing recloser is configured like its counterpart in a three-recloser system. TiePoint configuration and operation is similar in all three topologies.

5.4.5.4 Restoring Normal Operation

The "Reset Logic" section covered previously explains on the steps involved in resetting the LCM function and activated again safely when reclosers working in different modes. All the restoration steps should be performed before in full compliance with all applicable safety procedures before resetting the LCM functionality in RER620 relay.

5.4.6 Signals

Table 318: DLCM input signals

Name	Type	Default	Description
S1_ENABLE	Boolean	FALSE	Source 1 enable or disable
S2_ENABLE	Boolean	FALSE	Source 2 enable or disable
RESET_IN	Boolean	FALSE	Reset input
BLOCK	Boolean	FALSE	Block input

Table 319: DLCM output signals

Name	Type	Description
LCM_TRIP	Boolean	Trip output, valid only in Sectionalize t mode
LCM_CLOSE	Boolean	Trip output, valid only in Tie point mode
SET_GROUP_CHANGE	Boolean	Output used to activate Alternate settings in mid point and tie point modes
SWOTF	Boolean	Binary output to operate the recloser in lock-out or non-reclose mode
S1_STATUS	Boolean	source1 status
S2_STATUS	Boolean	source2 status
S1_DISABLED	Boolean	source1 enable
S2_DISABLED	Boolean	source2 enable
RESET_OUT	Boolean	Reset output

5.4.7 Settings

Table 320: DLCM group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=ON 0=OFF			1=OFF	Operation on/off of loop control
LCM mode	1=Sectionalizer 2=Mid point 3=Tie point 4=Disabled			4=Disabled	Loop control functionality operating mode based on the recloser type
Dead bus threshold	0.001 … 2.000	xVn		1.000	Voltage level setting (RMS line to neutral) for detecting dead bus
Live bus threshold	0.001 … 2.000	xVn		1.000	Voltage level setting (RMS line to neutral) for detecting live bus.
Dead bus time	1…600	seconds		5	Time duration that voltage should be below the threshold to determine the bus is dead.
Live bus time	1…600	seconds		5	Time duration that voltage should be above the threshold to determine the bus is live.
Volt regain time	0…5	seconds		0	When the voltage is lost on a line and the deadbus time is running, if the voltage comes back above the live bus threshold for this amount of time, the dead bus timer will reset.
Line side src	1=S1 2=S2			1=S1	Line side source
Vt config line	1 … 3			3	Number of Voltage channels on line side
Vt config load	1 … 3			3	Number of Voltage channels on load side
Vt line enable	1=TRUE 0=FALSE			0=FALSE	To include the voltages on line side for making decisions
Vt load enable	1=TRUE 0=FALSE			0=FALSE	To include the voltages on load side for making decisions
Vt line phase	0=PhA 1=PhB 2=PhC			0=PhA	The connected phase if one voltage channel is used in line side.
Vt load phase	0=PhA 1=PhB 2=PhC			0=PhA	If one voltage channel is used in load side which phase is connected
Sect3POpmode	0=All Phase 1=Any Phase			1=Any Phase	Single or three phase operational mode (valid only in sectionalizing mode)
En set grp chg	1=TRUE 0=FALSE			0=FALSE	Setting group switching is enabled (Valid for Tie point and mid point mode only)
Reset on power up	1=TRUE 0=FALSE			0=FALSE	Reset on power up setting (valid only in sectionalizing and midpoint modes)
Sectionalizing reset	1=TRUE 0=FALSE			0=FALSE	Automatic resetting of loop control in sectionalizing mode
SWOTF time	0….120	seconds		5	Switch on to fault time to operate the mid point recloser in lock out mode or non reclose mode after the loop control sequence is initiated.

5.5 Multipurpose Generic Up-Down Counter (UDFCNT)

5.5.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Multipurpose generic up-down counter	UDFCNT	UDFCNT	UDFCNT

5.5.2 Function block

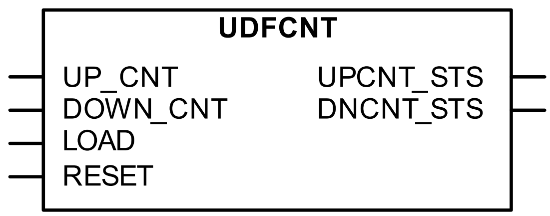


Figure 189: Function block

5.5.3 Functionality

The generic up-down counter function UDFCNT counts up or down for each positive edge of the corresponding inputs. The counter value output can be reset to zero or pre-set to some other value, if required

The UDFCNT function provides up-count and down-count status outputs, which specify the relation of the counter value to a loaded preset value and to zero respectively.

5.5.4 Operation principle

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

The operation of UDFCNT can be described by using a module diagram (see Figure 190).

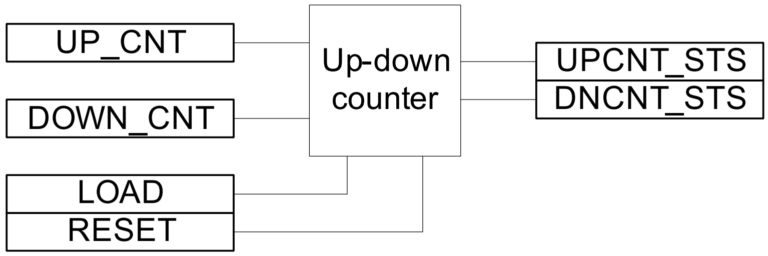


Figure 190: Functional module diagram

Up-down counter

Each rising edge of the UP_CNT input increments the counter value CNT_VAL by one and each rising edge of the DOWN_CNT input decrements the CNT_VAL by one. If there is a rising edge at both the inputs UP_CNT and DOWN_CNT, then the counter value CNT_VAL is unchanged. The CNT_VAL is available through the Monitored data view.

The counter value CNT_VAL is stored in a non-volatile memory. The range of the counter is 0...+2147483647. The count of CNT_VAL saturates at the final value of 2147483647, that is, no further increment is possible.

The value of the setting *Counter load value* is loaded into counter value CNT_VAL either when the LOAD input is set to TRUE or when the *Load Counter* is set to “Load” in the LHMI. Till the LOAD input is TRUE, it prevents all further counting.

The function also provides status outputs UPCNT_STS and DNCNT_STS. The UPCNT_STS is set to TRUE when the CNT_VAL is greater than or equal to setting Counter load value. DNCNT_STS is set to TRUE when the CNT_VAL is equal to zero.

The RESET input is used for resetting of the function. When this input is set to TRUE or when the *Reset counter* is set to “reset” the CNT_VAL is forced to zero.

5.5.5 Signals

Table 321: UDFCNT input signals

Name	Type	Default	Description
UP_CNT	BOOL	FALSE	Input for up counting
DOWN_CNT	BOOL	FALSE	Input for down counting
LOAD	BOOL	FALSE	Load the counter to preset value
RESET	BOOL	FALSE	Reset of the function

Table 322: UDFCNT output signals

Name	Type	Description
UPCNT_STS	BOOL	Status of the up counting
DNCNT_STS	BOOL	Status of the down counting

Table 323: UDFCNT Monitored inputs signals

Name	Type	Default	Description
UP_CNT	BOOL	FALSE	Input for up counting
DOWN_CNT	BOOL	FALSE	Input for down counting
LOAD	BOOL	FALSE	Load the counter to preset value
RESET	BOOL	FALSE	Reset of the function

Table 324: UDFCNT Monitored output signals

Name	Type	Description
UPCNT_STS	BOOL	Status of the up counting
DNCNT_STS	BOOL	Status of the down counting
CNT_VAL	INTEGE R	Output of counter

5.5.6 Settings

Table 325: UDFCNT non-group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-		On	Operation Mode On/Off
Counter Load Value	0....214748364 7	-	1	10000	Preset Counter Value
Reset Counter	Cancel Reset	-		Cancel	Reset Counter Value
Preset Counter	Cancel Load	-		Cancel	Load Counter Value to preset value

Section 6 Condition monitoring functions

6.1 Circuit breaker condition monitoring 52CM

6.1.1 Identification

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

6.1.2 Function block

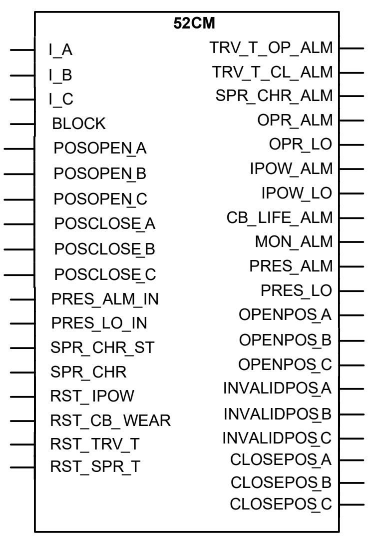


Figure 191: Function block

6.1.3 Functionality

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

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

6.1.4 Operation principle

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

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

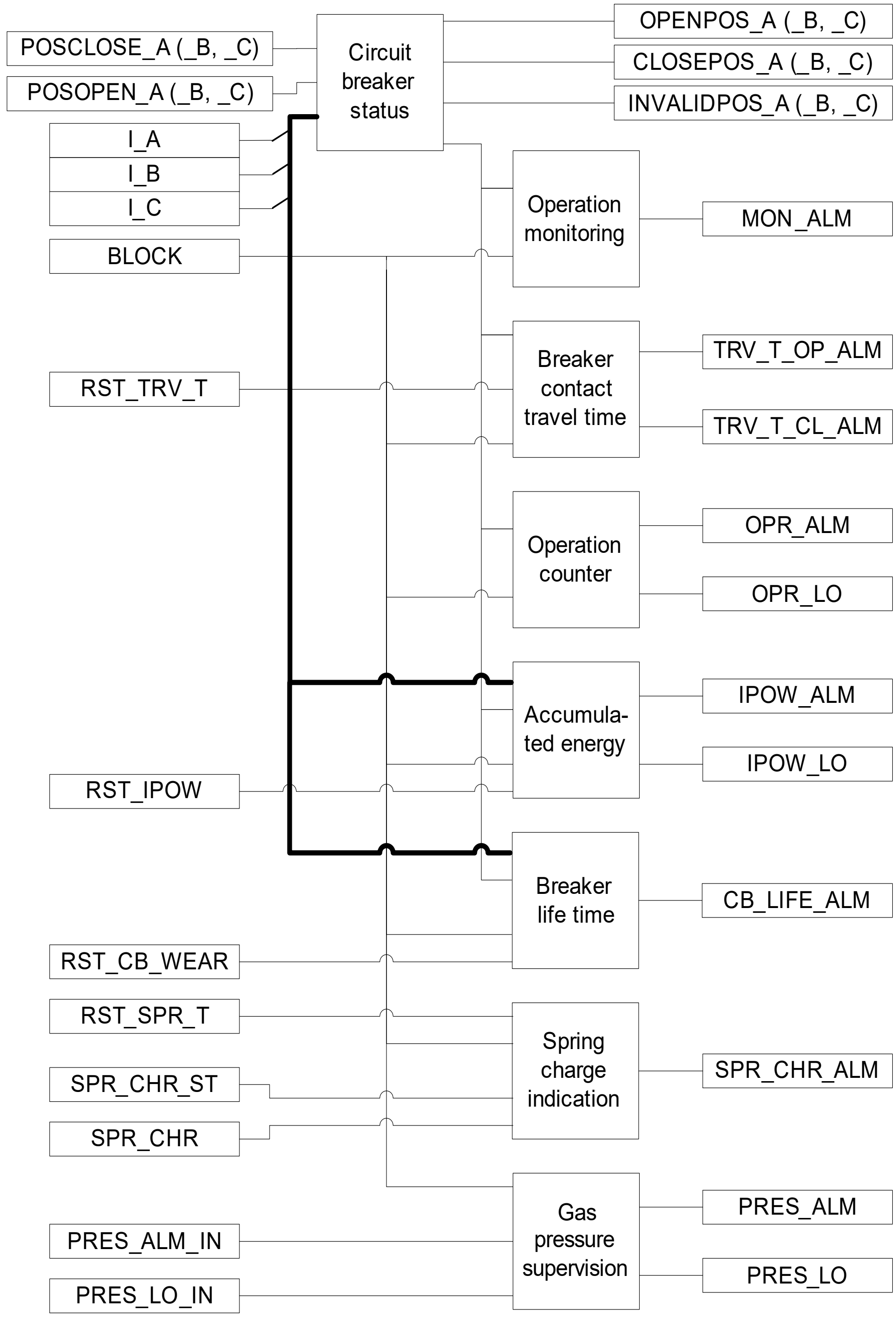


Figure 192: Functional module diagram

6.1.4.1 Circuit breaker status

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

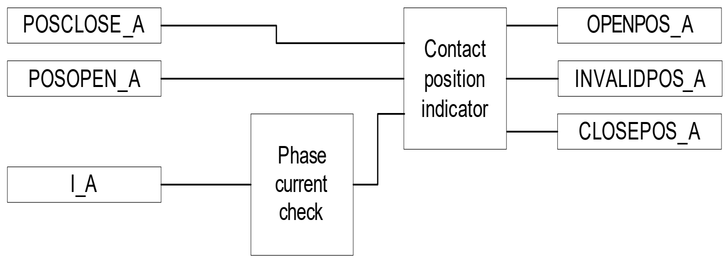


Figure 193: Functional module diagram for monitoring circuit breaker status (Typical pole, shown for Phase A)

Phase current check

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

Contact position indicator

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

The status of the breaker is indicated with the binary outputs OPENPOS_A(_B,_C), INVALIDPOS_A(_B,_C), and CLOSEPOS_A(_B,_C) for open, intermediate, and closed position respectively.

6.1.4.2 Circuit breaker operation monitoring

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

This subfunction requires two position inputs POSOPEN_A(_B,_C) and POSCLOSE_A(_B,_C) from the circuit breaker.

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

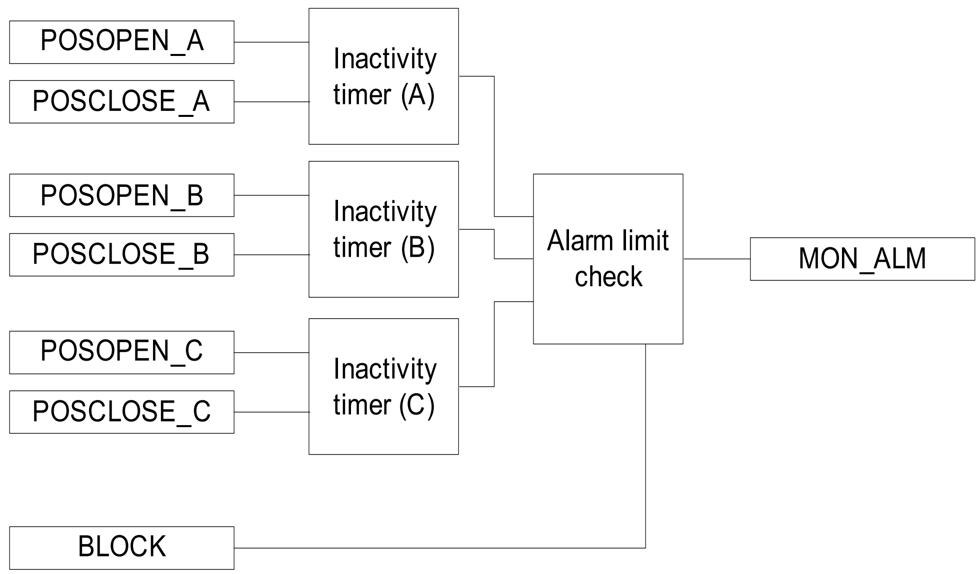


Figure 194: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

Inactivity timer

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

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

Alarm limit check

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

6.1.4.3 Breaker contact travel time

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

This subfunction requires two position inputs `POSOPEN_A(_B,_C)` and `POSCLOSE_A(_B,_C)` from the circuit breaker.

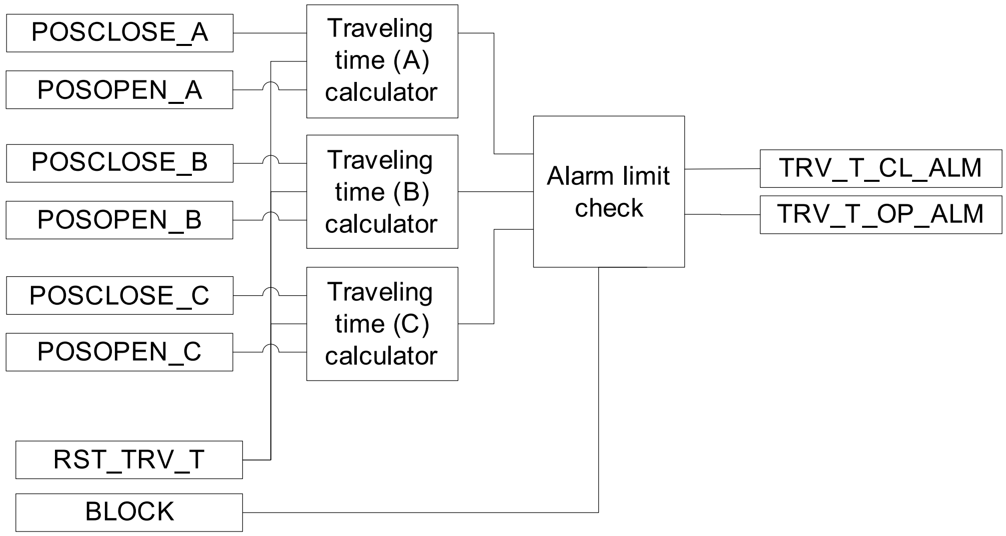


Figure 195: Functional module diagram for breaker contact travel time

Traveling time calculator

The contact travel time of the breaker is calculated from the time between auxiliary contacts' state change. The open travel time is measured between the opening of the `POSCLOSE_A(_B,_C)` auxiliary contact and the closing of the `POSOPEN_A(_B,_C)` auxiliary contact. Travel time is also measured between the opening of the `POSOPEN` auxiliary contact and the closing of the `POSCLOSE_A(_B,_C)` auxiliary contact.

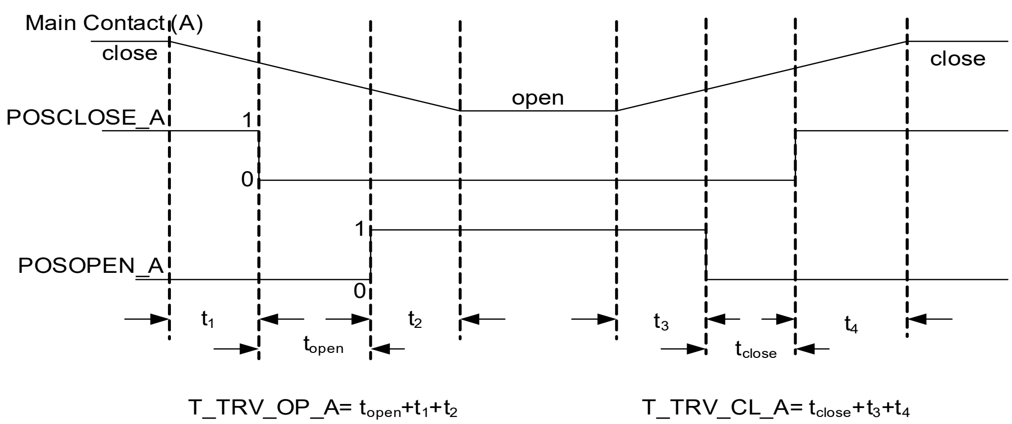


Figure 196: Travel time calculation

There is a time difference t_1 between the start of the main contact opening and the opening of the `POSCLOSE_A(_B,_C)` auxiliary contact. Similarly, there is a time gap t_2 between the time when the `POSOPEN_A(_B,_C)` auxiliary contact opens and the main contact is completely open. Therefore, in order to incorporate the time t_1+t_2, a correction factor needs to be added with t_{open} to get the actual opening time. This factor is added with the

Opening time Cor (=t_1+t_2). The closing time is calculated by adding the value set with the *Closing time Cor* (t_3+t_4) setting to the measured closing time.

The last measured opening travel time `T_TRV_OP_A(_B,_C)` and the closing travel time `T_TRV_CL_A(_B,_C)` are available through the Monitored data view on the LHMI or through tools via communications.

Alarm limit check

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

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

6.1.4.4 Operation counter

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

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

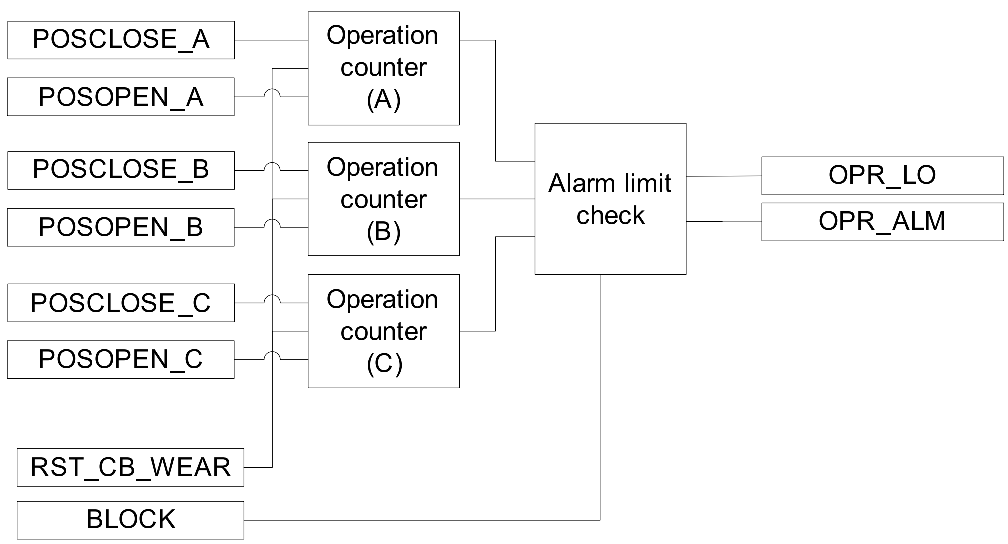


Figure 197: Functional module diagram for counting circuit breaker operations

Operation counter

The operation counter counts the number of operations based on the state change of the binary auxiliary contacts inputs POSCLOSE_A(_B,_C) and POSOPEN_A(_B,_C).

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

Alarm limit check

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

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

6.1.4.5 Accumulation of $I^y t$

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

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

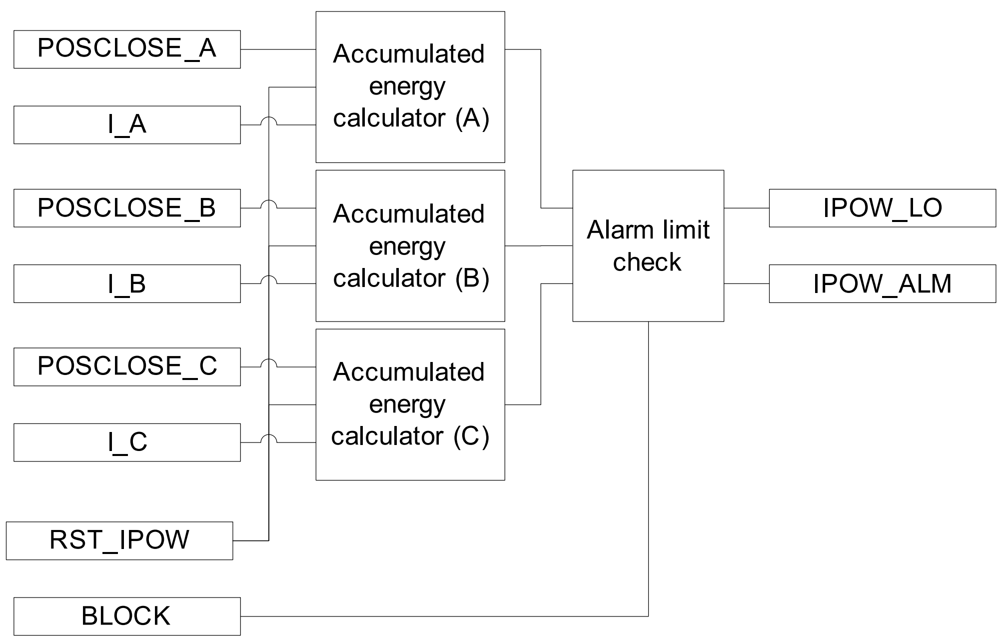


Figure 198: Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

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

The calculation is initiated with the POSCLOSE_A(_B,_C) input open events. It ends when the RMS current becomes lower than the *Acc stop current* setting value.

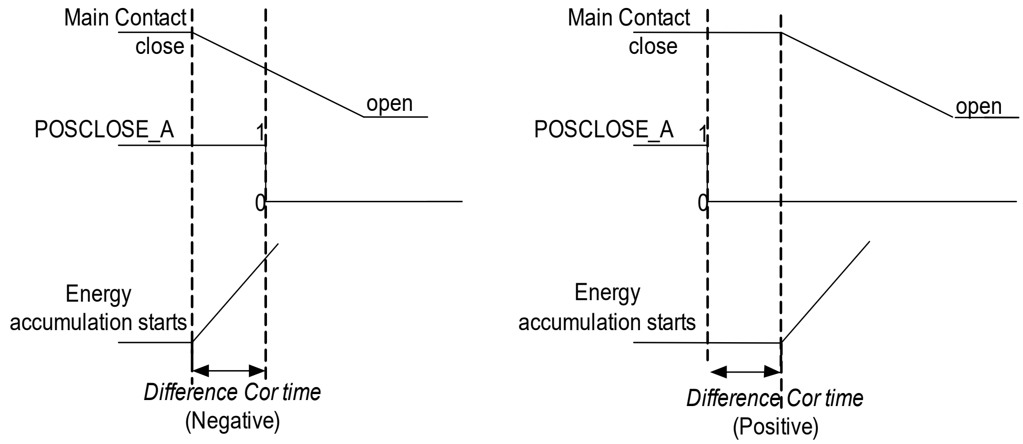


Figure 199: Significance of the Difference Cor time setting

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

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

Alarm limit check

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

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

6.1.4.6 Remaining life of the circuit breaker

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

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

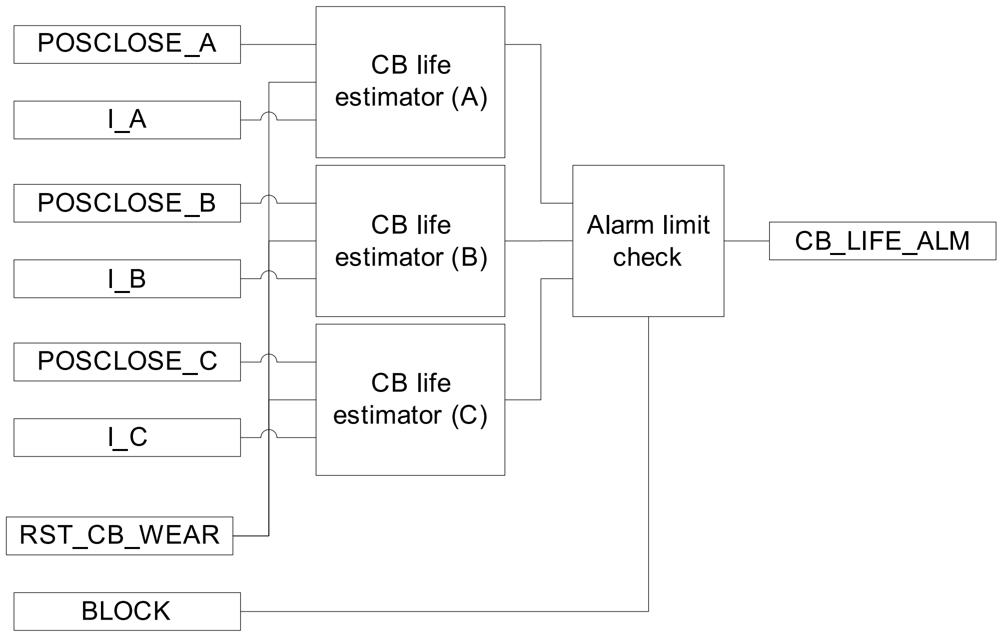


Figure 200: Functional module diagram for estimating the life of the circuit breaker

Circuit breaker life estimator

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

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

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

Alarm limit check

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

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

6.1.4.7 Circuit breaker spring charged indication

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

This subfunction is not applicable to magnetic actuators.

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

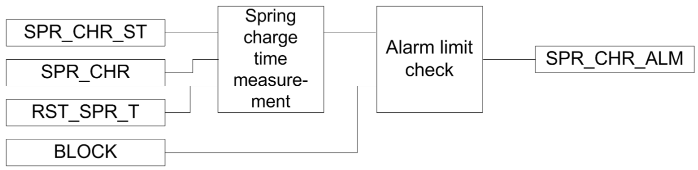


Figure 201: Functional module diagram for circuit breaker spring charged indication and alarm

Spring charge time measurement

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

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

Alarm limit check

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

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

6.1.4.8 Gas pressure supervision

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

This subfunction is not applicable to vacuum interruption.

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

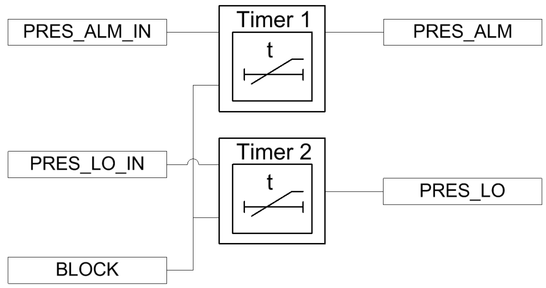


Figure 202: Functional module diagram for circuit breaker gas pressure alarm

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

Timer 1

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

Timer 2

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

6.1.5 Application

52CM includes different metering and monitoring subfunctions.

Circuit breaker status

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

Circuit breaker operation monitoring

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

Breaker contact travel time

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

Operation counter

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

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

Accumulation of $I^y t$

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

Remaining life of the breaker

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

Example for estimating the remaining life of a circuit breaker

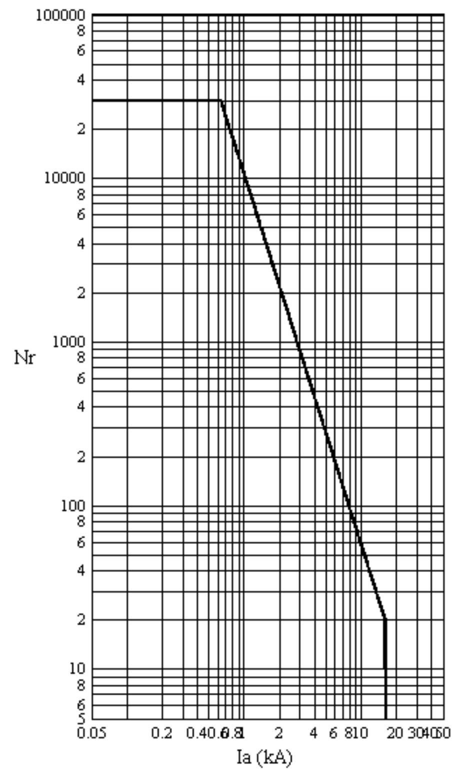


Figure 203: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

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

Calculation of Directional Coefficient

The directional coefficient is calculated according to the formula:

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

(Equation 42)

I_r Rated operating current = 630 A
I_f Rated fault current = 16 kA
A Op number rated = 30000
B Op number fault = 20

Calculation for estimating the remaining life

The equation shows that there are 30,000 possible operations at the rated operating current of 630 A and 20 operations at the rated fault current 16 kA. Therefore, if the tripping current is 10 kA, the operation counts from the curve at 10kA is about 60. One operation at 10 kA will result in a reduction in the breaker life by 30,000/60=500 operations. If the remaining life of the circuit breaker is 15,000 operations prior to this tripping, after one operation of 10 kA, the remaining life of the circuit breaker is 15,000-500=14,500 at the rated operating current. Breaker life reduction for one operation at current level I can also be estimated by the following formula,

$$\text{Remaining life reduction} = \left(\frac{I}{I_r}\right)^{-\text{Directional Coef}}$$

Spring charged indication

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

Gas pressure supervision

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

6.1.6 Signals

Table 326: 52CM Input signals

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

Table 327: 52CM Output signals

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

Name	Type	Description
CLOSEPOS_B	BOOLEAN	CB is in closed position, phase B
CLOSEPOS_C	BOOLEAN	CB is in closed position, phase C

6.1.7 Settings

Table 328: 52CM Non group settings

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

6.1.8 Monitored data

Table 329: 52CM Monitored data

Name	Type	Values (Range)	Unit	Description
T_TRV_OP_A	FLOAT32	0...60000	ms	Travel time of the CB during opening operation, phase A
T_TRV_OP_B	FLOAT32	0...60000	ms	Travel time of the CB during opening operation, phase B
T_TRV_OP_C	FLOAT32	0...60000	ms	Travel time of the CB during opening operation, phase C
T_TRV_CL_A	FLOAT32	0...60000	ms	Travel time of the CB during closing operation, phase A
T_TRV_CL_B	FLOAT32	0...60000	ms	Travel time of the CB during closing operation, phase B
T_TRV_CL_C	FLOAT32	0...60000	ms	Travel time of the CB during closing operation, phase C
T_SPR_CHR	FLOAT32	0.00...99.99	s	The charging time of the CB spring
NO_OPR_A	INT32	0...99999		Number of CB operation cycle, phase A
NO_OPR_B	INT32	0...99999		Number of CB operation cycle, phase B
NO_OPR_C	INT32	0...99999		Number of CB operation cycle, phase C
INA_DAYS_A	INT32	0...9999		The number of days CB has been inactive, phase A
INA_DAYS_B	INT32	0...9999		The number of days CB has been inactive, phase B
INA_DAYS_C	INT32	0...9999		The number of days CB has been inactive, phase C
CB_LIFE_A	INT32	-9999...9999		CB Remaining life phase A
CB_LIFE_B	INT32	-9999...9999		CB Remaining life phase B
CB_LIFE_C	INT32	-9999...9999		CB Remaining life phase C
IPOW_A	FLOAT32	0.00...1000000.00		Accumulated currents power (Iyt), phase A
IPOW_B	FLOAT32	0.00...1000000.00		Accumulated currents power (Iyt), phase B
IPOW_C	FLOAT32	0.00...1000000.00		Accumulated currents power (Iyt), phase C
52CM	Enum	1=enabled 2=blocked 3=test 4=test/blocked 5=disabled		Status

6.1.9 Technical data

Table 330: 52CM Technical data

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

6.2 Fuse failure supervision 60

6.2.1 Identification

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

6.2.2 Function block

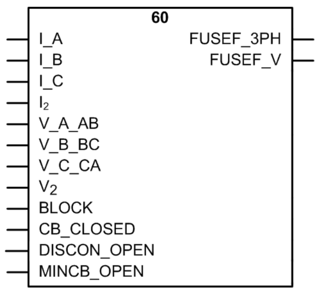


Figure 204: Function block

6.2.3 Functionality

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

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

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

6.2.4 Operation principle

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

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

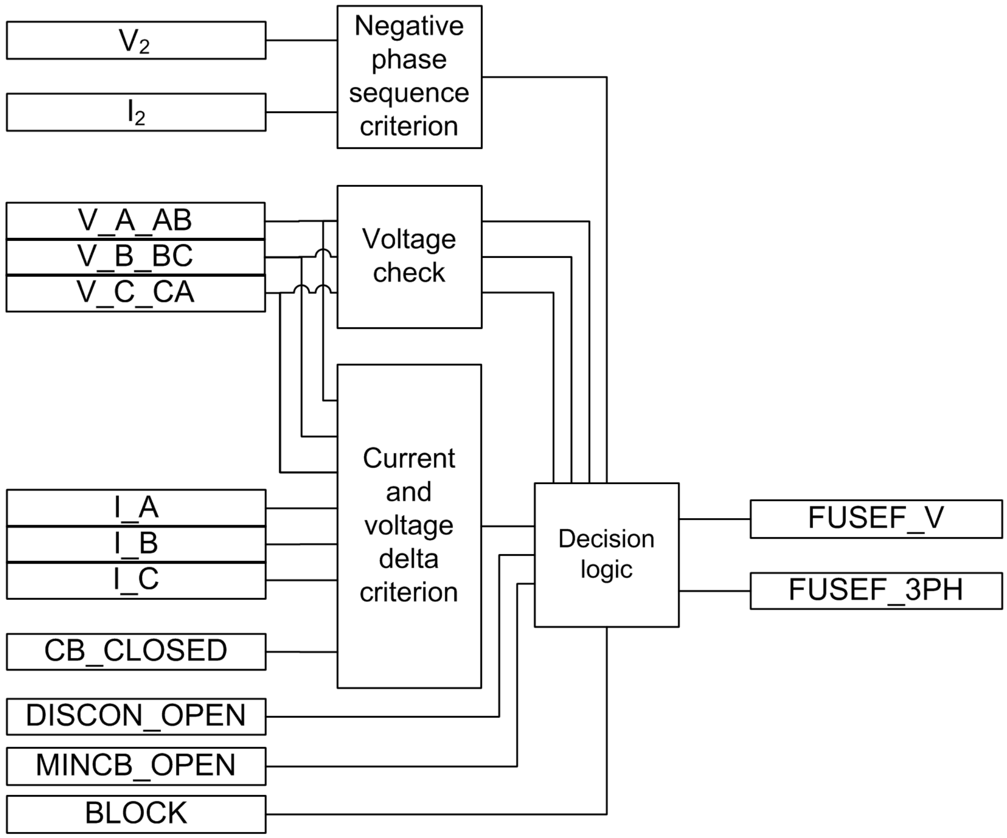


Figure 205: Functional module diagram

Negative phase-sequence criterion

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

Voltage check

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

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

Current and voltage delta criterion

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

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

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

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

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

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

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

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

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

Decision logic

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

Table 331: Fuse failure output control

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

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

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

6.2.5 Application

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

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

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

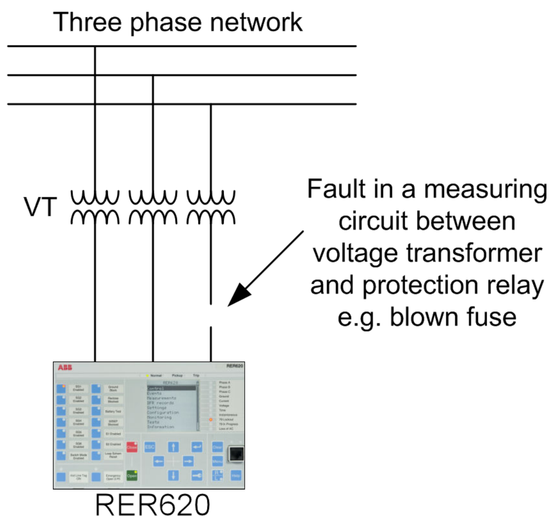


Figure 206: Fault in a circuit from the voltage transformer to the relay

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

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

6.2.6 Signals

Table 332: 60 Input signals

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

Table 333: 60 Output signals

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

6.2.7 Settings

Table 334: 60 Non group settings

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

6.2.8 Monitored data

Table 335: 60 Monitored data

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

6.2.9 Technical data

Table 336: 60 Technical data

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

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

Section 7 Measurement functions

7.1 Basic measurements

7.1.1 Functions

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

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

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

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

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

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

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

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

7.1.2 Measurement functionality

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

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

Demand value calculation

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

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

Value reporting

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

- Zero point clamping
- Deadband supervision
- Limit value supervision

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

Zero point clamping

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

Table 337: Zero point clamping limits

Function	Zero clamping limit
Three-phase current measurement (IA, IB, IC)	0.3% of nominal (In)[1]
Three-phase voltage measurement (VA, VB, VC)	1% of nominal (Vn)
Ground current measurement (IG)	1% of nominal (In)
Ground voltage measurement (VG)	1% of nominal (Vn)
Phase sequence current measurement (I1, I2, I0)	1% of the nominal (In)
Phase sequence voltage measurement (V1, V2, V0)	1% of the nominal (Vn)
Three-phase power and energy measurement (P, E)	1.5% of the nominal (Sn)

1) *See Table 276 for limitations.*

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.

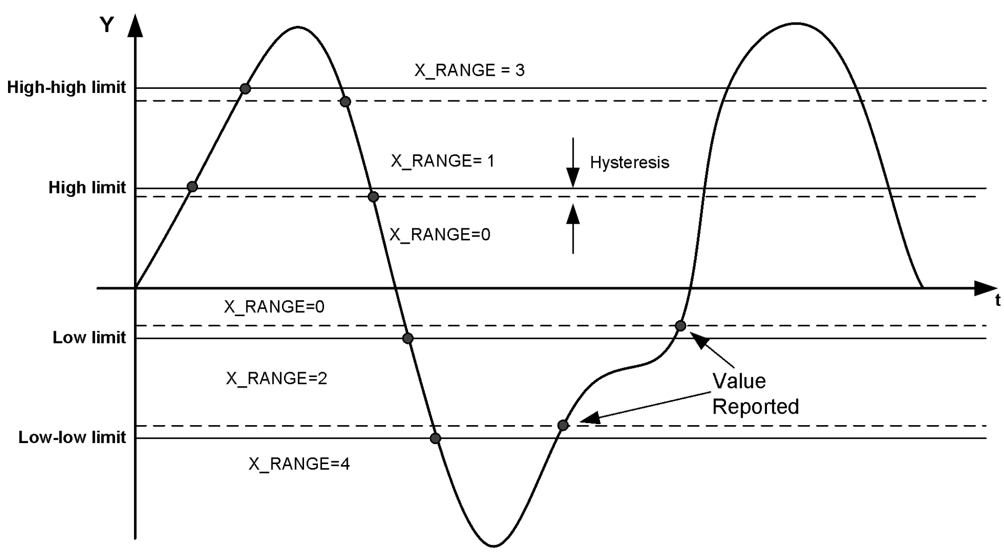


Figure 207: Presentation of operating limits

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

Table 338: Settings for limit value supervision

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

Deadband supervision

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

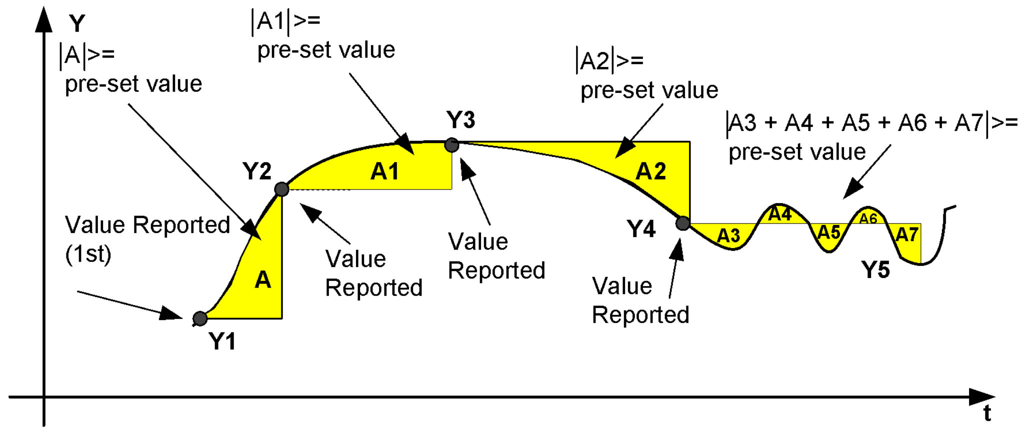


Figure 208: Integral deadband supervision

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

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

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

(Equation 43)

Example for IA, IB, IC:

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

`I_INST_A` = `I_DB_A` = 0.30

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

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

Table 339: Parameters for deadband calculation

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

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

Power and energy calculation

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

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

(Equation 44)

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

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

(Equation 45)

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

(Equation 46)

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

(Equation 47)

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

(Equation 48)

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.

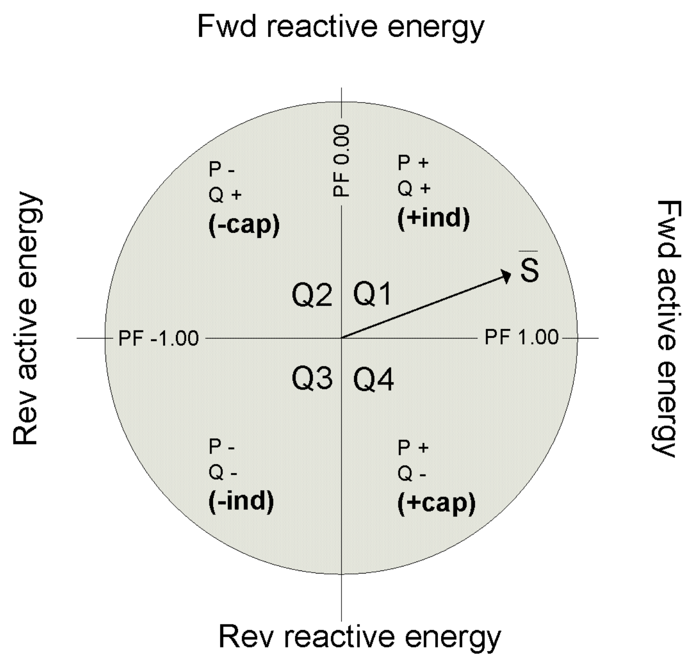


Figure 209: Complex power and power quadrants

Table 340: Power quadrants

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

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

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

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

Sequence components

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

$$\bar{I}_0 = (\bar{I}_A + \bar{I}_B + \bar{I}_C)/3$$
(Equation 49)

$$\bar{I}_1 = (\bar{I}_A + a \cdot \bar{I}_B + a^2 \cdot \bar{I}_C)/3$$
(Equation 50)

$$\bar{I}_2 = (\bar{I}_A + a^2 \cdot \bar{I}_B + a \cdot \bar{I}_C)/3$$
(Equation 51)

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

$$\bar{V}_0 = (\bar{V}_A + \bar{V}_B + \bar{V}_C)/3$$
(Equation 52)

$$\bar{V}_1 = (\bar{V}_A + a \cdot \bar{V}_B + a^2 \cdot \bar{V}_C)/3$$
(Equation 53)

$$\bar{V}_2 = (\bar{V}_A + a^2 \cdot \bar{V}_B + a \cdot \bar{V}_C)/3$$
(Equation 54)

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

$$\bar{V}_1 = (\bar{V}_{AB} - a^2 \cdot \bar{V}_{BC})/3$$
(Equation 55)

$$\bar{V}_2 = (\bar{V}_{AB} - a \cdot \bar{V}_{BC})/3$$
(Equation 56)

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 and control 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 relay analog measurement chain can be verified during normal service by a periodic comparison of the measured value from the relay to other independent meters.

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

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

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

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

7.1.4 Three-phase current IA, IB, IC

7.1.4.1 Identification

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

7.1.4.2 Function block

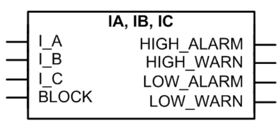


Figure 210: Function block

7.1.4.3 Signals

Table 341: IA,IB,IC Input signals

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

Table 342: IA,IB,IC Output signals

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

7.1.4.4 Settings

Table 343: IA,IB,IC Non group settings

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

7.1.4.5 Monitored data

Table 344: IA,IB,IC Monitored data

Name	Type	Values (Range)	Unit	Description
IA-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase A
IB-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase B
IC-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase C
Max demand phA	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase A
Max demand phB	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase B
Max demand phC	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase C
Time max demand phA	Timestamp			Time of maximum demand phase A
Time max demand phB	Timestamp			Time of maximum demand phase B
Time max demand phC	Timestamp			Time of maximum demand phase C
I_INST_A	FLOAT32	0.00...40.00	xIn	IA Amplitude, magnitude of instantaneous value
I_DB_A	FLOAT32	0.00...40.00	xIn	IA Amplitude, magnitude of reported value
I_DMD_A	FLOAT32	0.00...40.00	xIn	Demand value of IL1 current
I_RANGE_A	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IA Amplitude range
I_INST_B	FLOAT32	0.00...40.00	xIn	IB Amplitude, magnitude of instantaneous value
I_DB_B	FLOAT32	0.00...40.00	xIn	IB Amplitude, magnitude of reported value
I_DMD_B	FLOAT32	0.00...40.00	xIn	Demand value of IL2 current
I_RANGE_B	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IB Amplitude range
I_INST_C	FLOAT32	0.00...40.00	xIn	IC Amplitude, magnitude of instantaneous value
I_DB_C	FLOAT32	0.00...40.00	xIn	IC Amplitude, magnitude of reported value
I_DMD_C	FLOAT32	0.00...40.00	xIn	Demand value of IL3 current
I_RANGE_C	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IC Amplitude range

7.1.4.6 Technical data

Table 345: IA, IB, IC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	±0.5% or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

Note: The relay may indicate non-zero phase current measurements in the range of 0.003...0.01 x In when the recloser is in the open state.

7.1.5 Three-phase voltage VA, VB, VC

7.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase voltage	VMMXU	3U	VA, VB, VC

7.1.5.2 Function block

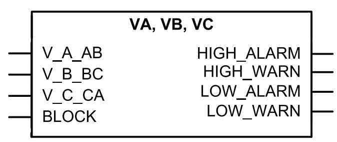


Figure 211: Function block

7.1.5.3 Signals

Table 346: VA, VB, VC Input signals

Name	Type	Default	Description
V_A_AB	SIGNAL	0	Phase A voltage
V_B_BC	SIGNAL	0	Phase B voltage
V_C_CA	SIGNAL	0	Phase C voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 347: VA, VB, VC Output signals

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

7.1.5.4 Settings

Table 348: VA, VB, VC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
Num of phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required by limit supervision
V high high limit	0.00...4.00	xVn		1.40	High alarm voltage limit
V high limit	0.00...4.00	xVn		1.20	High warning voltage limit
V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit
V low low limit	0.00...4.00	xVn		0.00	Low alarm voltage limit
V deadband	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001% s)

7.1.5.5 Monitored data

Table 349: VA, VB, VC Monitored data

Name	Type	Values (Range)	Unit	Description
VAB-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase AB
VBC-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase B
VCA-kV	FLOAT32	0.00...4.00	xVn	Measured phase to phase voltage amplitude phase C
V_INST_AB	FLOAT32	0.00...4.00	xVn	VAB Amplitude, magnitude of instantaneous value
V_DB_AB	FLOAT32	0.00...4.00	xVn	VAB Amplitude, magnitude of reported value
V_RANGE_AB	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VAB Amplitude range
V_INST_BC	FLOAT32	0.00...4.00	xVn	VBC Amplitude, magnitude of instantaneous value
V_DB_BC	FLOAT32	0.00...4.00	xVn	VBC Amplitude, magnitude of reported value
V_RANGE_BC	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VBC Amplitude range
V_INST_CA	FLOAT32	0.00...4.00	xVn	VCA Amplitude, magnitude of instantaneous value
V_DB_CA	FLOAT32	0.00...4.00	xVn	VCA Amplitude, magnitude of reported value
V_RANGE_CA	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		VCA Amplitude range
V_INST_A	FLOAT32	0.00...4.00	xVn	VA Amplitude, magnitude of instantaneous value
V_INST_B	FLOAT32	0.00...4.00	xVn	VB Amplitude, magnitude of instantaneous value
V_INST_C	FLOAT32	0.00...4.00	xVn	VC Amplitude, magnitude of instantaneous value

7.1.5.6 Technical data

Table 350: VA, VB, VC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz (Secondary PT voltages): At voltages range 0.01…1.15 X V_n ±0.5% or ±0.002 X V_n (SIM0001/CVD): At voltages range 0.20 to 1.4 X V_n ±1% or ±0.005 X V_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.6 Ground current IG

7.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Neutral current	RESCMMXU	I0	IG

7.1.6.2 Function block

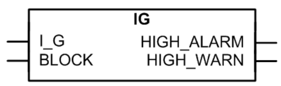


Figure 212: Function block

7.1.6.3 Signals

Table 351: IG Input signals

Name	Type	Default	Description
IG	SIGNAL	0	Ground current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 352: IG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.6.4 Settings

Table 353: IG Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
A Hi high limit res	0.00...40.00	xIn		0.20	High alarm current limit
A high limit res	0.00...40.00	xIn		0.05	High warning current limit
A deadband res	100...100000			2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001% s)

7.1.6.5 Monitored data

Table 354: IG Monitored data

Name	Type	Values (Range)	Unit	Description
IG-A	FLOAT32	0.00...40.00	xIn	Measured ground current
IG_INST	FLOAT32	0.00...40.00	xIn	Ground current Amplitude, magnitude of instantaneous value
IG_DB	FLOAT32	0.00...40.00	xIn	Ground current Amplitude, magnitude of reported value
IG_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Ground current Amplitude range

7.1.6.6 Technical data

Table 355: IG Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±0.5% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.7 Ground voltage VG

7.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Ground voltage	RESVMMXU	U0	VG

7.1.7.2 Function block

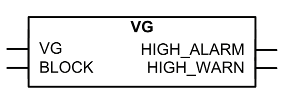


Figure 213: Function block

7.1.7.3 Signals

Table 356: VG Input signals

Name	Type	Default	Description
VG	SIGNAL	0	Ground voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 357: VG Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

7.1.7.4 Settings

Table 358: VG Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
V Hi high limit res	0.00...4.00	xVn		0.20	High alarm voltage limit
V high limit res	0.00...4.00	xVn		0.05	High warning voltage limit
V deadband res	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001% s)

7.1.7.5 Monitored data

Table 359: VG Monitored data

Name	Type	Values (Range)	Unit	Description
VG-kV	FLOAT32	0.00...4.00	xVn	Measured ground voltage
VG_INST	FLOAT32	0.00...4.00	xVn	Ground voltage Amplitude, magnitude of instantaneous value
VG_DB	FLOAT32	0.00...4.00	xVn	Ground voltage Amplitude, magnitude of reported value
VG_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Ground voltage Amplitude range

7.1.7.6 Technical data

Table 360: VG Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±0.5% or ±0.002 x V_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

7.1.8 Sequence current I1, I2, I0

7.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence current	CSMSQI	I1, I2, I0	I1, I2, I0

7.1.8.2 Function block

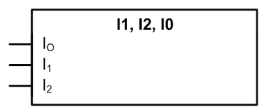


Figure 214: Function block

7.1.8.3 Signals

Table 361: I1, I2, I0 Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Zero sequence current
I_1	SIGNAL	0	Positive sequence current
I_2	SIGNAL	0	Negative sequence current

7.1.8.4 Settings

Table 362: I1, I2, I0 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Ps Seq A Hi high Lim	0.00...40.00	xIn		1.40	High alarm current limit for positive sequence current
Ps Seq A high limit	0.00...40.00	xIn		1.20	High warning current limit for positive sequence current
Ps Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for positive sequence current
Ps Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for positive sequence current
Ps Seq A deadband	100...100000			2500	Deadband configuration value for positive sequence current for integral calculation. (percentage of difference between min and max as 0,001% s)
Ng Seq A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for negative sequence current
Ng Seq A High limit	0.00...40.00	xIn		0.05	High warning current limit for negative sequence current
Ng Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for negative sequence current
Ng Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for negative sequence current
Ng Seq A deadband	100...100000			2500	Deadband configuration value for negative sequence current for integral calculation. (percentage of difference between min and max as 0,001% s)
Zro A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for zero sequence current
Zro A High limit	0.00...40.00	xIn		0.05	High warning current limit for zero sequence current
Zro A low limit	0.00...40.00	xIn		0.00	Low warning current limit for zero sequence current
Zro A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for zero sequence current
Zro A deadband	100...100000			2500	Deadband configuration value for zero sequence current for integral calculation. (percentage of difference between min and max as 0,001% s)

7.1.8.5 Monitored data

Table 363: I1, I2, I0 Monitored data

Name	Type	Values (Range)	Unit	Description
I2-A	FLOAT32	0.00...40.00	xIn	Measured negative sequence current
I1-A	FLOAT32	0.00...40.00	xIn	Measured positive sequence current
I0-A	FLOAT32	0.00...40.00	xIn	Measured zero sequence current
I2_INST	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, instantaneous value
I2_DB	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, reported value
I2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence current amplitude range
I1_INST	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, instantaneous value
I1_DB	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, reported value
I1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence current amplitude range
I0_INST	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, instantaneous value
I0_DB	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, reported value
I0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence current amplitude range

7.1.8.6 Technical data

Table 364: I1, I2, I0 Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±1.0% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,…

7.1.9 Phase sequence voltage V1, V2, V0

7.1.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence voltage	VSMSQI	U1, U2, U0	V1, V2, V0

7.1.9.2 Function block

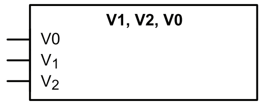


Figure 215: Function block

7.1.9.3 Signals

Table 365: V1, V2, V0 Input signals

Name	Type	Default	Description
V_0	SIGNAL	0	Zero sequence voltage
V_1	SIGNAL	0	Positive phase sequence voltage
V_2	SIGNAL	0	Negative phase sequence voltage

7.1.9.4 Settings

Table 366: V1, V2, V0 Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Ps Seq V Hi high Lim	0.00...4.00	xVn		1.40	High alarm voltage limit for positive sequence voltage
Ps Seq V high limit	0.00...4.00	xVn		1.20	High warning voltage limit for positive sequence voltage
Ps Seq V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for positive sequence voltage
Ps Seq V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for positive sequence voltage
Ps Seq V deadband	100...100000			10000	Deadband configuration value for positive sequence voltage for integral calculation. (percentage of difference between min and max as 0,001% s)
Ng Seq V Hi high Lim	0.00...4.00	xVn		0.20	High alarm voltage limit for negative sequence voltage
Ng Seq V High limit	0.00...4.00	xVn		0.05	High warning voltage limit for negative sequence voltage
Ng Seq V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for negative sequence voltage
Ng Seq V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for negative sequence voltage
Ng Seq V deadband	100...100000			10000	Deadband configuration value for negative sequence voltage for integral calculation. (percentage of difference between min and max as 0,001% s)
Zro V Hi high Lim	0.00...4.00	xVn		0.20	High alarm voltage limit for zero sequence voltage
Zro V High limit	0.00...4.00	xVn		0.05	High warning voltage limit for zero sequence voltage
Zro V low limit	0.00...4.00	xVn		0.00	Low warning voltage limit for zero sequence voltage
Zro V low low Lim	0.00...4.00	xVn		0.00	Low alarm voltage limit for zero sequence voltage
Zro V deadband	100...100000			10000	Deadband configuration value for zero sequence voltage for integral calculation. (percentage of difference between min and max as 0,001% s)

7.1.9.5 Monitored data

Table 367: V1, V2, V0 Monitored data

Name	Type	Values (Range)	Unit	Description
V2-kV	FLOAT32	0.00...4.00	xVn	Measured negative sequence voltage
V1-kV	FLOAT32	0.00...4.00	xVn	Measured positive sequence voltage
V0-kV	FLOAT32	0.00...4.00	xVn	Measured zero sequence voltage
V2_INST	FLOAT32	0.00...4.00	xVn	Negative sequence voltage amplitude, instantaneous value
V2_DB	FLOAT32	0.00...4.00	xVn	Negative sequence voltage amplitude, reported value
V2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence voltage amplitude range
V1_INST	FLOAT32	0.00...4.00	xVn	Positive sequence voltage amplitude, instantaneous value
V1_DB	FLOAT32	0.00...4.00	xVn	Positive sequence voltage amplitude, reported value
V1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence voltage amplitude range
V0_INST	FLOAT32	0.00...4.00	xVn	Zero sequence voltage amplitude, instantaneous value
V0_DB	FLOAT32	0.00...4.00	xVn	Zero sequence voltage amplitude, reported value
V0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence voltage amplitude range

7.1.9.6 Technical data

Table 368: V1, V2, V0 Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz At voltages in range 0.01…1.15 x V_n
	±1.0% or ±0.002 x V_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

7.1.10 Single and Three-phase power, powerfactor and Three Phase energy measurement P, SP, E

7.1.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase power and energy measurement	APEMMXU	P,SP, E	P,SP, E

7.1.10.2 Function block

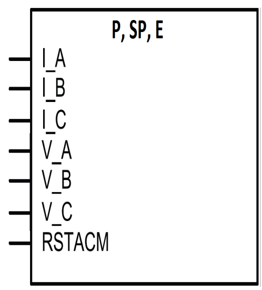


Figure 216: Function block

7.1.10.3 Signals

Table 369: P,E Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
V_A	SIGNAL	0	Phase A voltage
V_B	SIGNAL	0	Phase B voltage
V_C	SIGNAL	0	Phase C voltage
RSTACM	BOOLEAN	0=False	Reset of accumulated energy reading

7.1.10.4 Settings

Table 370: P,SP,E Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=Enable 5=Disable			1=Enable	Operation Off / On
Power unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the power related values
Energy unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the energy related values
Active power Dir	1=Forward 2=Reverse			1=Forward	Direction of active power flow: Forward, Reverse
Reactive power Dir	1=Forward 2=Reverse			1=Forward	Direction of reactive power flow: Forward, Reverse
Forward Wh Initial	0...999999999		1	0	Preset Initial value for forward active energy
Reverse Wh Initial	0...999999999		1	0	Preset Initial value for reverse active energy
Forward WArh Initial	0...999999999		1	0	Preset Initial value for forward reactive energy
Reverse WArh Initial	0...999999999		1	0	Preset Initial value for reverse reactive energy

7.1.10.5 Monitored data

Table 371: P,SP,E Monitored data

Name	Type	Values (Range)	Unit	Description
S-kVA	FLOAT32	-999999.9...999999.9	kVA	Total Apparent Power
P-kW	FLOAT32	-999999.9...999999.9	kW	Total Active Power
Q-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Total Reactive Power
PF	FLOAT32	-1.00...1.00		Average Power factor
SA-kVA	FLOAT32	-999999.9...999999.9	kVA	Phase A Apparent Power
SB-kVA	FLOAT32	-999999.9...999999.9	kVA	Phase B Apparent Power
SC-kVA	FLOAT32	-999999.9...999999.9	kVA	Phase C Apparent Power
PA-kW	FLOAT32	-999999.9...999999.9	kW	Phase A Active Power
PB-kW	FLOAT32	-999999.9...999999.9	kW	Phase B Active Power
PC-kW	FLOAT32	-999999.9...999999.9	kW	Phase C Active Power
QA-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Phase A Reactive Power
QB-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Phase B Reactive Power
QC-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Phase C Reactive Power
PFA	FLOAT32	-1.00...1.00		Phase A Power factor
PFB	FLOAT32	-1.00...1.00		Phase B Power factor
PFC	FLOAT32	-1.00...1.00		Phase C Power factor
S_INST	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value
S_DB	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value
P_INST	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value
P_DB	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value
Q_INST	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value
Q_DB	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value
PF_INST	FLOAT32	-1.00...1.00		Power factor, magnitude of instantaneous value
PF_DB	FLOAT32	-1.00...1.00		Power factor, magnitude of reported value
EA_RV_ACM	INT128	0...999999999	kWh	Accumulated reverse active energy value
ER_RV_ACM	INT128	0...999999999	kVArh	Accumulated reverse reactive energy value
EA_FWD_ACM	INT128	0...999999999	kWh	Accumulated forward active energy value
ER_FWD_ACM	INT128	0...999999999	kVArh	Accumulated forward reactive energy value
SA_INST	FLOAT32	-999999.9...999999.9	kVA	Phase A Apparent power, magnitude of instantaneous value
SA_DB	FLOAT32	-999999.9...999999.9	kVA	Phase A Apparent power, magnitude of reported value

Name	Type	Values (Range)	Unit	Description
PA_INST	FLOAT32	-999999.9...999999.9	kW	Phase A Active power, magnitude of instantaneous value
PA_DB	FLOAT32	-999999.9...999999.9	kW	Phase A Active power, magnitude of reported value
QA_INST	FLOAT32	-999999.9...999999.9	kVAr	Phase A Reactive power, magnitude of instantaneous value
QA_DB	FLOAT32	-999999.9...999999.9	kVAr	Phase A Reactive power, magnitude of reported value
PFA_INST	FLOAT32	-1.00...1.00		Phase A Power factor, magnitude of instantaneous value
PFA_DB	FLOAT32	-1.00...1.00		Phase A Power factor, magnitude of reported value
SB_INST	FLOAT32	-999999.9...999999.9	kVA	Phase B Apparent power, magnitude of instantaneous value
SB_DB	FLOAT32	-999999.9...999999.9	kVA	Phase B Apparent power, magnitude of reported value
PB_INST	FLOAT32	-999999.9...999999.9	kW	Phase B Active power, magnitude of instantaneous value
PB_DB	FLOAT32	-999999.9...999999.9	kW	Phase B Active power, magnitude of reported value
QB_INST	FLOAT32	-999999.9...999999.9	kVAr	Phase B Reactive power, magnitude of instantaneous value
QB_DB	FLOAT32	-999999.9...999999.9	kVAr	Phase B Reactive power, magnitude of reported value
PFB_INST	FLOAT32	-1.00...1.00		Phase B Power factor, magnitude of instantaneous value
PFB_DB	FLOAT32	-1.00...1.00		Phase B Power factor, magnitude of reported value
SC_INST	FLOAT32	-999999.9...999999.9	kVA	Phase C Apparent power, magnitude of instantaneous value
SC_DB	FLOAT32	-999999.9...999999.9	kVA	Phase C Apparent power, magnitude of reported value
PC_INST	FLOAT32	-999999.9...999999.9	kW	Phase C Active power, magnitude of instantaneous value
PC_DB	FLOAT32	-999999.9...999999.9	kW	Phase C Active power, magnitude of reported value
QC_INST	FLOAT32	-999999.9...999999.9	kVAr	Phase C Reactive power, magnitude of instantaneous value
QC_DB	FLOAT32	-999999.9...999999.9	kVAr	Phase C Reactive power, magnitude of reported value
PFC_INST	FLOAT32	-1.00...1.00		Phase C Power factor, magnitude of instantaneous value
PFC_DB	FLOAT32	-1.00...1.00		Phase C Power factor, magnitude of reported value

7.1.10.6 Technical data

Table 372: P,SP, E Technical data

Characteristic	Value
Operation accuracy	At all three currents in range 0.10…1.20 x I_n At all three voltages in range 0.50…1.15 x V_n At the frequency f_n ±1Hz Active power and energy in range |PF| > 0.71 Reactive power and energy in range |PF| < 0.71
	±1.5% for power (S, P and Q) ±0.015 for power factor ±1.5% for energy
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

7.1.11 Frequency

7.1.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Frequency measurement	FMMXU1	F	F

7.1.11.2 Function block

Figure 217: Function block

7.1.11.3 Signals

Table 373: FMMXU Input signals

Name	Type	Default	Description
F	SIGNAL	—	Measured system frequency

7.1.11.4 Settings

Table 374: FMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
F high high limit	35.00...75.00	Hz		60.00	High alarm frequency limit
F high limit	35.00...75.00	Hz		55.00	High warning frequency limit
F low limit	35.00...75.00	Hz		45.00	Low warning frequency limit
F low low limit	35.00...75.00	Hz		40.00	Low alarm frequency limit
F deadband	100...100000			1000	Deadband configuration value for integral calculation (percentage of difference between min and max as 0,001% s)

7.1.11.5 Monitored data

Table 375: 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

7.1.11.6 Technical data

Table 376: FMMXU Technical data

Characteristic	Value
Operation accuracy	±10 mHz (in measurement range 35 - 75 Hz)

Section 8 Recording functions

8.1 Digital fault recorder DFR (RDRE)

8.1.1 Functionality

The relay is provided with a digital fault recorder featuring up to 12 analog and 64 binary signal channels. The analog channels can be set to record either the waveform or the trend of the currents and voltage measured.

The analog channels can be set to trigger the recording function when the measured value falls below or exceeds the set values. The binary signal channels can be set to start a recording on the rising or the falling edge of the binary signal or both.

By default, the binary channels are set to record external or internal relay signals, for example the start or trip signals of the relay stages, or external blocking or control signals. Binary relay signals such as a protection start or trip signal, or an external relay control signal over a binary input can be set to trigger the recording. The recorded information is stored in a non-volatile memory and can be uploaded for subsequent fault analysis.

8.1.1.1 Recorded analog inputs

The current RER 620 release does not support selection of analog channels for disturbance (DFR) recorder. 10 channels of RDRE/DFR component are pre-mapped to following analog inputs: IL1, IL2, IL3, Io, U1,U2, U3, U2A, U2B,U2C.

All analog inputs of the digital fault recorder that are enabled are included in the recording when triggered appropriately.

8.1.1.2 Triggering alternatives

The recording can be triggered by any or several of the following alternatives:

- Triggering according to the state change of any or several of the binary channels of the digital fault recorder. The user can set the level sensitivity with the *Level trigger mode* parameter of the corresponding binary channel.
- Triggering on limit violations of the analog channels of the digital fault recorder (high and low limit)
- Manual triggering via the *Trig recording* parameter (LHMI or communication)
- Periodic triggering.

Regardless of the triggering type, each recording generates events through state changes of the *Recording started*, *Recording made* and *Recording stored* status parameters. The *Recording stored* parameter indicates that the recording has been stored to the non-volatile memory. In addition, every analog channel and binary channel of the digital fault recorder has its own *Channel triggered* parameter. Manual trigger has the *Manual triggering* parameter and periodic trigger has the *Periodic triggering* parameter. A state change in any of these parameters also generates an event that gives individual information about the reason of the triggering. COMTRADE files provide unambiguous information about the reason of the triggering, usually only for the binary channels but in some cases also for the analog channels.

Triggering by binary channels

Input signals for the binary channels of the digital fault recorder can be formed from any of the digital signals that can be dynamically mapped. A change in the status of a monitored signal triggers the recorder according to the configuration and settings. Triggering on the rising edge of a digital input signal means that the recording sequence starts when the input signal is activated. Correspondingly, triggering on the falling edge means that the recording sequence starts when the active input signal resets. It is also possible to trigger from both edges. In addition, if preferred, the monitored signal can be non-triggering. The trigger setting can be set individually for each binary channel of the digital fault recorder with the *Level trigger mode* parameter of the corresponding binary channel.

Triggering by analog channels

The trigger level can be set for triggering in a limit violation situation. The user can set the limit values with the *High trigger level* and *Low trigger level* parameters of the corresponding analog channel. Both high level and low level violation triggering can be active simultaneously for the same analog channel. If the duration of the limit violation condition exceeds the filter time of approximately 50 ms, the recorder triggers. In case of a low level limit violation, if the measured value falls below approximately 0.05 during the filter time, the situation is considered to be a circuit-breaker operation and therefore, the recorder does not trigger. This is useful especially in undervoltage situations. The filter time of approximately 50 ms is common to all the analog channel triggers of the digital fault recorder. The value used for triggering is the calculated peak-to-peak value. 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.

8.1.2 Length of recordings

The user can define the length of a recording with the *Record length* parameter. The length is given as the number of fundamental cycles.

According to the memory available and the number of analog channels used, the digital fault recorder automatically calculates the remaining amount of recordings that fit into the available recording memory. The user can see this information with the `Rem. amount of rec` monitored data. The fixed memory size allocated for the recorder can fit in two recordings that are ten seconds long. The recordings contain data from all analog and binary channels of the digital fault recorder, at the sample rate of 32 samples per fundamental cycle.

The user can view the number of recordings currently in memory with the `Number of recordings` monitored data. The currently used memory space can be viewed with the `Rec. memory used` monitored data. It is shown as a percentage value.

The maximum number of recordings is 100.

8.1.2.1 Sampling frequencies

The sampling frequency of the digital fault recorder analog channels depends on the set rated frequency. One fundamental cycle always contains the amount of samples set with the *Storage rate* parameter. Since the states of the binary channels are sampled once per task execution of the digital fault recorder, the sampling frequency of binary channels is 400 Hz at the rated frequency of 50 Hz and 480 Hz at the rated frequency of 60 Hz.

Table 377: Sampling frequencies of the digital fault recorder analog channels

Storage rate (samples per fundamental cycle)	Recording length	Sampling frequency of analog channels, when the rated frequency is 50 Hz	Sampling frequency of binary channels, when the rated frequency is 50 Hz	Sampling frequency of analog channels, when the rated frequency is 60 Hz	Sampling frequency of binary channels, when the rated frequency is 60 Hz
32	1* Record length	1600 Hz	400 Hz	1920 Hz	480 Hz
16	2* Record length	800 Hz	400 Hz	960 Hz	480 Hz
8	4 * Record length	400 Hz	400 Hz	480 Hz	480 Hz

8.1.2.2 Uploading of recordings

The relay stores COMTRADE files to the `C:\COMTRADE\` folder. The files can be uploaded with the PCM tool 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.

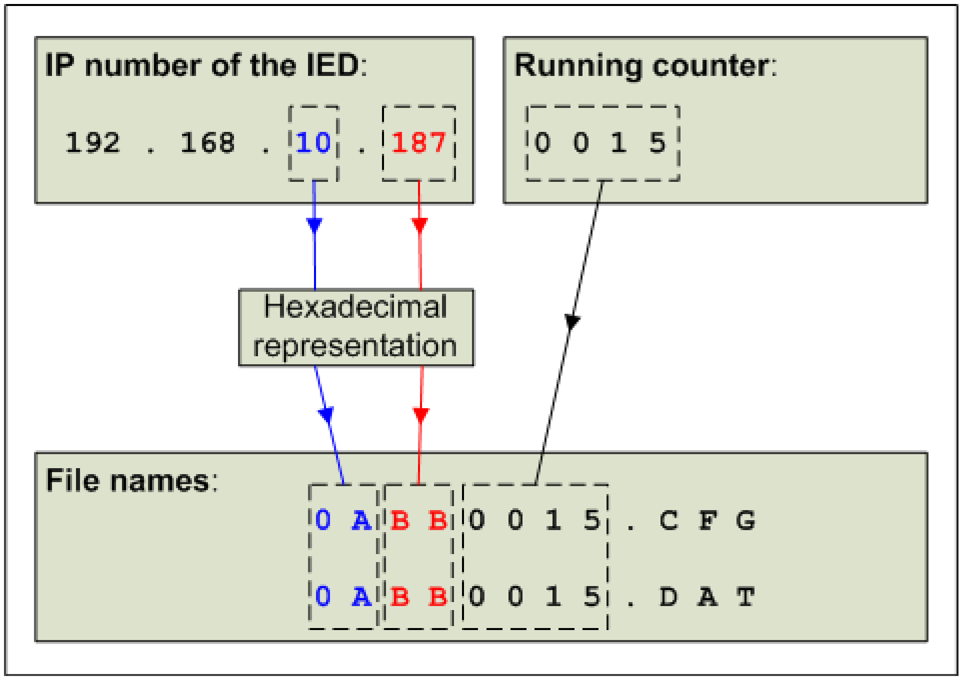


Figure 218: Digital fault recorder file naming

The naming convention of 8+3 characters is used in COMTRADE file naming. The file name is composed of the last two octets of the 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.

8.1.2.3 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 the PCM tool or any appropriate computer software, which can access the relay's `C:\COMTRADE` folder. The disturbance recording is not removed from the relay 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 the PCM tool 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.

8.1.2.4 Storage mode

The digital fault recorder can capture data in two modes: waveform and trend mode. The user can set the storage mode individually for each trigger source with the *Storage mode* parameter of the corresponding analog channel or binary channel, the *Stor. mode manual* parameter for manual trigger and the *Stor. mode periodic* parameter for periodic trigger.

In the waveform mode, the samples are captured according to the *Storage rate* and *Pre-trg length* parameters.

In the trend mode, one RMS value is recorded for each enabled analog channel, once per fundamental cycle. The binary channels of the digital fault recorder are also recorded once per fundamental cycle in the trend mode.

Only post-trigger data is captured in trend mode.

The trend mode enables recording times of 32 * *Record length*.

8.1.2.5 Pre-trigger and post-trigger data

The waveforms of the digital fault recorder analog channels and the states of the digital fault recorder binary channels are constantly recorded into the history memory of the recorder. The user can adjust the percentage of the data duration preceding the triggering, that is, the so-called pre-trigger time, with the *Pre-trg length* parameter. The duration of the data following the triggering, that is, the so-called post-trigger time, is the difference between the recording length and the pre-trigger time. Changing the pre-trigger time resets the history data and the current recording under collection.

8.1.2.6 Operation modes

Digital fault recorder has two operation modes: saturation and overwrite mode. The user can change the operation mode of the digital fault recorder with the *Operation mode* parameter.

Saturation mode

In saturation mode, the captured recordings cannot be overwritten with new recordings. Capturing the data is stopped when the recording memory is full, that is, when the maximum number of recordings is reached. In this case, the event is sent via the state change (TRUE) of the *Memory full* parameter. When there is memory available again, another event is generated via the state change (FALSE) of the *Memory full* parameter.

Overwrite mode

When the operation mode is “Overwrite” and the recording memory is full, the oldest recording is overwritten with the pre-trigger data collected for the next recording. Each time a recording is overwritten, the event is generated via the state change of the *Overwrite of rec.* parameter. The overwrite mode is recommended, if it is more important to have the latest recordings in the memory. The saturation mode is preferred, when the oldest recordings are more important.

New triggerings are blocked in both the saturation and the overwrite mode until the previous recording is completed. On the other hand, a new triggering can be accepted before all pre-trigger samples are collected for the new recording. In such a case, the recording is as much shorter as there were pre-trigger samples lacking.

8.1.2.7 Exclusion mode

Exclusion mode is on, when the value set with the *Exclusion time* parameter is higher than zero. During the exclusion mode, new triggerings are ignored if the triggering reason is the same as in the previous recording. The *Exclusion time* parameter controls how long the exclusion of triggerings of same type is active after a triggering. The exclusion mode only applies to the analog and binary channel triggerings, not to periodic and manual triggerings.

When the value set with the *Exclusion time* parameter is zero, the exclusion mode is disabled and there are no restrictions on the triggering types of the successive recordings.

The exclusion time setting is global for all inputs, but there is an individual counter for each analog and binary channel of the digital fault recorder, counting the remaining exclusion time. The user can monitor the remaining exclusion time with the *Exclusion time rem* parameter of the corresponding analog or binary channel. The *Exclusion time rem* parameter counts downwards.

8.1.3 Configuration

The user can configure the digital fault recorder with the PCM600 tool or any tool supporting the IEC 61850 standard.

The user can enable or disable the digital fault recorder with the *Operation* parameter under the **Configuration/Digital fault recorder/General** menu.

One analog signal type of the relay can be mapped to each of the analog channels of the digital fault recorder. The mapping is done with the *Channel selection* parameter of the corresponding analog channel. The name of the analog channel is user-configurable. The user can modify it by writing the new name to the *Channel id text* parameter of the corresponding analog channel.

Any external or internal digital signal of the relay which can be dynamically mapped can be connected to the binary channels of the digital fault recorder. These signals can be, for example, the start and trip signals from protection function blocks or the external binary inputs of the relay. The connection is made with dynamic mapping to the binary channel of the digital fault recorder using, for example, *SMT* of PCM600. It is also possible to connect several digital signals to one binary channel of the digital fault recorder. In that case, the signals can be combined with logical functions, for example AND and OR. The user can configure the name of the binary channel and modify it by writing the new name to the *Channel id text* parameter of the corresponding binary channel.

Note that the *Channel id text* parameter is used in COMTRADE configuration files as a channel identifier.

The recording always contains all binary channels of the digital fault recorder. If one of the binary channels is disabled, the recorded state of the channel is continuously FALSE and the state changes of the corresponding channel are not recorded. The corresponding channel name for disabled binary channels in the COMTRADE configuration file is Unused BI.

To enable or disable a binary channel of the digital fault recorder, the user can set the *Operation* parameter of the corresponding binary channel to the values *“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 *Recording started* parameter can be used to control the indication LEDs of the relay. The output of the *Recording started* parameter is TRUE due to the triggering of the digital fault recorder, until all the data for the corresponding recording is recorded.

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

8.1.4 Application

The digital fault 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 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 digital fault recorder. The task execution interval for the digital fault recorder is the same as for the protection functions. During the COMTRADE conversion, the digital status values are repeated so that the sampling frequencies of the analog and binary channels correspond to each other. This is required by the COMTRADE standard.

The digital fault recorder follows the 1999 version of the COMTRADE standard and uses the binary data file format.

8.1.5 Settings

Table 378: Non-group general settings for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Digital fault 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[1]	Operation mode of the recorder
Exclusion time	0...1 000 000	ms	1	0	The time during which triggerings of same type are ignored
Storage rate	32, 16, 8	samples per fundamental cycle		32	Storage rate of the waveform recording
Periodic trig time	0...604 800	s	10	0	Time between periodic triggerings
Stor. mode periodic	0=Waveform 1=Trend / cycle		1	0	Storage mode for periodic triggering
Stor. mode manual	0=Waveform 1=Trend / cycle		1	0	Storage mode for manual triggering

[1] The default setting for RA02 is “Overwrite”.

Table 379: Non-group analog channel settings for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Analog channel is enabled or disabled.
Channel selection	1 = IA 2 = IB 3 = IC 4 = IG 5 = VA 6 = VB 7 = VC 8 = VA2 9 = VB2 10 = VC2 11 = Disabled 12 = Disabled		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

Table 380: Non-group binary channel settings for digital fault recorder

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 381: Control data for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Trig recording	0=Cancel 1=Trig				Trigger the disturbance recording
Clear recordings	0=Cancel 1=Clear				Clear all recordings currently in memory

8.1.6 Monitored data

Table 382: Monitored data for digital fault recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Number of recordings	0...100				Number of recordings currently in memory
Rem. amount of rec.	0...100				Remaining amount of recordings that fit into the available recording memory, when current settings are used
Rec. memory used	0...100	%			Storage mode for the binary channel
Time to trigger	0...604 800	s			Time remaining to the next periodic triggering

Section 9 Other functions

9.1 Uninterruptible Power Supply UPS

9.1.1 Function block

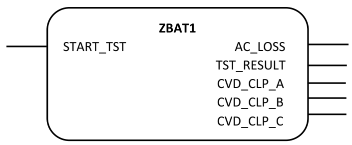


Figure 219: UPS function block

9.1.2 Functionality

The RER620 UPS (Uninterruptible Power Supply) is a subsystem for the RER620 recloser controller. It is implemented in a separate case (see Figure 220) and is powered by the control power which may be AC or DC. The UPS can operate over a wide range of control voltages.

The main UPS function is to enable operation of the RER620 after the loss of control power for a period of time that depends on the amp hour rating of the battery. A 12 amp hour battery will power the total system for about 38 hours with a standard load. The RER620 UPS incorporates a battery management system that includes both battery charging and battery test functions.

The RER620 UPS case includes an auxiliary power output that may be used to power a modem, radio, etc.

There is also a voltage boost function integrated into the RER620 UPS system that provides up to 250Vdc. This power source, in combination with an external capacitor, is used to operate a variety of magnetic actuators.

The UPS incorporates a high current dry contact output that is temperature controlled. This output can be used to switch on and off the low-voltage-cabinet heater.

The RER620 UPS is microprocessor controlled and is capable of external communications through its communications port. The main purpose for this communication is to receive instructions from the RER620 Control and to transmit status, and battery test results to the RER620 Control.

Figure 220: Uninterruptible Power Supply (UPS) case

The following sections describe in detail the following functions of the UPS:

- Input power requirements
- Input power measurement
- Loss of input power alarm
- Battery management
- Auxiliary power supply
- Actuator drive power supply (boost supply)
- Heater control switch
- RER620 power
- RS485 commutations

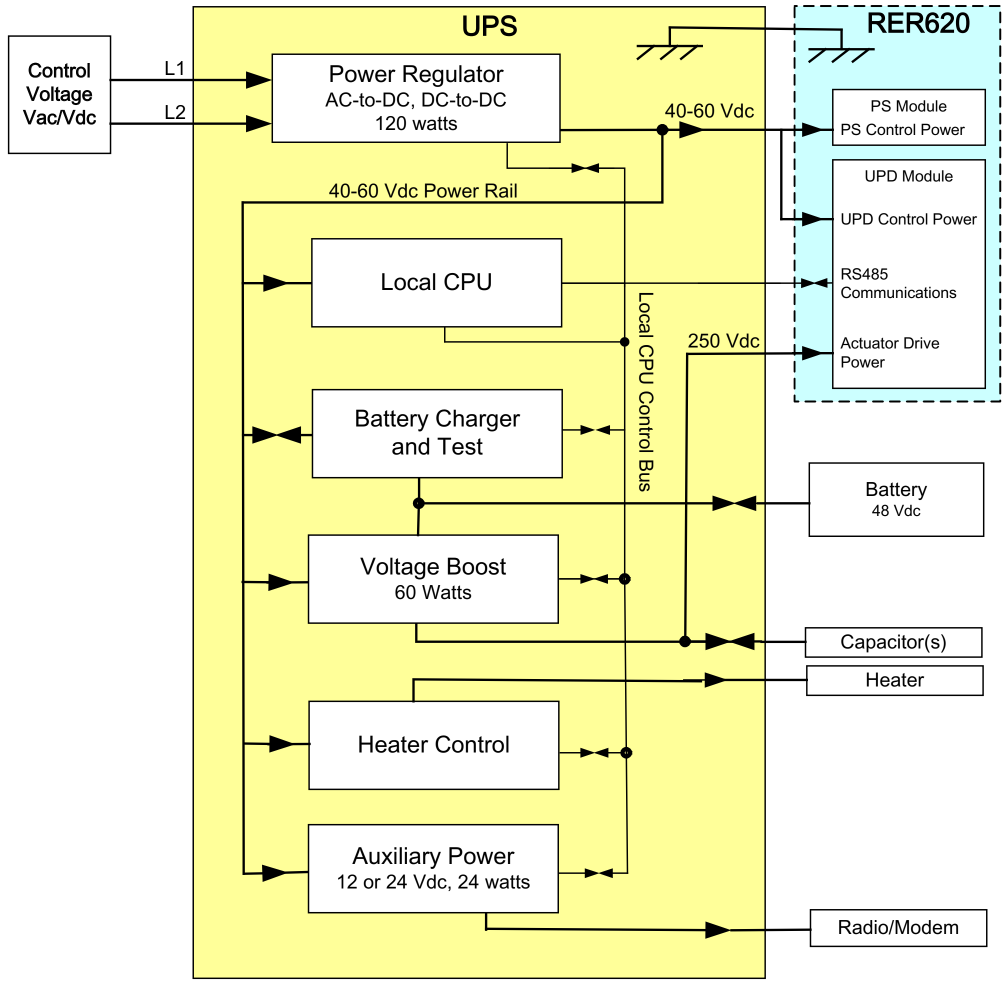


Figure 221: Uninterruptible Power Supply (UPS) block diagram

9.1.2.1 Input power requirements

The power input circuit includes surge protection that will react to both differential and common mode noise.

The UPS may be powered by AC or DC. The incoming power supplies a 120 watt DC-to-DC power supply. There are two versions of the UPS. One version covers a 125 Vdc and 120 Vac range, while the other covers a 250 Vdc and 240 Vac range. There is a comparator that monitors the incoming power and will switch off the DC-to-DC if the voltage is not inside a specified tolerance.

Table 383: Tolerances for AC supply power

UPS Voltage Class	Minimal V ON for Rising AC	Minimal V OFF for Falling AC	Maximum V OFF for Rising AC	Maximum V ON for Falling AC
120vac (ANSI)	70 to 82 AC	80 to 68 AC	150 to 170 AC	155 to 136 AC
240vac (EU)	134 to 145 AC	140 to 130 AC	264 to 294 AC	288 to 268 AC

Table 384: Tolerances for DC supply power

UPS Voltage Class	Minimal V ON for Rising DC	Minimal V OFF for Falling DC	Maximum V OFF for Rising DC	Maximum V ON for Falling DC
120vac (ANSI)	93 to 104 Vdc	91 to 80 Vdc	183 to 205 Vdc	200 to 185 Vdc
240vac (EU)	178 to 203 Vdc	168 to 187 Vdc	360 to 400 Vdc	400 to 365 Vdc

9.1.3 Input Power Measurement

The UPS can measure the input voltage if powered by AC. This measurement is accomplished with a capacitor voltage divided (CVD) network.

In pole-mounted applications, the control power is always AC. No UPS internal decisions are made based on the CVD measurement. (The loss-of-control-power alarm is based off the 60 Vdc rail inside the UPS, not the CVD measurement.) The CVD measurement is simply reported back to the RER620, which can report it to central control.

The AC power source in almost all systems has one of its two leads referenced to earth ground. The AC voltage lead that is not referenced to ground is referred to as the Hot lead, or L1. The lead that is referenced to earth ground is referred to as Neutral, or L2. The UPS is expecting a power source that has L2 connected to earth ground, and that lead is to be connected to the UPS L2 connection point.

The UPS AC voltage measurement will draw attention to an incorrectly wired recloser, but there are exceptions. Present AC control power is derived from a residential transformer or a single bushing PT. These power sources have the L2 and earth ground connection at the same potential. It is possible to power an RER recloser from a dual bushing PT where the AC is “floating.” There may even be parts of the world that supplies residents with floating AC. In such a situation, the RER620 will report the voltage off by a significant amount from the actual voltage. The RER620 has an input power calibration function that may be used to correct the voltage measurement in cases where there is no connection between L2 and earth ground, or to increase the accuracy of the measurement.

9.1.3.1 Loss of UPS input power alarm.

The UPS is equipped with a form-C dry contacts that will provide an alarm in the event of power loss. The alarm contacts are energized if input power is present (AC or DC) to the UPS or if the 60 Vdc rail within the UPS is above 57 Vdc. When input power is present, pins 2 and 3 of connector W2 are connected. When there is insufficient power, pins 1 and 2 are connected.

In addition, the Loss of input power alarm is also transmitted to the RER620 via the RS485 communication link.

9.1.3.2 Battery management

Battery management consists of three functions:

- battery test
- battery charging
- battery start

Battery test

This function tests the battery's charge and overall health by briefly connecting a low resistance load parallel to the battery and then measuring the battery voltage. The battery voltage before the load was applied and the voltage during the time the load is applied may be compared to determine battery's health. The load is about 1.5 ohms. The connection time for the load is 0.1 seconds. Ten voltage measurements are taken and averaged together in the last 25 milliseconds of the test period to calculate the battery voltage test measurement. After the battery is tested, a cool down period of around 2 minutes for the UPS's battery load resistors is required. During the cool down period the battery test function is blocked

If the battery test function is blocked, the output channel "Battery Tested OK" of ZBAT1 function will be FALSE. If the battery function is blocked, the battery test voltage will be zero. The measurements taken during the battery test may be read only once. Then the measurements are zeroed.

Battery charging

The battery charger is designed to charge a 48 Vdc lead-acid battery. The charger has maximum charge wattage of 40 watts. But the charge is firmware controlled in such a way that the full charging wattage is applied only when the battery’s voltage is in the range 30 to 48 Vdc. At the lower end of this range, it is not known whether the battery is very discharged or the battery is defective. If the recloser is operating off batteries, then the system is switched off when the battery voltage reaches about 40 Vdc, so the battery voltage should never be below 40 Vdc. At around 48 to 50 Vdc, the battery charge current is decreased to start the transition to a float or trickle charge mode.

The maximum charge voltage is dependent on temperature. If the batteries are at a high temperature the maximum charge voltage is decreased. At lower temperatures the maximum charge voltage is increased. At room temperature the battery charge voltage is about 55 Vdc.

The boost function has priority over the battery charger. When the UPS is in boost mode the battery charger is off.

Battery start

The UPS has a function that will start the RER620-controlled recloser system if the battery is charged to a voltage of about 44 Vdc. In order to start the UPS using battery power, the power switch S1 must be pressed and held for about five seconds. Once operating using battery power, the RER620 will continue to operate until the battery voltage discharges down to about 40 Vdc, at which time the UPS will disconnect the battery from the system.

If one desires to switch off the system while operating on battery power (before the battery discharges to 40 Vdc), open the battery fuse block.

9.1.3.3 Auxiliary Power Supply

The UPS has an isolated 30 watt output Auxiliary Power Supply (APS) for auxiliary equipment such as radios, modems, etc. The APS has two output voltage settings, 12 Vdc and 24 Vdc. The voltage selection is made by communications from the RER620. The supply may be switched on or off by communications as well. In applications where the supply is not needed, switching it off will extend the battery life. Once set, the APS will remember its settings after a UPS system reset. If the supply has never been setup, its default value is 12 Vdc and switched off. The recommended maximum steady load for the APS is 24 watts.

The APS is not fused, but it is protected with protection firmware and hardware that will allow for load power to exceed 24 watts for only limited periods of time. The firmware protection is based on two I2T (Current squared * Time) curves, one fast and one slow. The slow curve will go into pickup at 24 watts and, if just over pickup, will timeout in about 3 minutes. The fast curve will go into pickup at 28 watts and, if just over pickup, will timeout in about 15 seconds. If the APS shuts down due to a timeout on the fast or slow curve, then there is a three minute cool down time. At the expiration of the cool down timer the supply is switched back on and the RER620 is notified.   The hardware instantaneous protection circuit will shutdown the APS at about 38 watts and will retry to start the supply about once a second.

9.1.3.4 Actuator Drive Power Source (Boost Supply)

The UPS has a programmable power supply that has a range from 60 Vdc to 250 Vdc. The output from this supply provides the power to operate the actuators for the recloser. Usually the voltage selection is made once through communication from the RER620 and left at that setting for the life of the UPS unit. The default voltage is 240 Vdc. The wattage for this power supply may peak as high as 80 watts during fast reclose operations when multiple pole operations are required in quick succession. The power source for this supply is the 60 Vdc rail within the UPS. The voltage from the 60 Vdc rail is increased by means of an inductor, diode, and FET arrangement common in flyback type boost circuits.

This supply has sufficient wattage to harm itself if driving a low impedance load. To help prevent this, there is a 300 ohm resistor used in series with the 60 Vdc rail used to charge the supply's load. If the load can not be charged to about 40 Vdc through the 300 ohm resistor, then the relay contacts (RA1) that bypass this resistor will not engage. The boost will not operate until RA1 has closed.

The output from this supply will remain charged for many hours after the UPS has been powered down if not discharged with an external load.

9.1.3.5 Heater control switch

The heater relay (RA3) is used to control the low-voltage-cabinet heater. The UPS makes use of its integrated temperature sensor to determine when the heater should engage. The UPS can also select to switch off the heater in the event there is no or limited input power.

The heater will not be energized when operating off battery back up power. For example if AC power is limited and a pole operation has just occurred, the heater may be switch off so more available power can go into charging the boost capacitor. This circuit can conduct and switch 8 amps at 250 Vac continuously.

The heater relay (RA3) is connected to connector W2, pins 7 and 8. If the temperature is above 27C RA3 is always off. If the temperature is below 20C RA3 is always energized. If the temperature is between 68°F and 81°F (20°C and 27°C), the state of RA3 is determined by a rising temperature or a falling temperature. The temperature sensor is located inside the UPS case, in the corner of the UPS close to the microprocessor.

9.1.3.6 RER620 power

Power to the RER620 is provided by UPS connector W1 pins 7 (+60 Vdc) and 8 (return). This connection can provide about 30 watts. (In normal operation the RER620 will consume about 15 watts.) When the UPS is operating from battery power, the supplied voltage is the battery's positive voltage. Hence, the voltage range for this power source is 40 Vdc to 60 Vdc.

9.1.3.7 RS485 communications

The communication link between the UPD and the UPS is a half-duplex (2 wires) RS485 serial channel. The UPS RS485 communications link is isolated.

The UPD acts as master, the UPS as slave.

- Transmission speed for the UPD-UPS serial interface (SCI) is fixed at 19200 bps.
- 8 data bits
- No parity
- 1 stop bit

9.1.4 Connections

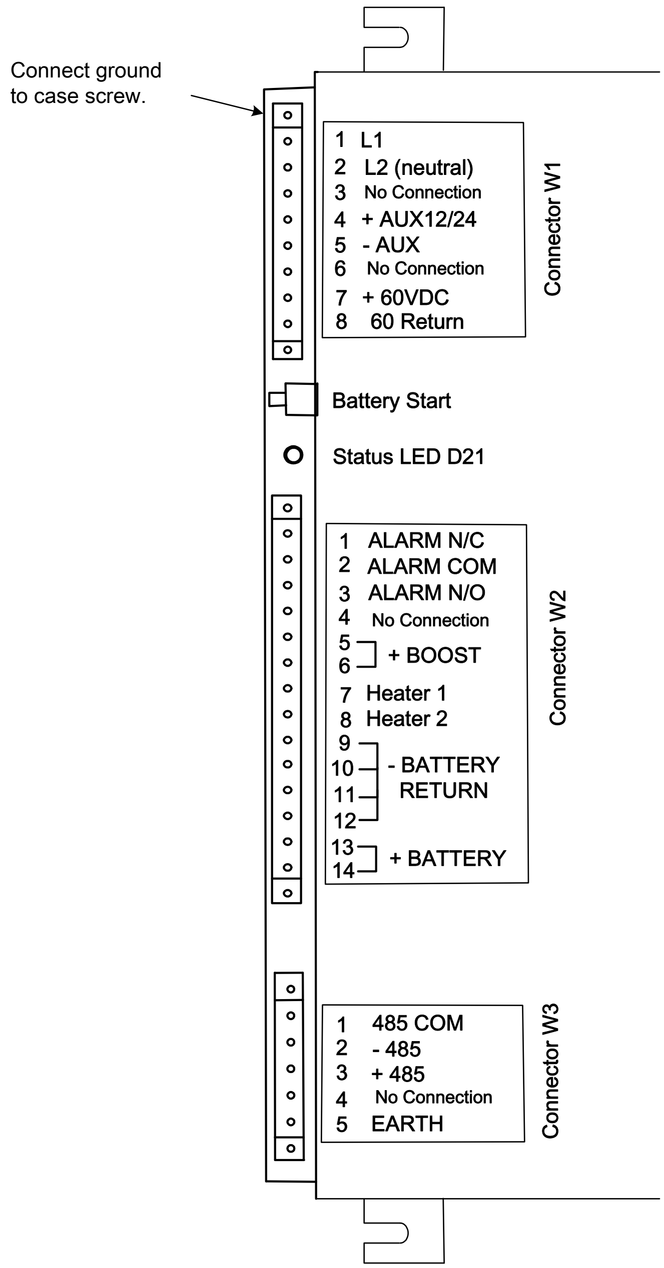


Figure 222: Uninterruptible Power Supply (UPS) connections

9.1.5 Signals

Table 385: UPS input signals

Name	Type	Default	Description
START_TST	BOOLEAN	0=False	This tests the battery's charge and overall health by briefly connecting a low resistance load parallel to the battery and then measuring the battery voltage. The battery voltage before the load was applied and the voltage during the time the load is applied are compared to determine battery health. The load is about 1.5 ohms, and the connection time for the load is 0.1 seconds. Ten measurements are taken and averaged together in the last 25 milliseconds of the test period resulting in the battery voltage test measurement. After the battery is tested, a cool down period for the UPS's battery load resistors is required. During the cool down period, the battery test function is blocked.
Reset UPS	BOOLEAN	0=False	Resets the microprocessor of the UPS

Table 386: UPS output signals

Name	Type	Description
TST_VOLT	SIGNAL	Battery voltage after test in Vdc
TST_RESULT	ENUM	Indicates the battery test result: 0 = Ready for battery test 1 = Battery test is registered 2 = Battery interrupt for PWM3 is now enabled and is used as a timer 3 = Battery test in process (lasts about 0.075 second during which Boost and Battery Charge functions are disabled 4 = Battery test in process, and measurements are being taking (lasts about 0.025 second 5 = Battery test has been completed for 25 milliseconds, now take non-test battery voltage 6 = In cool-down period 7 = 60VDC rail voltage too low to test 8 = Within ten seconds of reset (must be at least 10 seconds out of reset to start battery test)

9.1.6 CVD Voltage Clamping

It is possible for some embedded Capacitor Voltage Divider (CVD) sensors to measure, a voltage in excess of +/-4% tolerance, under conditions of extreme humidity or wetting of pole surfaces. The 'CVD clamping' function clamps the measured voltage from the CVD sensors, to within +/- 4% of a reference voltage. The Clamping function is intended to be used with certain types of reclosers, please contact ABB for further clarification.

The necessary reference voltage can be obtained by connecting three external potential transformers (PTs) to the V1abc or V2abc analog inputs of the relay [Refer to Figure 186]. Alternately, in the absence of the three external PTs, the PT used to power up the recloser control cabinet may be used as the reference when connected to the V1abc or V2abc inputs of the relay [Refer to Figure 187]. All applicable limitations are listed at the end of the section.

Connection examples

- With three external PTs

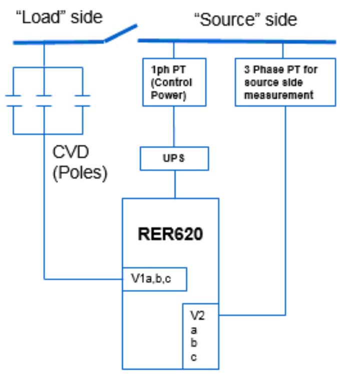


Figure 223: Installation with three phase PT

- Without three external PTs (PT used to power up the recloser is used as reference).

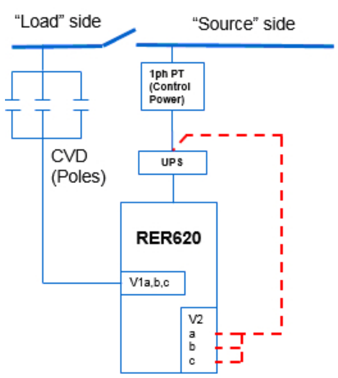


Figure 224: Installation with single phase PT

The CVD Voltage Clamping function is based on the following table, where V1x, x=a,b,c, are the CVD voltage measurements, V2x, x=a,b,c, are the reference PT voltage measurements, and V2n is the nominal voltage defined in the relay structure, Configuration-> Analog inputs->Voltage 2-> Secondary voltage.

Table 387: Clamping logic

Recloser Position	Justification Conditions	Adjusted CVD Measurements
Closed	V1x > 1.04*V2x	V1x = 1.04*V2x
	0.85*V2x ≤ V1x < 0.96*V2x	V1x = 0.96*V2x
	All other conditions	No clamping
Open	V2x ≥ 0.90*V2n AND V1x > 1.04*V2x	V1x = 1.04*V2x
	All other conditions	No clamping

When enabling the CVD Voltage Clamping function, the following assumptions and limitations exist:

1. The Clamping function is applicable only for the Wye-connected PT installation, single or three phase.
2. For single phase PT installation, the CVD clamping is applicable only to a nominal 120Vac low voltage cabinet control power.
3. For single phase PT installation, the voltage based protections and measurement alarms on the reference side should be disabled.
4. The Clamping function affects only the voltage amplitudes.
5. When no reference voltage is available, the Clamping function should be disabled; otherwise, V1 will report the actual CVD values when the poles are open and report zeroes when the poles are closed.
6. If both V1 and V2 are CVDs or both are PTs, the voltages measurements will not be adjusted.
7. It is recommended that voltage based protections are either not used or blocked when the Clamping function is enabled.

9.1.7 Settings

Table 388: Non-group settings for UPS

Parameter	Values (Range)	Unit	Step	Default	Description
Aux Mode	1 = on 0 = off	bin	1	0=off	Aux supply set to on/off
Aux Voltage	1 = 24V 0 =12V	bin	1	0=12V	Aux supply set to 12V or 24V
Boost Voltage	60...250	Vdc	1	240Vdc	The boost voltage (also referred to as the “250Vdc rail”) is the power source for actuator operation. The boost voltage is adjustable via communications. This voltage is connected to the drain side of the IBGT on the UPD board. This voltage may change with the needs of each pole type driven by the UPD. The value is a non-signed byte. Setting the Boost voltage to 60 will switch off the function.

Table 389: Non-group settings for CVD clamping

Parameter	Values (Range)	Unit	Step	Default	Description
CVD clamping	1 = enable 0 = disable	bin	1	0=disable	CVD Voltage Clamping

9.1.8 Monitored data

Table 390: Monitored data for UPS

Parameter	Values (Range)	Unit	Step	Default	Description
Battery V	0...255	Vdc	1		Battery voltage
Battery charge I	0...2.50	Amp	0.01		Battery charge current Amps
Temperature	-70...+150	°C	1		UPS temperature in degrees Celsius.
AC Input V	1...400	Vac	1		AC input voltage to UPS. For a UPS powered by DC, this value will be zero.
AC_LOSS	0 = false 1 = true (AC is OK)	bin	1		Indication of Loss of AC
Aux Status	0 = off 1 = on	bin	1	0=off	Indicates if the AUX supply is on/off
Aux voltage	1 = 24V 0 = 12V	bin	1	0=12V	Value of Aux voltage
Aux Load I	0...4.00	Amp	0.01		Value of Aux current
AUX Protection	0 = Normal Operation 1 = In shutdown caused by Short Time Over Current 2 = In shutdown caused by Long Time Over Current 3 = In shutdown caused by 60vdc rail too low (less then 35vdc)				
Internal Rail 12V	0...2	Vdc	0.1		12V rail voltage
Internal Rail 60V	0...255	Vdc	1		60V rail voltage
Boost voltage	0...255	Vdc	1		Boost voltage
Battery execution result	0 = Ready for battery test 1 = Battery test is registered 2 = Battery interrupt for PWM3 is now enabled and is used as a timer 3 = Battery test in process (lasts about 0.075 second during which Boost and Battery Charge functions are disabled 4 = Battery test in process, and measurements are being taking (lasts about 0.025 second 5 = Battery test has been completed for 25 milliseconds, now take non-test battery voltage 6 = In cool-down period 7 = 60VDC rail voltage too low to test 8 = Within ten seconds of reset (must be at least 10 seconds out of reset to start battery test)				
UPS Relay status	0 = off 1 = on	bin	1		Battery UPS status is on/off
Heater switch	0 = off 1 = on	bin	1		Heater switch is on/off
Days since reset	0...1240	day	1		Time that has passed since the last reset. This timer will rollover if the UPS operates 3.4 years without a reset.
Hours since reset	0...24	hour	1		See above
Minutes since reset	0...60	min	1		See above

Parameter	Values (Range)	Unit	Step	Default	Description
UPS Fw Version:	00.0...99.9	ver	0.1		UPS firmware version
UPS Hw Version:	00.0...99.9	ver	0.1		UPS hardware version
UPS Bootldr Version:	00.0...99.9	ver	0.1		UPS boot-loader version

Table 391: Monitored data for CVD clamping

Parameter	Values (Range)	Unit	Step	Default	Description
CVD_CLP_A	1=True 0=False	bin	1	0=False	Phase A CVD clamping Status
CVD_CLP_B	1=True 0=False	bin	1	0=False	Phase B CVD clamping Status
CVD_CLP_C	1=True 0=False	bin	1	0=False	Phase C CVD clamping Status

9.2 Universal power drive UPD

9.2.1 Function block

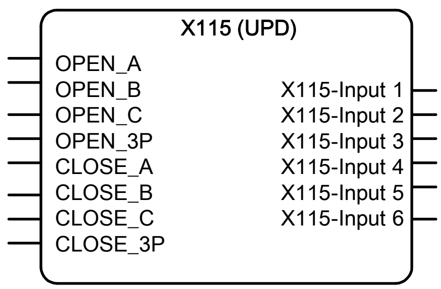


Figure 225: UPD function block

9.2.2 Functionality

The Universal Power Drive (UPD) module is designed specifically for the RER620. It is a two-width module in Slot 2 (X115) of the RER620 case. The UPD module is a single circuit board that provides six half-bridge drivers that are connected to form three independent electrical full-bridge drive channels. Each channel consists of four switches (FET/ IGBT) in a bridge arrangement. Two of the switches in each channel are high-side and two are low-side. The purpose of each channel is to allow current flow through an attached load to be in the forward or reverse direction. The intended load for each channel is single coil actuator. Each actuator is mechanically connected to a vacuum bottle switch. The actuator and vacuum bottle make up a single pole. The UPD is normally attached to three poles for control of a three-phase feeder in an electrical distribution system.

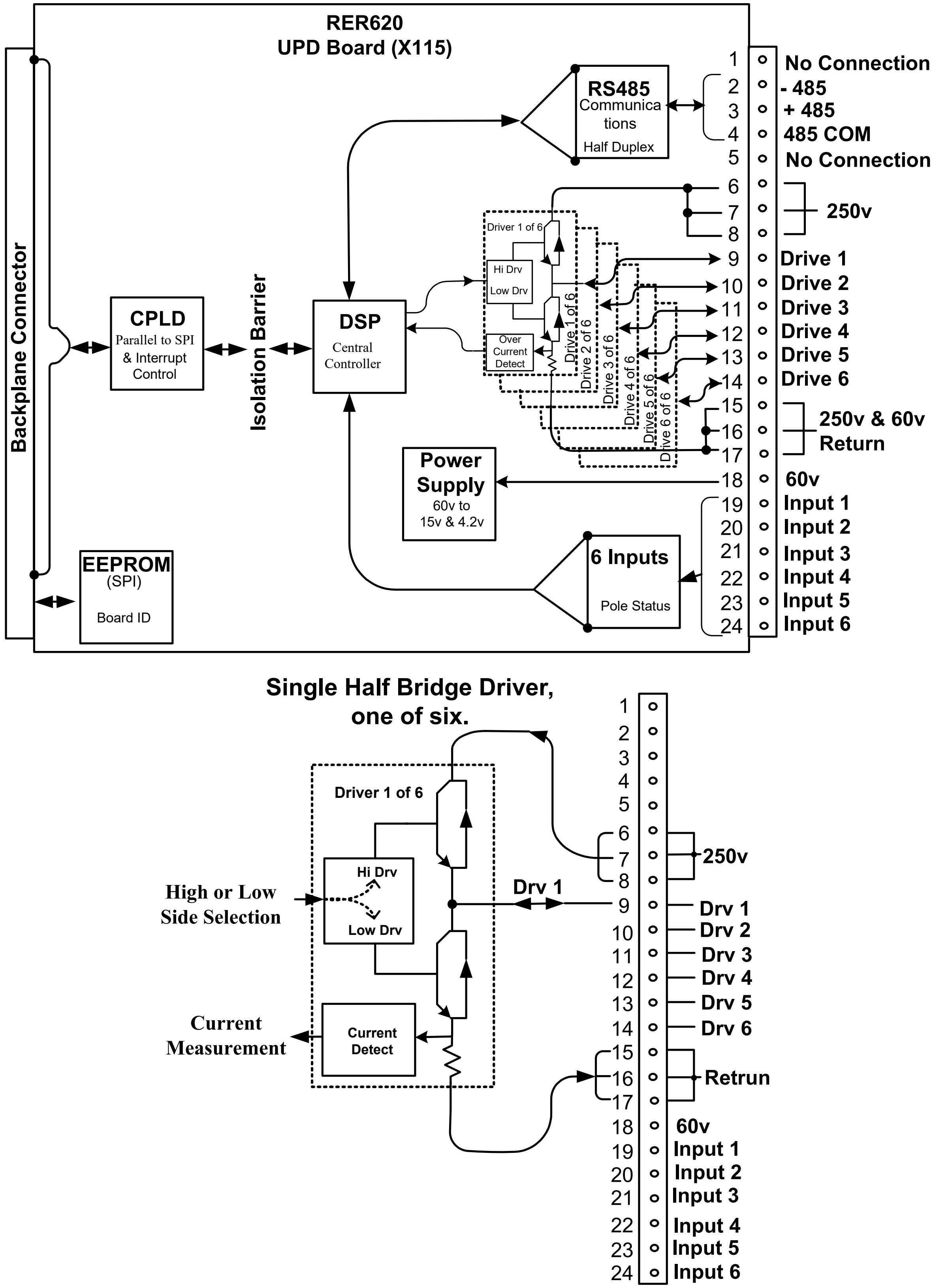


Figure 226: Universal Power Drive (UPD) block diagram

The UPD provides six high current drive channels of a proximally 60 amps max, and 250 Vdc maximum. The architecture of the six channels is that of a half bridge driver. When placed in service the six are grouped to form three full bridge drivers, so that each channel will provide its load with either positive or negative current flow. The UPD may drive its load via constant on or PWM method. The constant on mode does not apply to the highside driver, only the lowside.

Control of the UPD is through a parallel bus. The parallel bus is decoded by a CPLD located on the UPD. The CPLD supplies the decoded commands to a TI DSP via an SPI bus. The DSP controls the bridge drives. Data also flows in reverse, from the DSP, to the CPLD, to the parallel bus. The DSP is the master of the SPI bus and the CPLD the slave.

The UPD has an electrically isolated portion to protect the RER620 from electrical disturbances that may be received by the wiring connecting the UPD to the pole top High Voltage Cabinet. This isolated portion of the UPD is powered from two external voltage sources. One is a 250 Vdc source, and the other a 60 Vdc source. There is a switch mode power supply that converts the 60 Vdc to 15 Vdc and 4.2 Vdc.

The UPD is equipped with a two-wire, non-isolated, RS485 communication channel. The primary purpose for this communication channel is to provide a pass through connection between the RER620 CPU board and the UPS.

The UPD is equipped with six, non-isolated binary inputs that are designed for reading switches located in the High Voltage Cabinet.

9.2.3 Connections

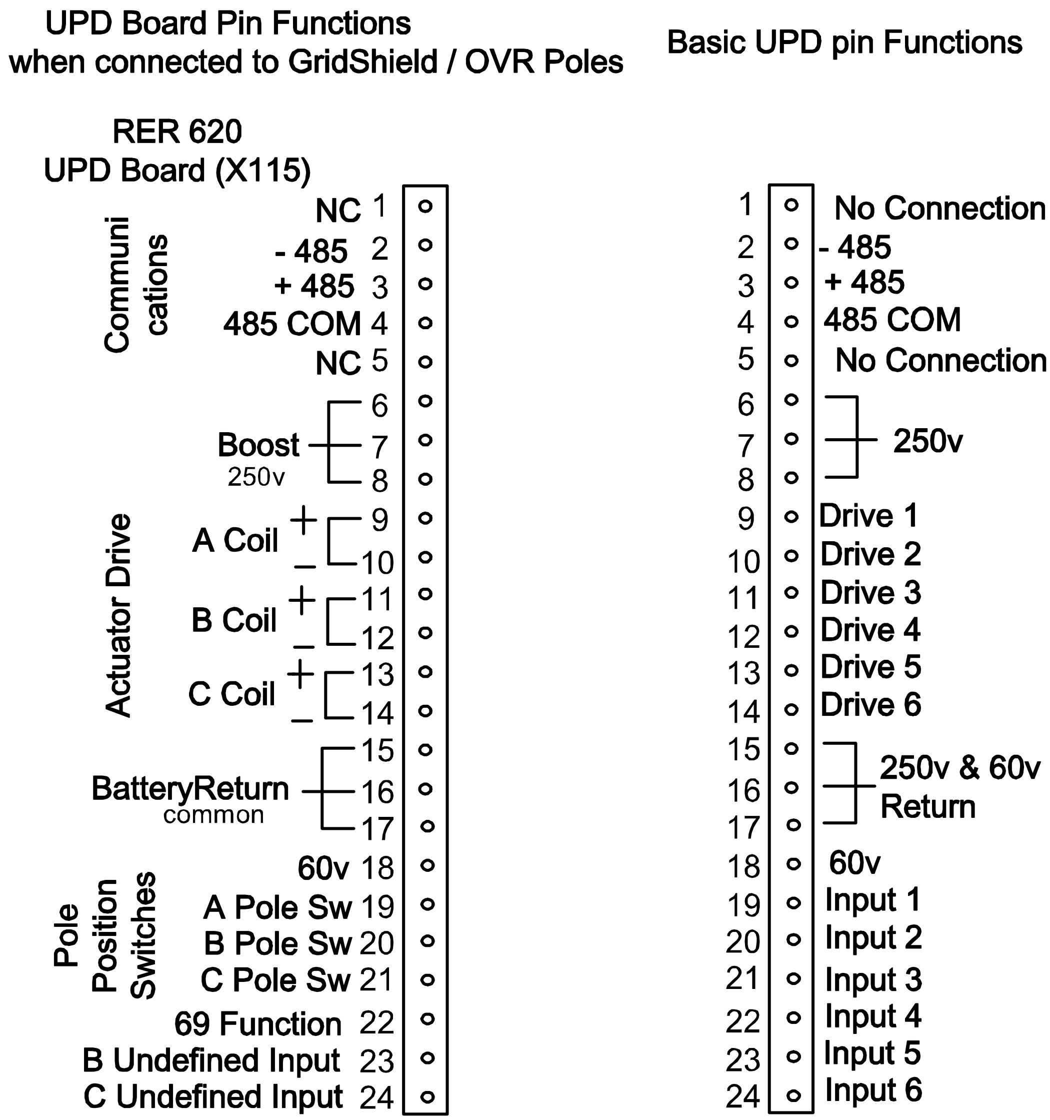


Figure 227: Universal Power Drive (UPD) connections

9.2.4 Signals

Table 392: UPD input signals

Name	Type	Default	Description
Pole Status Phase A	BOOLEAN	0=False	True if Pole A is open, false if closed.
Pole Status Phase B	BOOLEAN	0=False	True if Pole B is open, false if closed.
Pole Status Phase C	BOOLEAN	0=False	True if Pole C is open, false if closed.
Block for 69	BOOLEAN	0=False	Block close for 69 function

9.2.5 Settings

Table 393: Non-group settings for UPD RA01 and RA02

Parameter	Values (Range)	Unit	Step	Default	Description
Actuator Selection Profile	15/27OVR 550 Turn Coil 38kv 560 Turn Coil 15/27kv OVR A0 310 turns 38kv OVR 600 turns 15/27kv OVR SCA 38kv OVR SCA G&W Viper-ST Custom2			Funct. Appl. A Funct. Appl. B	Actuator selection profile

9.2.6 Monitored data

Table 394: UPD monitored inputs

Name	Type	Values (Range)	Unit	Description
Pole Status Phase A	Binary	0=False 1=True	1	True if Pole A is open, false if closed.
Pole Status Phase B	Binary	0=False 1=True	1	True if Pole B is open, false if closed.
Pole Status Phase C	Binary	0=False 1=True	1	True if Pole C is open, false if closed.
Block for 69	Binary	0=False 1=True	1	Block close for 69 function

Table 395: UPD monitored inputs

Name	Type	Values (Range)	Unit	Description
Last Pole Operation	Enum	Pass Fail	1	Last pole operation was successful or not successful.
Drive Voltage	Enum	OK Too Low	1	Drive voltage is sufficient or is too low for OCO.
Pole top switch vol	Enum	OK Too Low	1	Pole-top switch voltage is OK ro is too low.
General health	Enum	Pass Fail	1	Internal healcheck was OK or failed.
Actuator Cont. test	Enum	0=Actuator A failure 1=Actuator B failure 2=Actuator C failure 3=Cable disconnected 4= All actuator coils passed continuity test.	1	Actuator continuity test result

9.3 Programmable buttons FKEYGGIO

9.3.1 Function block

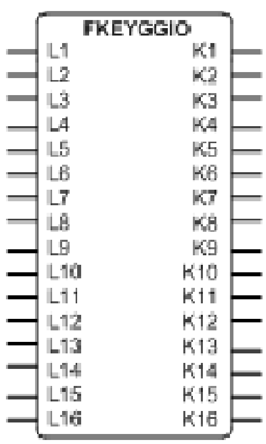


Figure 228: Function block

9.3.2 Functionality

The programmable function block FKEYGGIO is a simple interface between the panel and the application. The user input from the buttons available on the front panel is transferred to the assigned functionality and the corresponding LED is turned ON/OFF for indication. The behavior of each function key in the specific application is configured by connection with other application functions. This gives the maximum flexibility.

The LED input and its key output of FKEYGGIO are independent. To make the led on a pushbutton follow the state of the pushbutton, external glue logic is needed. The status of FKEYGGIO inputs and outputs are NOT saved to non-volatile memory.

9.3.3 Signals

Table 396: FKEYGGIO LED Indication signals

Name	Type	Description
L1	BOOLEAN	Programmable button LED Indication 1
L2	BOOLEAN	Programmable button LED Indication 2
L3	BOOLEAN	Programmable button LED Indication 3
L4	BOOLEAN	Programmable button LED Indication 4
L5	BOOLEAN	Programmable button LED Indication 5
L6	BOOLEAN	Programmable button LED Indication 6
L7	BOOLEAN	Programmable button LED Indication 7
L8	BOOLEAN	Programmable button LED Indication 8
L9	BOOLEAN	Programmable button LED Indication 9
L10	BOOLEAN	Programmable button LED Indication 10
L11	BOOLEAN	Programmable button LED Indication 11
L12	BOOLEAN	Programmable button LED Indication 12
L13	BOOLEAN	Programmable button LED Indication 13
L14	BOOLEAN	Programmable button LED Indication 14
L15	BOOLEAN	Programmable button LED Indication 15
L16	BOOLEAN	Programmable button LED Indication 16

Table 397: FKEYGGIO Programmable button Signals

Name	Type	Description
K1	BOOLEAN	Programmable button 1
K2	BOOLEAN	Programmable button 2
K3	BOOLEAN	Programmable button 3
K4	BOOLEAN	Programmable button 4
K5	BOOLEAN	Programmable button 5
K6	BOOLEAN	Programmable button 6
K7	BOOLEAN	Programmable button 7
K8	BOOLEAN	Programmable button 8
K9	BOOLEAN	Programmable button 9
K10	BOOLEAN	Programmable button 10
K11	BOOLEAN	Programmable button 11
K12	BOOLEAN	Programmable button 12
K13	BOOLEAN	Programmable button 13
K14	BOOLEAN	Programmable button 14
K15	BOOLEAN	Programmable button 15
K16	BOOLEAN	Programmable button 16

9.4 Move function block MVGAPC

9.4.1 Function block

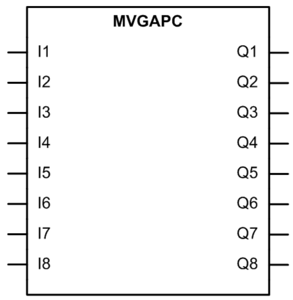


Figure 229: Function block

9.4.2 Functionality

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

9.4.3 Signals

Table 398: MVGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Q1 status
Q2	BOOLEAN	Q2 status
Q3	BOOLEAN	Q3 status
Q4	BOOLEAN	Q4 status
Q5	BOOLEAN	Q5 status
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

9.5 Pulse timer function block PTGAPC

9.5.1 Function block

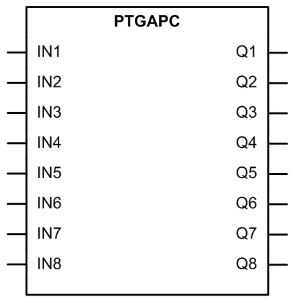


Figure 230: Function block

9.5.2 Functionality

The pulse timer function block PTGAPC contains eight independent timers. The function has a settable pulse length. Once the input is activated, the output is set for a specific duration using the *Pulse delay time* setting.

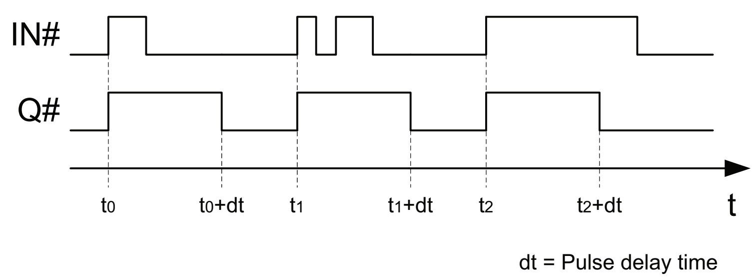


Figure 231: Timer operation

9.5.3 Signals

Table 399: PTGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status
IN3	BOOLEAN	0=False	Input 3 status
IN4	BOOLEAN	0=False	Input 4 status
IN5	BOOLEAN	0=False	Input 5 status
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 400: PTGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1 status
Q2	BOOLEAN	Output 2 status
Q3	BOOLEAN	Output 3 status
Q4	BOOLEAN	Output 4 status
Q5	BOOLEAN	Output 5 status
Q6	BOOLEAN	Output 6 status
Q7	BOOLEAN	Output 7 status
Q8	BOOLEAN	Output 8 status

9.5.4 Settings

Table 401: PTGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse delay time 1	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 2	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 3	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 4	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 5	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 6	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 7	0...3600000	ms	10	0	Pulse delay time
Pulse delay time 8	0...3600000	ms	10	0	Pulse delay time

Table 402: Generic timers, TPGAPC1...4

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

Table 403: Generic timers, TPSGAPC1

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

Table 404: Generic timers, TPMGAPC1

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	min	1	0	Minimum pulse time, range in minutes

9.5.5 Technical data

Table 405: PTGAPC Technical data

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

9.6 Generic control points SPCGGIO

9.6.1 Function block

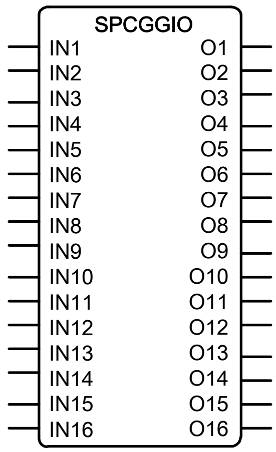


Figure 232: Function block

9.6.2 Functionality

The generic control points function block SPCGGIO can be used in combination with other function blocks such as FKEYGGIO. This block offers the capability to activate its output through a local or remote control. The local control is issued through the buttons in the front panel and the remote control is issued through communications. This block has two modes of operation. In pulsed mode, regardless of local or remote, the block generates an output pulse of preset duration. In toggle mode, a local pushbutton simply toggles the output signal for every input pulse received, whereas a remote command only does SET/RESET.

SPCSO1.output		Remote Command		SPCSO1.output
TRUE	⇨	SET	⇨	TRUE
TRUE	⇨	RESET	⇨	FALSE
FALSE	⇨	SET	⇨	TRUE
FALSE	⇨	RESET	⇨	FALSE

The status of SPCGGIO outputs ARE saved to non-volatile memory, so the relay can memorize these outputs even when power is cycled.

The input and output of SPCGGIO are mapped to the same IEC 61850 data path. Any ACT block that is connected to the input of a SPCGGIO must have a smaller execution order than SPCGGIO.

9.6.3 Signals

Table 406: SPCGGIO Input Signals

Name	Type	Description
IN1	BOOLEAN	Input 1 status
IN2	BOOLEAN	Input 2 status
IN3	BOOLEAN	Input 3 status
IN4	BOOLEAN	Input 4 status
IN5	BOOLEAN	Input 5 status
IN6	BOOLEAN	Input 6 status
IN7	BOOLEAN	Input 7 status
IN8	BOOLEAN	Input 8 status
IN9	BOOLEAN	Input 9 status
IN10	BOOLEAN	Input 10 status
IN11	BOOLEAN	Input 11 status
IN12	BOOLEAN	Input 12 status
IN13	BOOLEAN	Input 13 status
IN14	BOOLEAN	Input 14 status
IN15	BOOLEAN	Input 15 status
IN16	BOOLEAN	Input 16 status

Table 407: SPCGGIO Input Signals

Name	Type	Description
O1	BOOLEAN	Output 1 status
O2	BOOLEAN	Output 2 status
O3	BOOLEAN	Output 3 status
O4	BOOLEAN	Output 4 status
O5	BOOLEAN	Output 5 status
O6	BOOLEAN	Output 6 status
O7	BOOLEAN	Output 7 status
O8	BOOLEAN	Output 8 status
O9	BOOLEAN	Output 9 status
O10	BOOLEAN	Output 10 status
O11	BOOLEAN	Output 11 status
O12	BOOLEAN	Output 12 status
O13	BOOLEAN	Output 13 status
O14	BOOLEAN	Output 14 status
O15	BOOLEAN	Output 15 status
O16	BOOLEAN	Output 16 status

9.6.4 Settings

Table 408: SPCGGIO Outputs 1…16

Parameter	Values	Unit	Step	Default	Description
Operation mode	Off				
Toggle					
Pulsed			Off	Mode of operation for the function	
Pulse length	10…3600000	ms		1000	Length of the output pulse generated by the function
Description	SPCGGIO Output			SPCGGIO Output	User defined Description

9.7 Set-reset flip flops SRGAPC

9.7.1 Function block

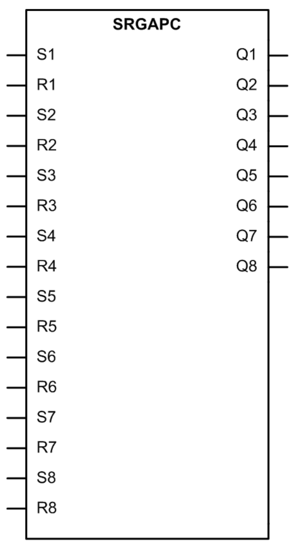


Figure 233: Function block

9.7.2 Functionality

The SRGAPC function block is a simple SR flip-flop with a memory that can be set or that can reset an output from the `S#` or `R#` inputs, respectively. SRGAPC contains eight independent set-reset flip-flop latches where the `SET` input has the higher priority over the `RESET` input. The status of each `Q#` output is retained in the nonvolatile memory. The individual reset for each `Q#` output is available on the LHMI or through tool via communication.

Table 409: Truth table for SRGAPC

S#	R#	Q#
0	0	0[1]
0	1	0
1	0	1
1	1	1

1. Keep state/no change

9.7.3 Signals

Table 410: SRGAPC Input signals

Name	Type	Default	Description
S1	BOOLEAN	0=False	Set Q1 output when set
R1	BOOLEAN	0=False	Resets Q1 output when set
S2	BOOLEAN	0=False	Set Q2 output when set
R2	BOOLEAN	0=False	Resets Q2 output when set
S3	BOOLEAN	0=False	Set Q3 output when set
R3	BOOLEAN	0=False	Resets Q3 output when set
S4	BOOLEAN	0=False	Set Q4 output when set
R4	BOOLEAN	0=False	Resets Q4 output when set
S5	BOOLEAN	0=False	Set Q5 output when set
R5	BOOLEAN	0=False	Resets Q5 output when set
S6	BOOLEAN	0=False	Set Q6 output when set
R6	BOOLEAN	0=False	Resets Q6 output when set
S7	BOOLEAN	0=False	Set Q7 output when set
R7	BOOLEAN	0=False	Resets Q7 output when set
S8	BOOLEAN	0=False	Set Q8 output when set
R8	BOOLEAN	0=False	Resets Q8 output when set

Table 411: SRGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Q1 status
Q2	BOOLEAN	Q2 status
Q3	BOOLEAN	Q3 status
Q4	BOOLEAN	Q4 status
Q5	BOOLEAN	Q5 status
Q6	BOOLEAN	Q6 status
Q7	BOOLEAN	Q7 status
Q8	BOOLEAN	Q8 status

9.7.4 Settings

Table 412: SRGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Reset Q1	0=Cancel 1=Reset			0=Cancel	Resets Q1 output when set
Reset Q2	0=Cancel 1=Reset			0=Cancel	Resets Q2 output when set
Reset Q3	0=Cancel 1=Reset			0=Cancel	Resets Q3 output when set
Reset Q4	0=Cancel 1=Reset			0=Cancel	Resets Q4 output when set
Reset Q5	0=Cancel 1=Reset			0=Cancel	Resets Q5 output when set
Reset Q6	0=Cancel 1=Reset			0=Cancel	Resets Q6 output when set
Reset Q7	0=Cancel 1=Reset			0=Cancel	Resets Q7 output when set
Reset Q8	0=Cancel 1=Reset			0=Cancel	Resets Q8 output when set

9.8 Time-delay-off timers TOFGAPC

9.8.1 Function block

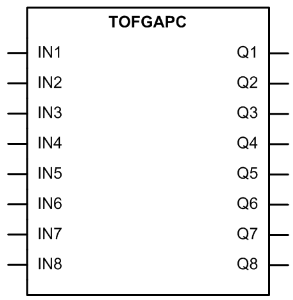


Figure 234: Function block

9.8.2 Functionality

The time-delay-off function block TOFGAPC can be used, for example, for a drop-off-delayed output related to the input signal. TOFGAPC contains eight independent timers. There is a settable delay in the timer. Once the input is activated, the output is set immediately. When the input is cleared, the output stays on until the time set with the *Off delay time* setting has elapsed.

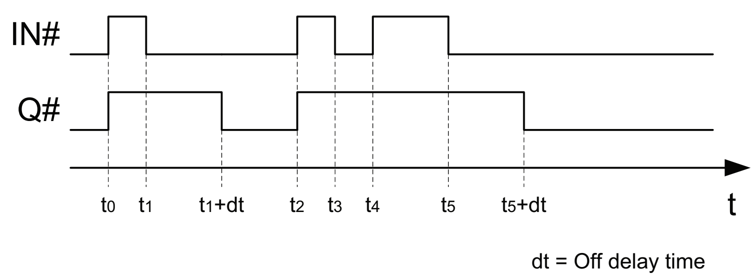


Figure 235: Timer operation

9.8.3 Signals

Table 413: TOFGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status
IN3	BOOLEAN	0=False	Input 3 status
IN4	BOOLEAN	0=False	Input 4 status
IN5	BOOLEAN	0=False	Input 5 status
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 414: TOFGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1 status
Q2	BOOLEAN	Output 2 status
Q3	BOOLEAN	Output 3 status
Q4	BOOLEAN	Output 4 status
Q5	BOOLEAN	Output 5 status
Q6	BOOLEAN	Output 6 status
Q7	BOOLEAN	Output 7 status
Q8	BOOLEAN	Output 8 status

9.8.4 Settings

Table 415: TOFGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Off delay time 1	0...3600000	ms	10	0	Off delay time
Off delay time 2	0...3600000	ms	10	0	Off delay time
Off delay time 3	0...3600000	ms	10	0	Off delay time
Off delay time 4	0...3600000	ms	10	0	Off delay time
Off delay time 5	0...3600000	ms	10	0	Off delay time
Off delay time 6	0...3600000	ms	10	0	Off delay time
Off delay time 7	0...3600000	ms	10	0	Off delay time
Off delay time 8	0...3600000	ms	10	0	Off delay time

9.8.5 Technical data

Table 416: TOFGAPC Technical data

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

9.9 Time-delay-on timers TONGAPC

9.9.1 Function block

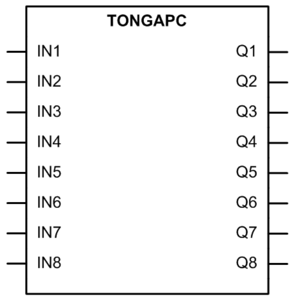


Figure 236: Function block

9.9.2 Functionality

The time-delay-on function block TONGAPC can be used, for example, for time-delaying the output related to the input signal. TONGAPC contains eight independent timers. The timer has a settable time delay. Once the input is activated, the output is set after the time set by the *On delay time* setting has elapsed.

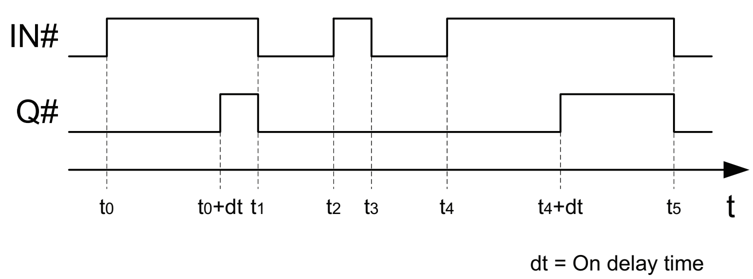


Figure 237: Timer operation

9.9.3 Signals

Table 417: TONGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2
IN3	BOOLEAN	0=False	Input 3
IN4	BOOLEAN	0=False	Input 4
IN5	BOOLEAN	0=False	Input 5
IN6	BOOLEAN	0=False	Input 6
IN7	BOOLEAN	0=False	Input 7
IN8	BOOLEAN	0=False	Input 8

Table 418: TONGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1
Q2	BOOLEAN	Output 2
Q3	BOOLEAN	Output 3
Q4	BOOLEAN	Output 4
Q5	BOOLEAN	Output 5
Q6	BOOLEAN	Output 6
Q7	BOOLEAN	Output 7
Q8	BOOLEAN	Output 8

9.9.4 Settings

Table 419: TONGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
On delay time 1	0...3600000	ms	10	0	On delay time
On delay time 2	0...3600000	ms	10	0	On delay time
On delay time 3	0...3600000	ms	10	0	On delay time
On delay time 4	0...3600000	ms	10	0	On delay time
On delay time 5	0...3600000	ms	10	0	On delay time
On delay time 6	0...3600000	ms	10	0	On delay time
On delay time 7	0...3600000	ms	10	0	On delay time
On delay time 8	0...3600000	ms	10	0	On delay time

9.9.5 Technical data

Table 420: TONGAPC Technical data

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

Section 10 General function block features

10.1 Definite time characteristics

10.1.1 Definite time operation

The DT mode is enabled when the *Operating curve type* setting is selected either as “ANSI Def. Time” or “IEC Def. Time”. In the DT mode, the `TRIP` output of the function is activated when the time calculation exceeds the set *Trip delay time*.

The user can determine the reset in the DT mode with the *Reset delay time* setting, which provides the delayed reset property when needed.

The *Type of reset curve* setting has no effect on the reset method when the DT mode is selected, but the reset is determined solely with the *Reset delay time* setting.

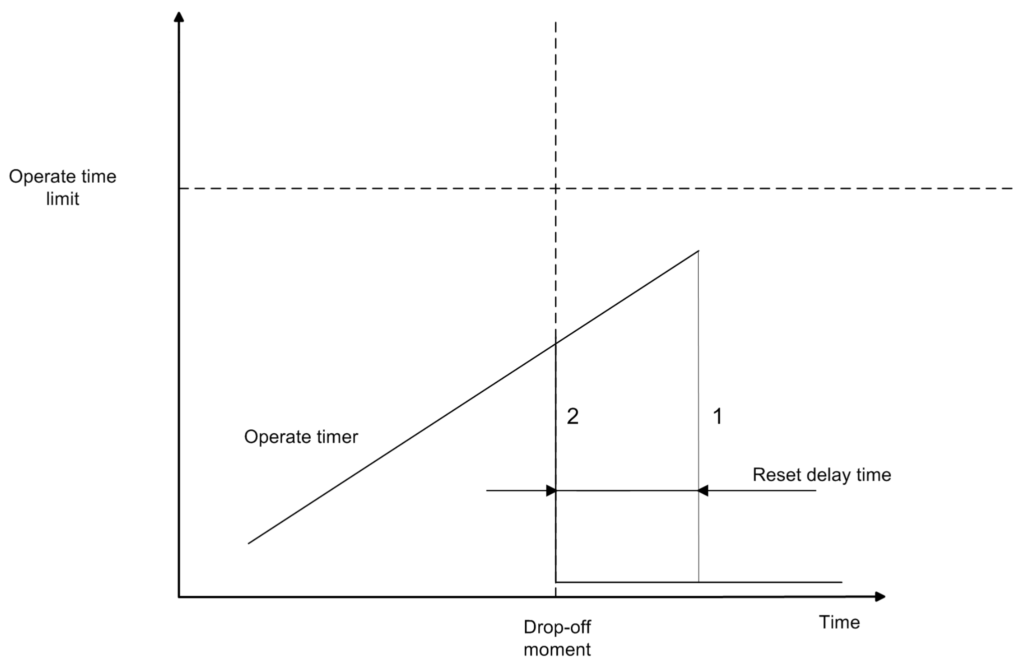


Figure 238: Operation of the counter in drop-off

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.

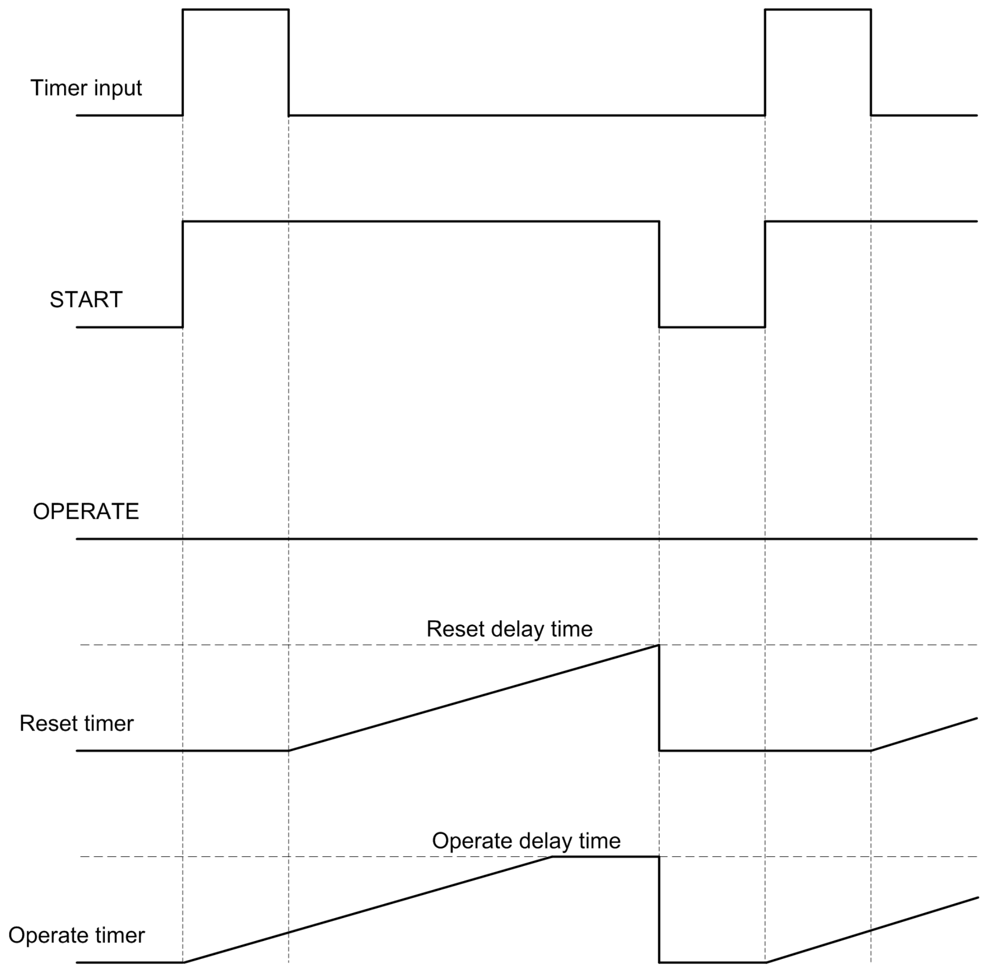


Figure 239: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 221, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Pickup value*. The input signal is inactive when the current is below the set *Pickup value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the `PICKUP` output and the trip timer starts elapsing. The reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. When the reset (drop-off) timer elapses, the trip timer is reset. Since this happens before another pickup occurs, the `TRIP` output is not activated.

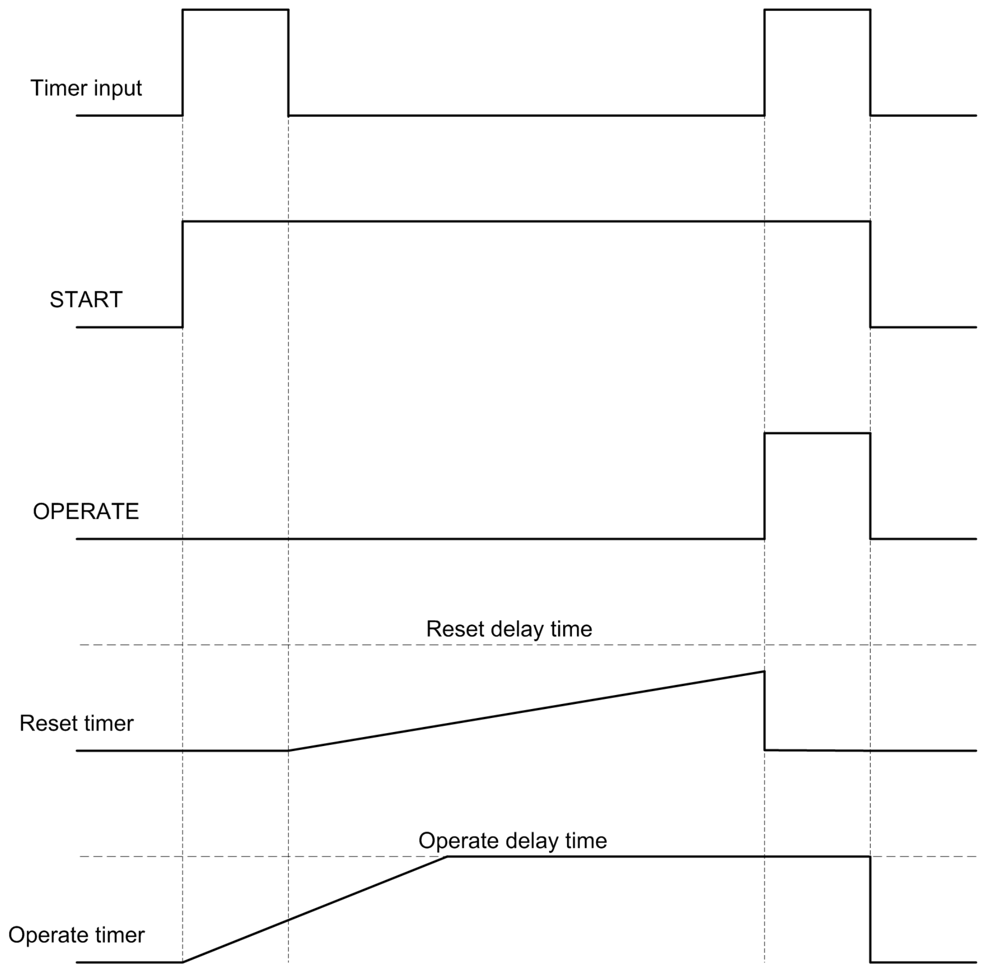


Figure 240: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 222, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Pickup value*. The input signal is inactive when the current is below the set *Pickup value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the `PICKUP` output and the trip timer starts elapsing. The reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. Another fault situation occurs before the reset (drop-off) timer has elapsed. This causes the activation of the `TRIP` output, since the trip timer already has elapsed.

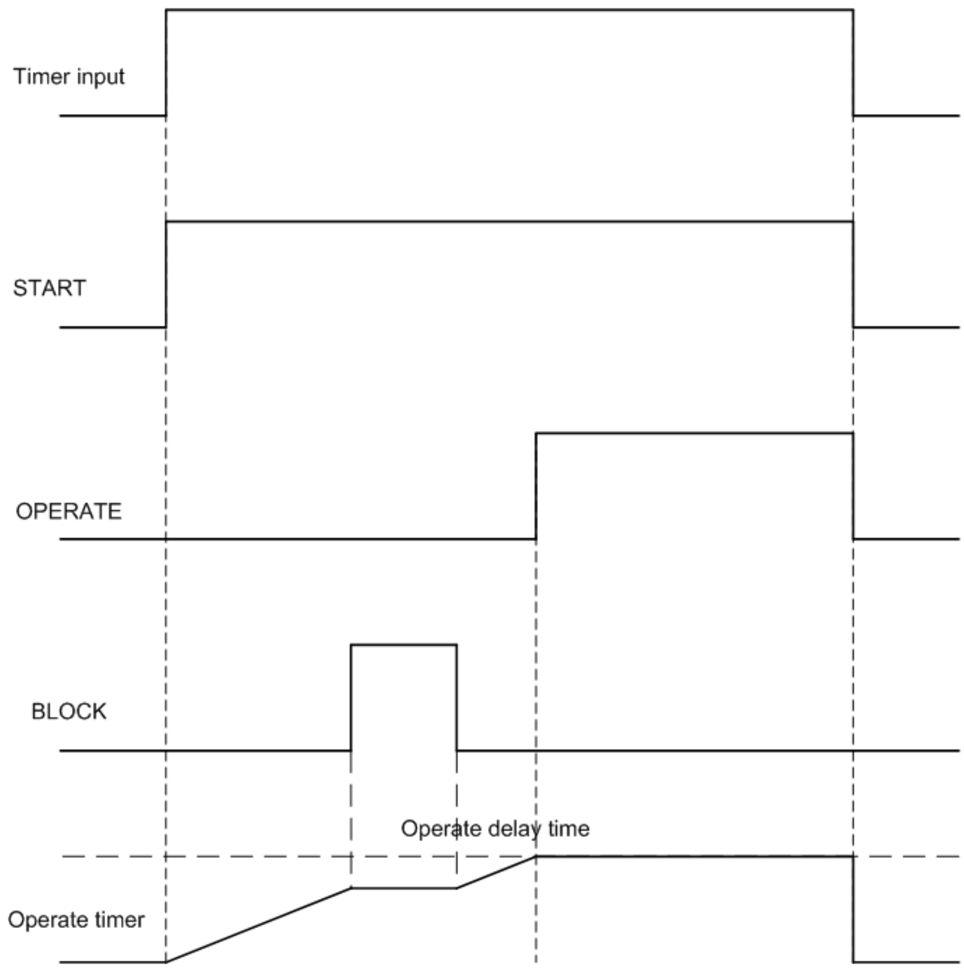


Figure 241: Operating effect of the `BLOCK` *input when the selected blocking mode is "Freeze timer"*

If the `BLOCK` input is activated when the trip timer is running, as described in Figure 223, the timer is frozen during the time `BLOCK` remains active. If the timer input is not active longer than specified by the *Reset delay time* setting, the trip timer is reset in the same way as described in Figure 221, regardless of the `BLOCK` input.

The selected blocking mode is "Freeze timer".

10.2 Current based inverse definite minimum time characteristics

10.2.1 IDMT curves for overcurrent protection

In inverse-time modes, the trip time depends on the momentary value of the current: the higher the current, the faster the trip time. The trip time calculation or integration starts immediately when the current exceeds the set *Pickup value* and the PICKUP output is activated.

The TRIP output of the component is activated when the cumulative sum of the integrator calculating the overcurrent situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time for the IDMT mode, that is, it is possible to limit the IDMT based trip time for not becoming too short. For example:

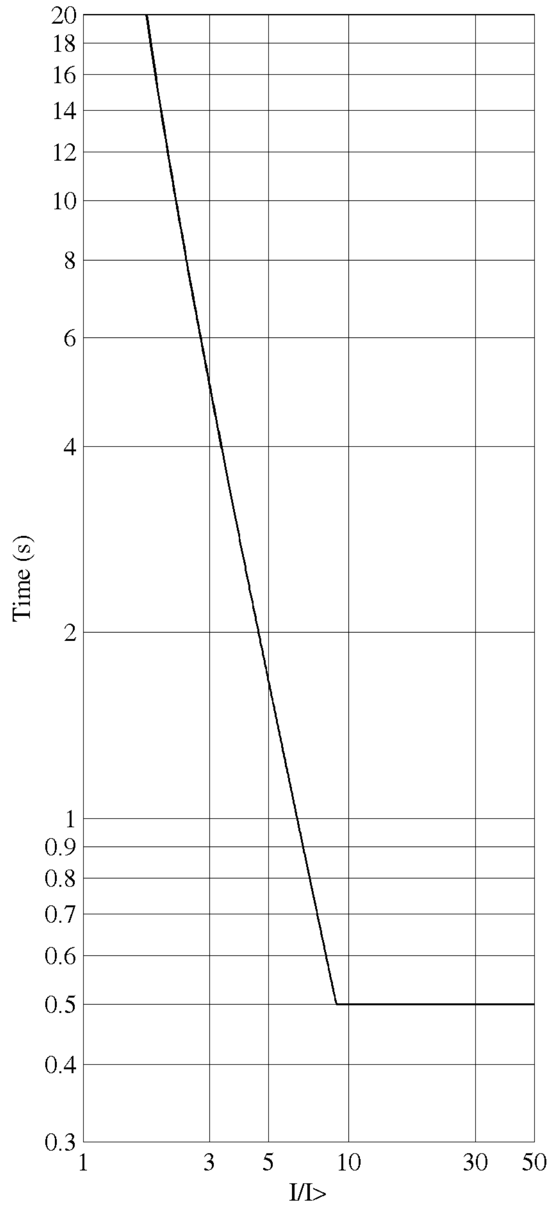


Figure 242: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 0.5 second

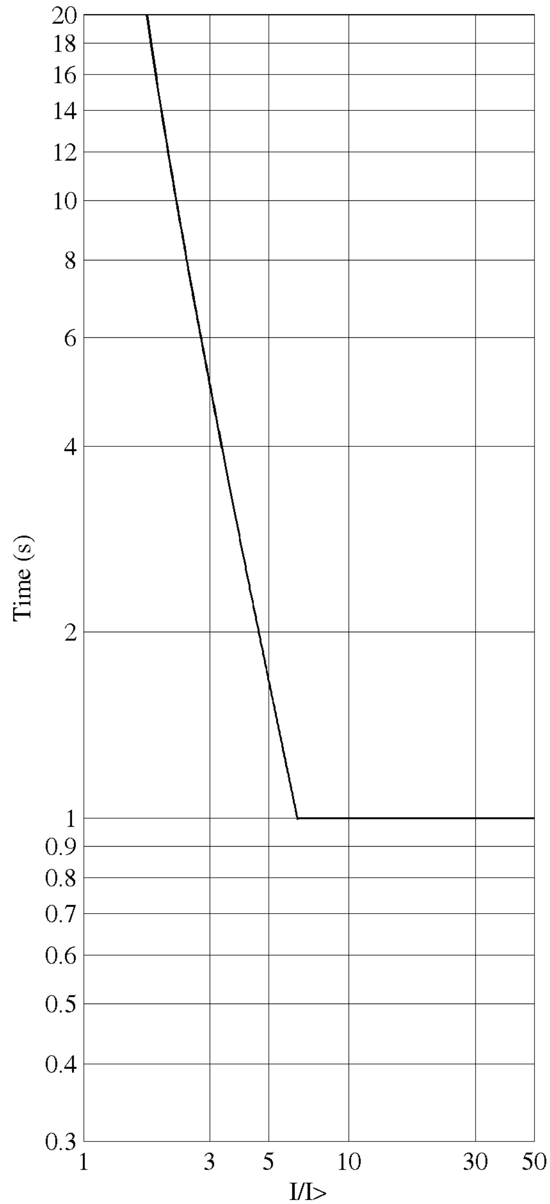


Figure 243: Trip time curves based on IDMT characteristic with the value of the Minimum trip time setting = 1 second

10.2.1.1 Standard inverse-time characteristics

For inverse-time operation, both IEC and ANSI/IEEE standardized inverse-time characteristics are supported.

The trip times for the ANSI and IEC IDMT curves are defined with the coefficients A, B and C.

The values of the coefficients can be calculated according to the formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>} \right)^{C} - 1} + B \right) \cdot k$$

(Equation 57)

t[s] t[s] = Trip time in seconds
I measured current
I> set *Pickup value*
k set *Time multiplier*

Table 421: Curve parameters for ANSI and IEC IDMT curves

Curve name	A	B	C
(1) ANSI Extremely Inverse	28.2	0.1217	2.0
(2) ANSI Very Inverse	19.61	0.491	2.0
(3) ANSI Normal Inverse	0.0086	0.0185	0.02
(4) ANSI Moderately Inverse	0.0515	0.1140	0.02
(6) Long Time Extremely Inverse	64.07	0.250	2.0
(7) Long Time Very Inverse	28.55	0.712	2.0
(8) Long Time Inverse	0.086	0.185	0.02
(9) IEC Normal Inverse	0.14	0.0	0.02
(10) IEC Very Inverse	13.5	0.0	1.0
(11) IEC Inverse	0.14	0.0	0.02
(12) IEC Extremely Inverse	80.0	0.0	2.0
(13) IEC Short Time Inverse	0.05	0.0	0.04
(14) IEC Long Time Inverse	120	0.0	1.0

The maximum guaranteed measured current is 50 x In for the current protection. When the set *Pickup value* exceeds 1.00 x In, the turn point where the theoretical IDMT characteristics are leveling out to the definite time can be calculated with the formula:

$$Turn\ point = \frac{50 \times In}{Pickup\ value}$$

(Equation 58)

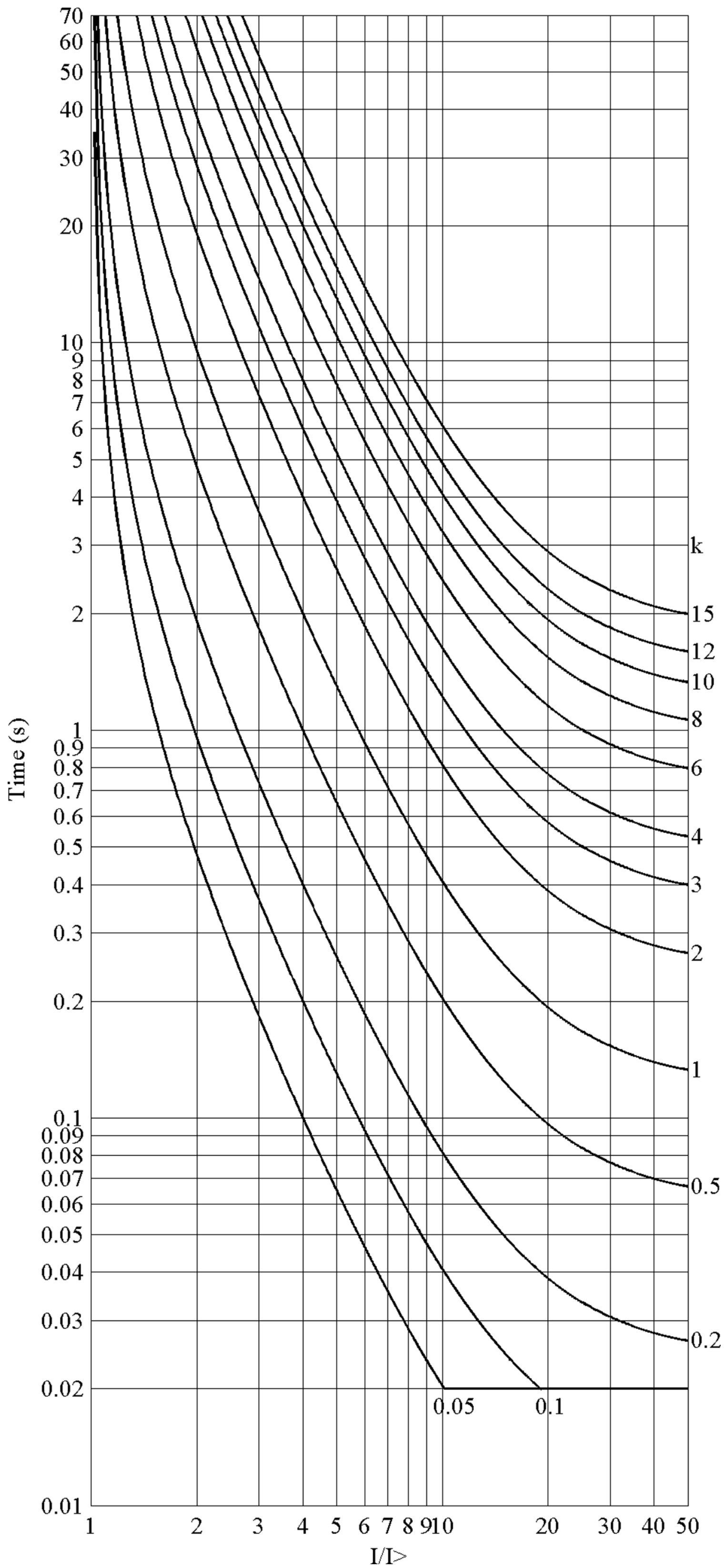


Figure 244: ANSI extremely inverse-time characteristics

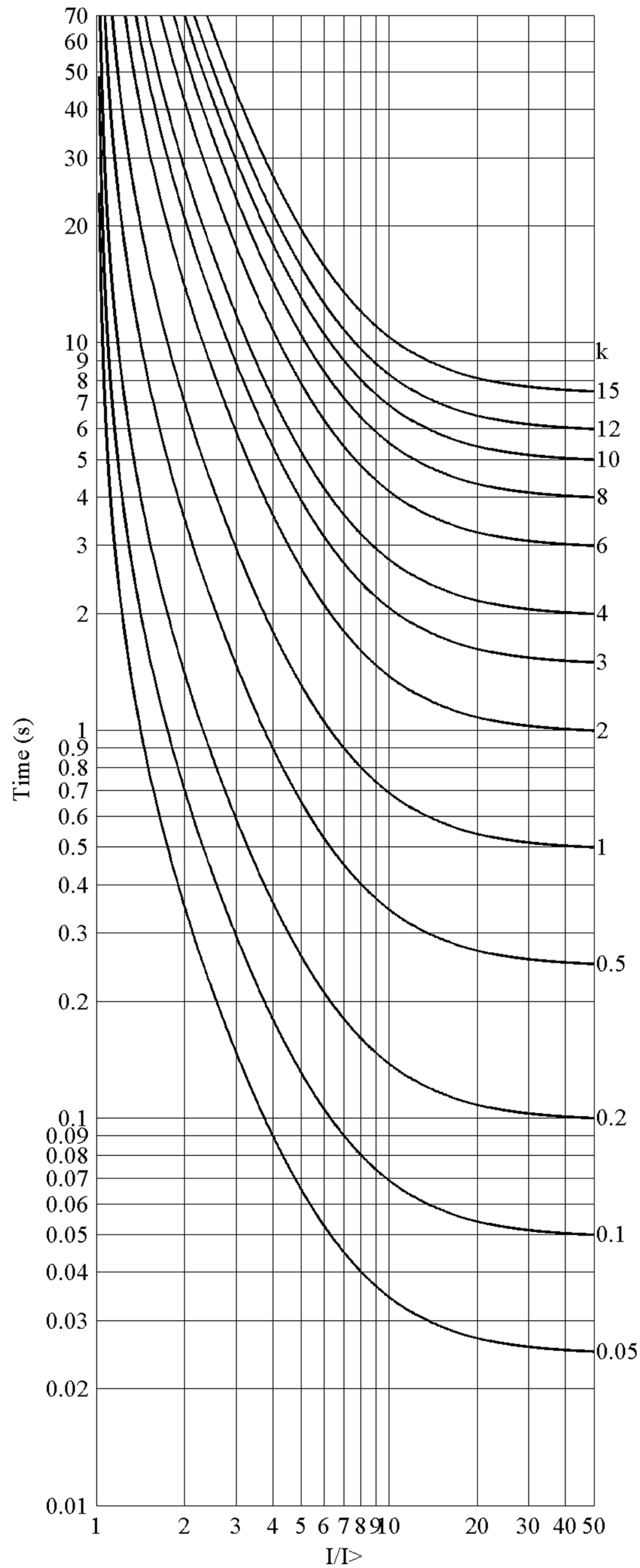


Figure 245: ANSI very inverse-time characteristics

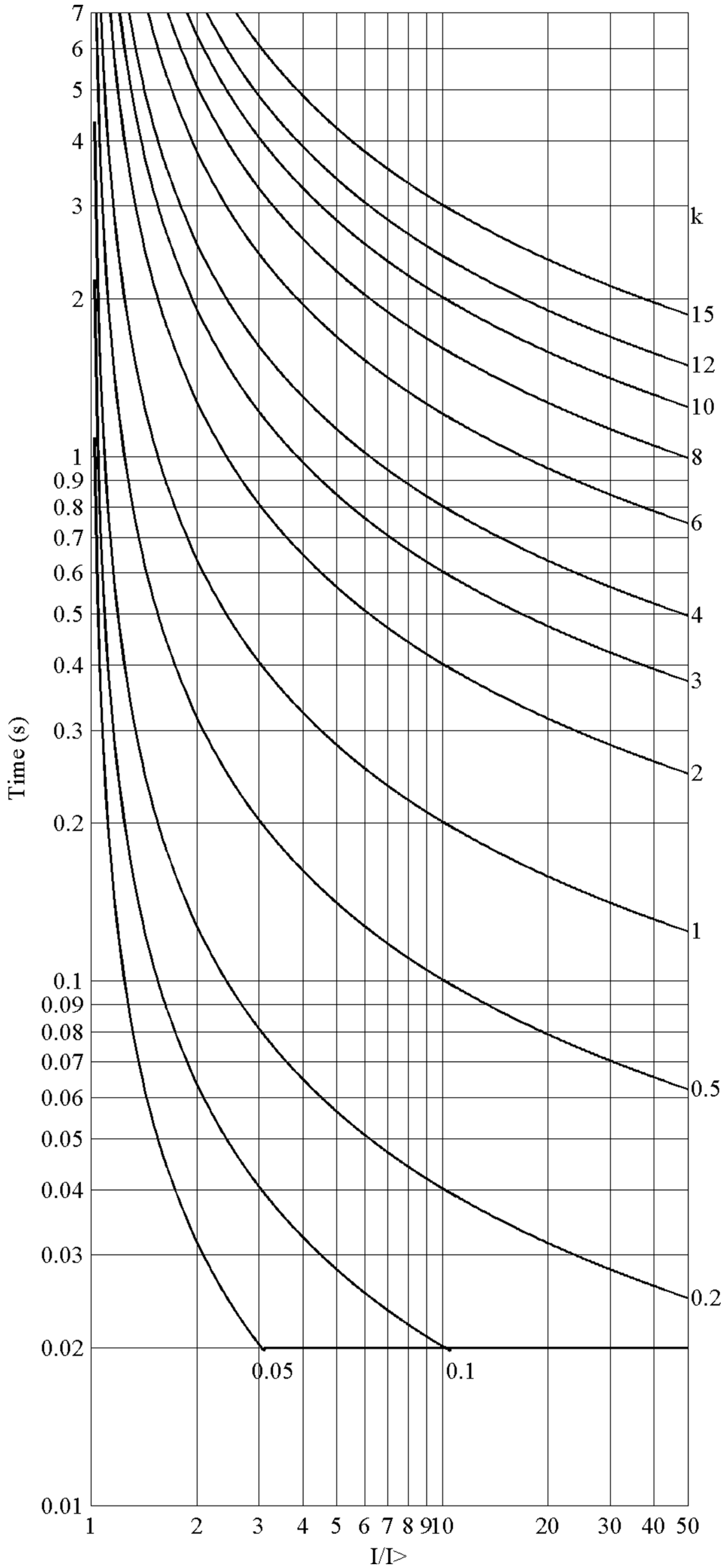


Figure 246: ANSI normal inverse-time characteristics

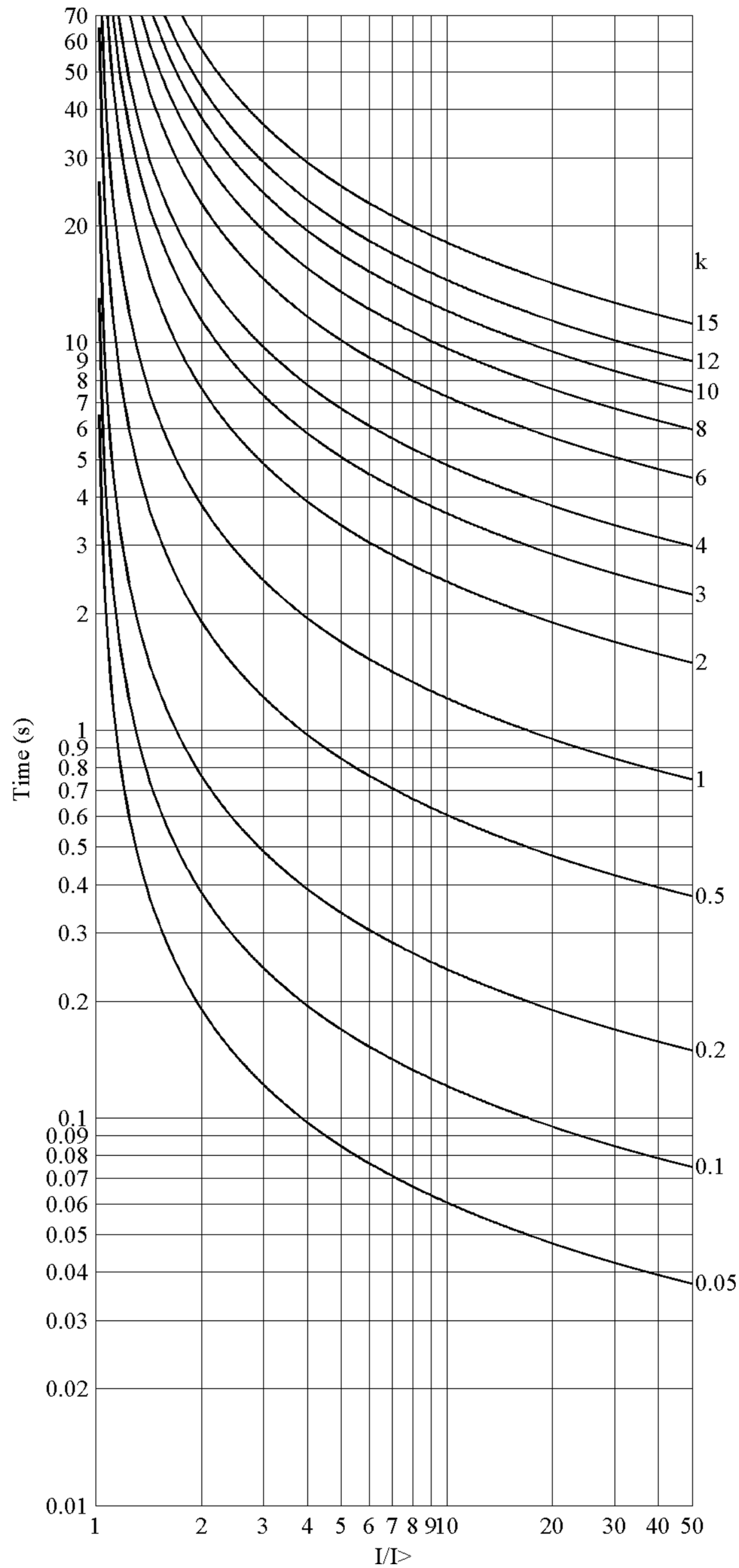


Figure 247: ANSI moderately inverse-time characteristics

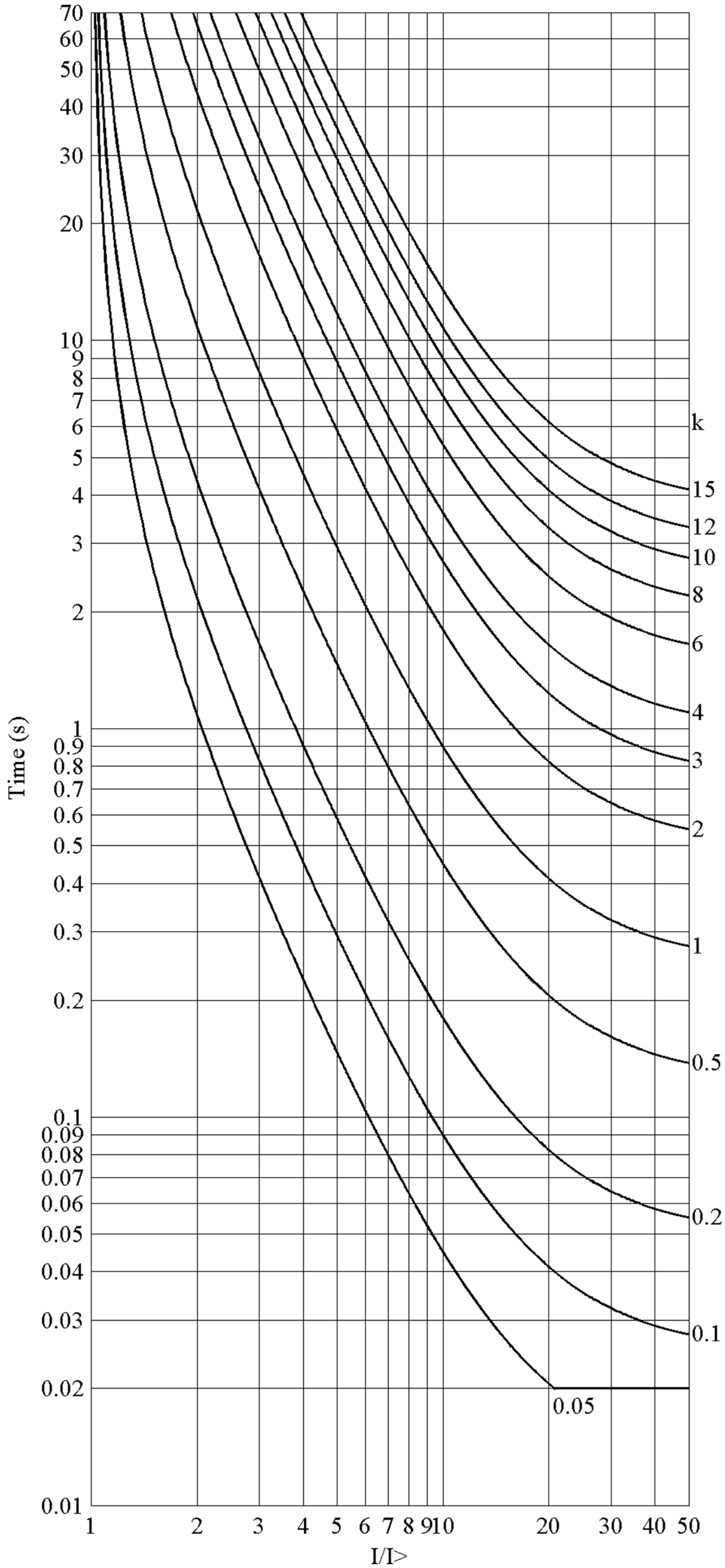


Figure 248: ANSI long-time extremely inverse-time characteristics

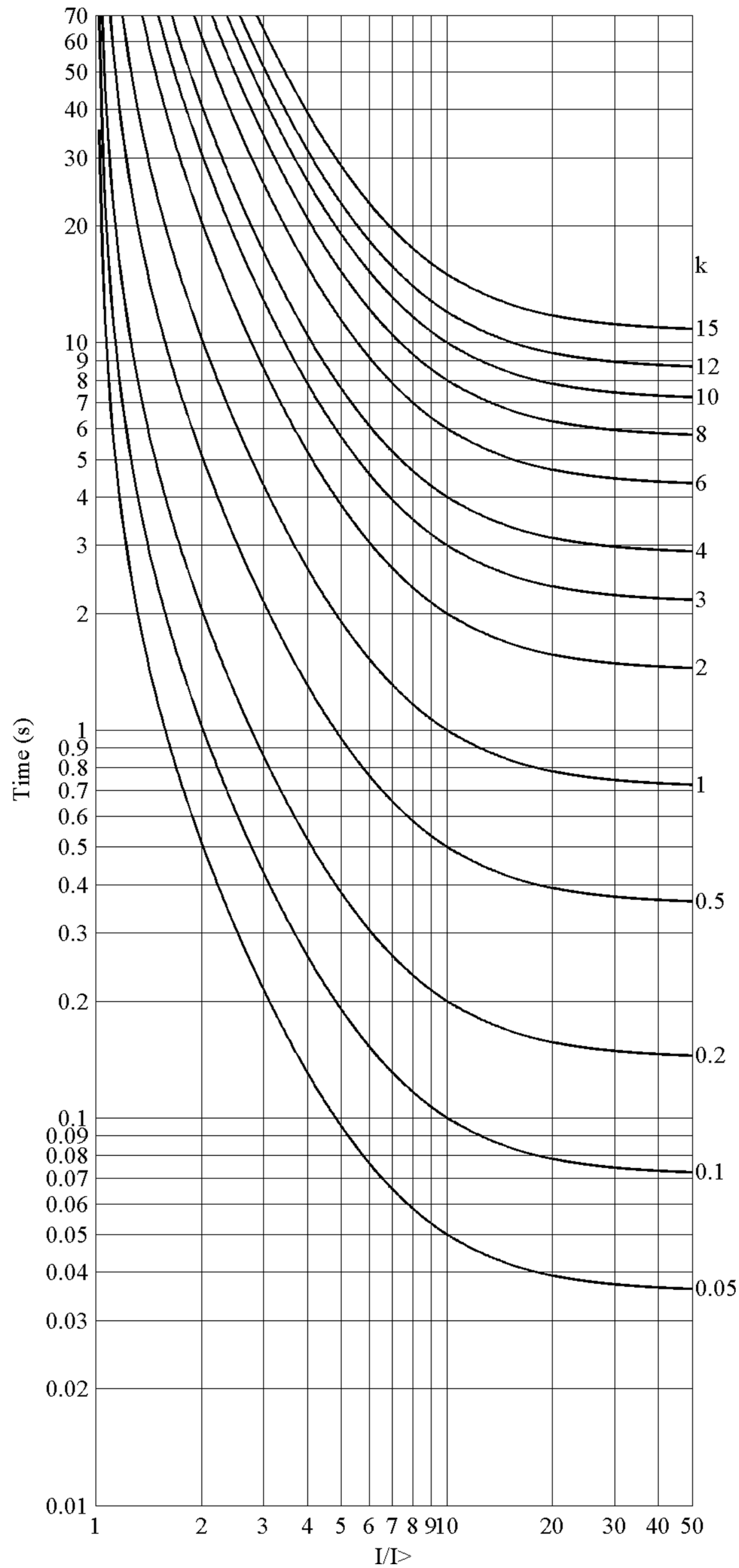


Figure 249: ANSI long-time very inverse-time characteristics

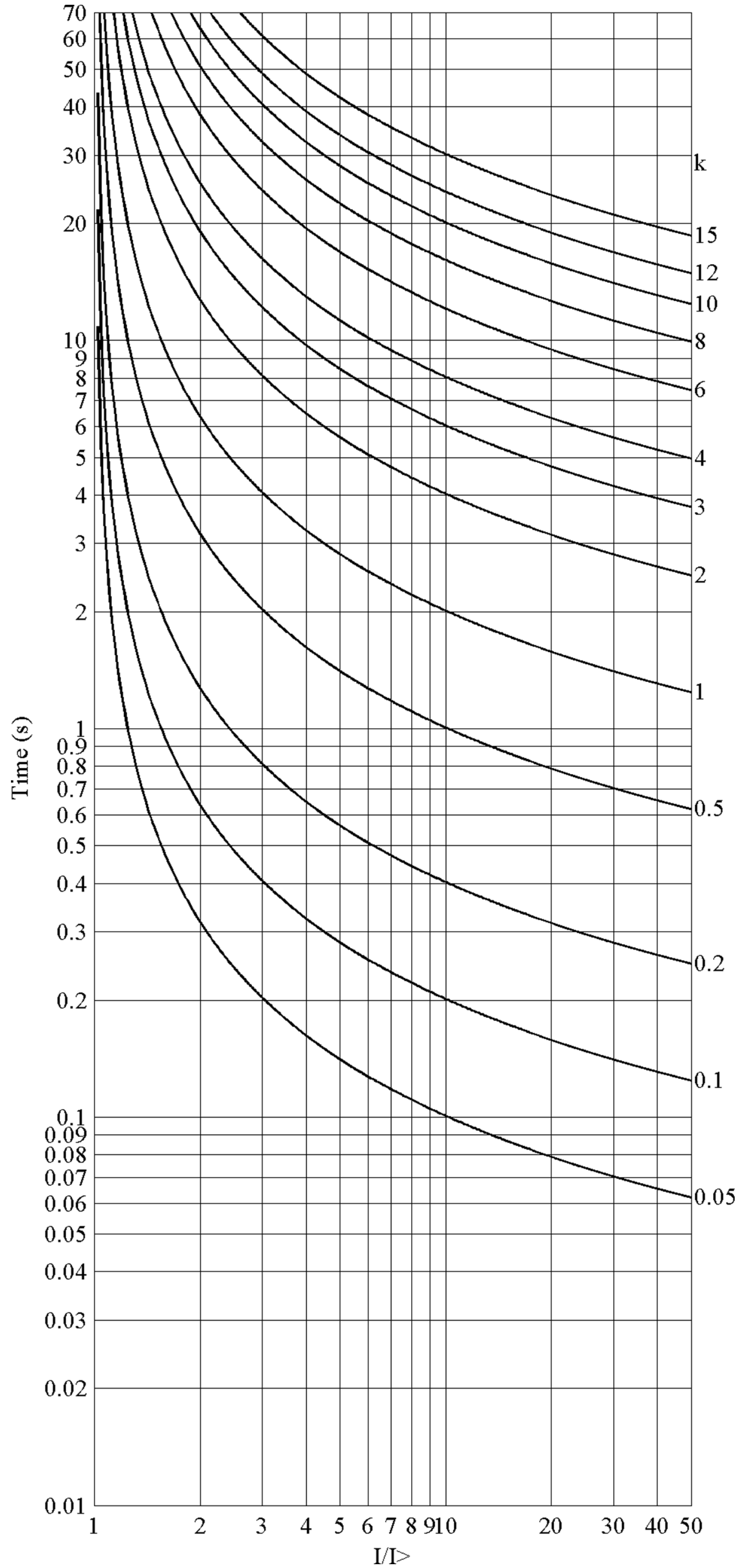


Figure 250: ANSI long-time inverse-time characteristics

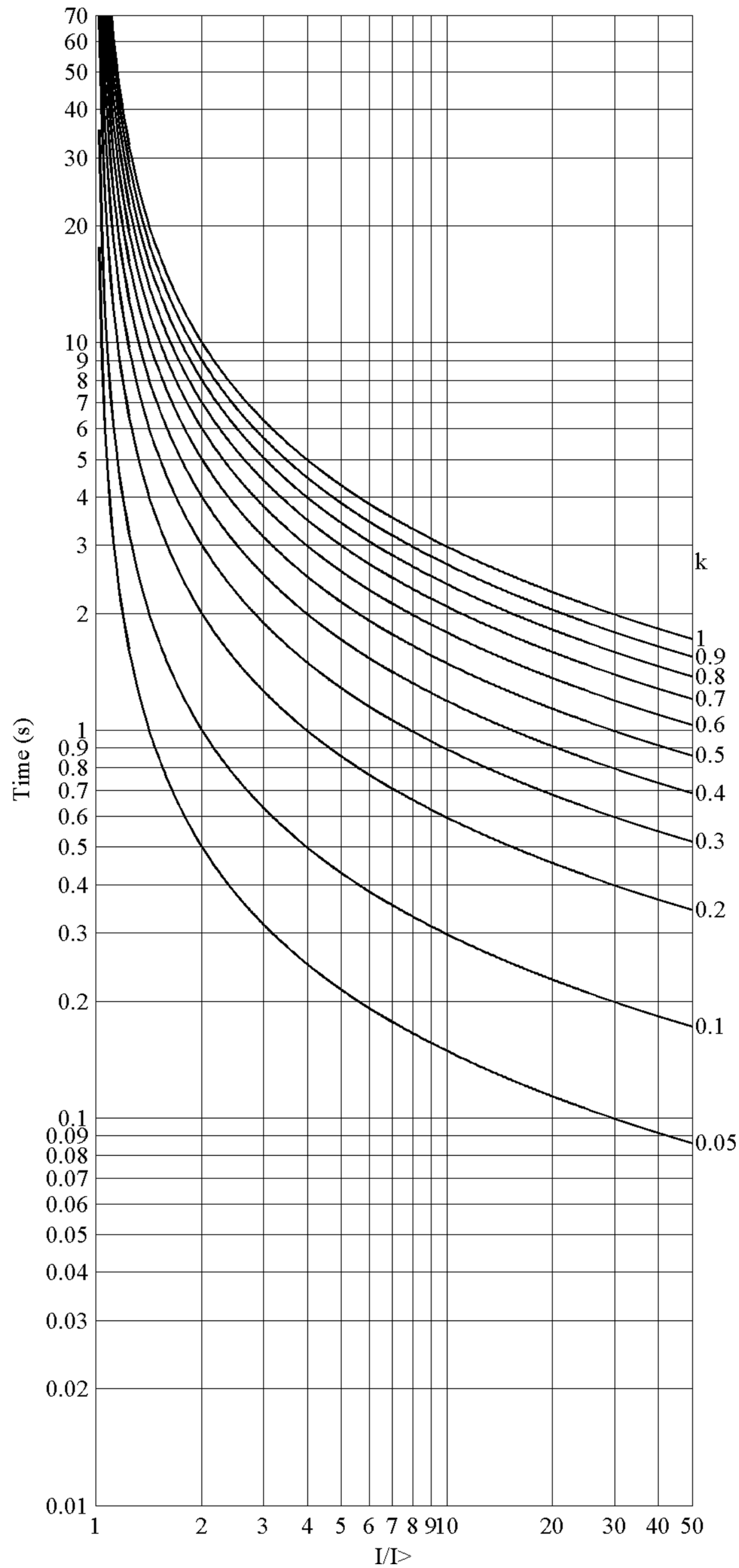


Figure 251: IEC normal inverse-time characteristics

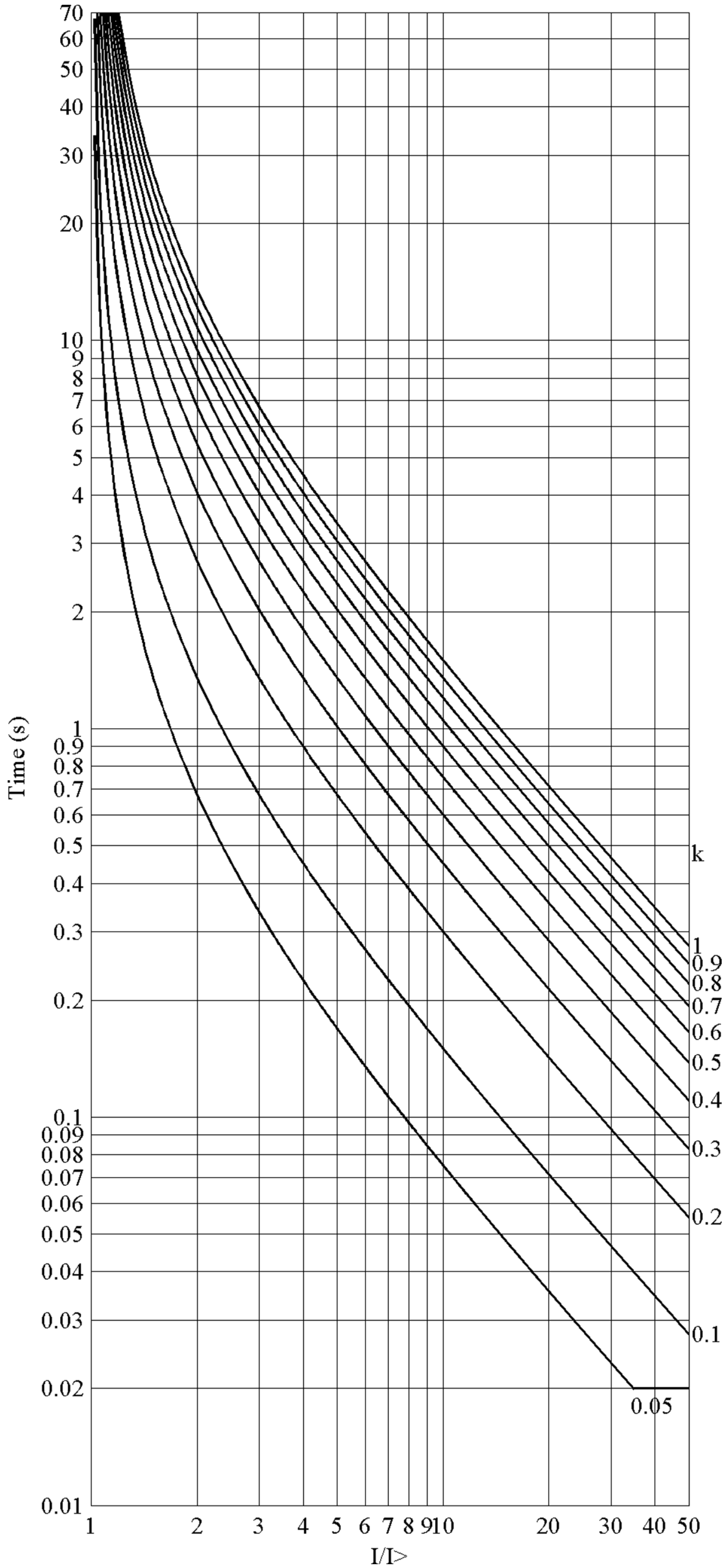


Figure 252: IEC very inverse-time characteristics

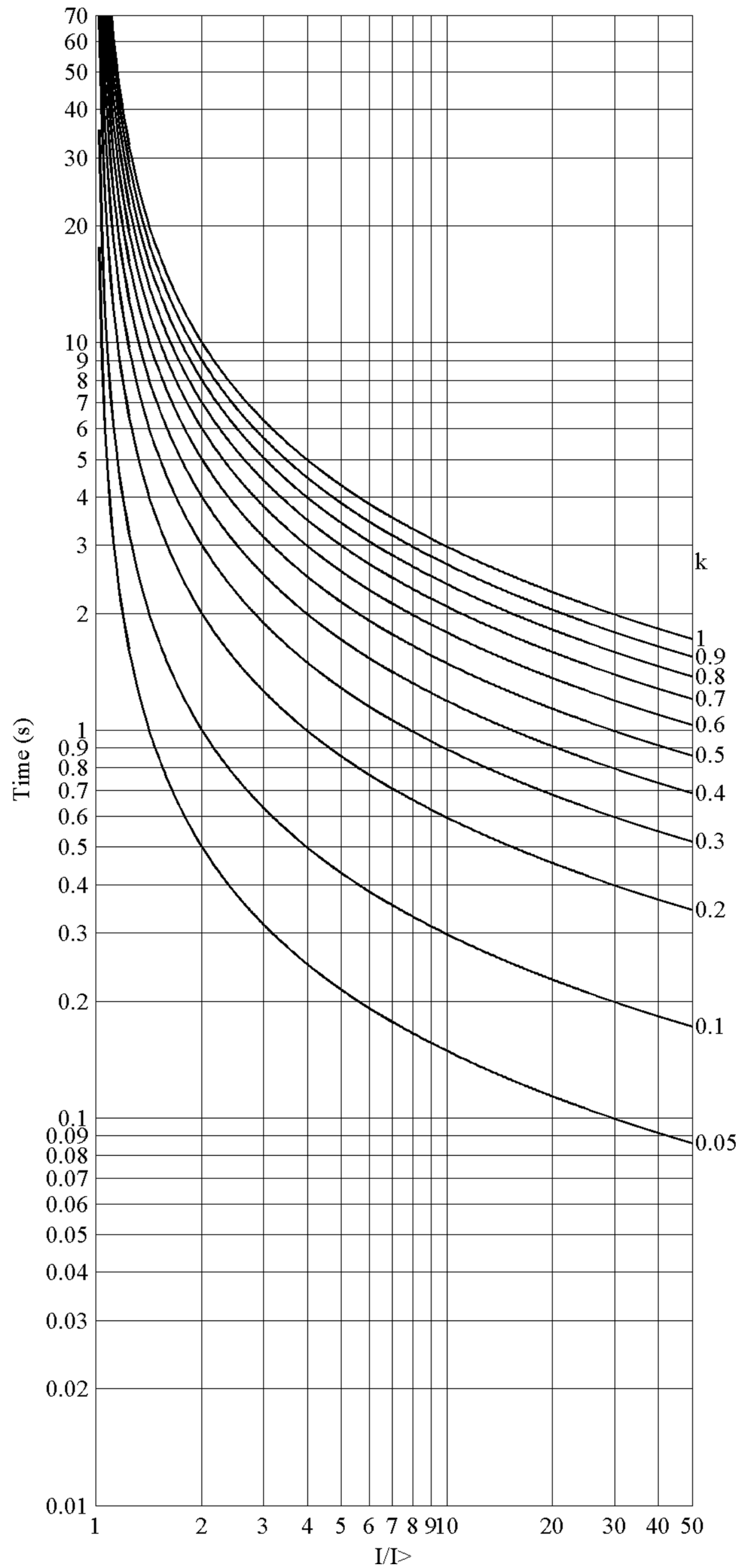


Figure 253: IEC inverse-time characteristics

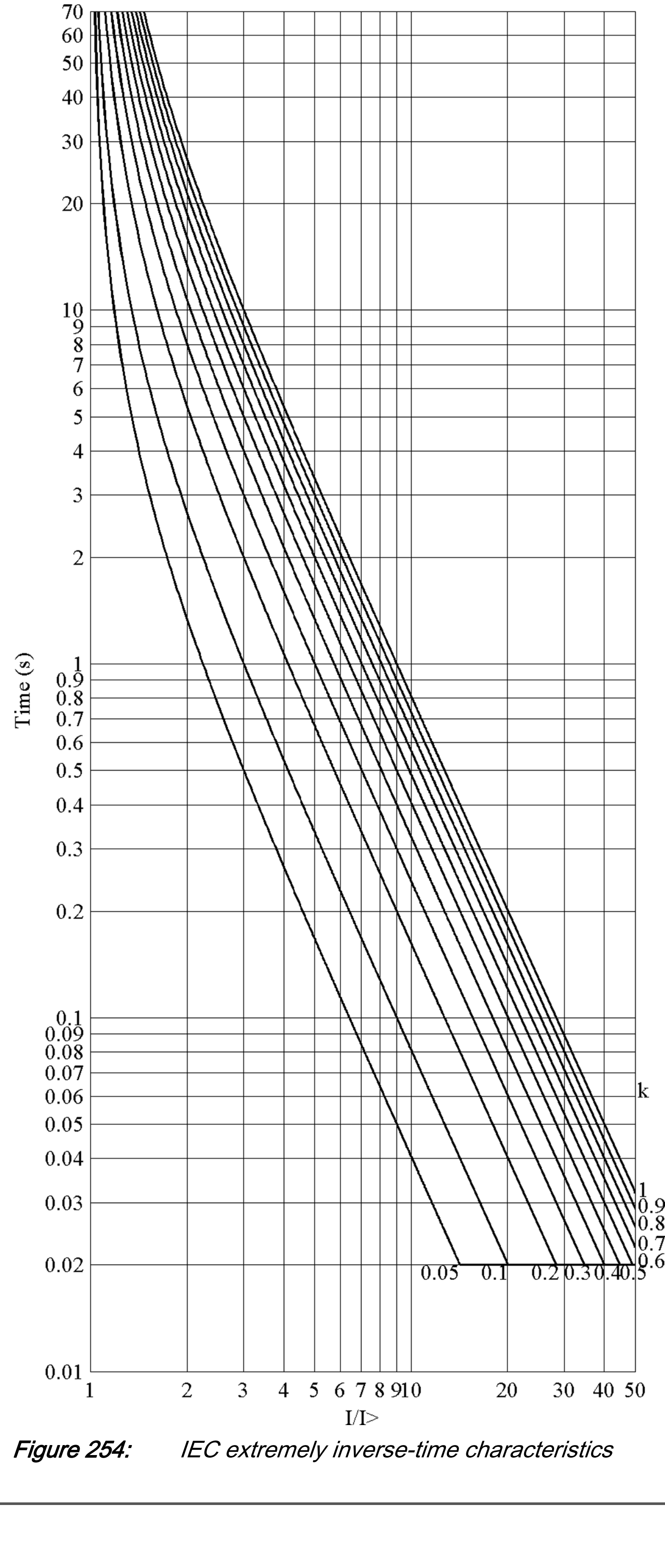


Figure 254: IEC extremely inverse-time characteristics

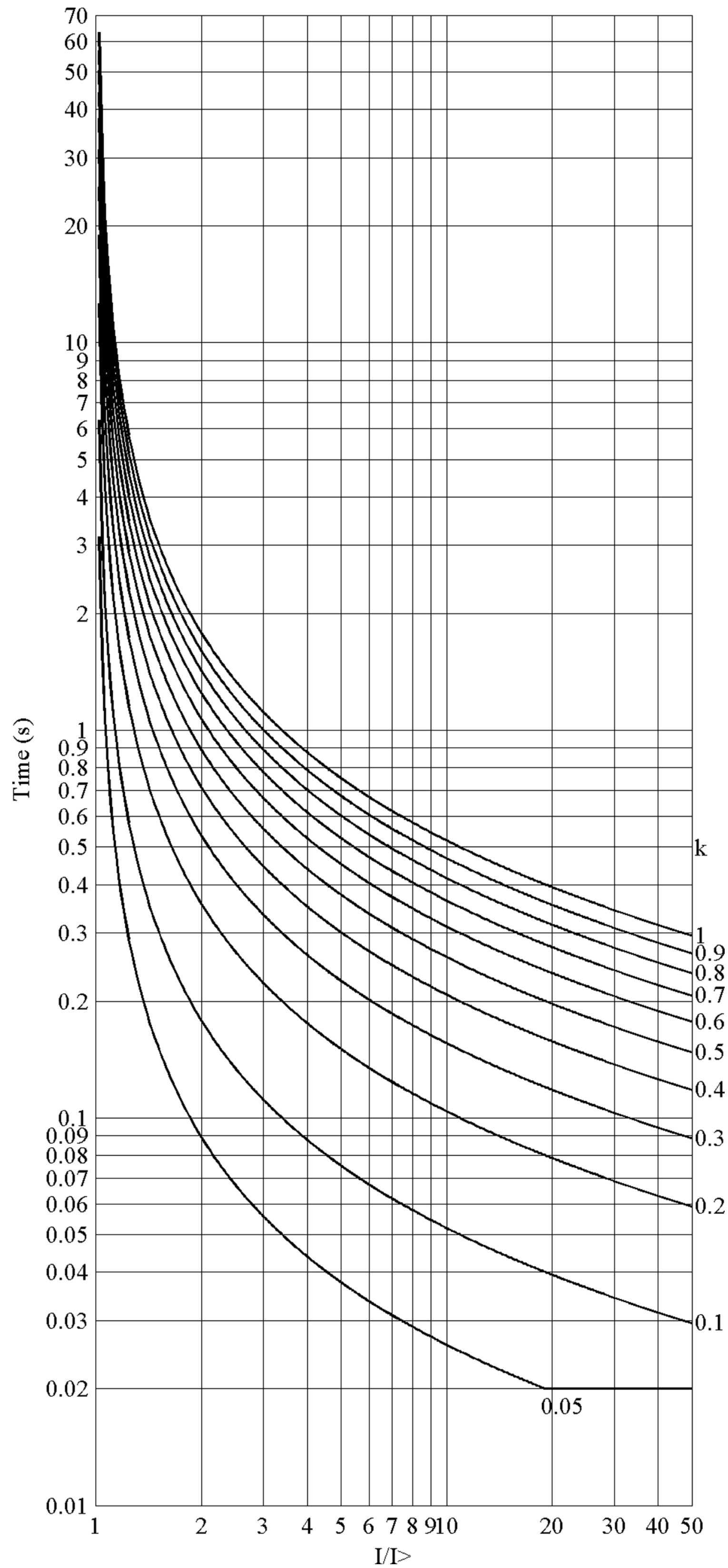


Figure 255: IEC short-time inverse-time characteristics

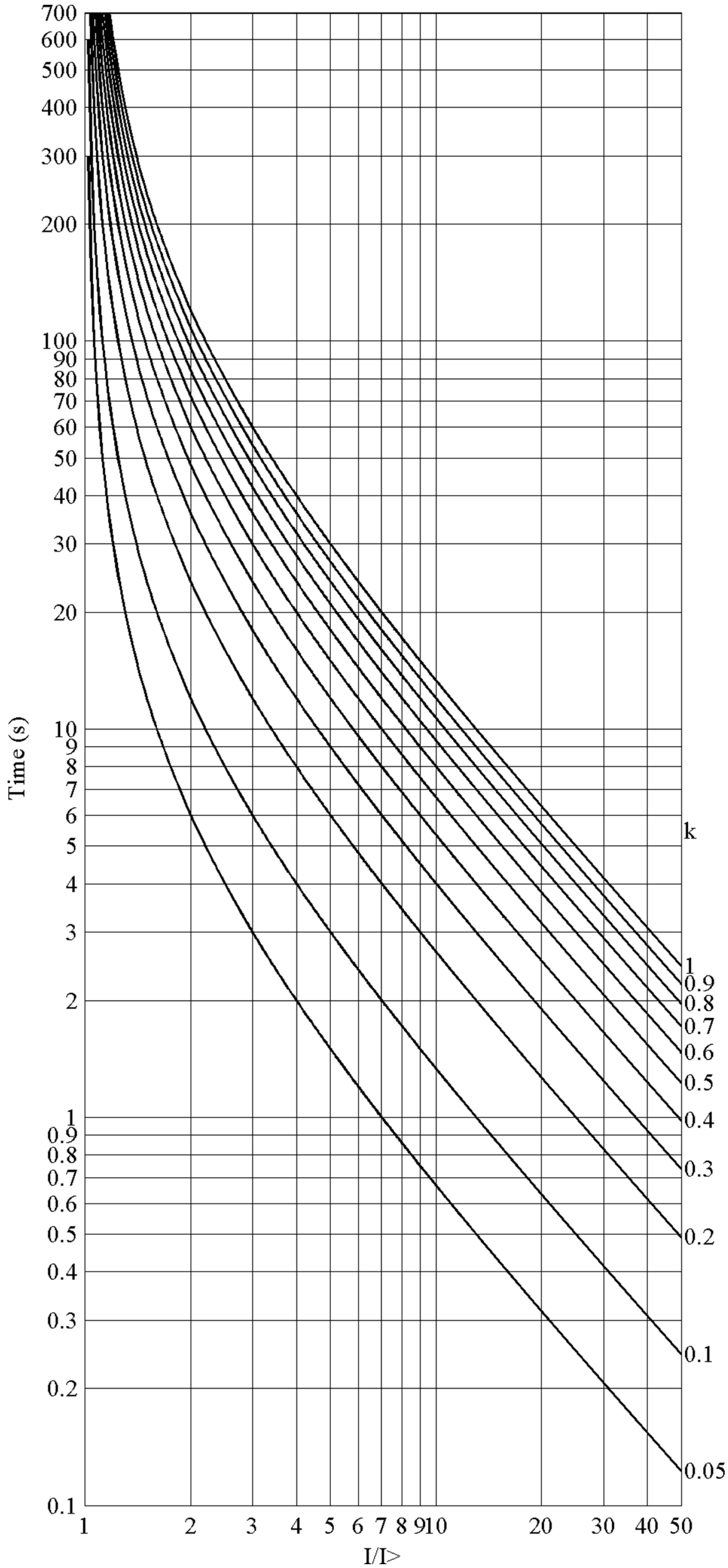


Figure 256: IEC long-time inverse-time characteristics

10.2.1.2 Recloser inverse-time characteristics

For inverse-time operation, standard recloser inverse-time characteristics are supported.

The trip times for the curves are defined with the coefficients A, B and C.

The values of the coefficients can be calculated according to the formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>}\right)^{C} - D} + B \right) \times k$$ (Equation 57)

t[s] Trip time in seconds
I measured current
I> set *Pickup value*
k set *Time multiplier*

Table 422: Curve parameters for recloser curves

Curve name	A	B	C	D
Recloser 1 (102)	Point to point data			
Recloser 2 (135)	11.4161	0.488986	1.84911	0.239257
Recloser 3 (140)	13.5457	0.992904	1.76391	0.379882
Recloser 4 (106)	Point to point data			
Recloser 5 (114)	Point to point data			
Recloser 6 (136)	Point to point data			
Recloser 7 (152)	Point to point data			
Recloser 8 (113)	1.68546	0.158114	1.78873	0.436523
Recloser 8+ (111)	1.42732	-0.003704	1.70112	0.366699
Recloser 8*	1.42302	-0.007846	1.42529	0.442626
Recloser 9 (131)	2.75978	5.10647	1.0353	0.614258
Recloser 11 (141)	21.6149	10.6768	2.69489	-0.67185
Recloser 13 (142)	Point to point data			
Recloser 14 (119)	Point to point data			
Recloser 15 (112)	Point to point data			
Recloser 16 (139)	Point to point data			
Recloser 17 (103)	Point to point data			
Recloser 18 (151)	Point to point data			
Recloser A (101)	Point to point data			
Recloser B (117)	4.22886	0.008933	1.7822	0.319885
Recloser C (133)	8.76047	0.029977	1.80788	0.380004
Recloser D (116)	5.23168	0.000462	2.17125	0.17205
Recloser E (132)	10.7656	0.004284	2.18261	0.249969
Recloser F (163)	Point to point data			
Recloser G (121)	Point to point data			

Curve name	A	B	C	D
Recloser H (122)	Point to point data			
Recloser J (164)	Point to point data			
Recloser K-Ground (165)	Point to point data			
Recloser K-Phase (162)	11.9847	-0.000324	2.01174	0.688477
Recloser L (107)	Point to point data			
Recloser M (118)	Point to point data			
Recloser N (104)	0.285625	-0.071079	0.911551	0.464202
Recloser P (115)	Point to point data			
Recloser P (115)	Point to point data			
Recloser R (105)	0.001015	-0.13381	0.00227	0.998848
Recloser T (161)	Point to point data			
Recloser V (137)	Point to point data			
Recloser W (138)	15.4628	0.056438	1.6209	0.345703
Recloser Y (120)	Point to point data			
Recloser Z (134)	Point to point data			

Note: Trip time is accurate when the time multiplier range is 0.1 - 4.0 for all reclose curves.

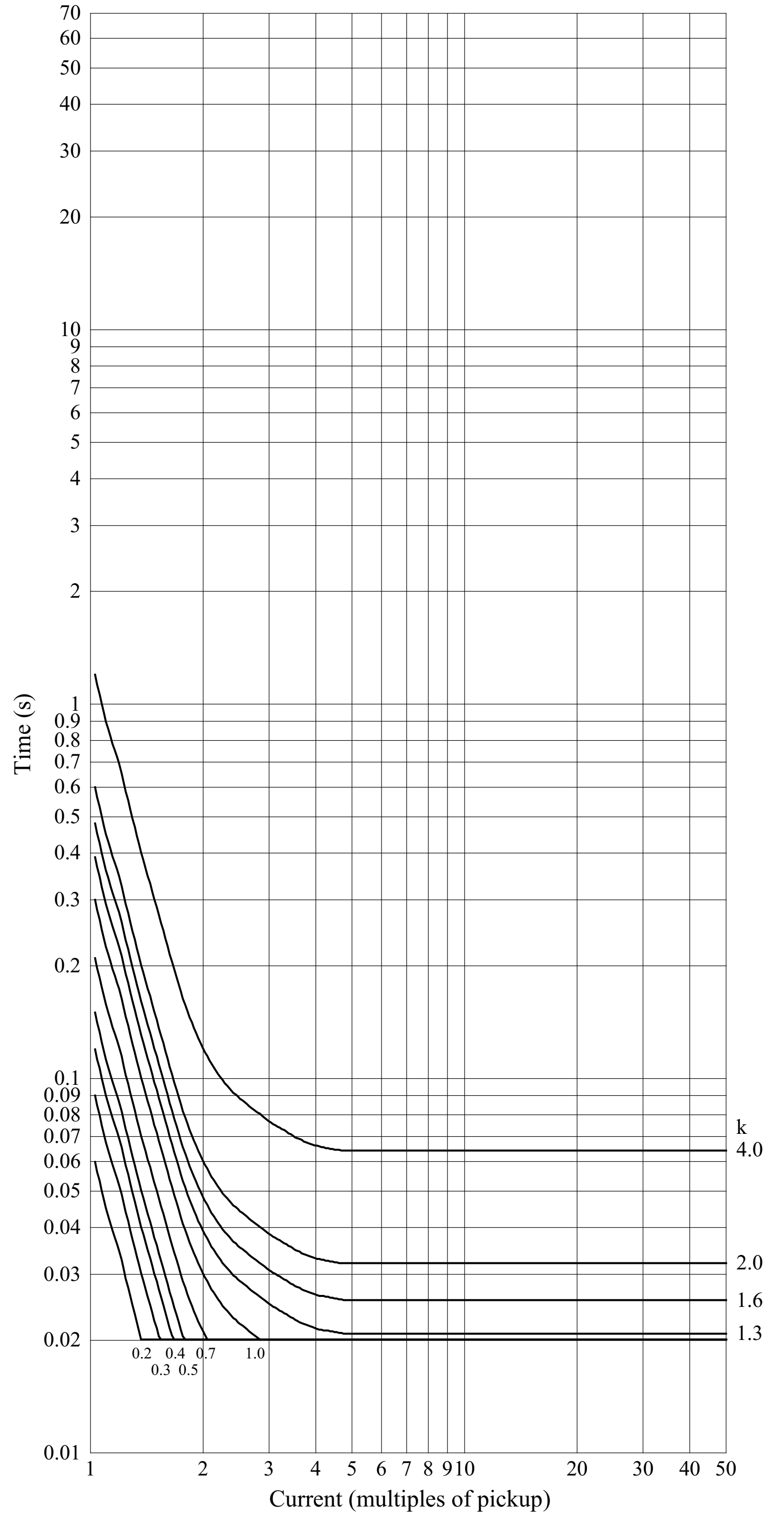


Figure 257: Recloser curve 1 (102)

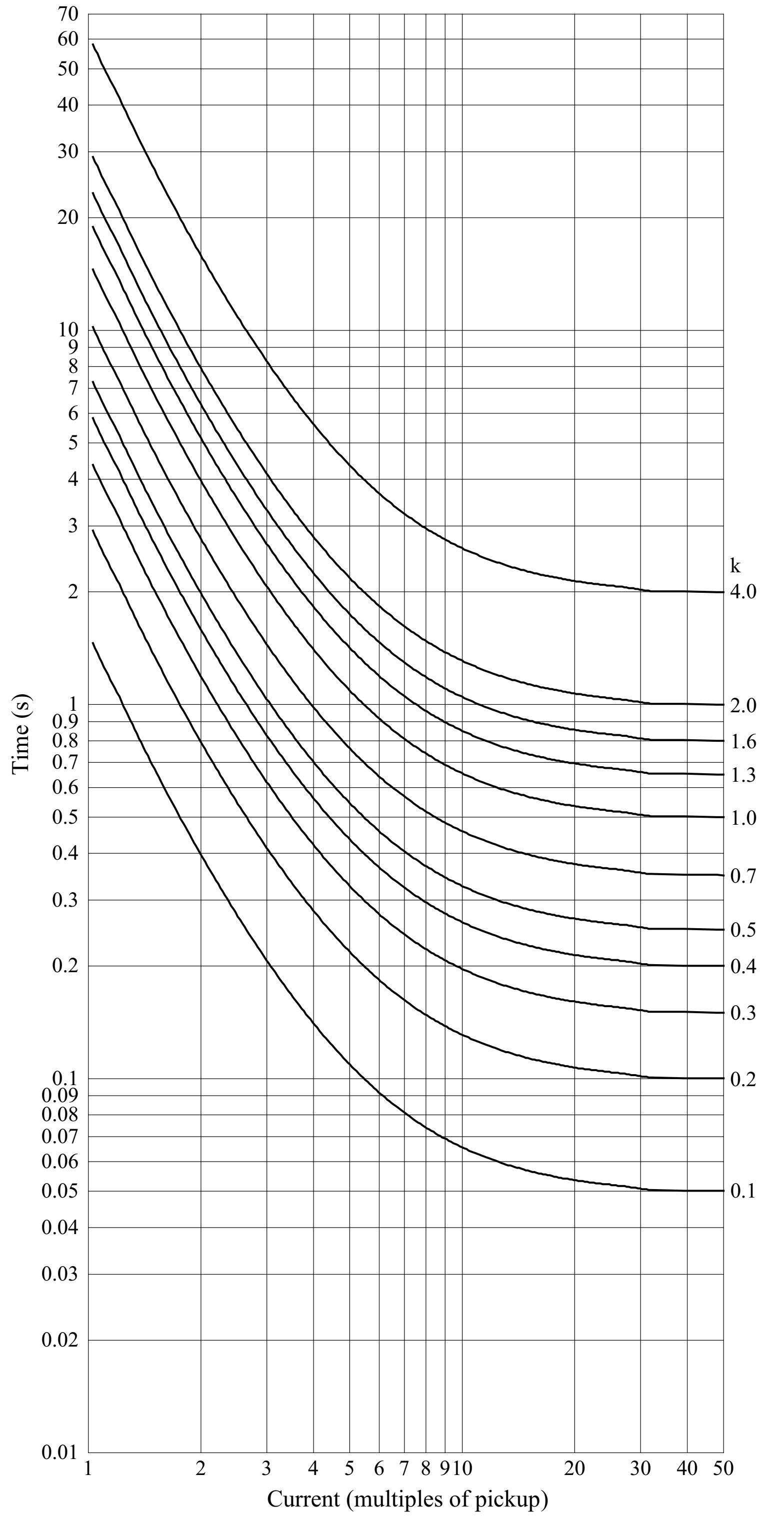


Figure 258: Recloser curve 2 (135)

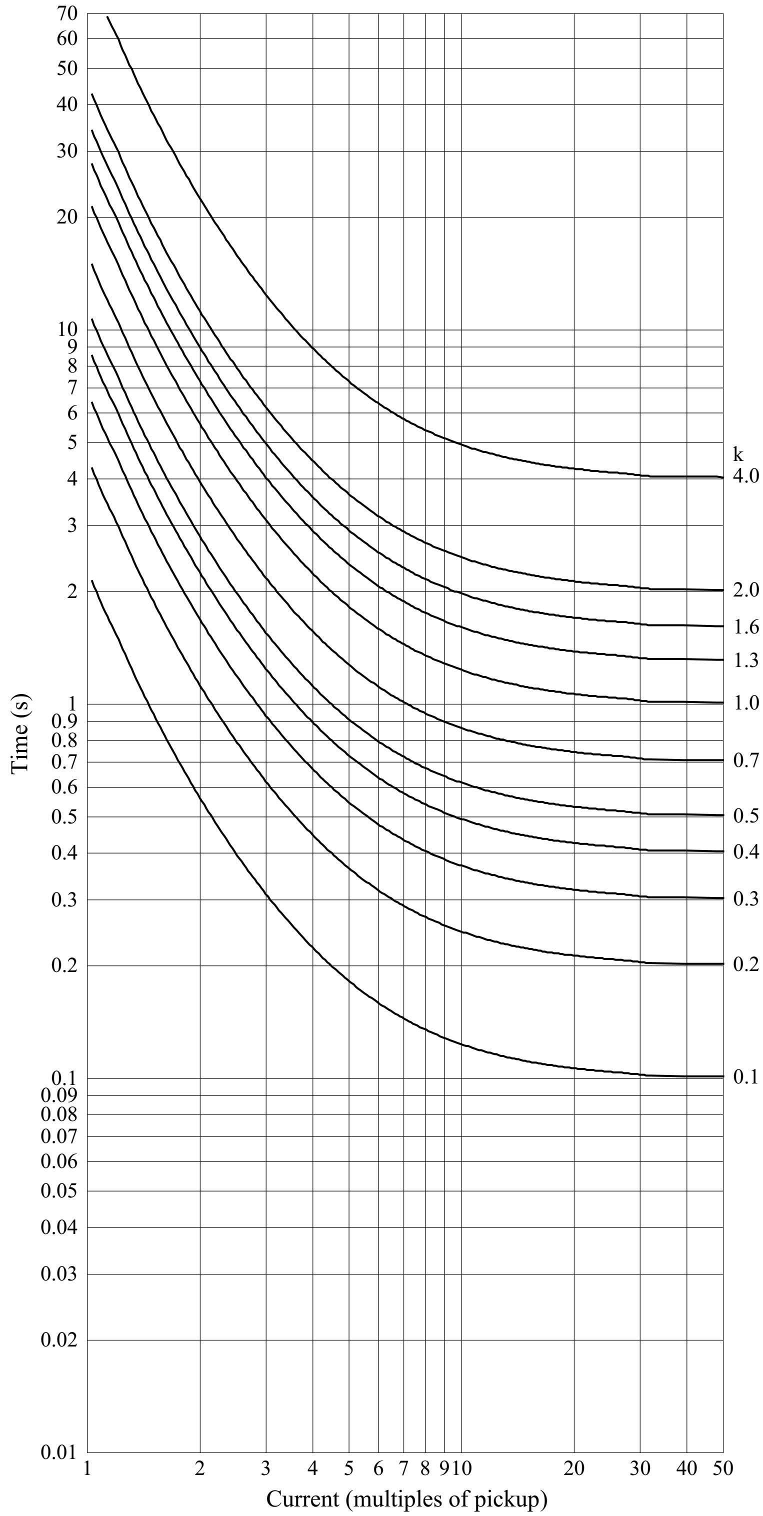


Figure 259: *Recloser curve 3 (140)*

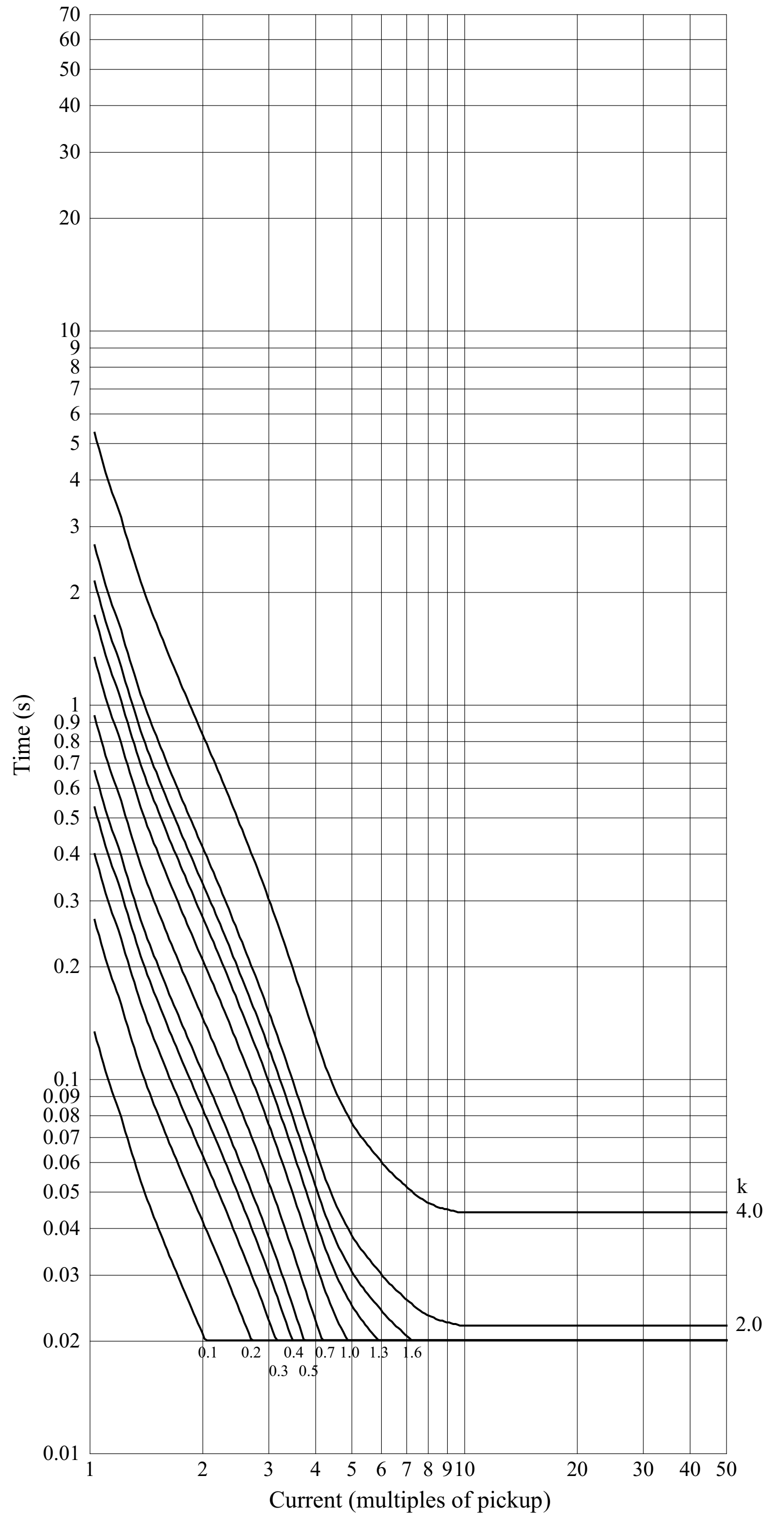


Figure 260: Recloser curve 4 (106)

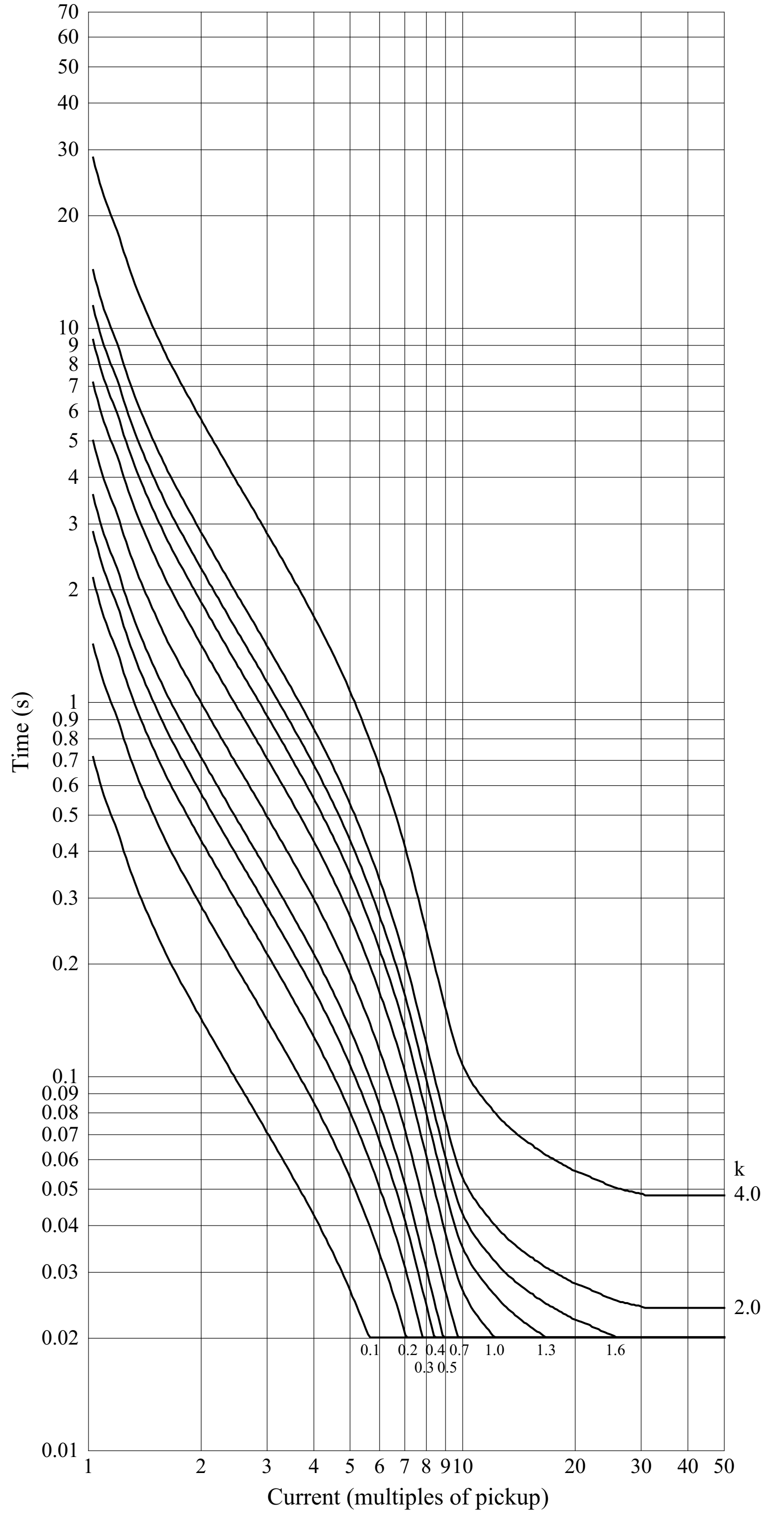


Figure 261: Recloser curve 5 (114)

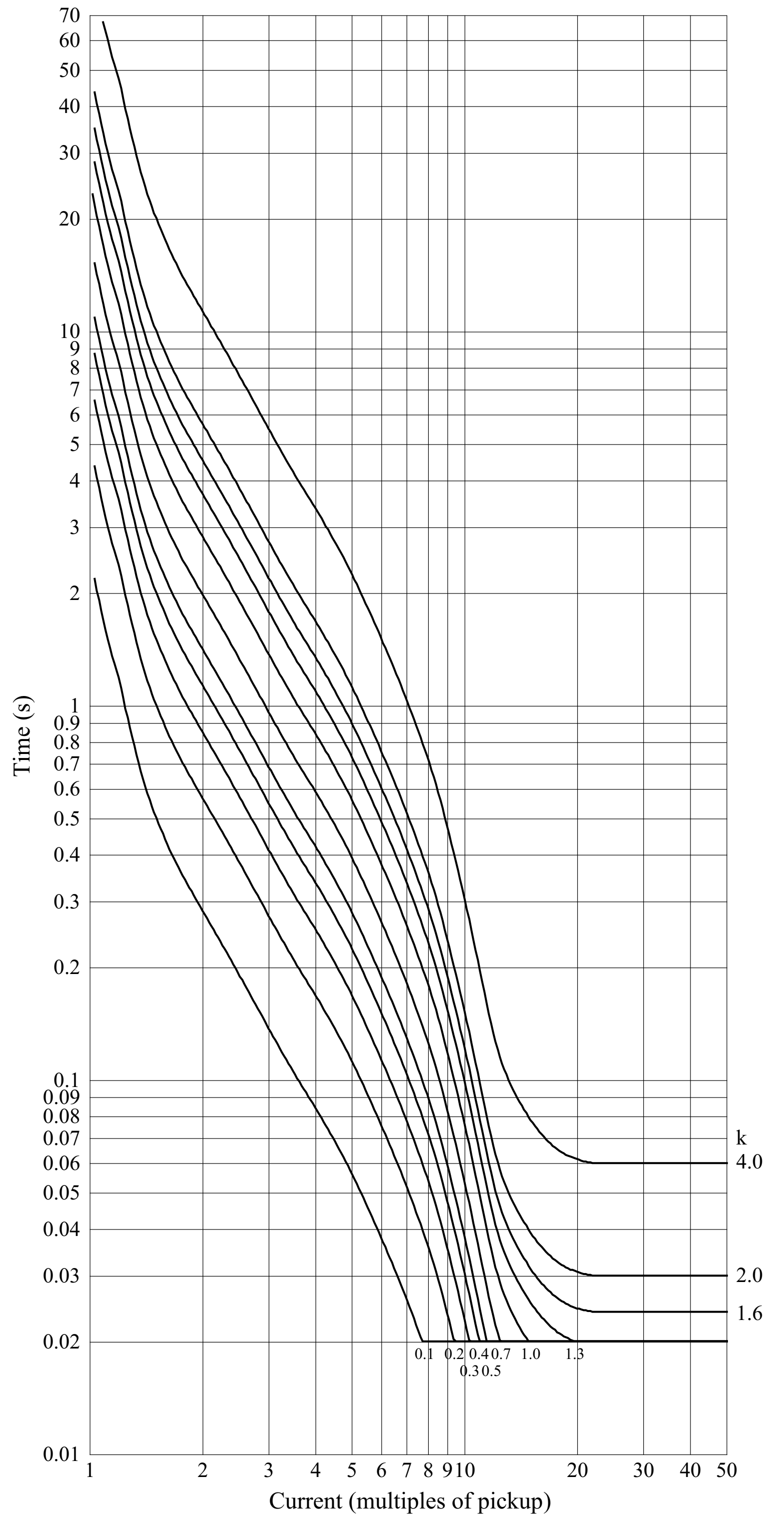


Figure 262: Recloser curve 6 (136)

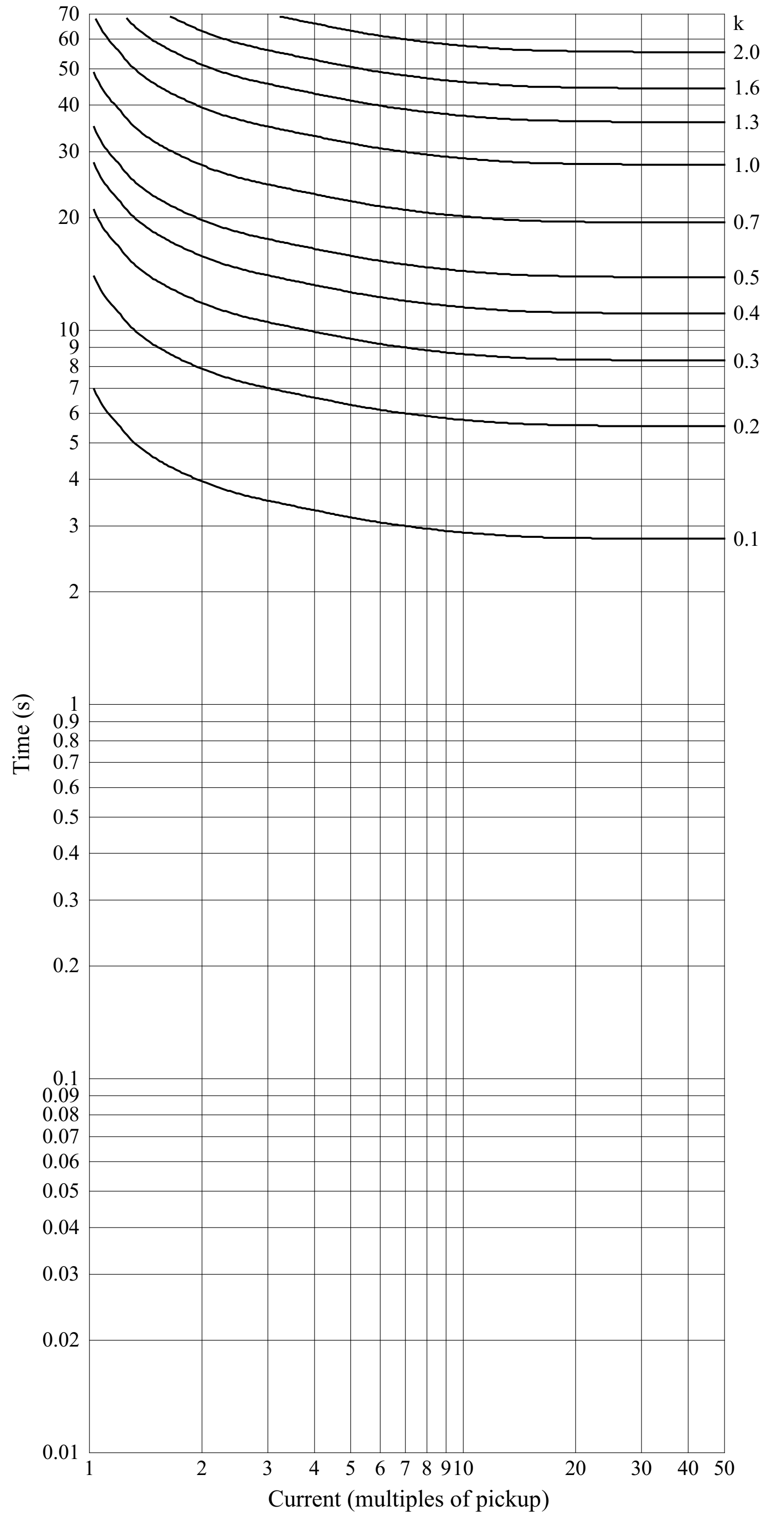


Figure 263: Recloser curve 7 (152)

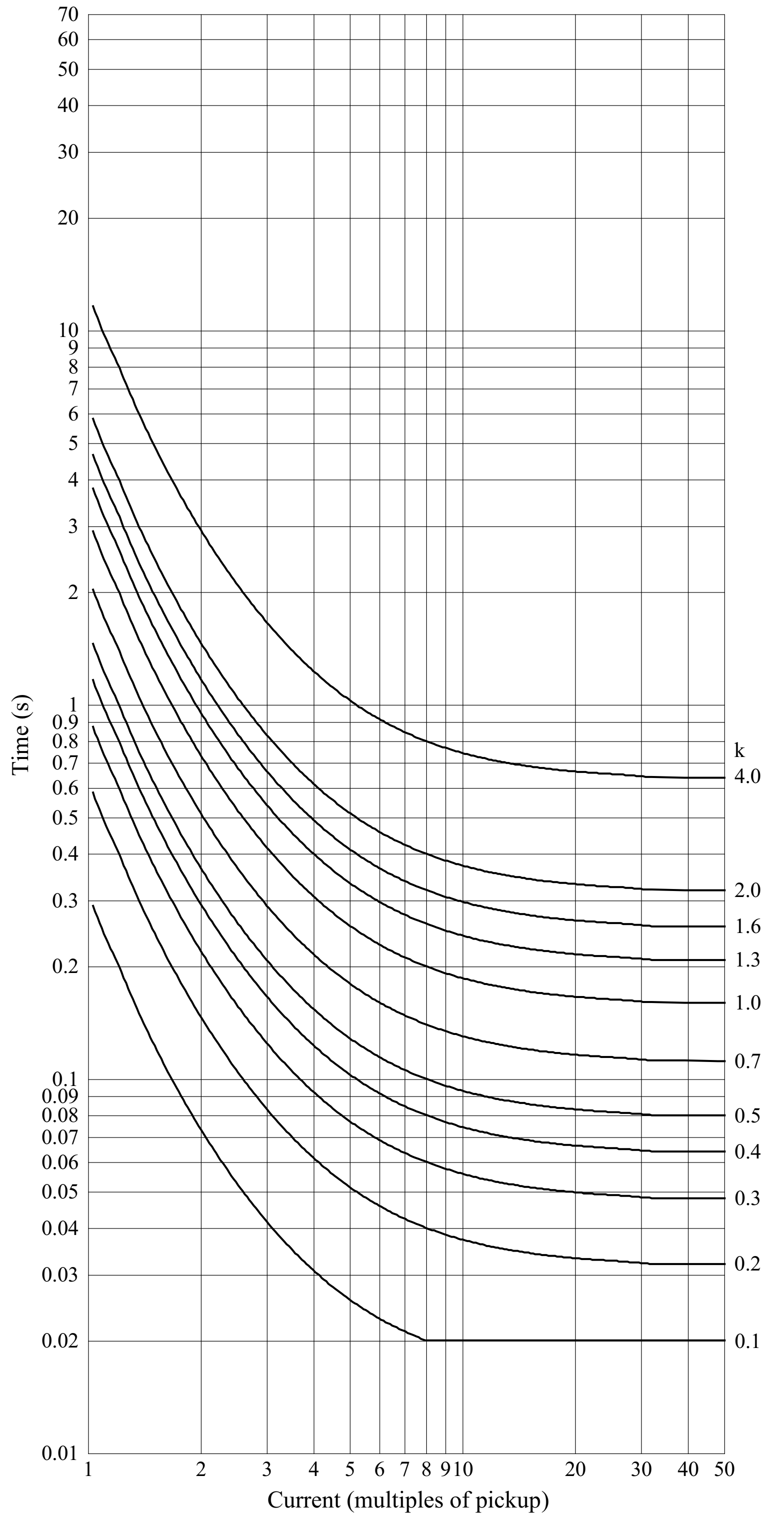


Figure 264: Recloser curve 8 (113)

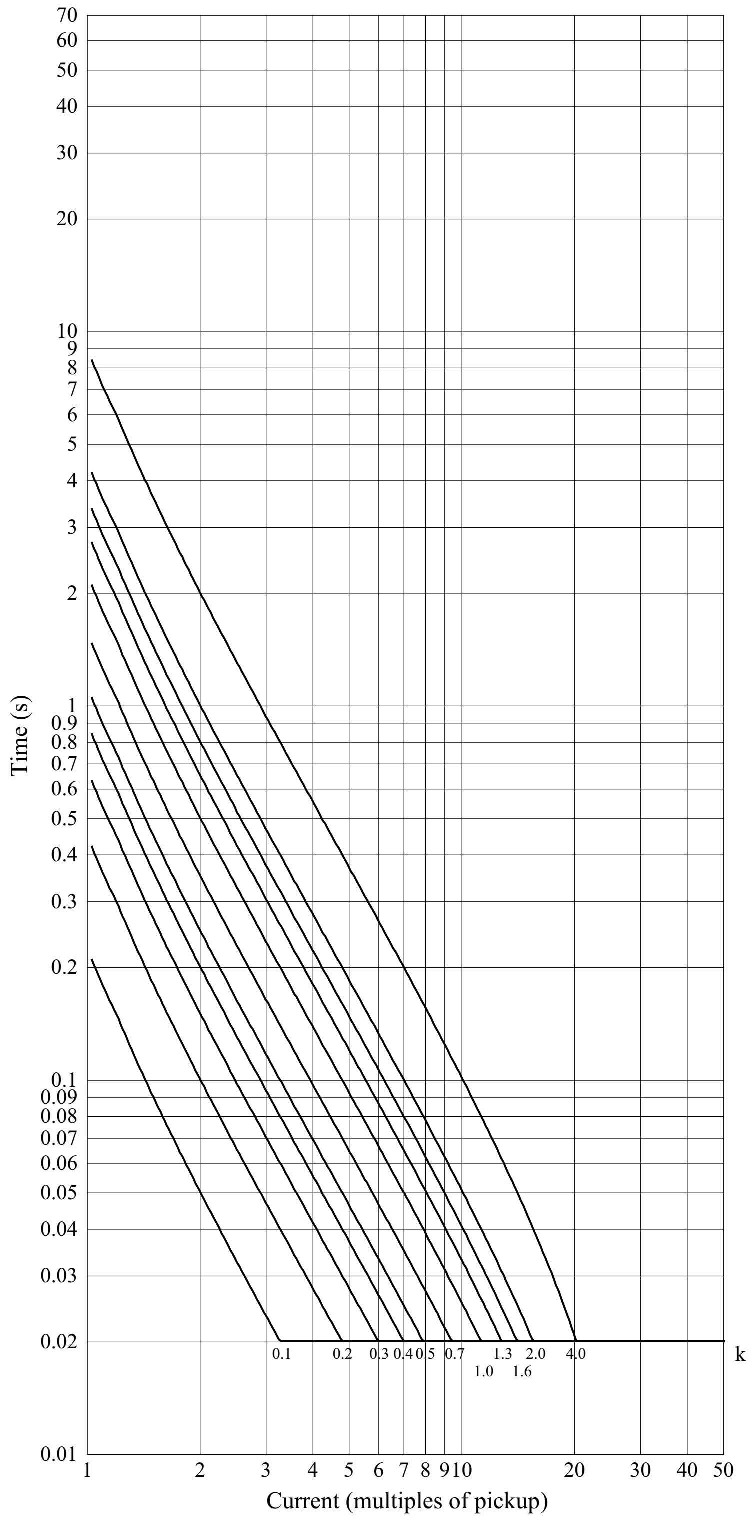


Figure 265: Recloser curve 8+ (111)

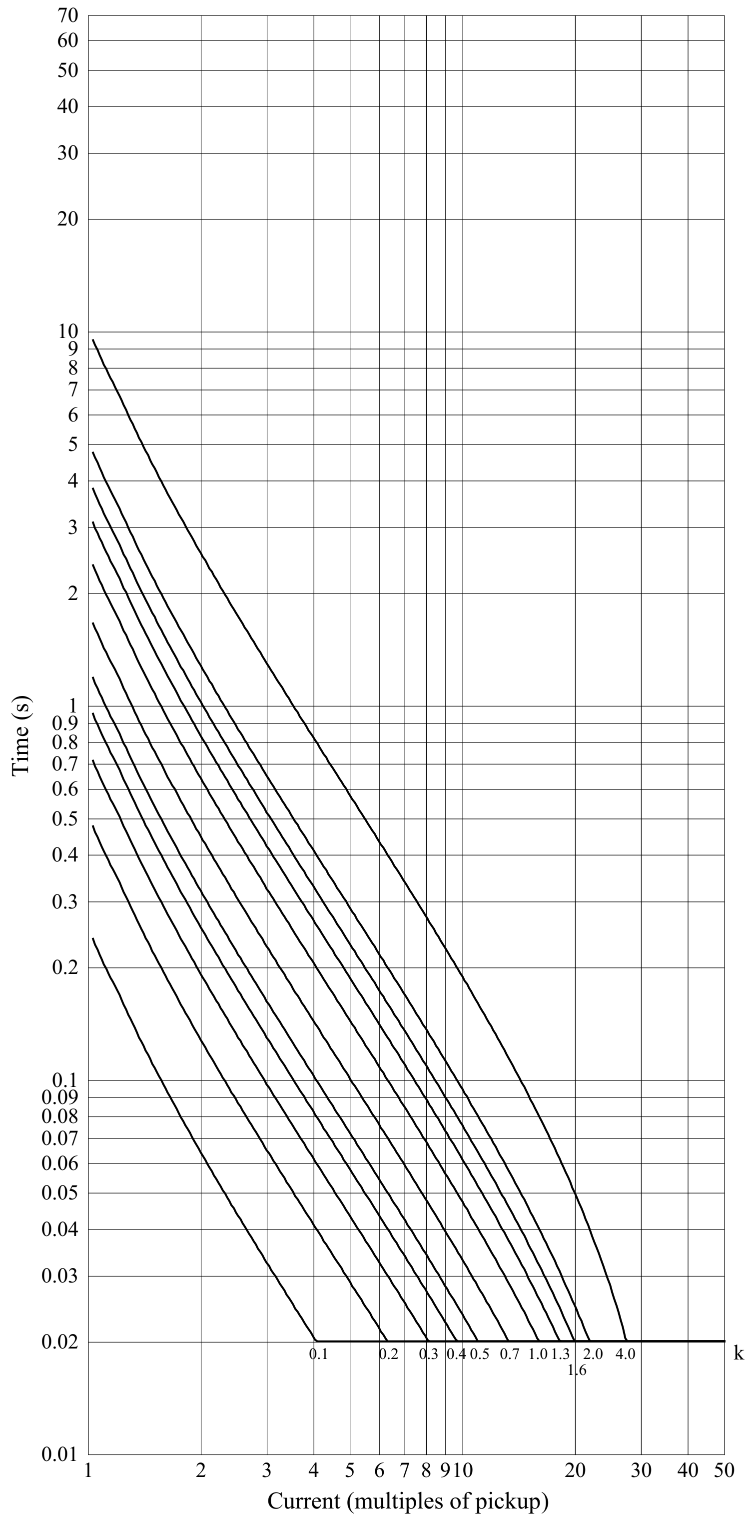


*Figure 266: Recloser curve 8**

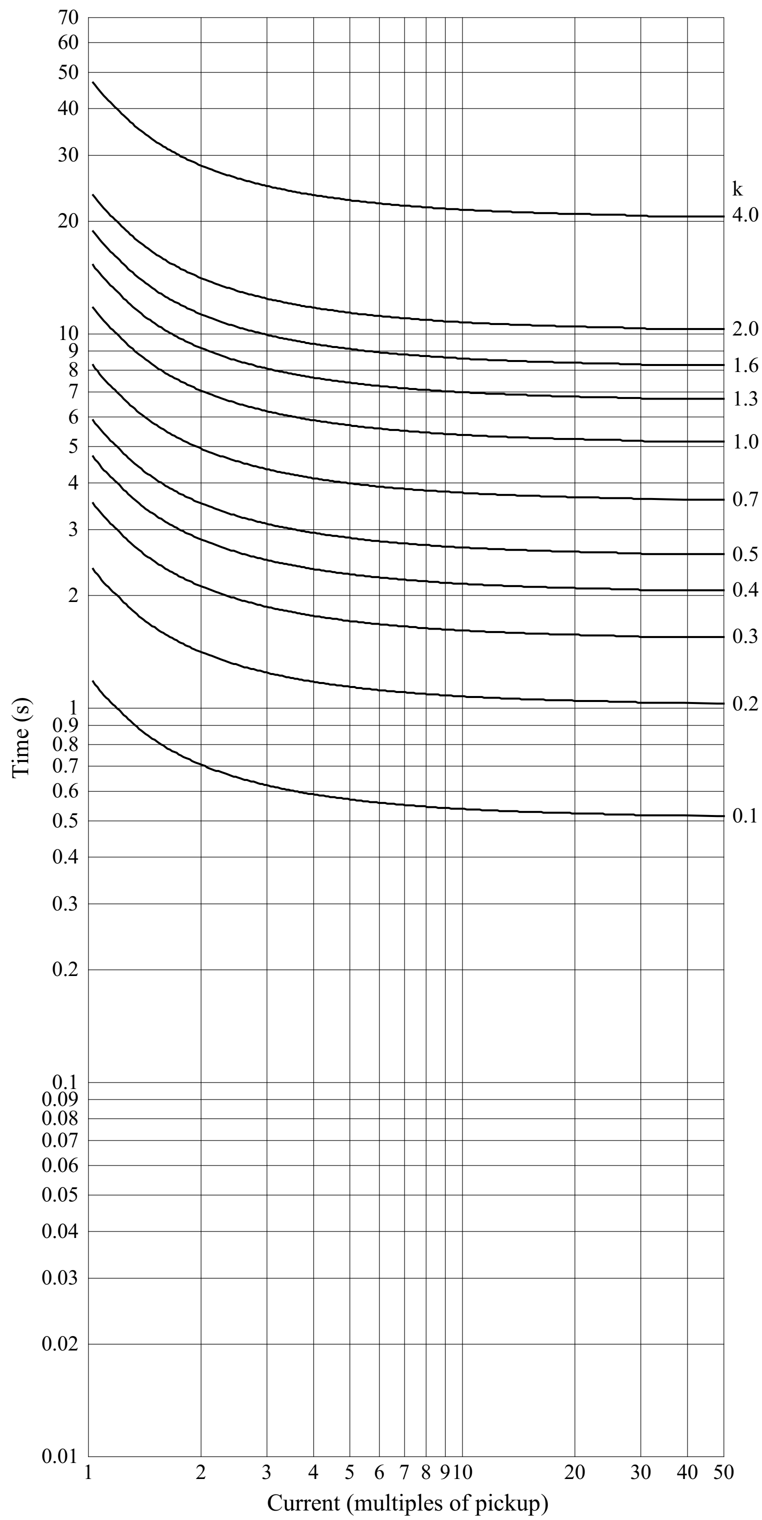


Figure 267: Recloser curve 9 (131)

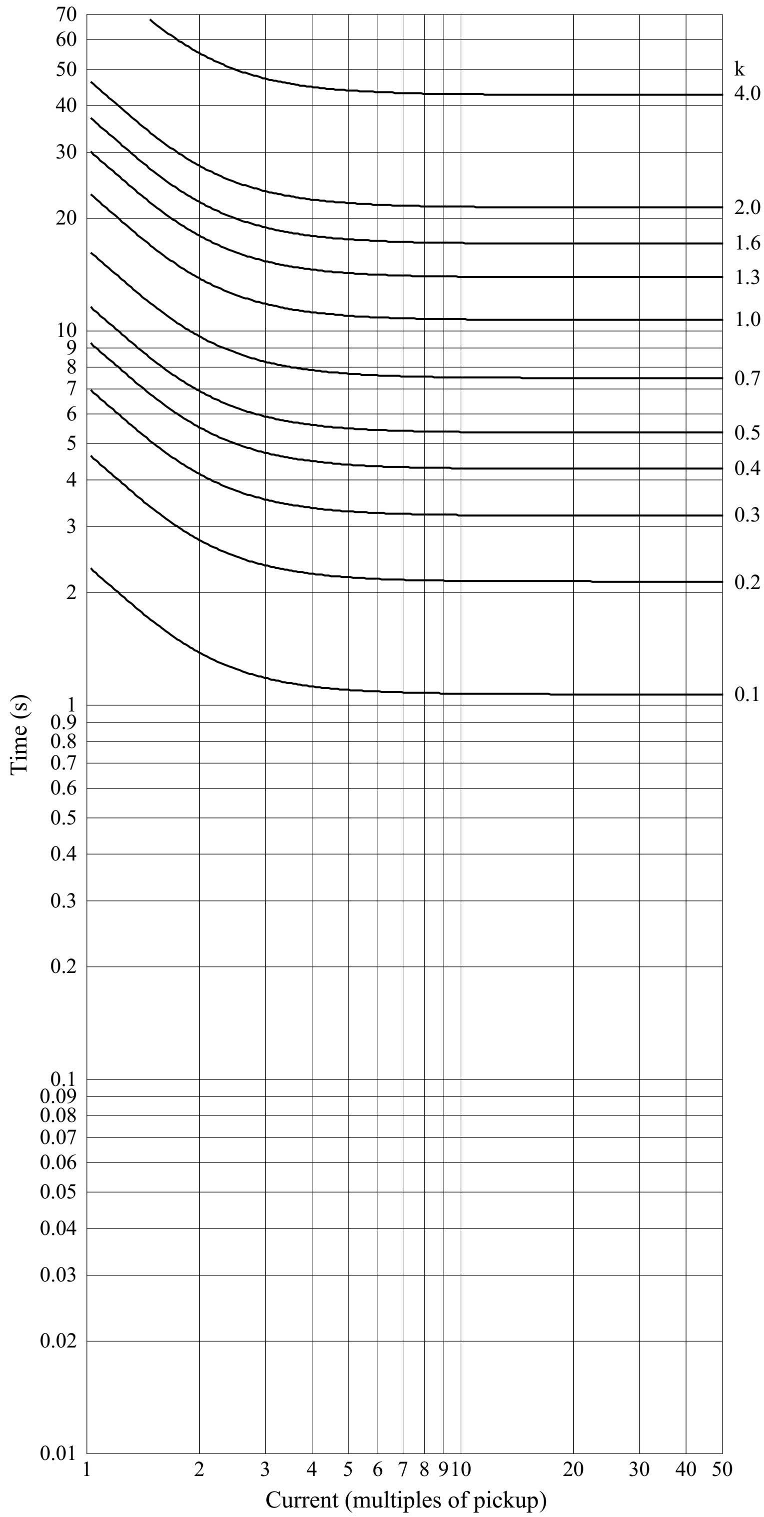


Figure 268: Recloser curve 11 (141)

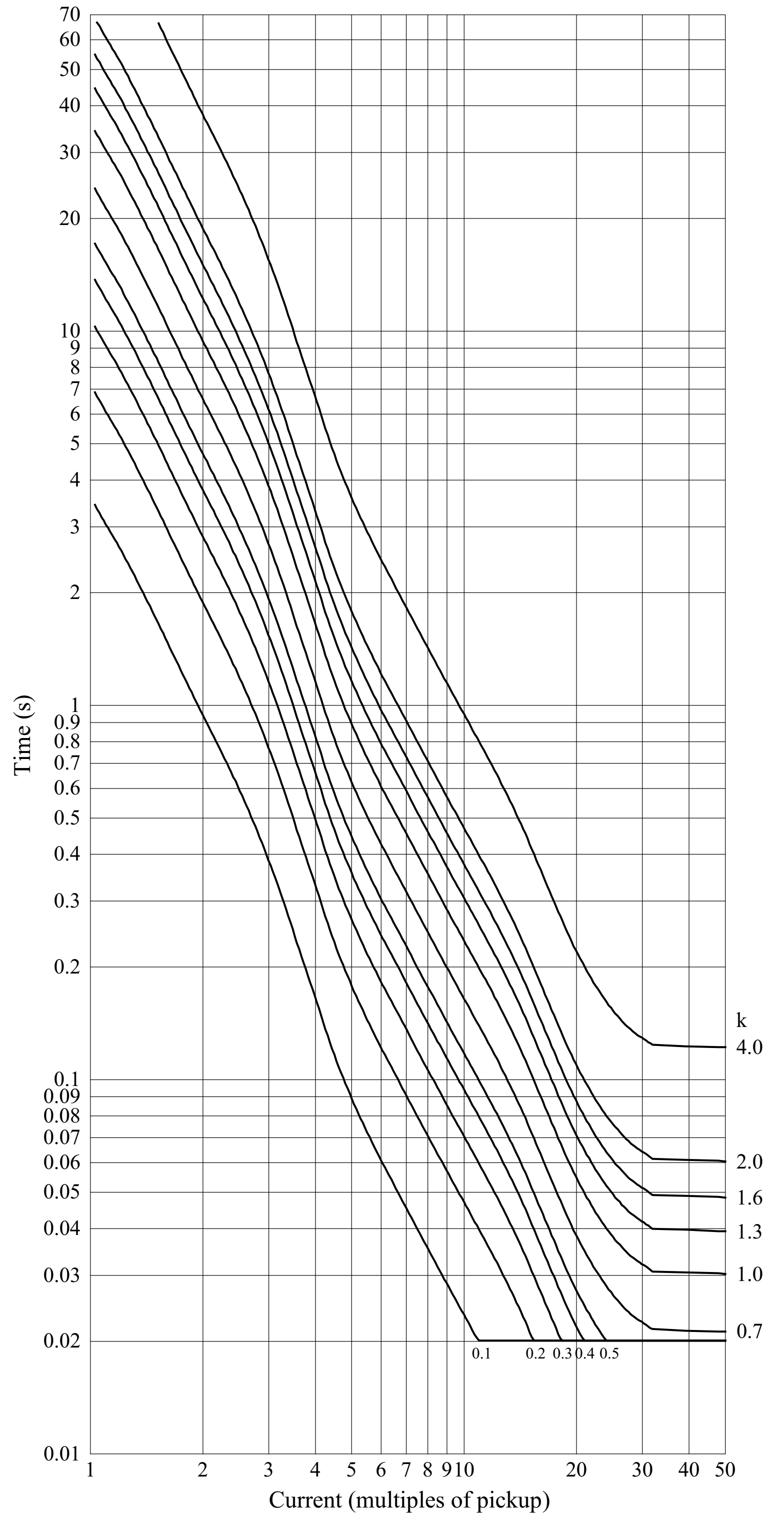


Figure 269: Recloser curve 13 (142)

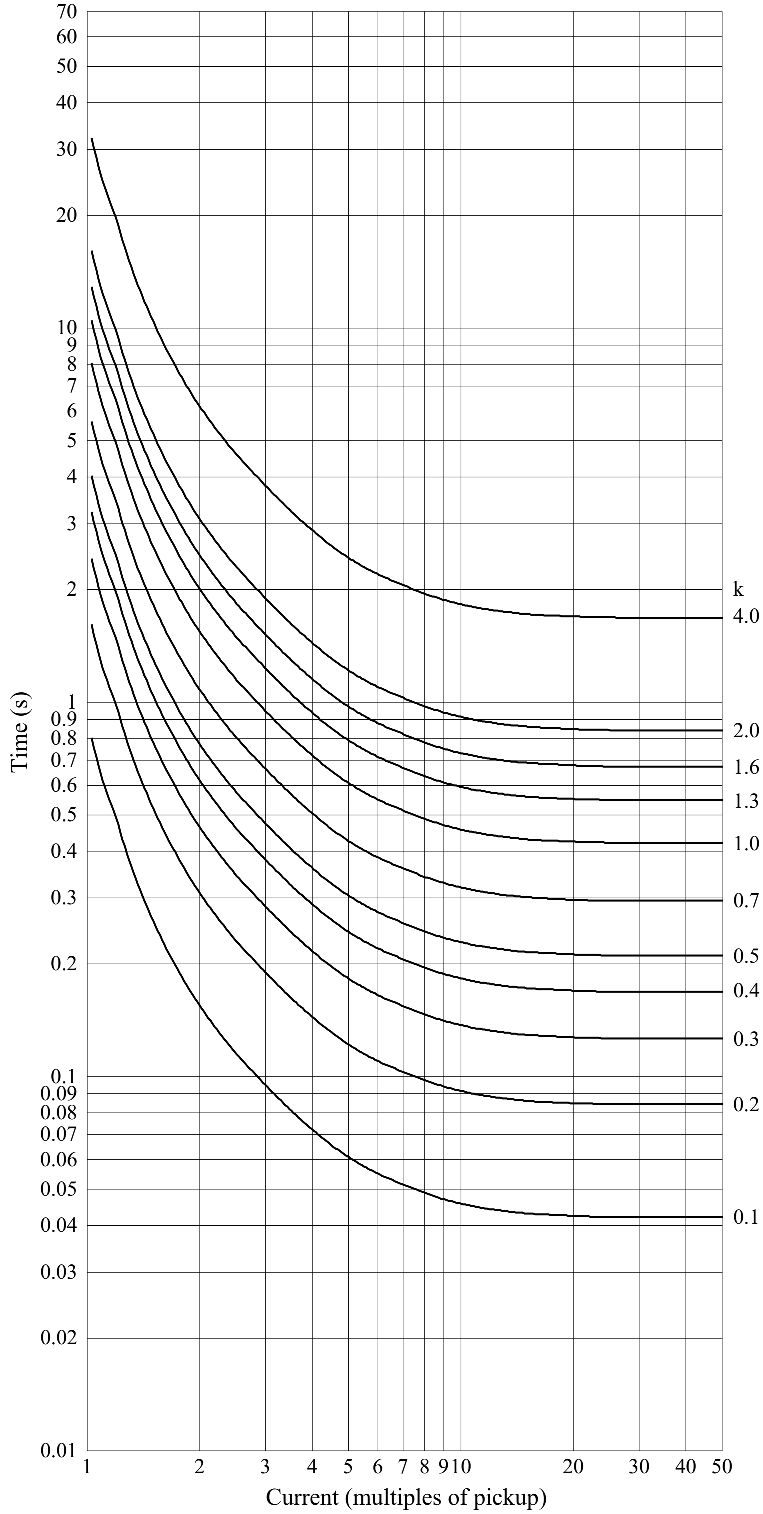


Figure 270: Recloser curve 14 (119)

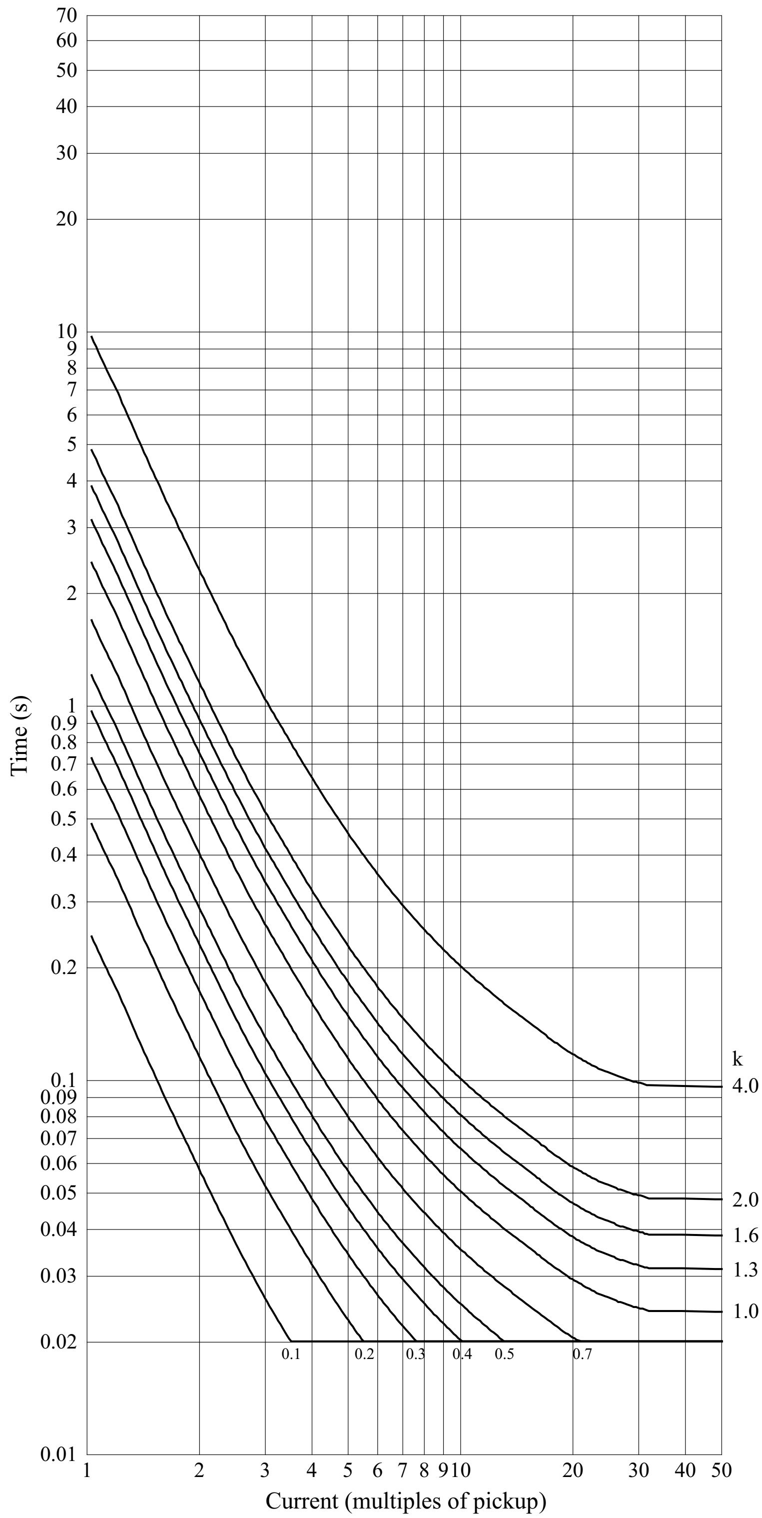


Figure 271: Recloser curve 15 (112)

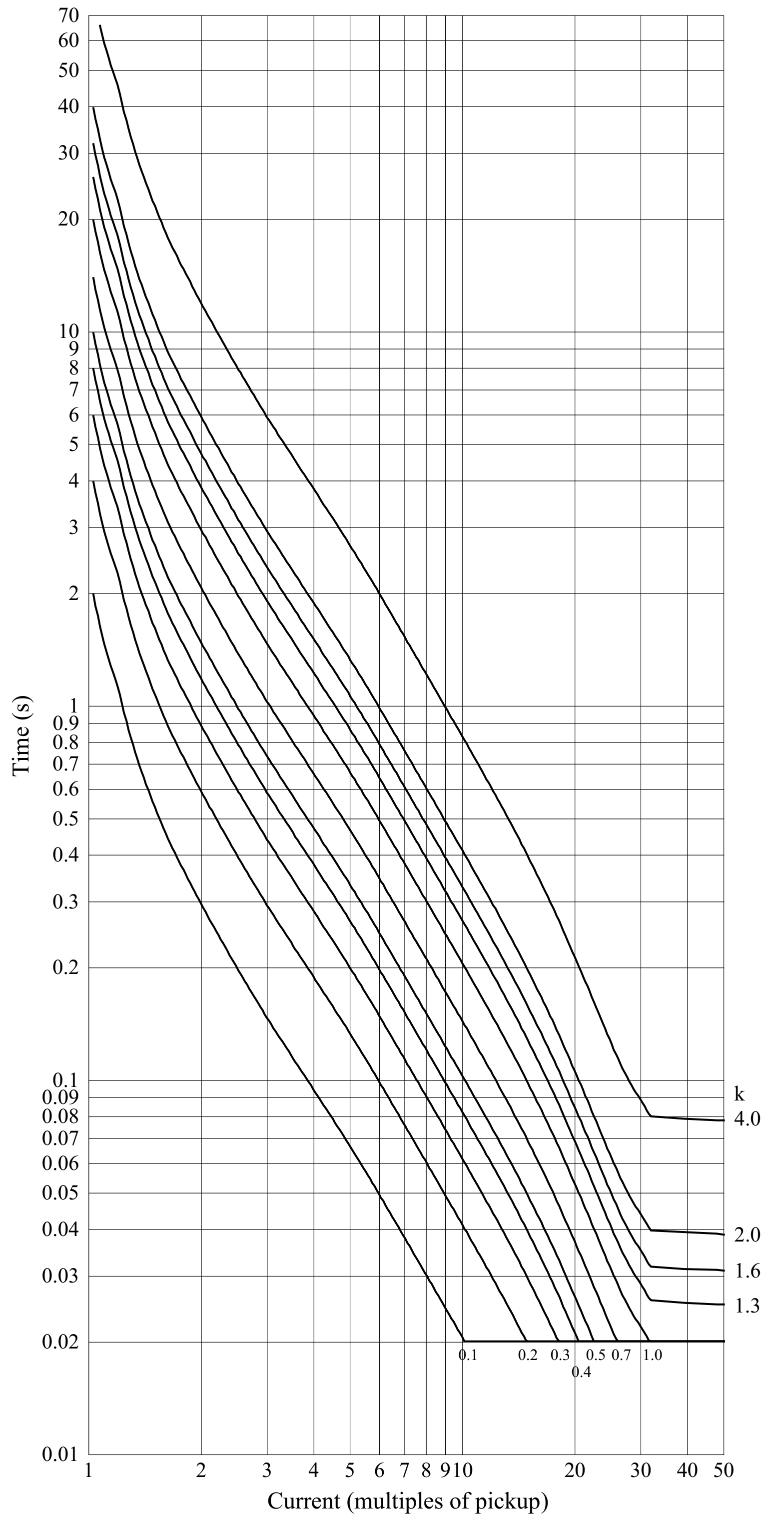


Figure 272: Recloser curve 16 (139)

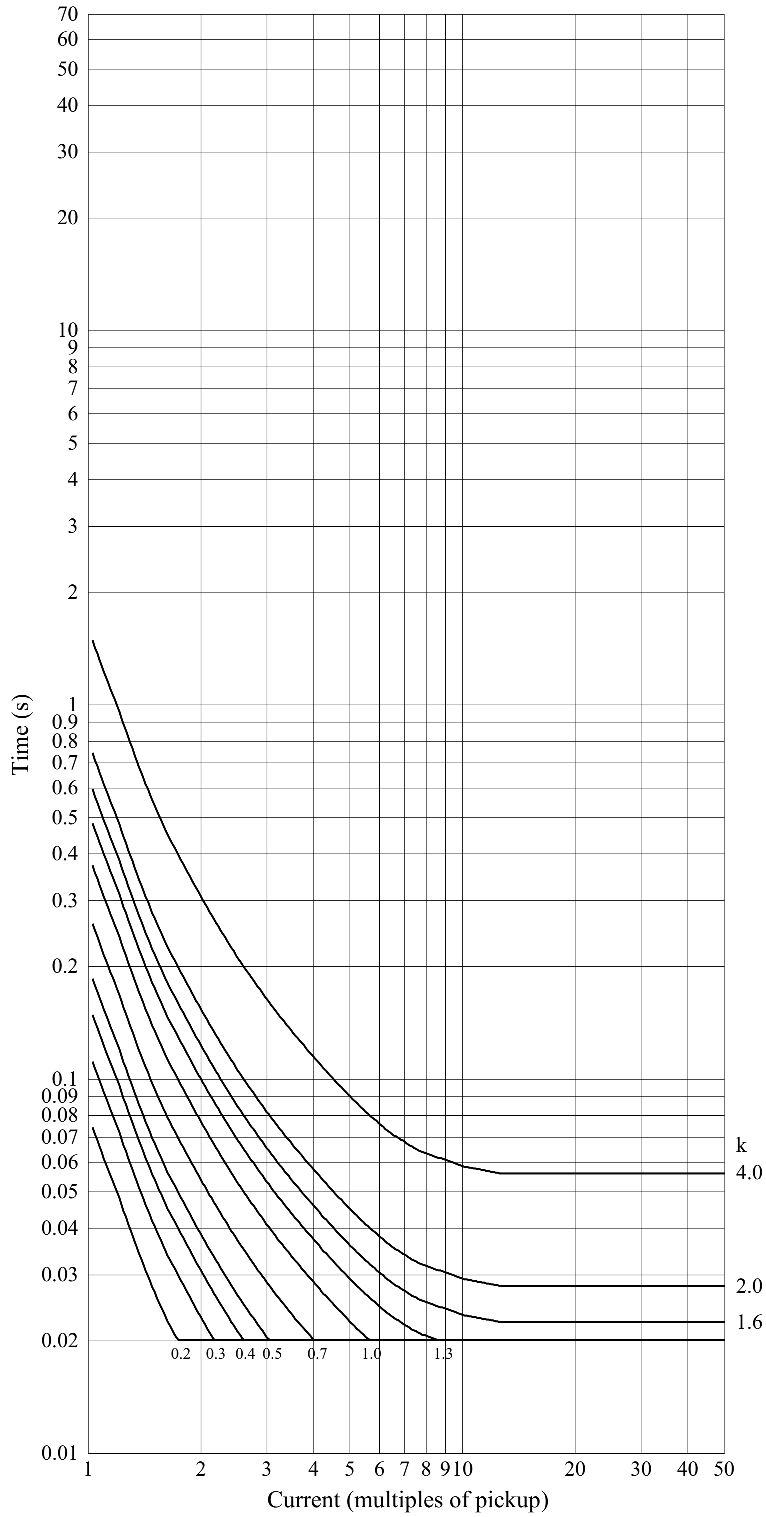


Figure 273: Recloser curve 17 (103)

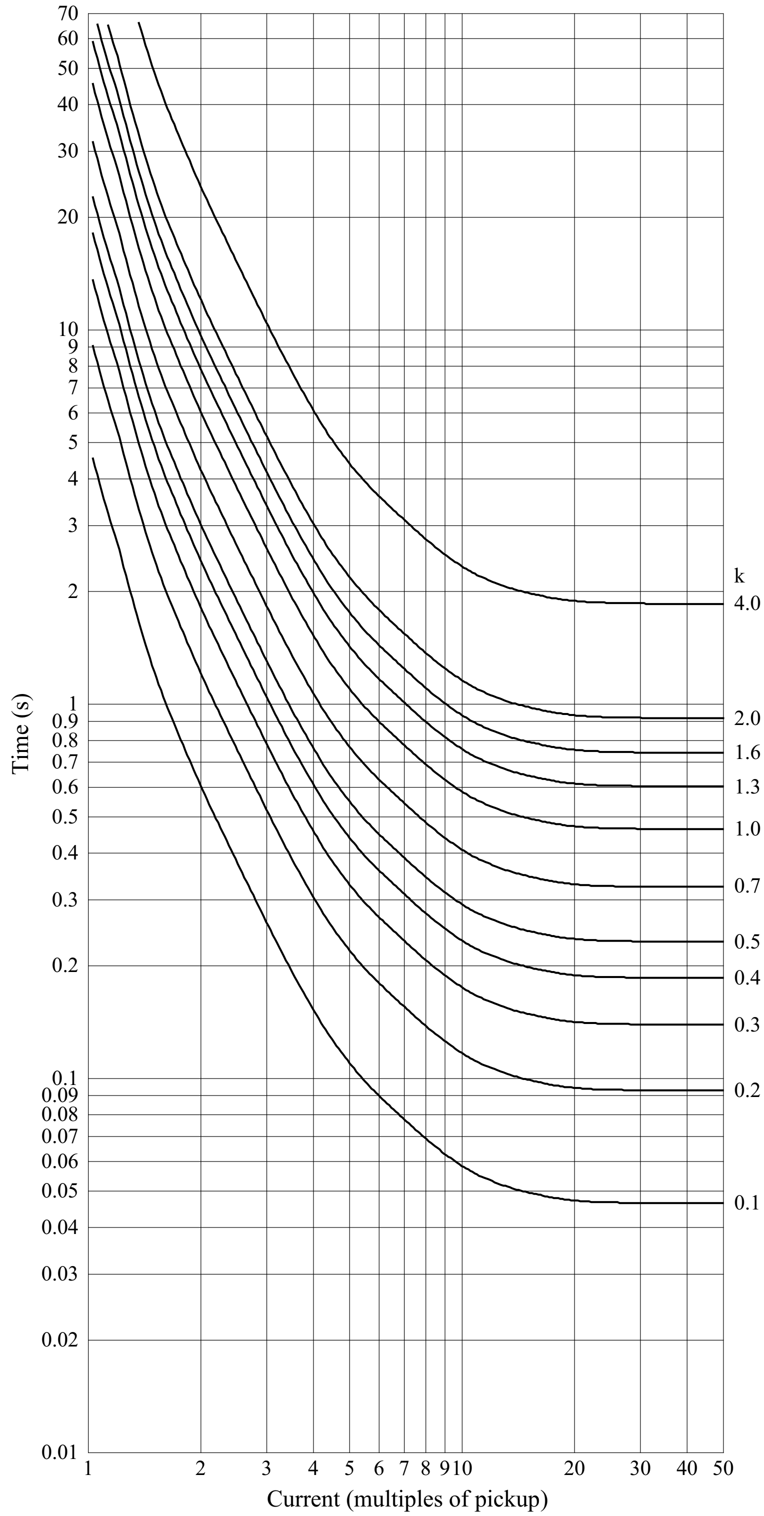


Figure 274: Recloser curve 18 (151)

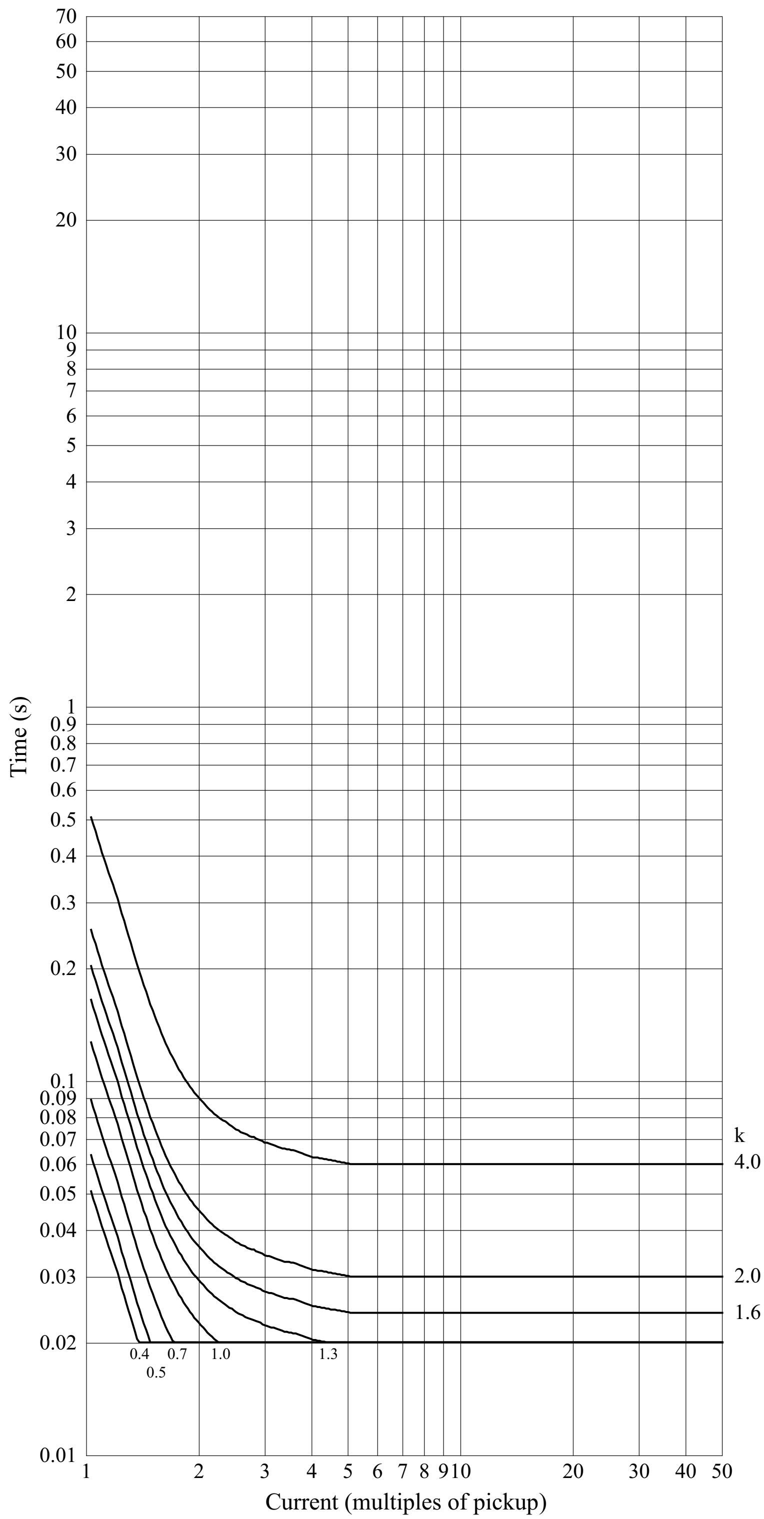


Figure 275: Recloser curve A (101)

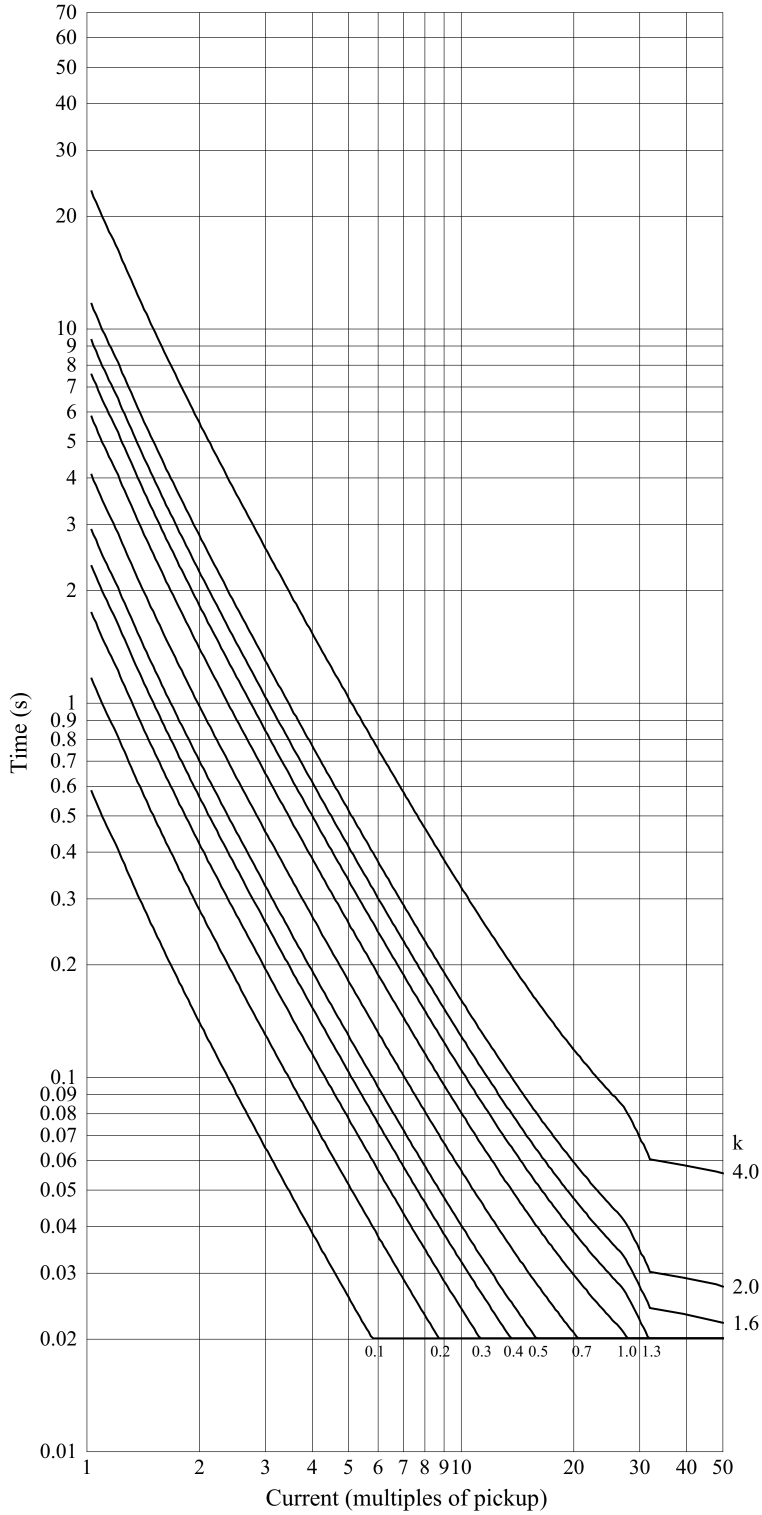


Figure 276: Recloser curve B (117)

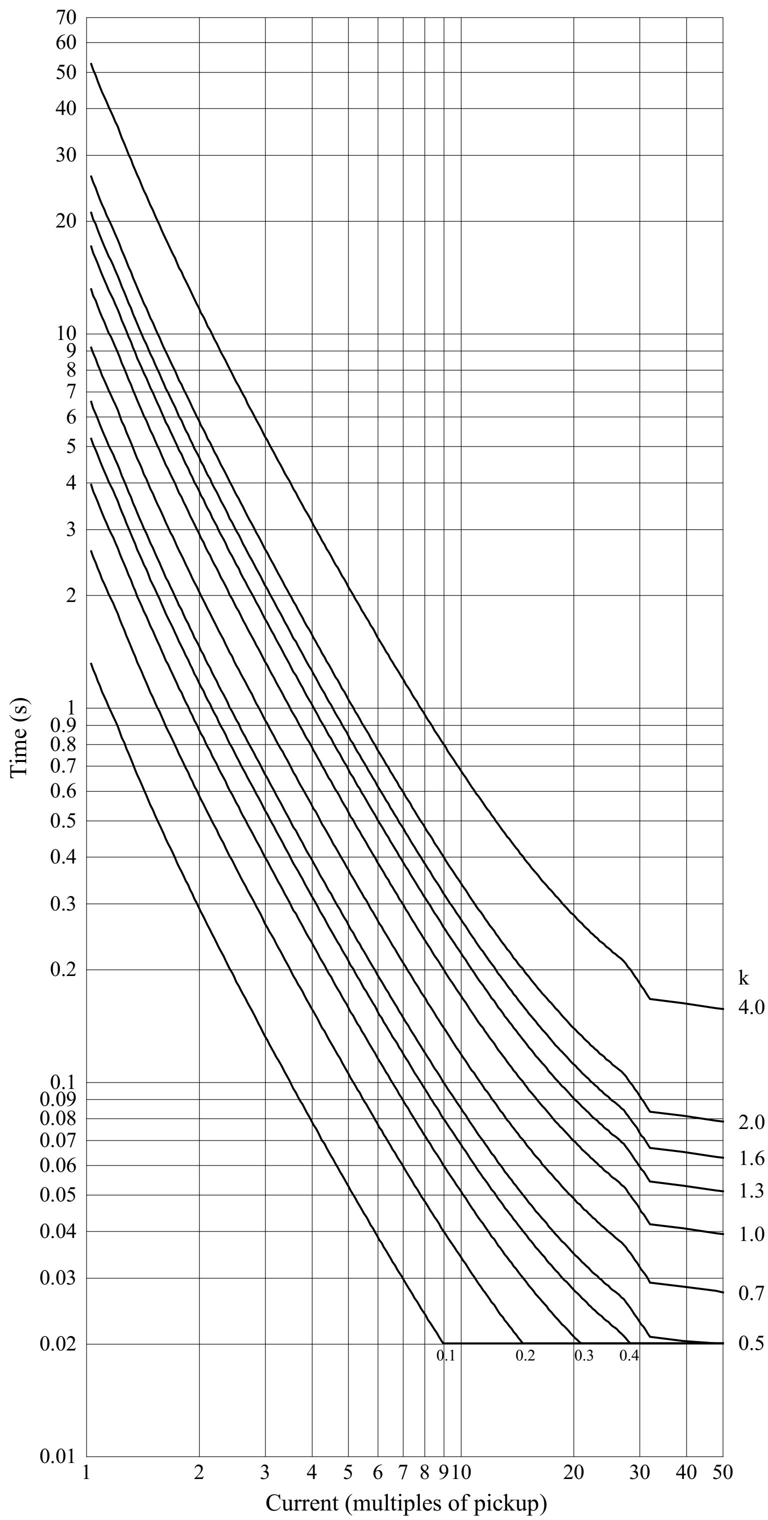


Figure 277: Recloser curve C (133)

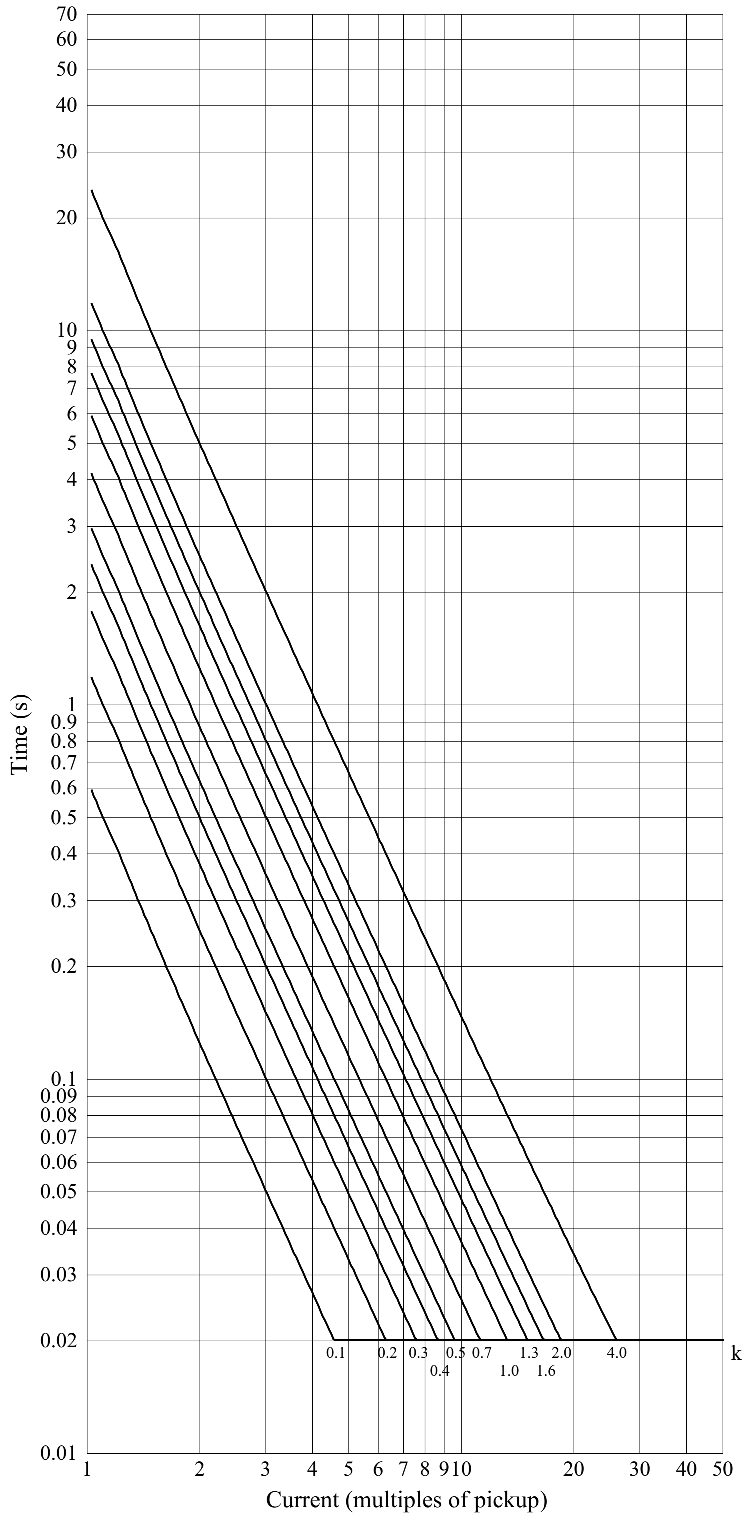


Figure 278: *Recloser curve D (116)*

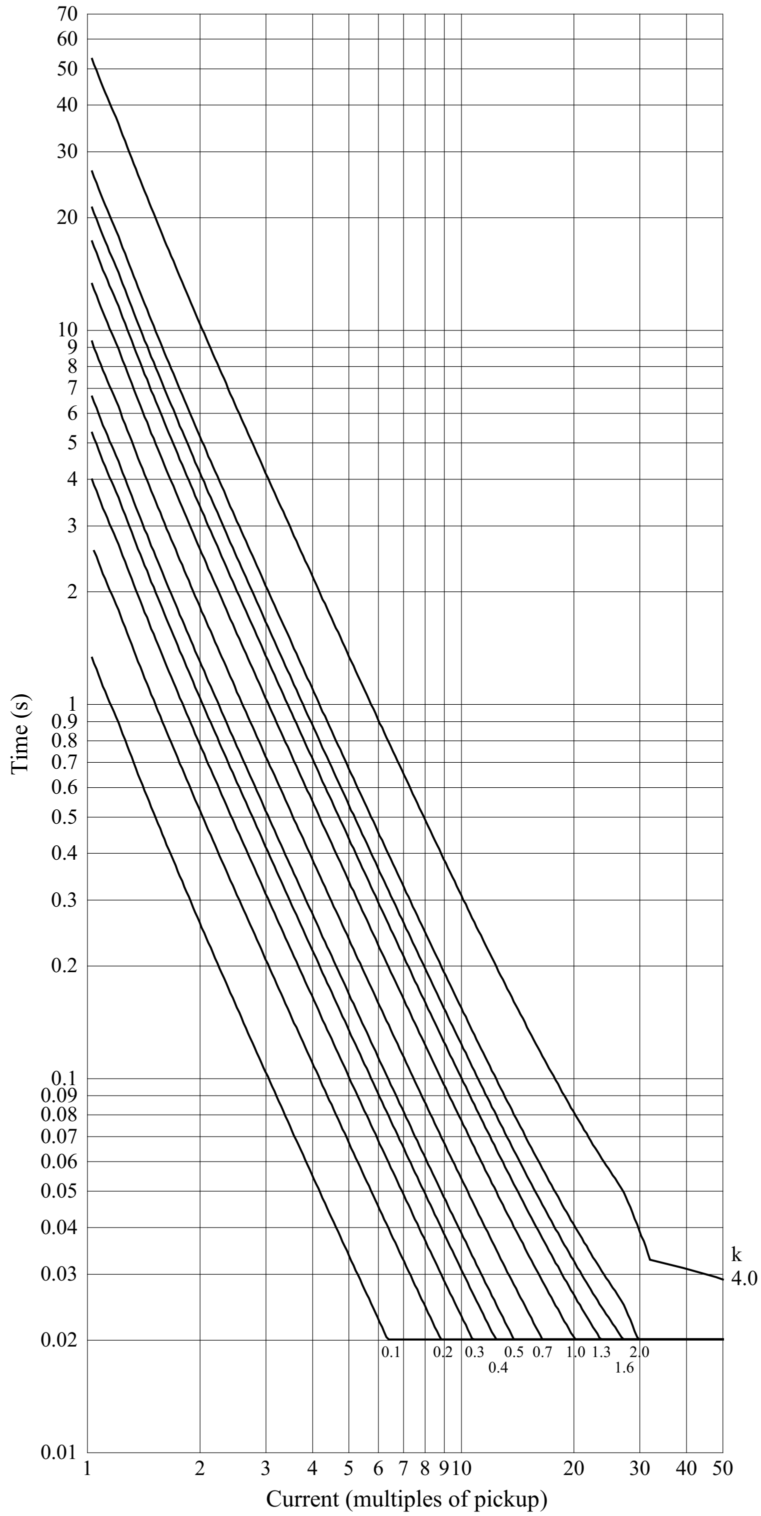


Figure 279: *Recloser curve E (132)*

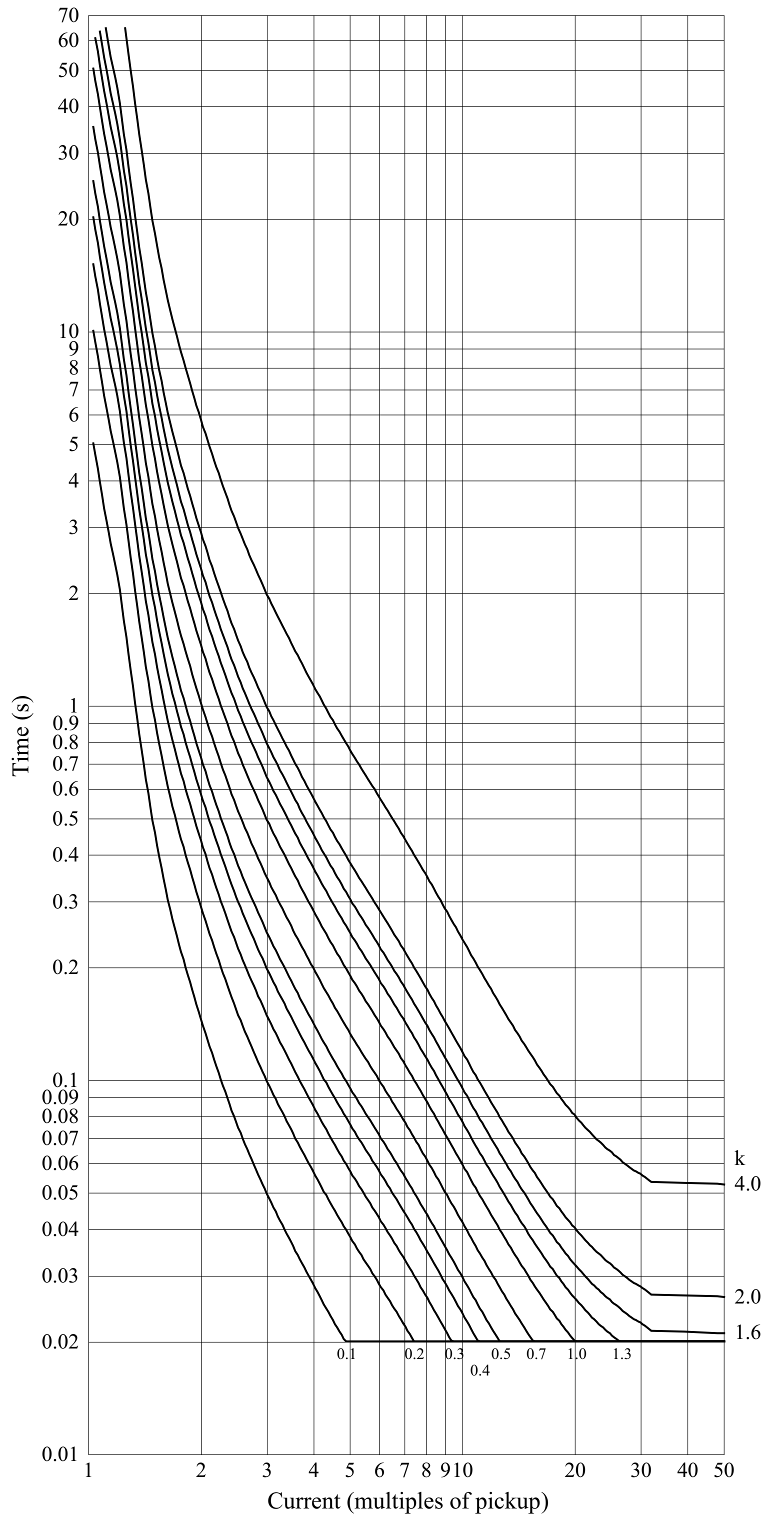


Figure 280: Recloser curve F (163)

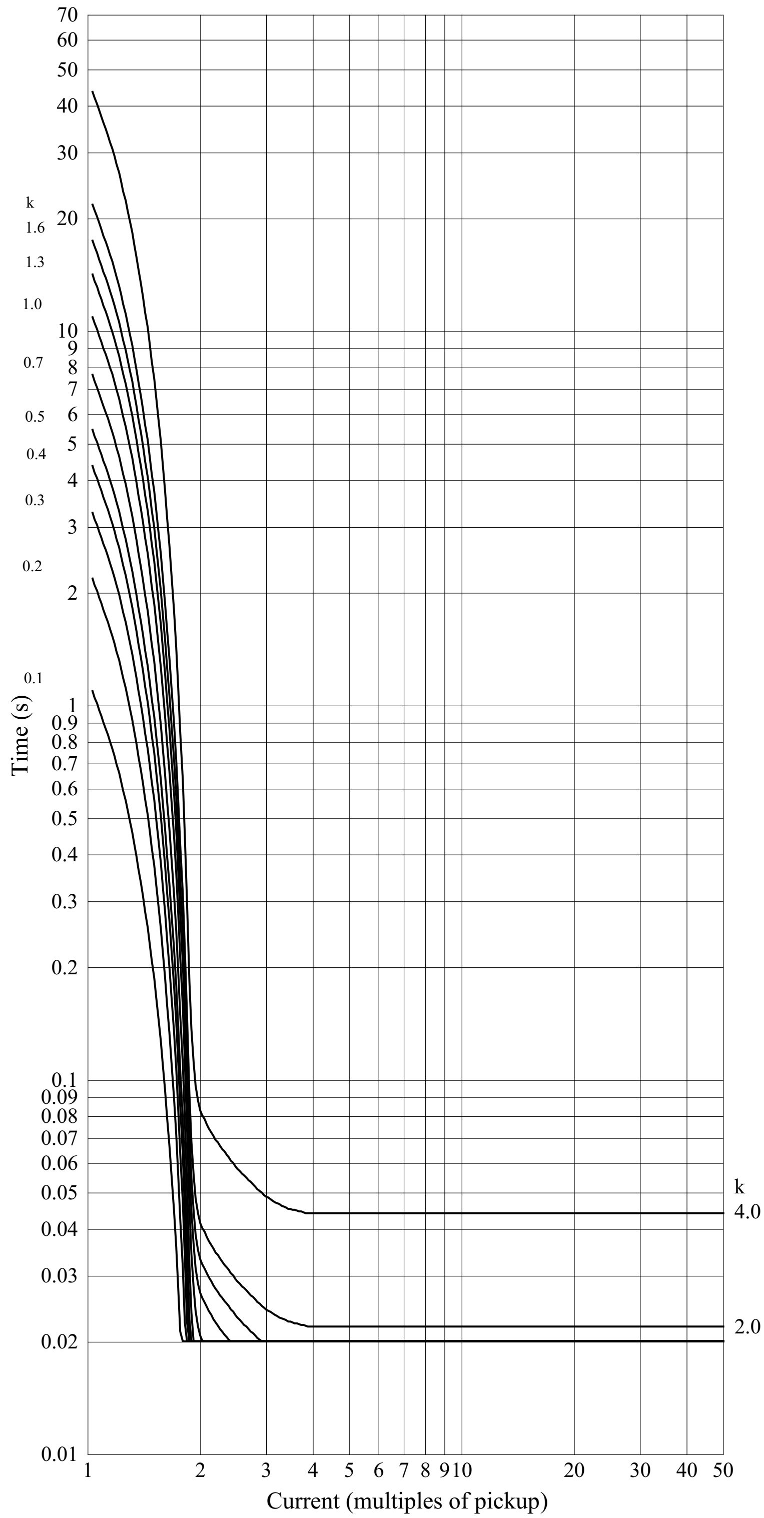


Figure 281: Recloser curve G (121)

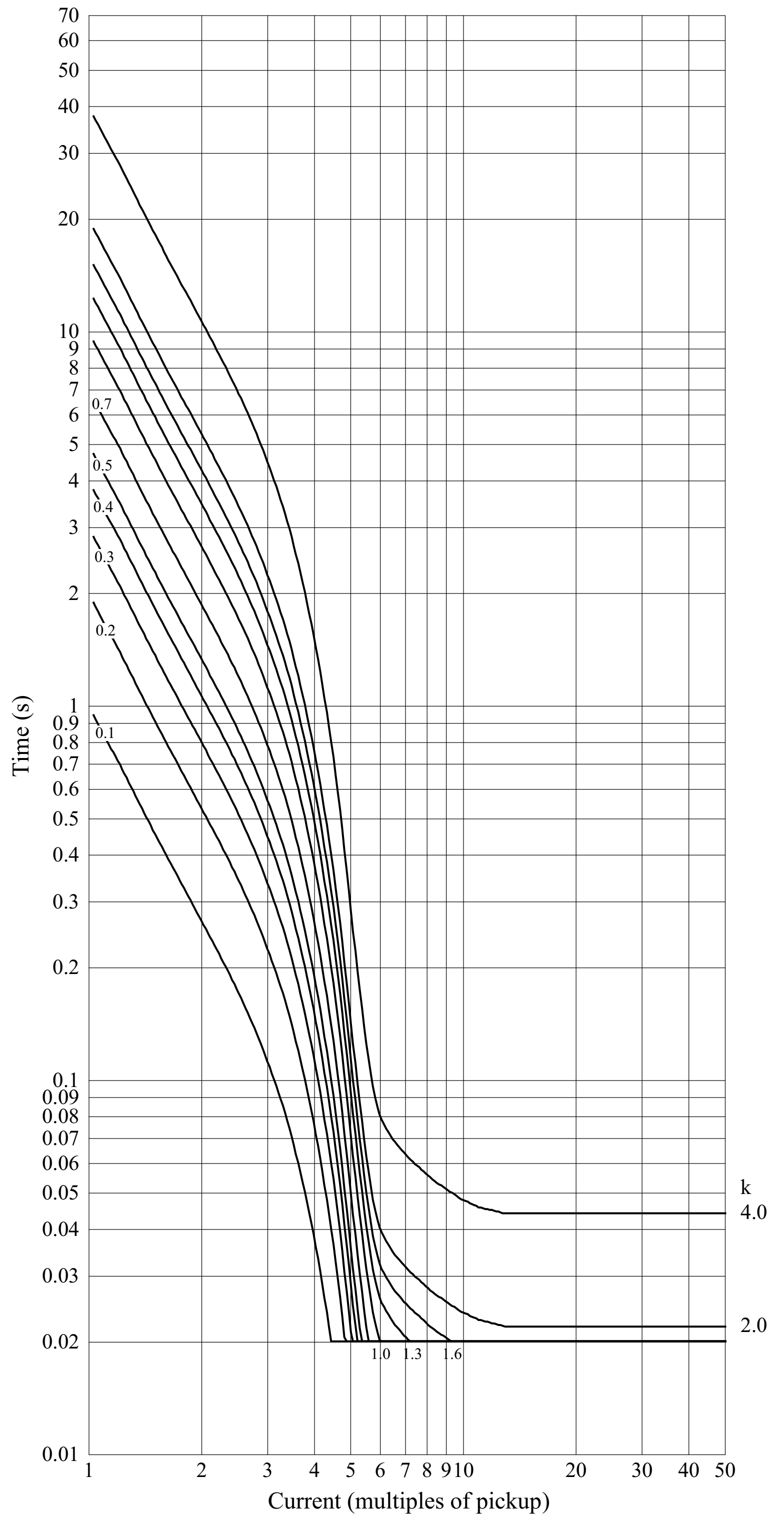


Figure 282: Recloser curve H (122)

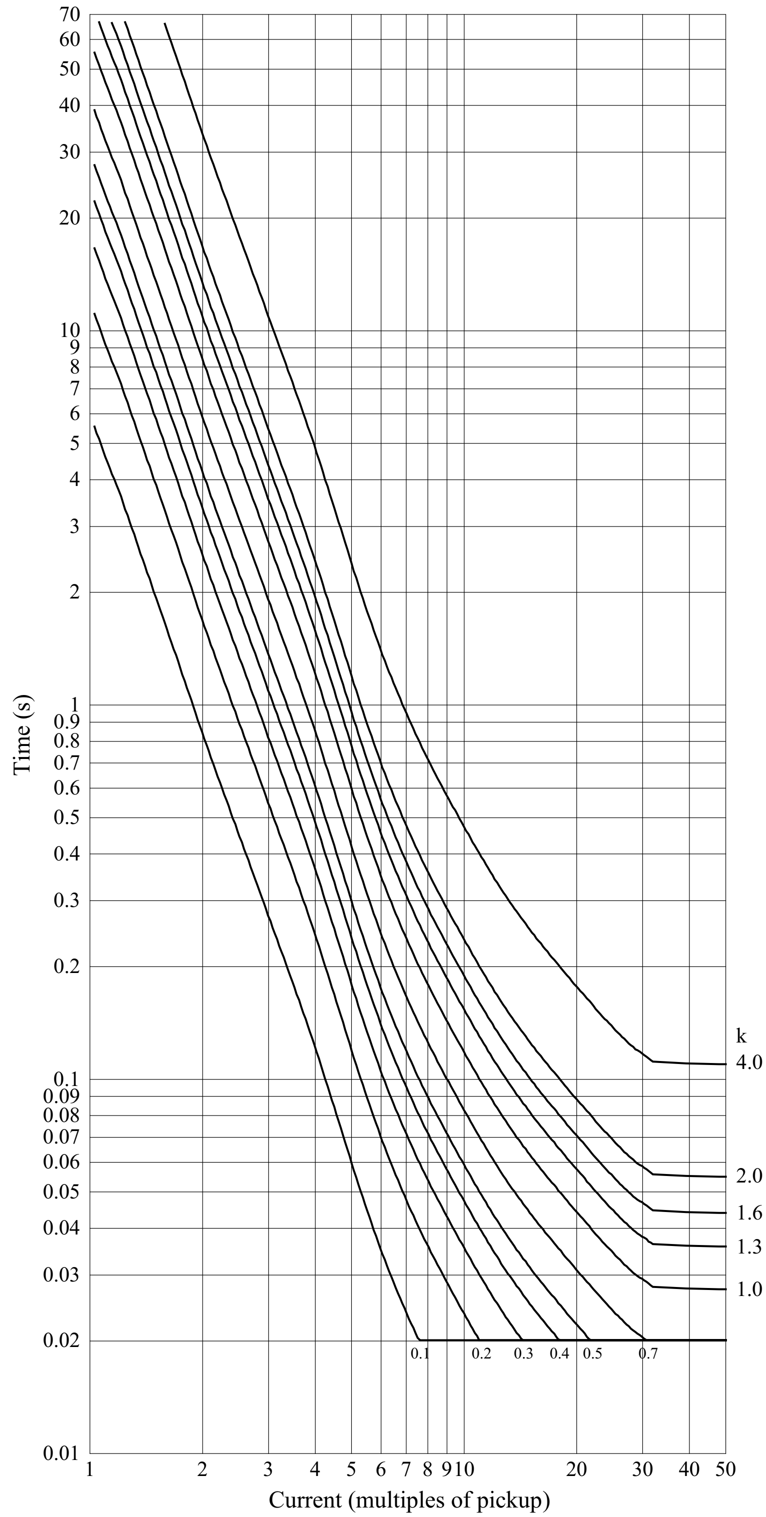


Figure 283: Recloser curve J (164)

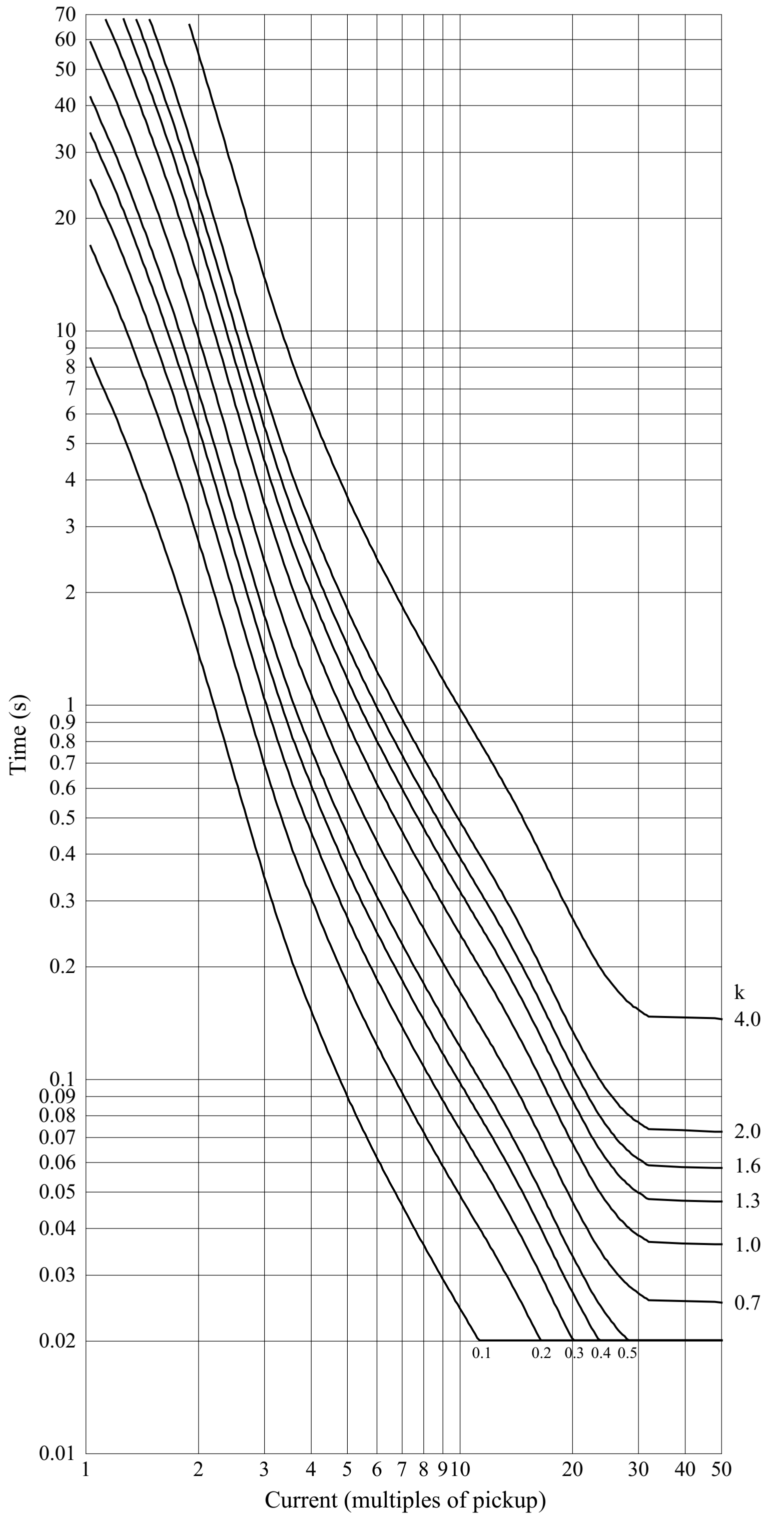


Figure 284: Recloser curve K-ground (165)

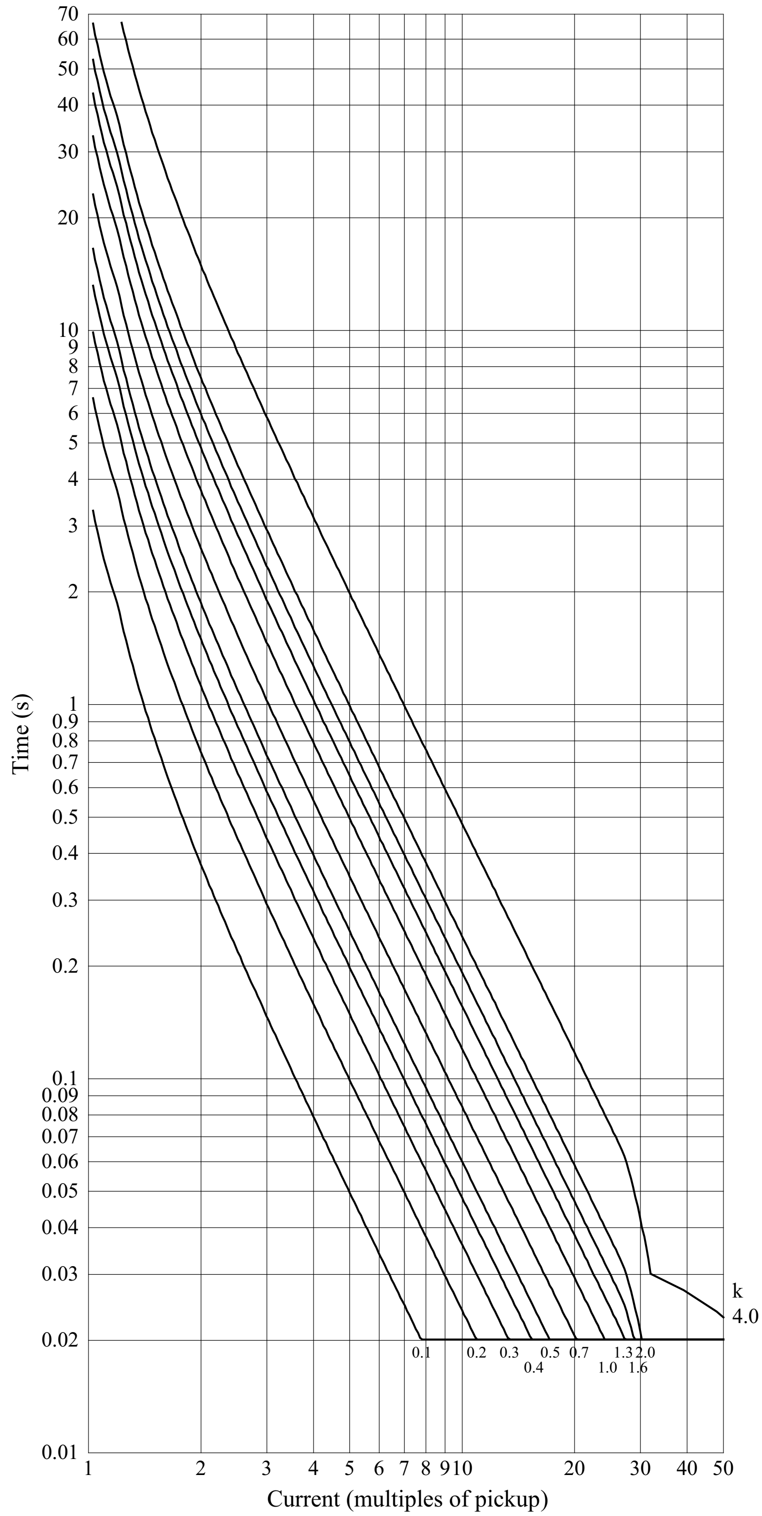


Figure 285: Recloser curve K-phase (162)

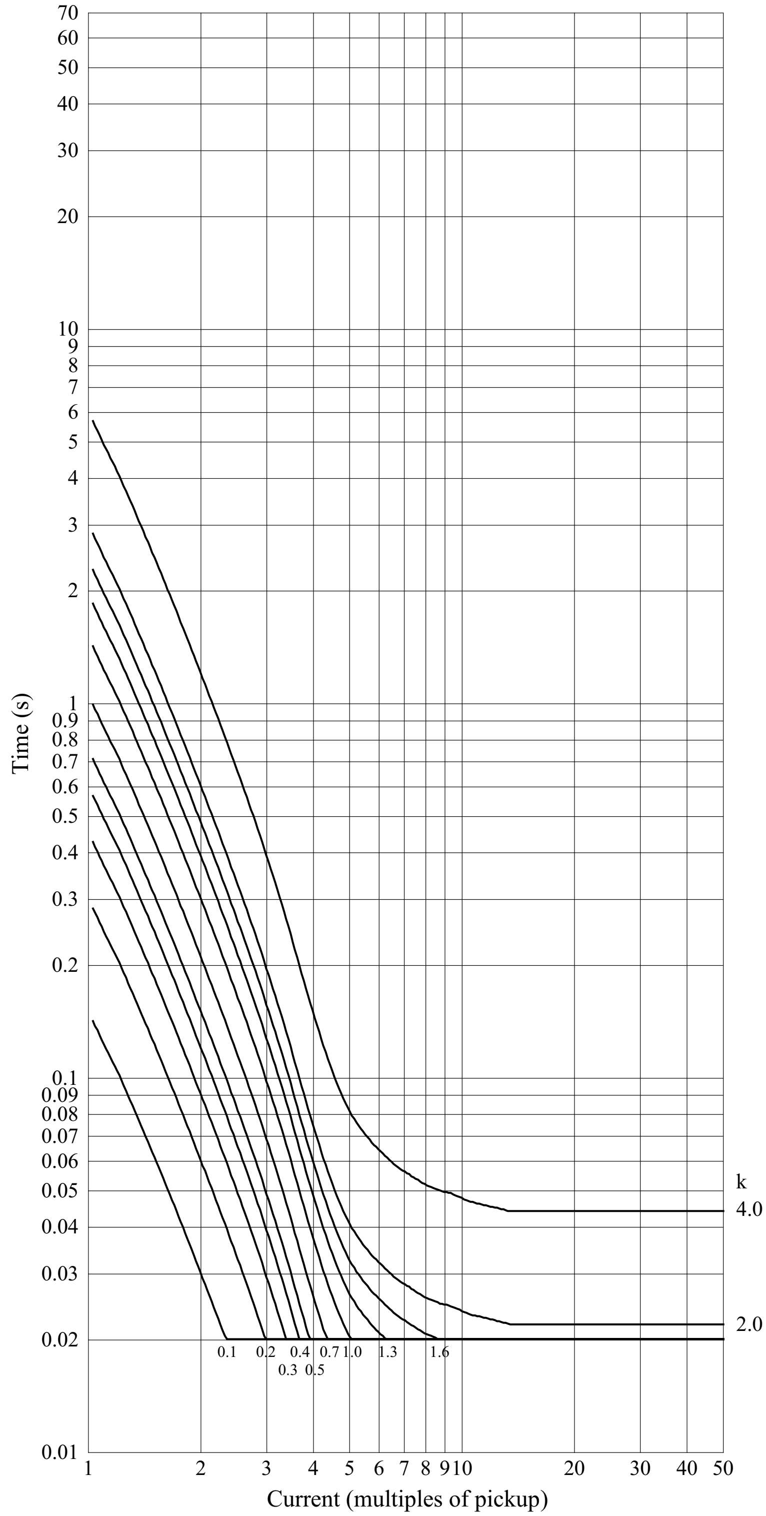


Figure 286: Recloser curve L (107)

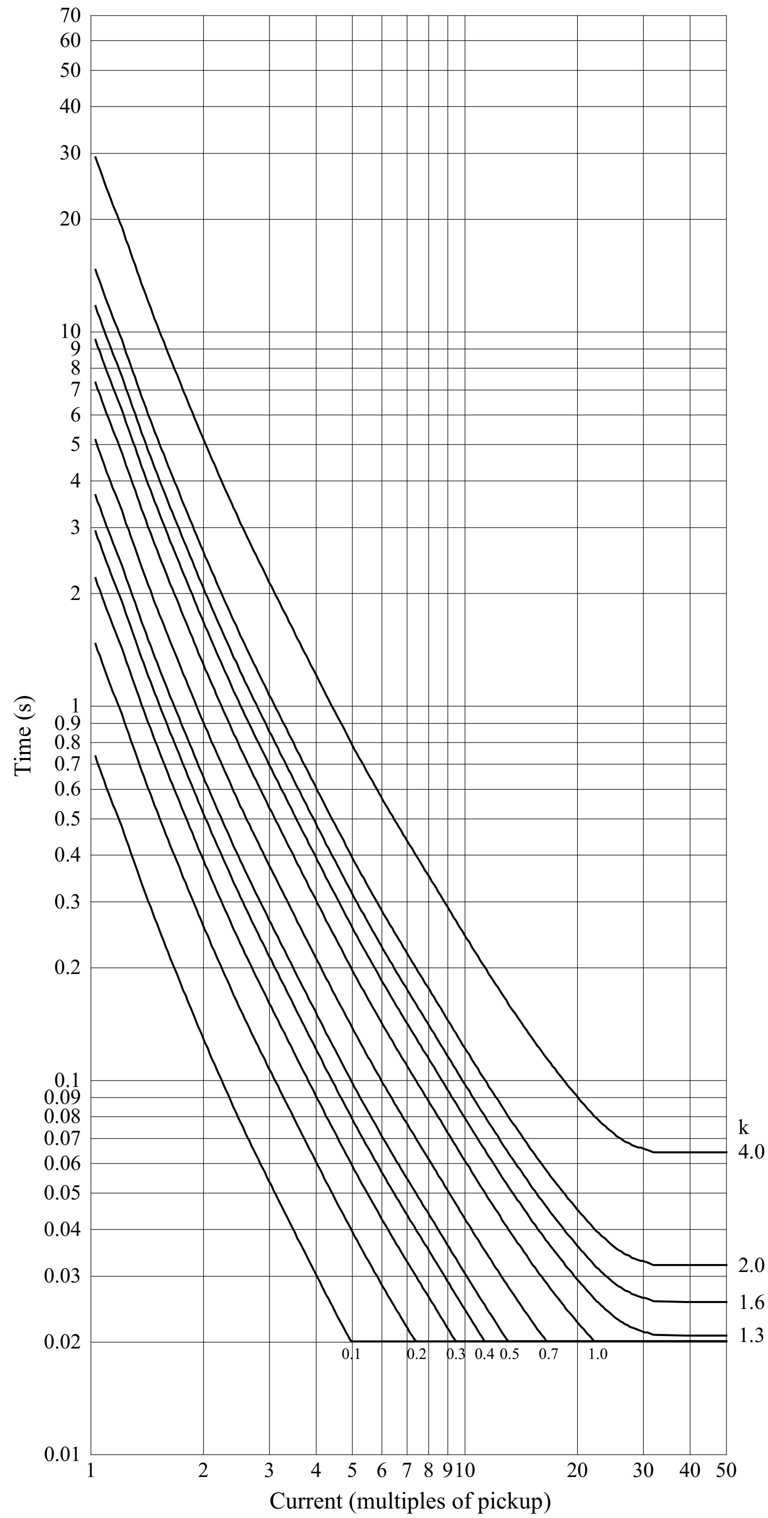


Figure 287: Recloser curve M (118)

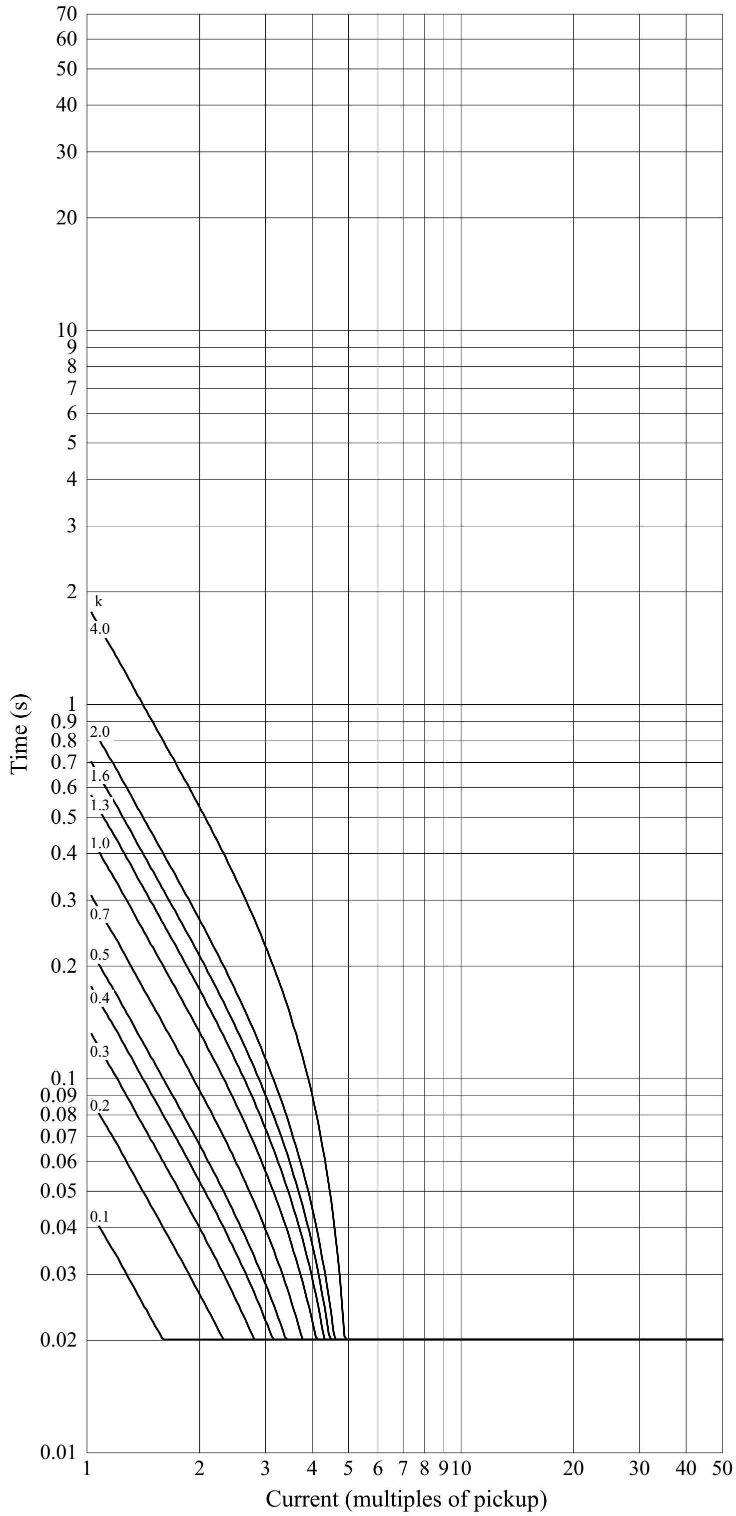


Figure 288: Recloser curve N (104)

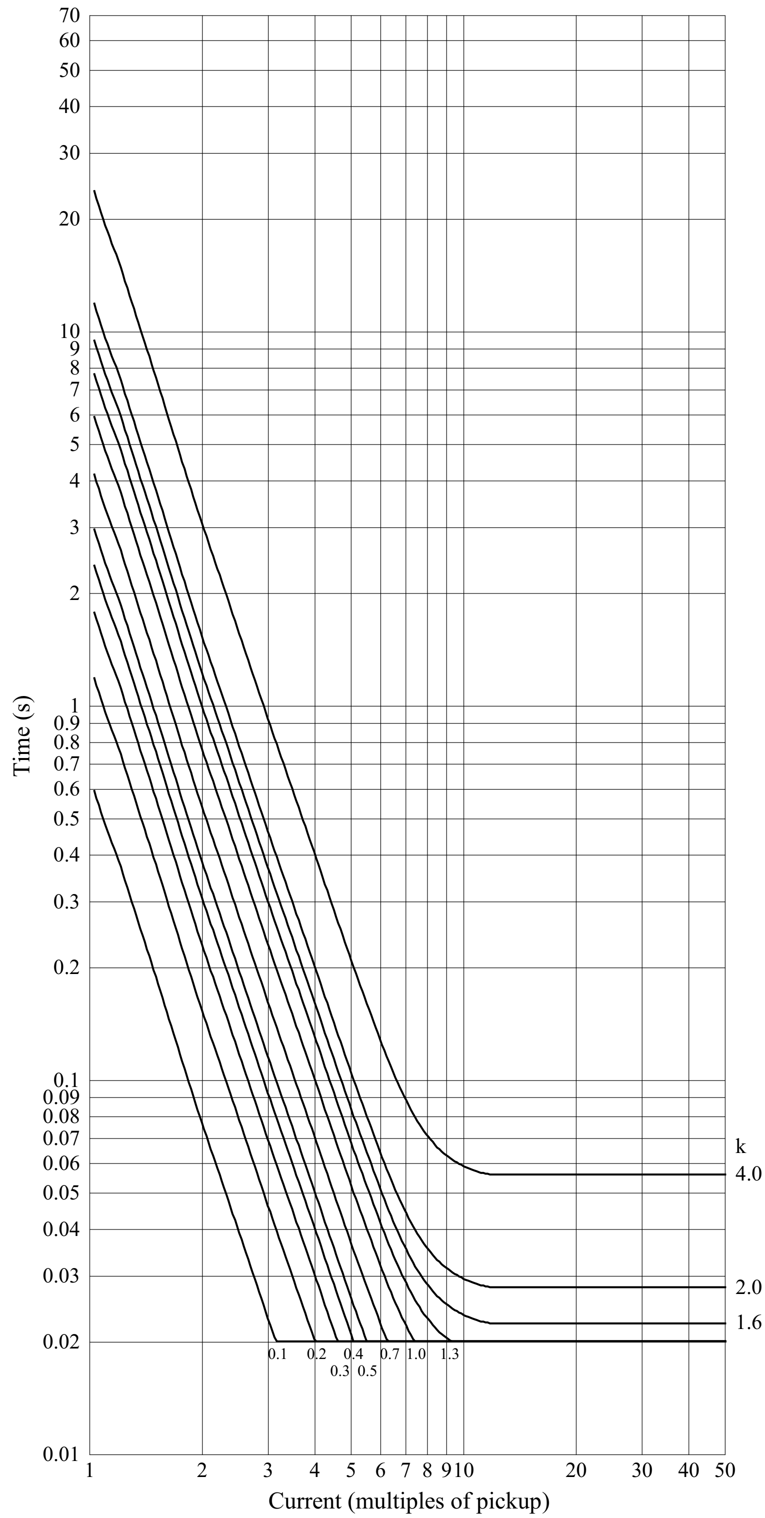


Figure 289: Recloser curve P (115)

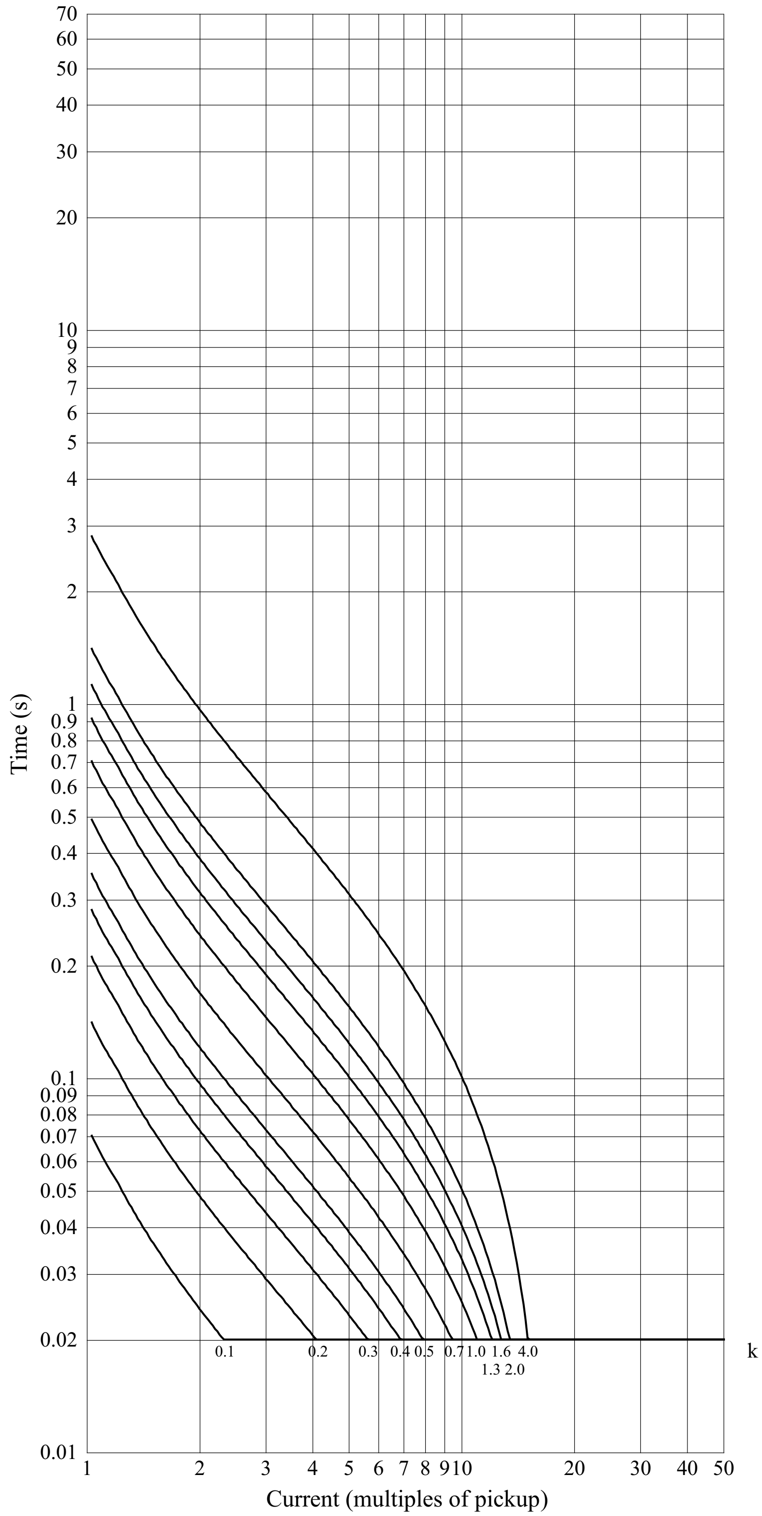


Figure 290: Recloser curve R (105)

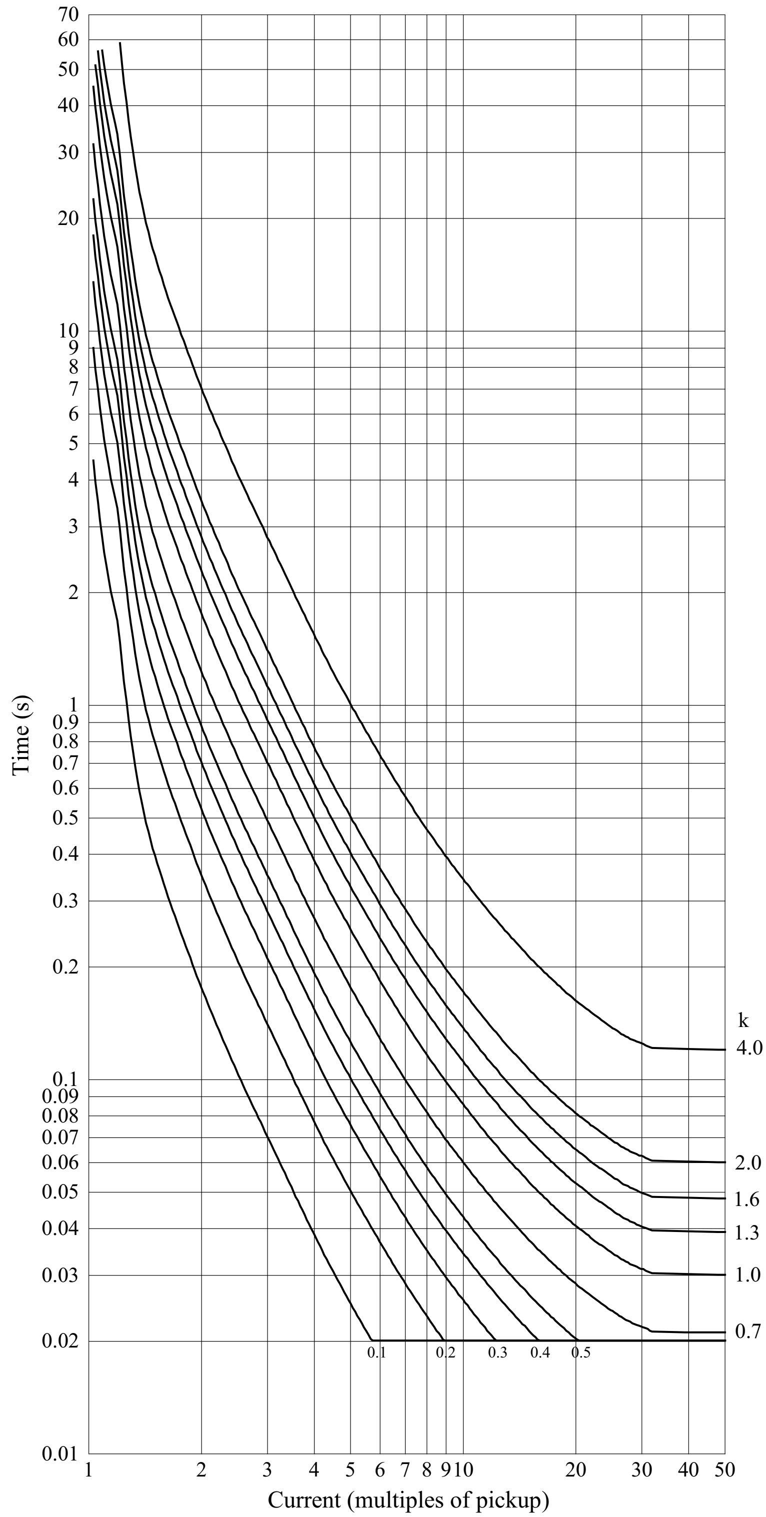


Figure 291: Recloser curve T (161)

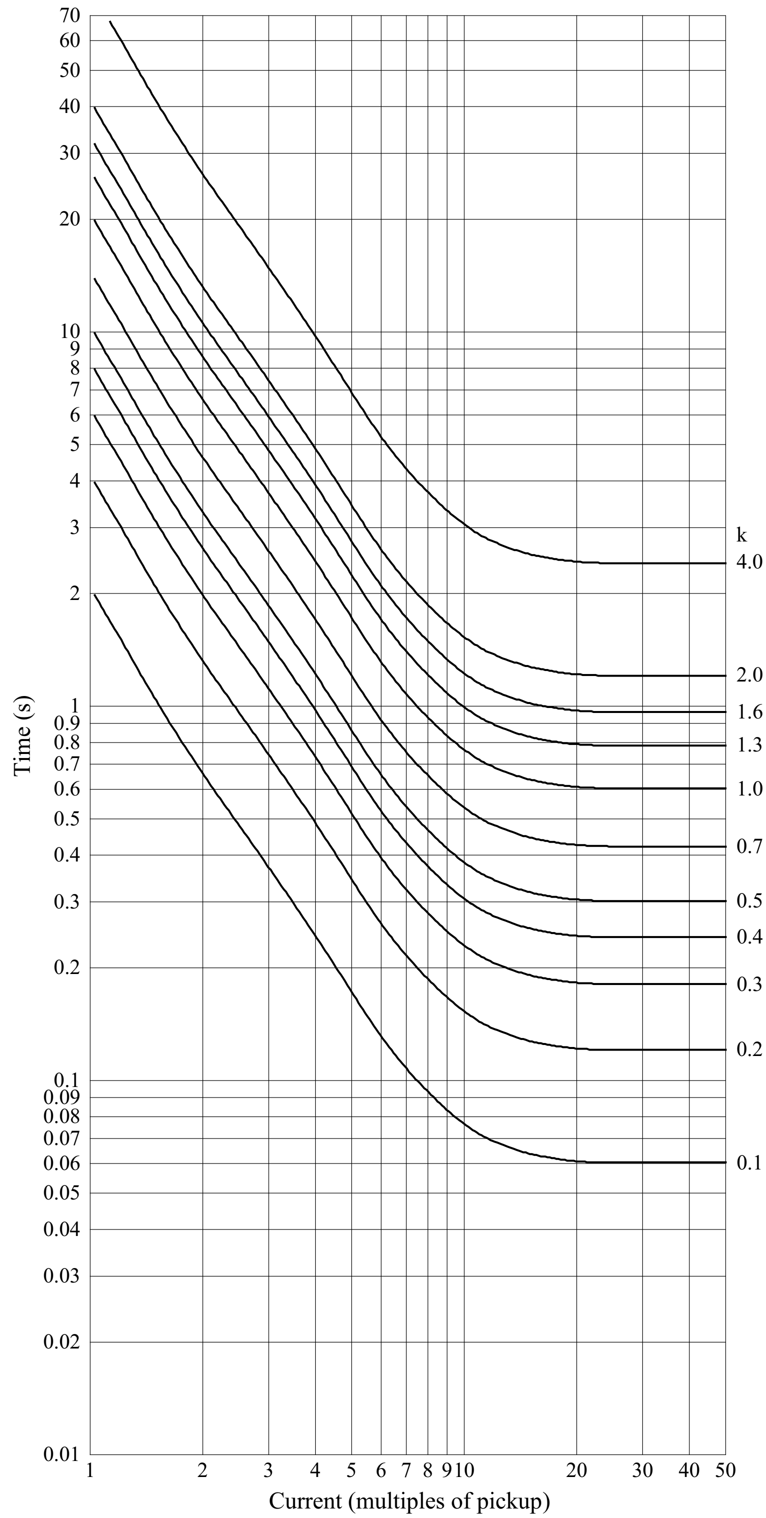


Figure 292: Recloser curve V (137)

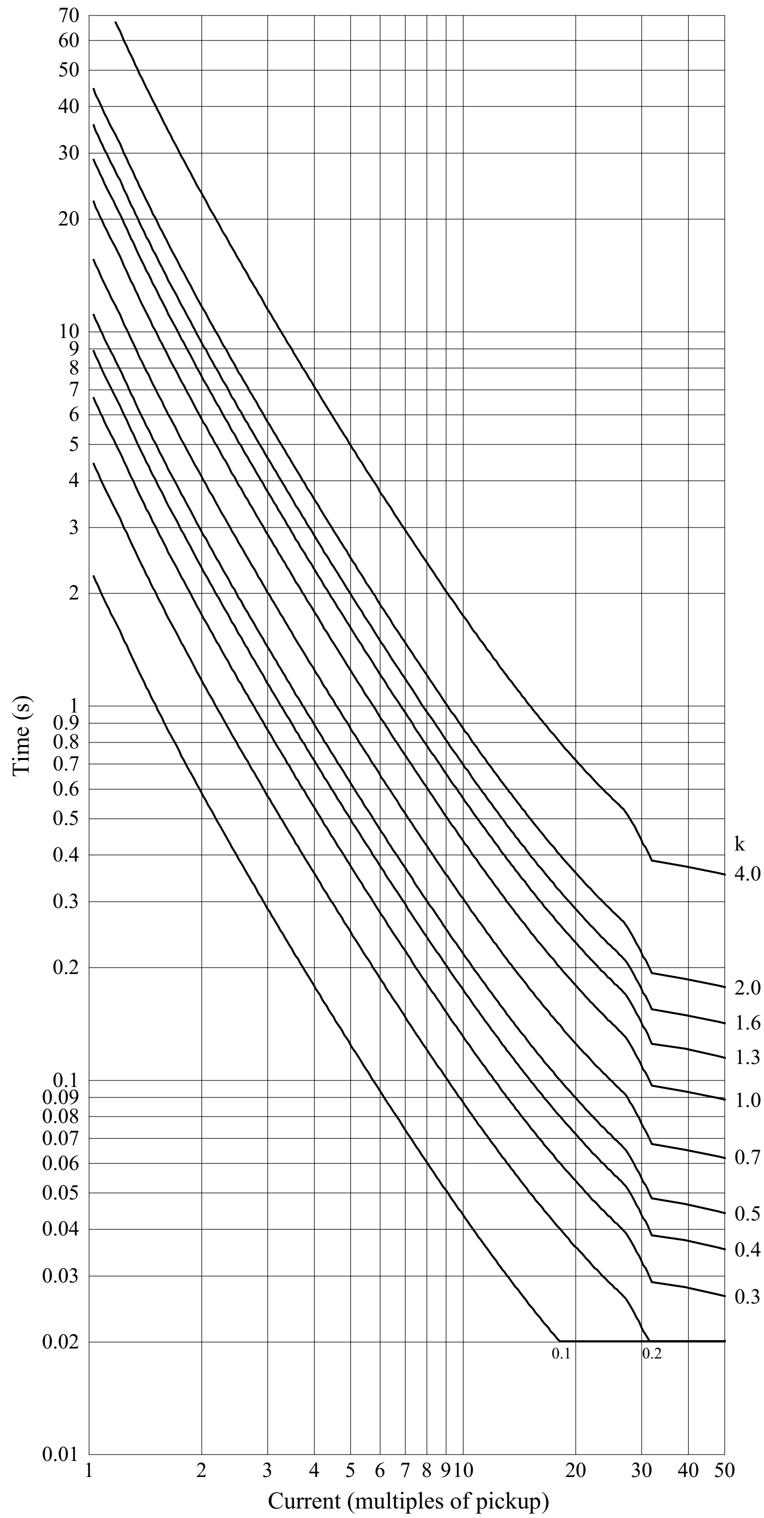


Figure 293: Recloser curve W (138)

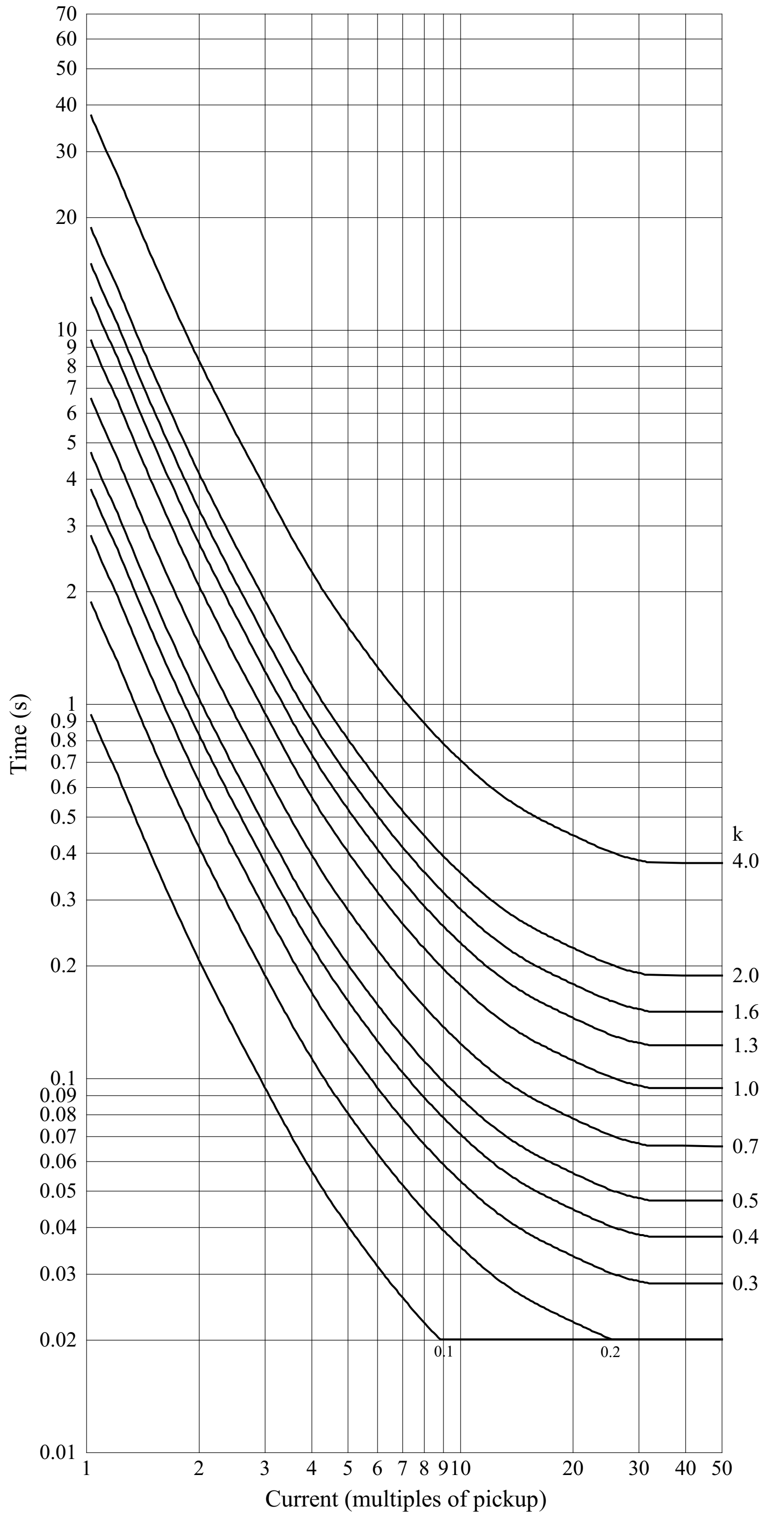


Figure 294: Recloser curve Y (120)

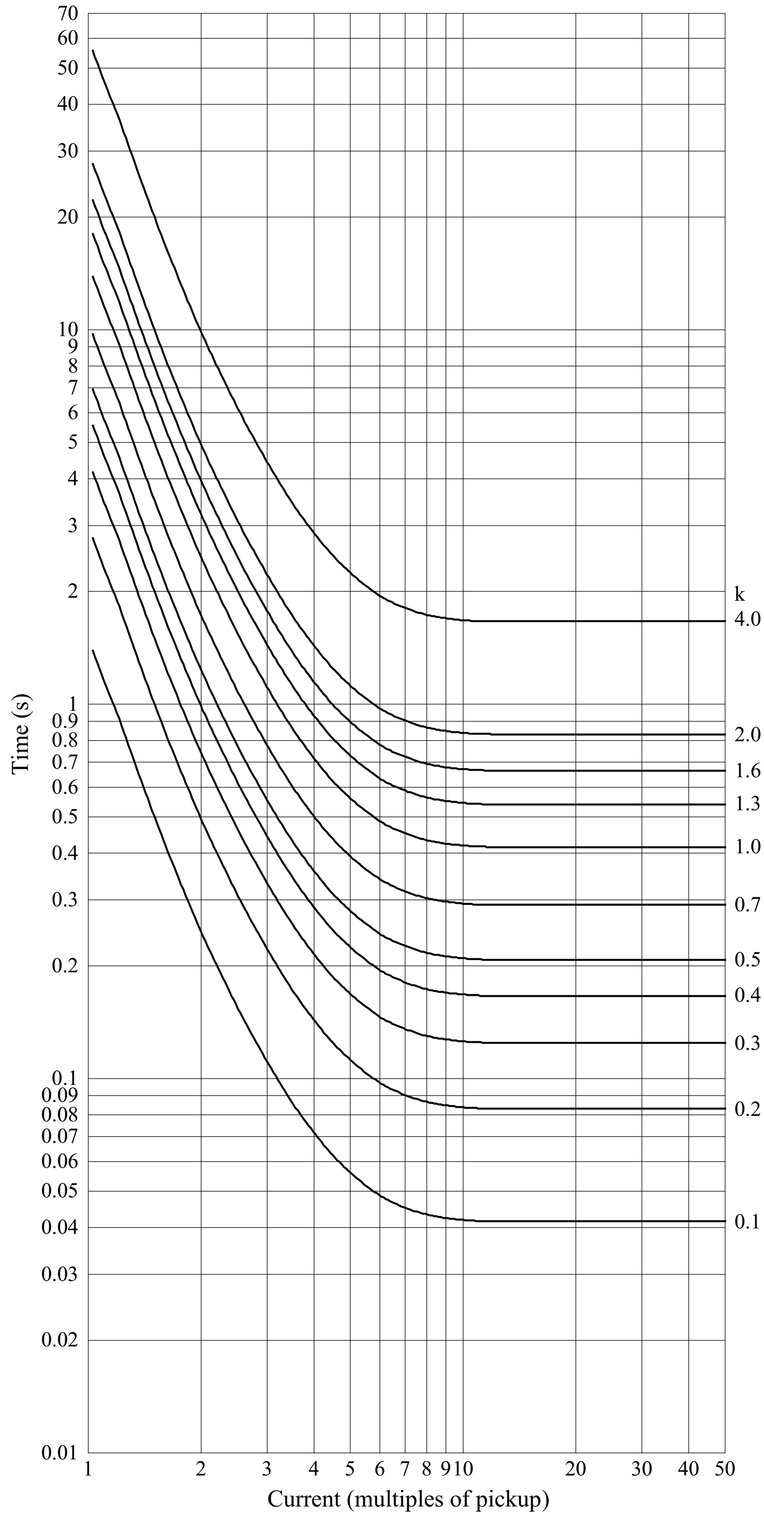


Figure 295: Recloser curve Z (134)

10.2.1.3 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 59)

t[s]	Trip time (in seconds)
A	set *Curve parameter A*
B	set *Curve parameter B*
C	set *Curve parameter C*
E	set *Curve parameter E*
I	Measured current
I>	set *Pickup value*
k	set *Time multiplier*

10.2.1.4 RI and RD-type inverse-time characteristics

The RI-type simulates the behavior of electromechanical relays. The RD-type is a ground-fault specific characteristic.

The RI-type is calculated using the formula

$$t[s] = \left(\frac{k}{0.339 - 0.236 \times \frac{I>}{I}} \right)$$

(Equation 60)

The RD-type is calculated using the formula

$$t[s] = 5.8 - 1.35 \times \text{In}\left(\frac{I}{k \times I>} \right)$$

(Equation 61)

t[s]	Trip time (in seconds)
k	set *Time multiplier*
I	Measured current
I>set	*Pickup value*

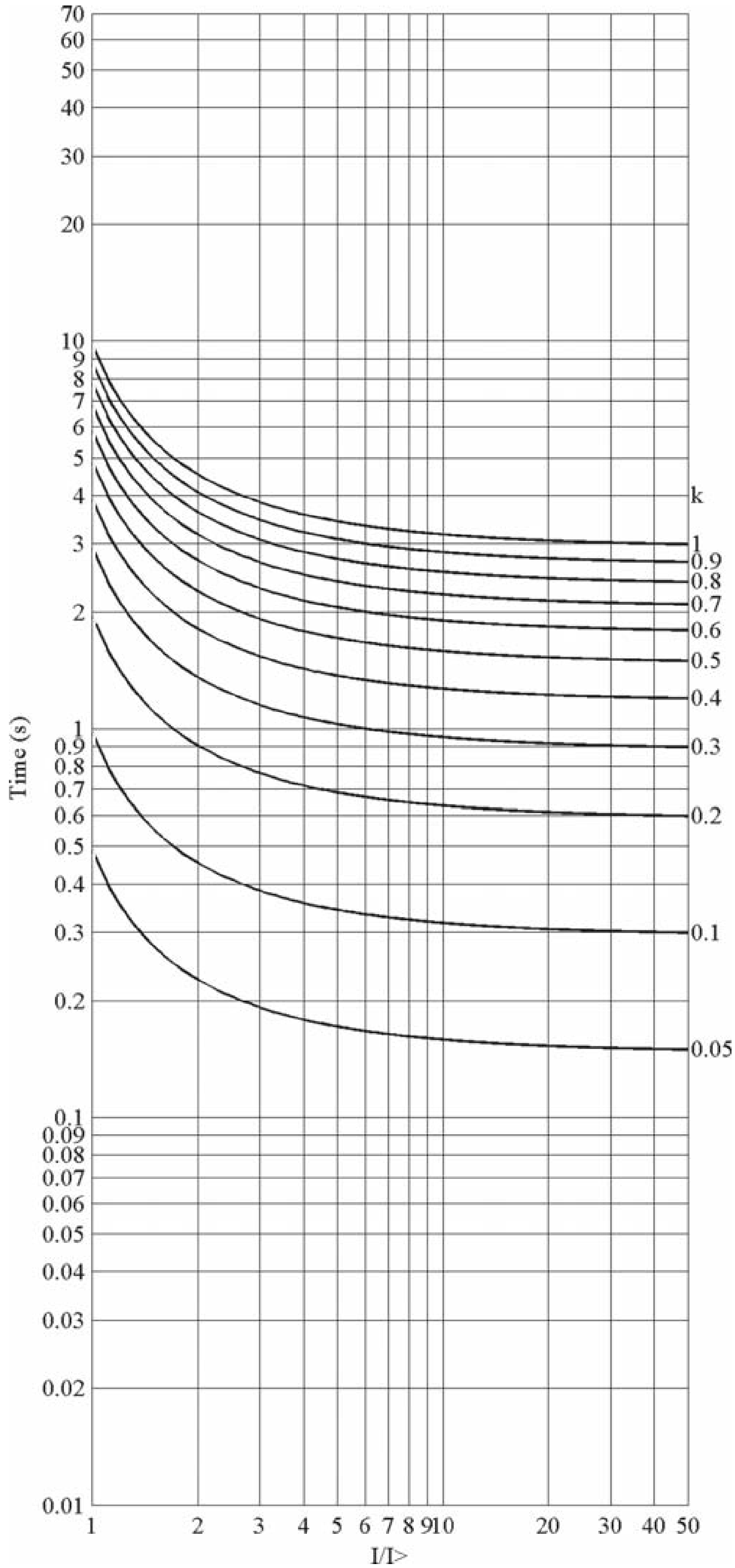


Figure 296: RI-type inverse-time characteristics

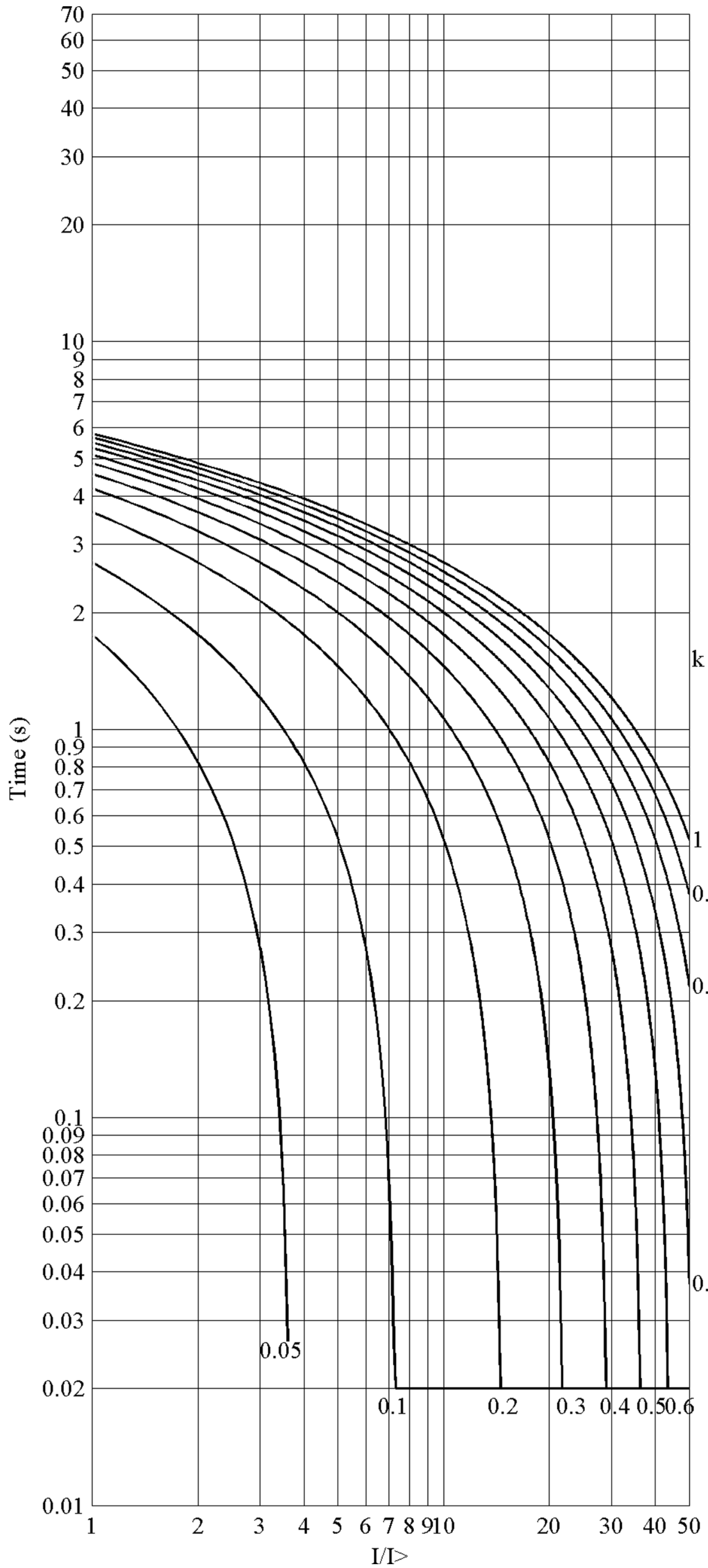


Figure 297: RD-type inverse-time characteristics

10.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting as follows:

Table 423: Values for reset mode

Setting name	Possible values
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset

Immediate reset

If the *Type of reset curve* setting in a drop-off case is selected as “Immediate”, the inverse timer resets immediately.

Definite time reset

The definite type of reset in the inverse-time mode can be achieved by setting the *Type of reset curve* parameter to “Def time reset”. As a result, the trip inverse-time counter is frozen for the time determined with the *Reset delay time* setting after the current drops below the set *Pickup value*, including hysteresis.The integral sum of the inverse-time counter is reset, if another pickup does not occur during the reset delay.

If the *Type of reset curve* setting is selected as “Def time reset”, the current level has no influence on the reset characteristic.

Inverse reset

Inverse reset curves are available only for ANSI and user-programmable curves. If you use other curve types, immediate reset occurs.

Standard delayed inverse reset

The reset characteristic required in ANSI (IEEE) inverse-time modes is provided by setting the *Type of reset curve* parameter to “Inverse reset”. In this mode, the time delay for reset is given with the following formula using the coefficient D, which has its values defined in the table below.

$$t[s] = \left(\frac{D}{\left(\frac{I}{I>}\right)^2 - 1} \right) \cdot k$$

(Equation 62)

t[s] Reset time (in seconds)
kset *Time multiplier*
I Measured current
I> set *Pickup value*

Table 424: 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

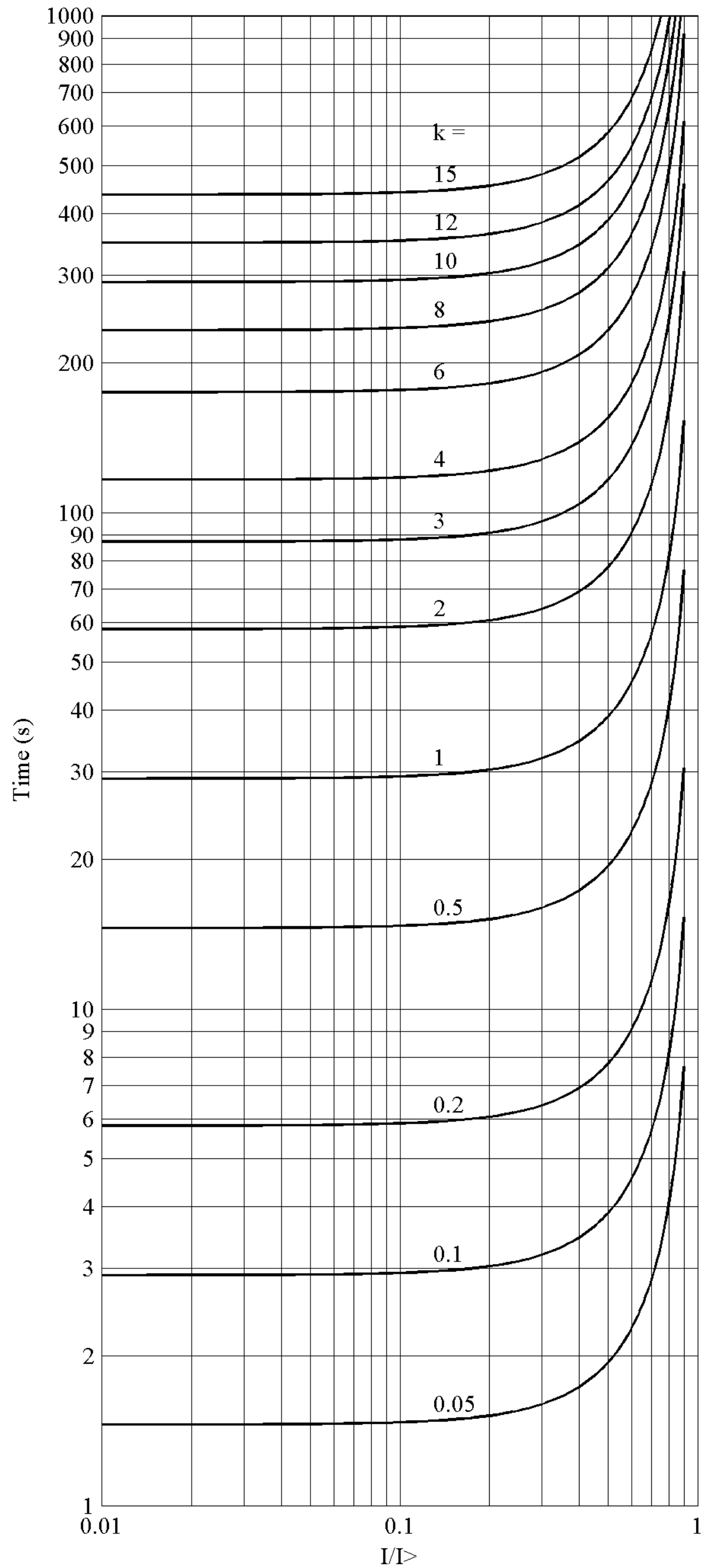


Figure 298: ANSI extremely inverse reset time characteristics

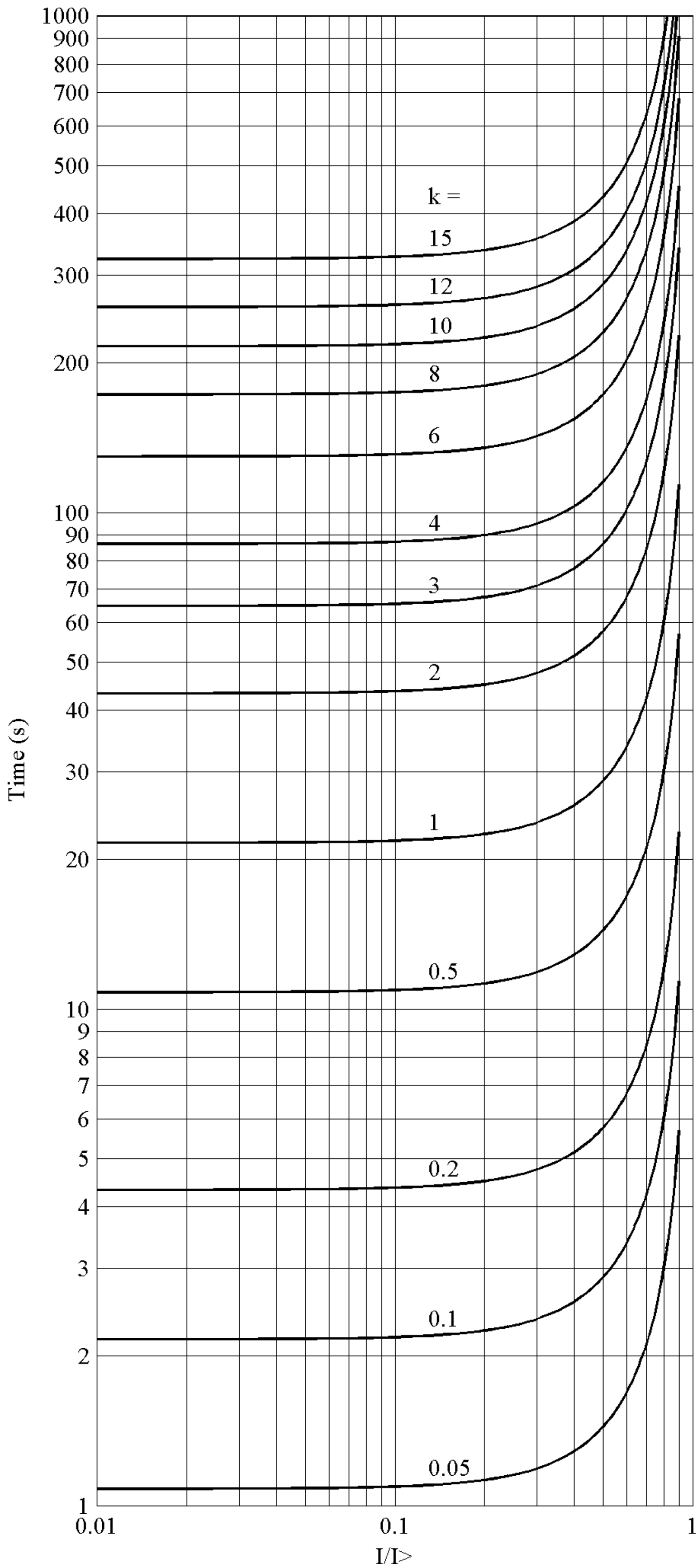


Figure 299: ANSI very inverse reset time characteristics

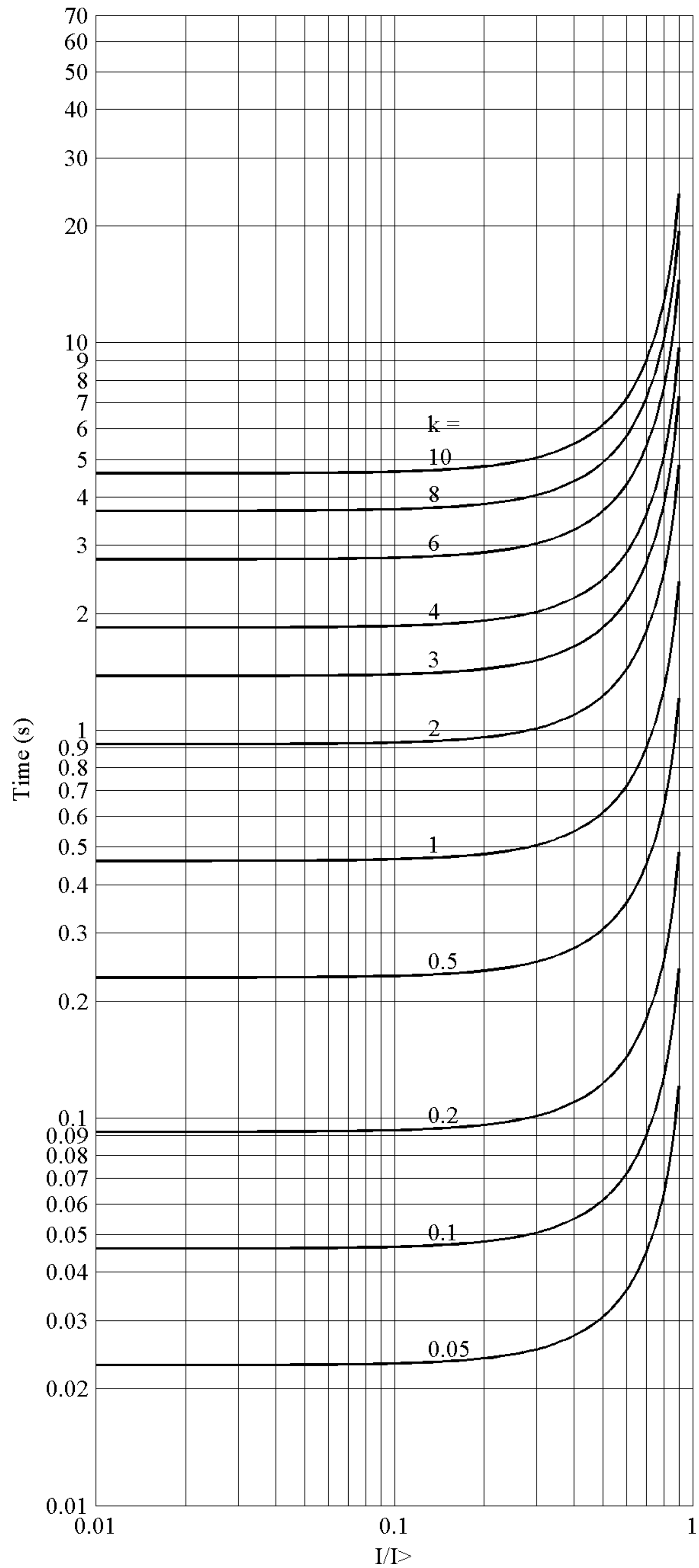


Figure 300: ANSI normal inverse reset time characteristics

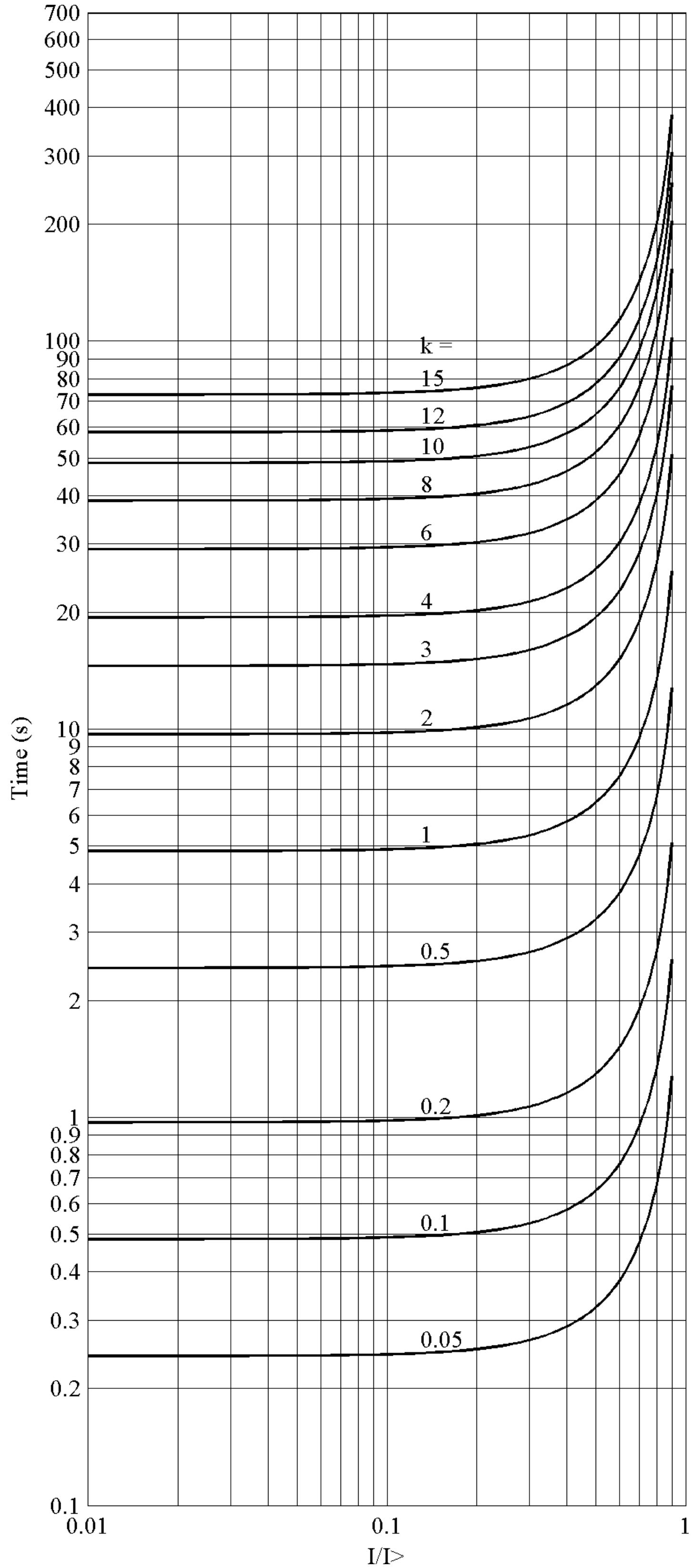


Figure 301: ANSI moderately inverse reset time characteristics

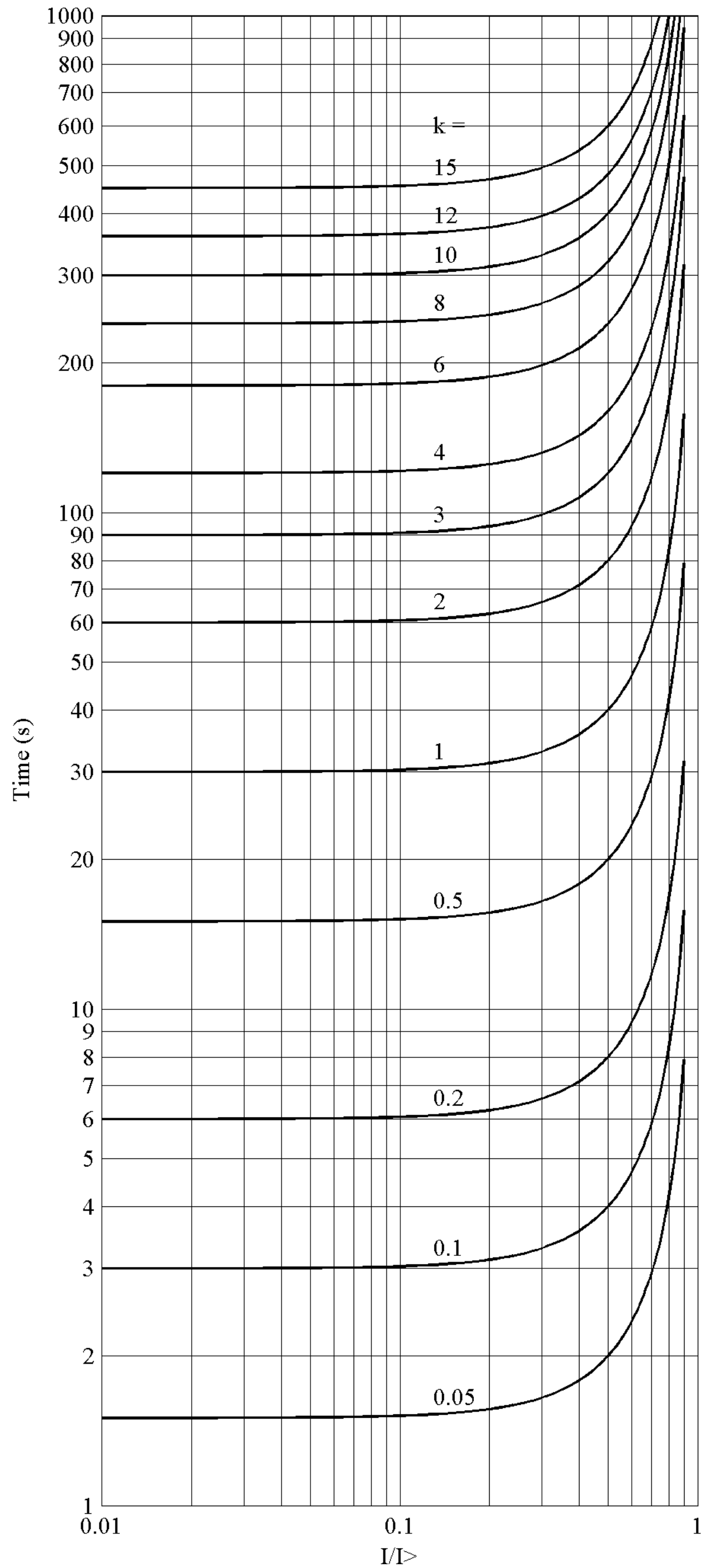


Figure 302: ANSI long-time extremely inverse reset time characteristics

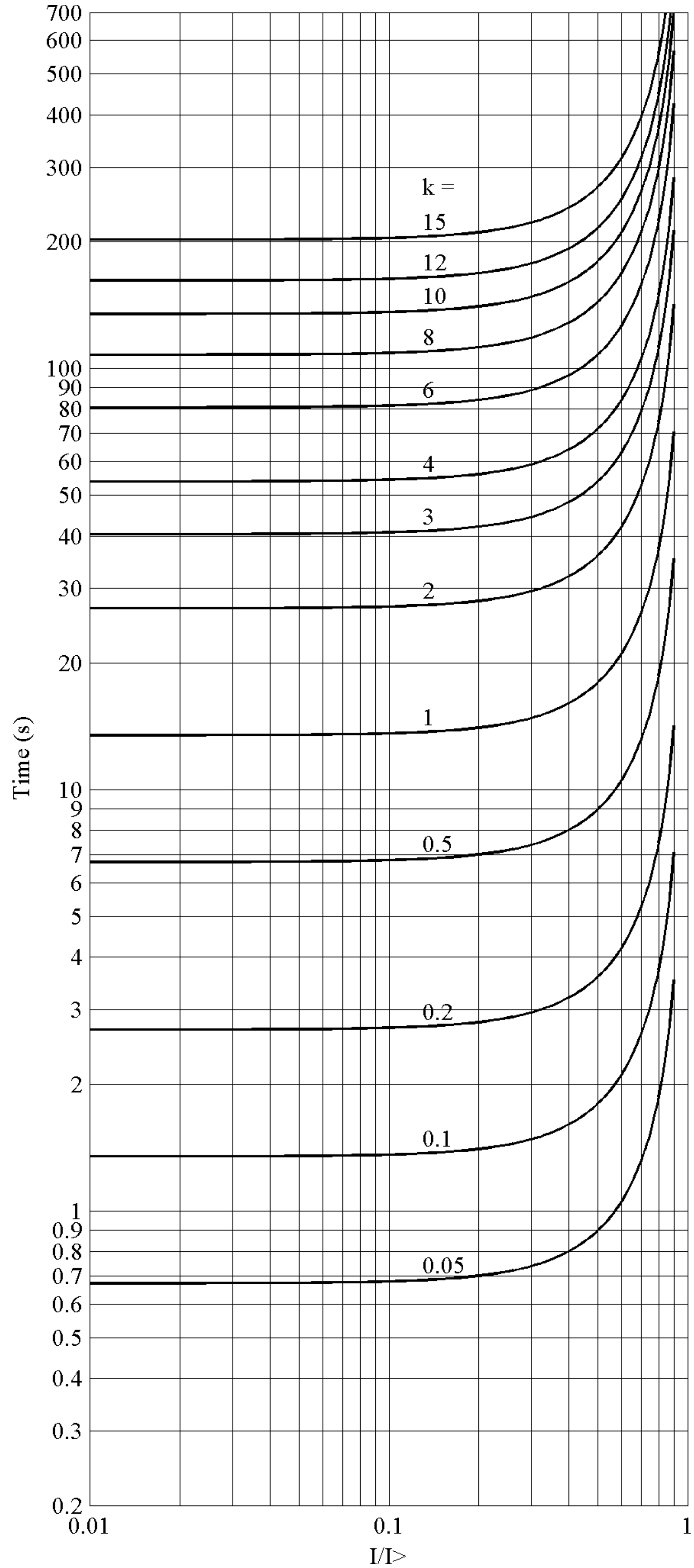


Figure 303: ANSI long-time very inverse reset time characteristics

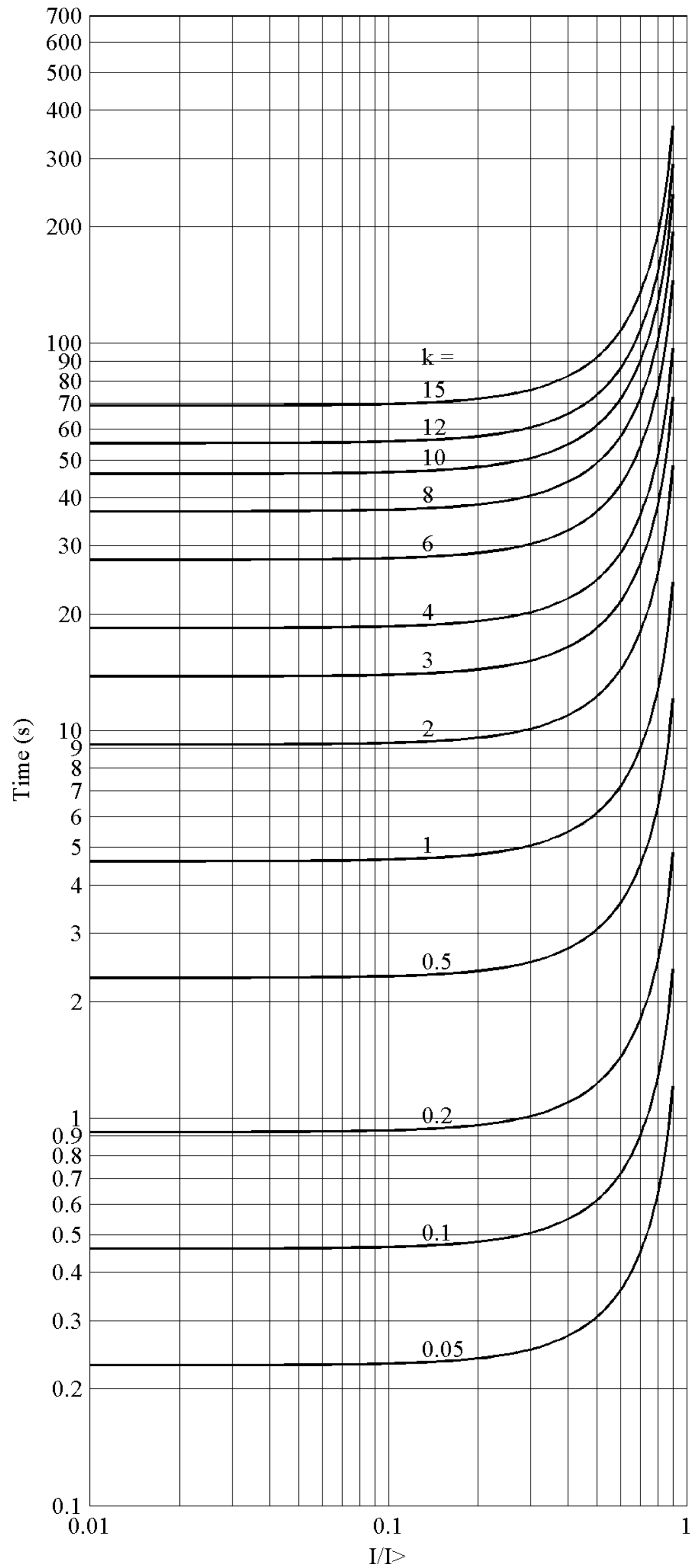


Figure 304: ANSI long-time inverse reset time characteristics

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 63)

t[s]	Reset time (in seconds)
k	set *Time multiplier*
D	set *Curve parameter D*
I	Measured current
I>	set *Pickup value*

10.2.3 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 relay needs to be blocked to enable the definite-time operation of another relay for selectivity reasons, especially if different relaying techniques (old and modern relays) are applied.

The selected blocking mode is “Freeze timer”.

The activation of the `BLOCK` input also lengthens the minimum delay value of the timer.

Activating the `BLOCK` input alone does not affect the operation of the `PICKUP` output. It still becomes active when the current exceeds the set *Pickup value*, and inactive when the current falls below the set *Pickup value* and the set *Reset delay time* has expired.

10.3 Voltage based inverse definite minimum time characteristics

10.3.1 IDMT curves for overvoltage protection

In inverse-time modes, the trip time depends on the momentary value of the voltage, the higher the voltage, the faster the trip time. The trip time calculation or integration starts immediately when the voltage exceeds the set value of the *Pickup value* setting and the `PICKUP` output is activated.

The `TRIP` output of the component is activated when the cumulative sum of the integrator calculating the overvoltage situation exceeds the value set by the inverse time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time for the IDMT mode, that is, it is possible to limit the IDMT based trip time for not becoming too short. For example:

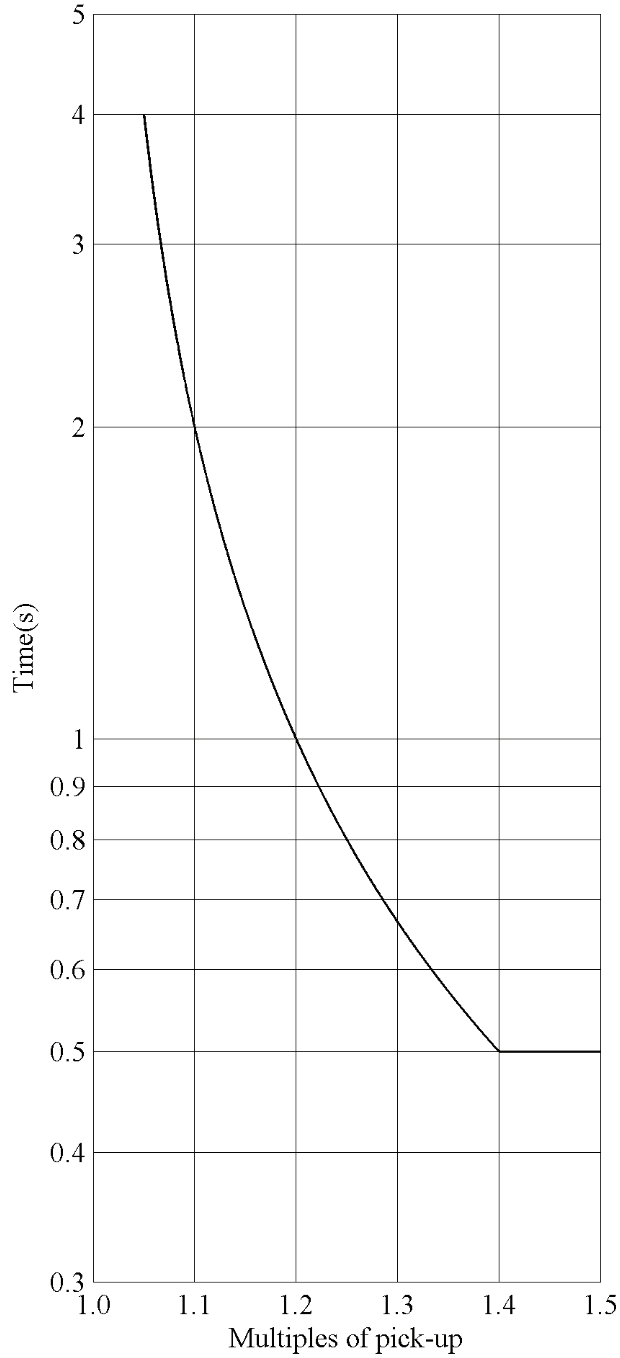


Figure 305: Trip time curve based on IDMT characteristic with Minimum trip time set to 0.5 second

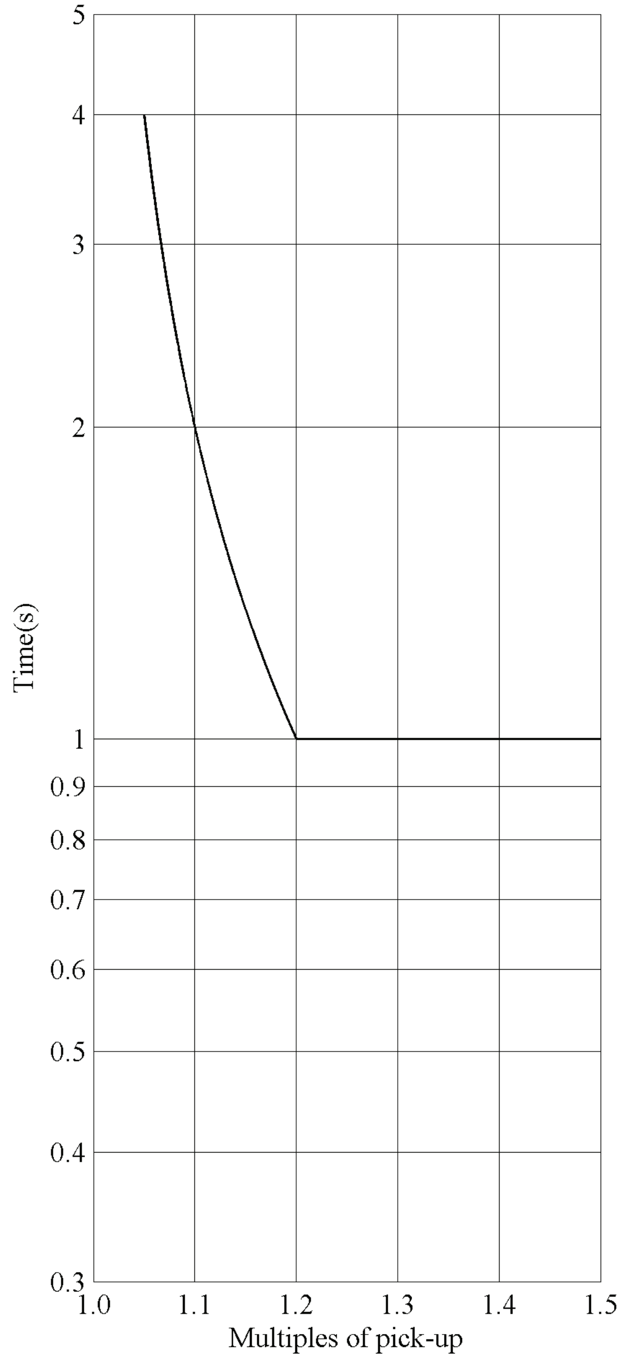


Figure 306: *Trip time curve based on IDMT characteristic with* Minimum trip time *set to 1 second*

10.3.1.1 Standard inverse-time characteristics for overvoltage protection

The trip times for the standard overvoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse trip time can be calculated with the formula:

$$t\left[s\right]=\frac{k\cdot A}{\left(B\times\frac{V-V>}{V>}-C\right)^{E}}+D$$

(Equation 64)

t [s] trip time in seconds
V measured voltage
V> the set value of *Pickup value*
k the set value of *Time multiplier*

Table 425: 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

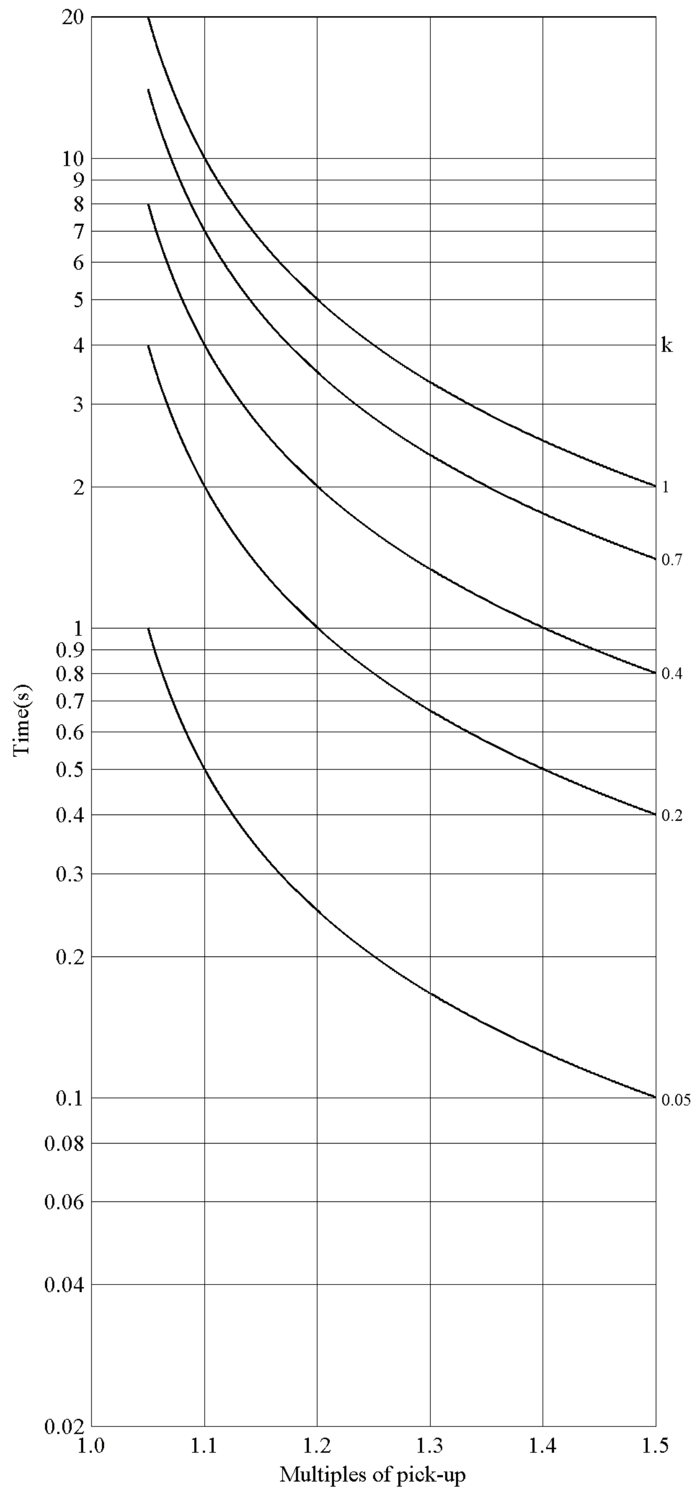


Figure 307: Inverse curve A characteristic of overvoltage protection

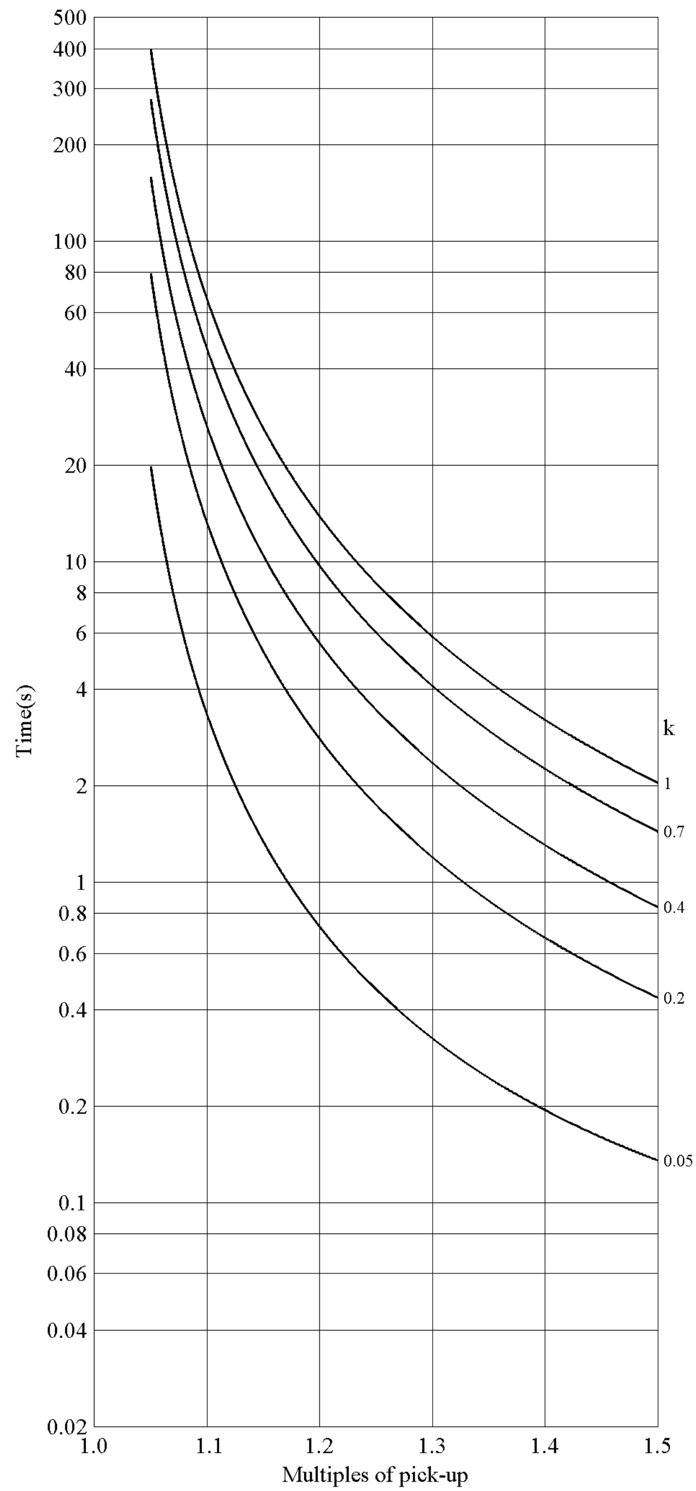


Figure 308: Inverse curve B characteristic of overvoltage protection

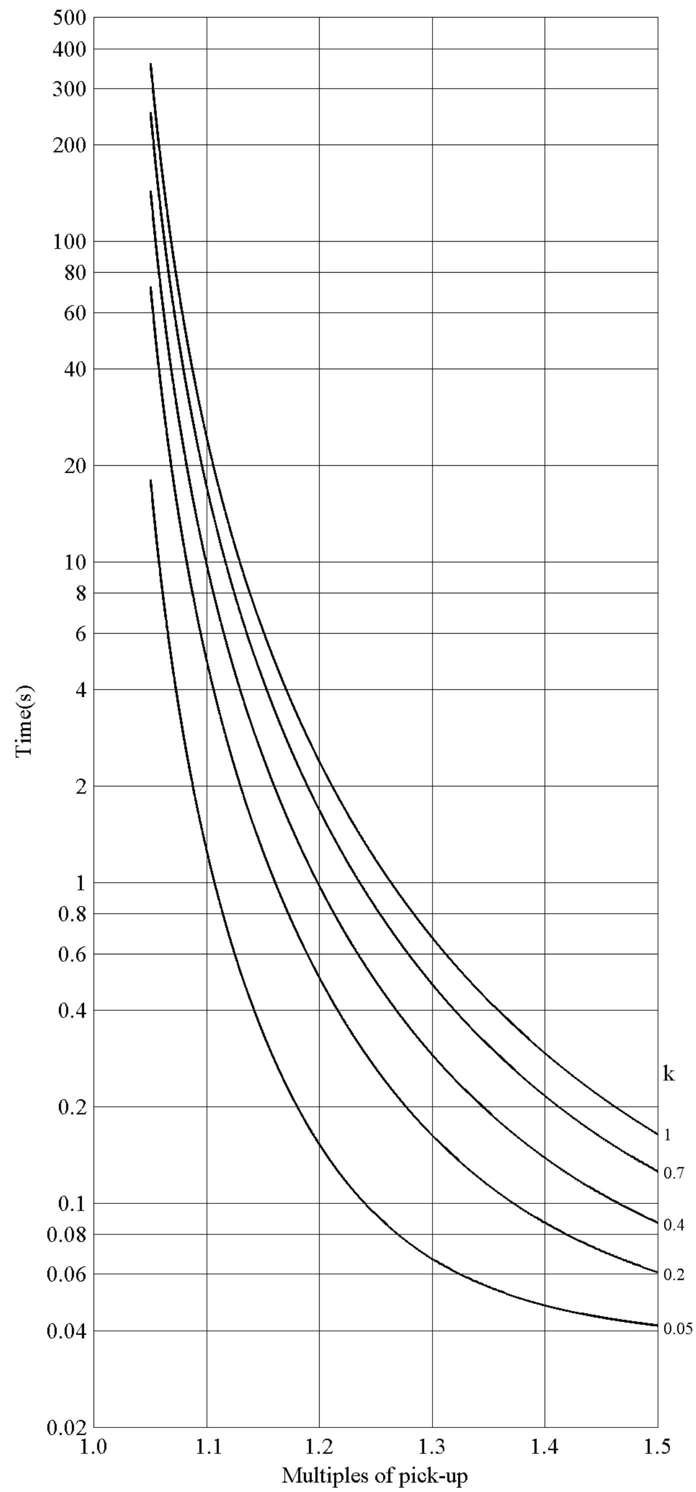


Figure 309: Inverse curve C characteristic of overvoltage protection

10.3.1.2 User programmable inverse-time characteristics for overvoltage protection

The user can define the curves by entering the parameters using the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V - V>}{V>} - C\right)^{E}} + D$$

(Equation 65)

t[s]	trip time in seconds
A	the set value of *Curve parameter A*
B	the set value of *Curve parameter B*
C	the set value of *Curve parameter C*
D	the set value of *Curve parameter D*
E	the set value of *Curve parameter E*
V	measured voltage
V>	the set value of *Pickup value*
k	the set value of *Time multiplier*

10.3.1.3 IDMT curve saturation of overvoltage protection

For the overvoltage IDMT mode of operation, the integration of the trip time does not start until the voltage exceeds the value of *Pickup value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared to *Pickup value*. For example, due to the curve equation B and C, the characteristics equation output is saturated in such a way that when the input voltages are in the range of *Pickup value* to *Curve Sat Relative* in percent over *Pickup value*, the equation uses *Pickup value* * (1.0 + *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio V/V> exceeds the unity, *Curve Sat Relative* is also set for it. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning the discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum trip time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

10.3.2 IDMT curves for undervoltage protection

In the inverse-time modes, the trip time depends on the momentary value of the voltage, the lower the voltage, the faster the trip time. The trip time calculation or integration starts immediately when the voltage goes below the set value of the *Pickup value* setting and the `PICKUP` output is activated.

The `TRIP` output of the component is activated when the cumulative sum of the integrator calculating the undervoltage situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum trip time* setting defines the minimum trip time possible for the IDMT mode. For setting a value for this parameter, the user should carefully study the particular IDMT curve.

10.3.2.1 Standard inverse-time characteristics for undervoltage protection

The trip times for the standard undervoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse trip time can be calculated with the formula:

$$t\left[s\right]=\frac{k\cdot A}{\left(B\times\frac{V<-V}{V<}-C\right)^{E}}+D$$

(Equation 66)

t [s] trip time in seconds
V measured voltage
V< the set value of the *Pickup value* setting
k the set value of the *Time multiplier* setting

Table 426: 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

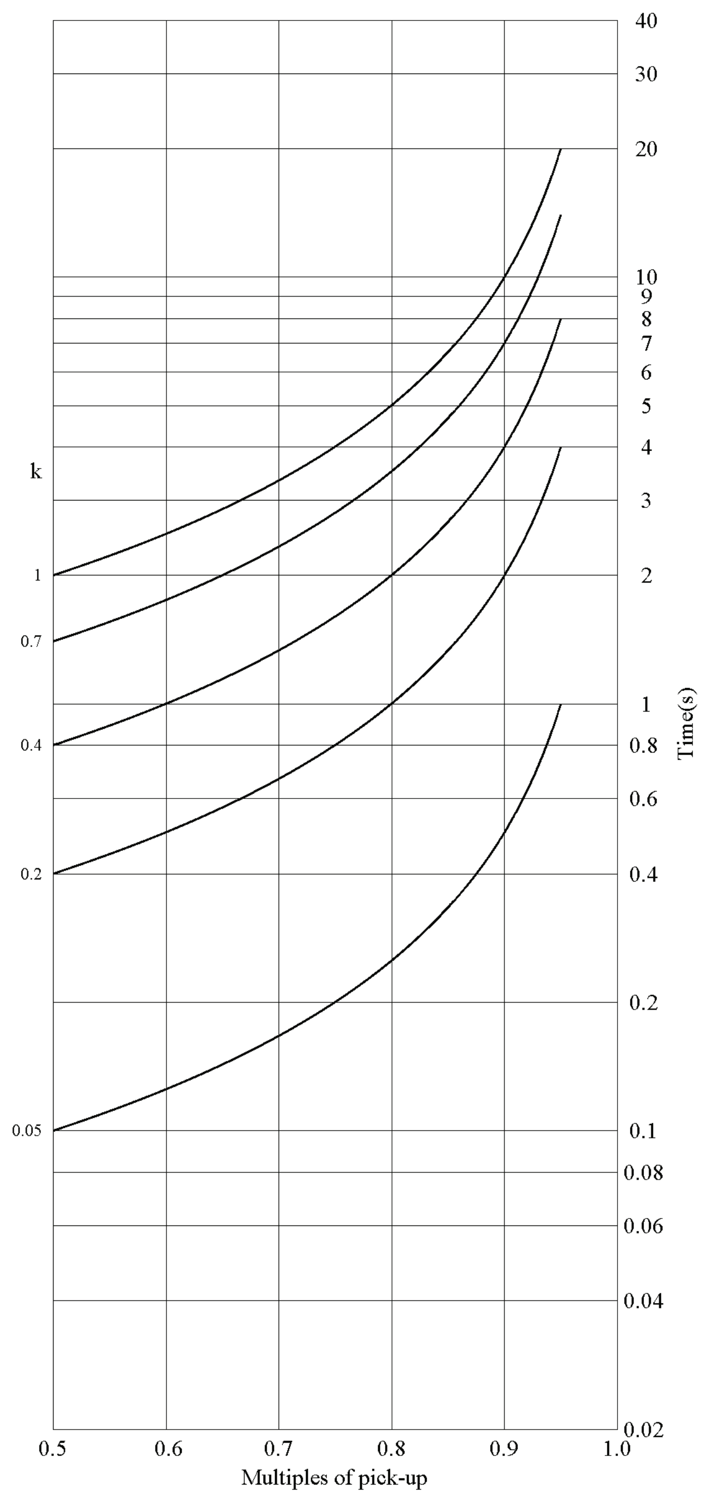


Figure 310: Inverse curve A characteristic of undervoltage protection

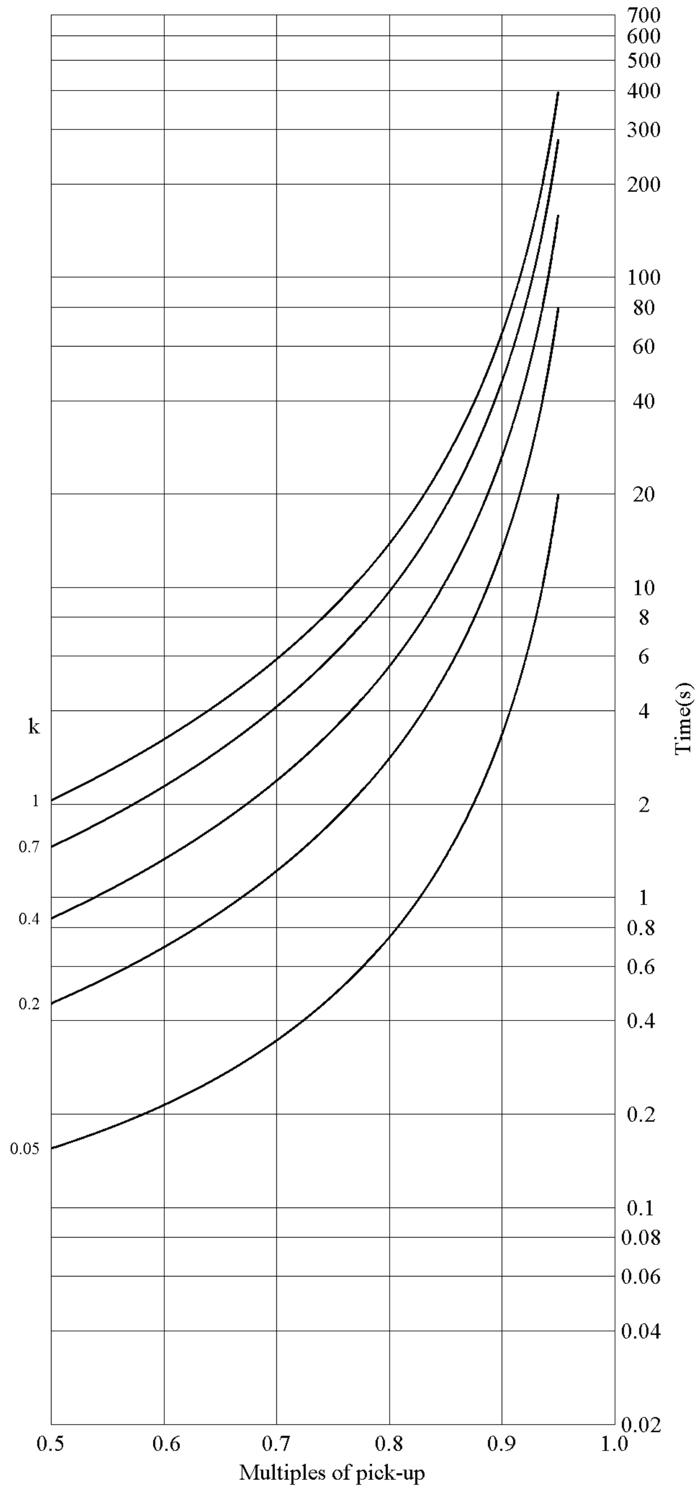


Figure 311: Inverse curve B characteristic of undervoltage protection

10.3.2.2 User-programmable inverse-time characteristics for undervoltage

protection

The user can define curves by entering parameters into the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{V < -V}{V <} - C\right)^{E}} + D$$

(Equation 67)

t[s]	trip time in seconds
A	the set value of *Curve parameter A*
B	the set value of *Curve parameter B*
C	the set value of *Curve parameter C*
D	the set value of *Curve parameter D*
E	the set value of *Curve parameter E*
V	measured voltage
V<	the set value of *Pickup value*
k	the set value of *Time multiplier*

10.3.2.3 IDMT curve saturation of undervoltage protection

For the undervoltage IDMT mode of operation, the integration of the trip time does not start until the voltage falls below the value of *Pickup value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared with *Pickup value*. For example, due to the curve equation B, the characteristics equation output is saturated in such a way that when input voltages are in the range from *Pickup value* to *Curve Sat Relative* in percents under *Pickup value*, the equation uses *Pickup value* * (1.0 - *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio V/V> exceeds the unity, *Curve Sat Relative* is set for it as well. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning also discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum trip time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

10.4 Measurement modes

In many current or voltage dependent function blocks, there are four alternative measuring principles:

- RMS
- DFT which is a numerically calculated fundamental component of the signal
- Peak-to-peak
- Peak-to-peak with peak backup

Consequently, the measurement mode can be selected according to the application.

In extreme cases, for example with high overcurrent or harmonic content, the measurement modes function in a slightly different way. The 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 68)

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 relay inputs. Consequently, this mode is usually used in conjunction with high and instantaneous stages, where the suppression of harmonics is not so important. In addition, the peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.

Peak-to-peak with peak backup

The peak-to-peak with peak backup measurement principle is selected with the *Measurement mode* setting using the value *"*P-to-P+backup*"*. It is similar to the peak-to-peak mode, with the exception that it has been enhanced with the peak backup. In the peak-to-peak with peak backup mode, the function starts with two conditions: the peak-to-peak value is above the set pickup current or the peak value is above two times the set *Pickup value*. The peak backup is enabled only when the function is used in the DT mode in high and instantaneous stages for faster operation.

Section 11 Requirements for measurement transformers

11.1 Current transformers

11.1.1 Current transformer requirements for non-directional overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden. The protection settings of the relay should be defined in accordance with the CT performance as well as other factors.

Appropriate 'C' class CT should be used based on the total resistances of the CT secondary circuit. If other accuracy class CTs are used then refer the following discussions.

11.1.1.1 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 427: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The 5P class provides a better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering, and so on) of the relay.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it might have severe effects on the performance of the protection relay.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

11.1.1.2 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 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 relay. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended pickup current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to trip, the pickup current should be set using the formula:

Current pickup value < 0.7 x (I_{kmin} / I_{1n})

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection relay inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The trip time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a.

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the pickup current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed relay operation. To ensure the time selectivity, the delay must be taken into account when setting the trip times of successive relays.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time constant of the DC component of the fault current, when the current is only slightly higher than the pickup current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the trip time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

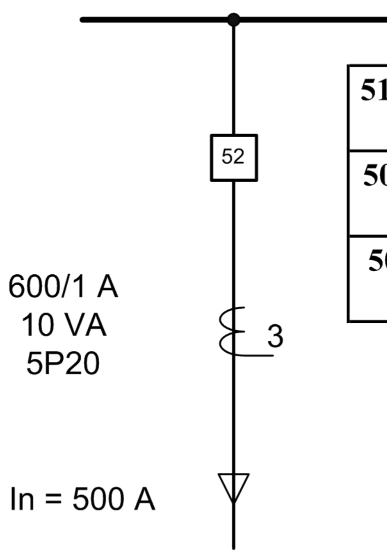
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the pickup current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

F_a > 20*Current pickup value / I_{1n}

The Current pickup value is the primary pickup current setting of the relay.

11.1.1.3 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.



51P	**1200 A**	**2.00 x I_{2n}**
	0.75 s	**0.75 s**
50P-1/2	**1800A**	**3.00 x I_{2n}**
	0.50 s	**0.50 s**
50P-3	**3500 A**	**5.83 x I_{2n}**
	0.20 s	**0.20 s**

Figure 312: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next relay (not visible in the figure above). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the pickup current settings have to be defined so that the relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in the figure above.

For the application point of view, the suitable setting for instantaneous stage (50P-3) in this example is 3 500 A (5.83 x I_{2n}). For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 12 Relay physical connections

All external circuits are connected to the terminals on the rear panel of the relay.

- Connect each signal connector (X100 and X110) terminal with one 14 or 16 Gauge wire. Use 12 or 14 Gauge wire for CB trip circuit.
- Connect each ring-lug terminal for signal connector X120 with one of maximum 14 or 16 Gauge wire.
- Connect each ring-lug terminal for CTs/VTs with one 12 Gauge wire.

12.1 Protective ground connections

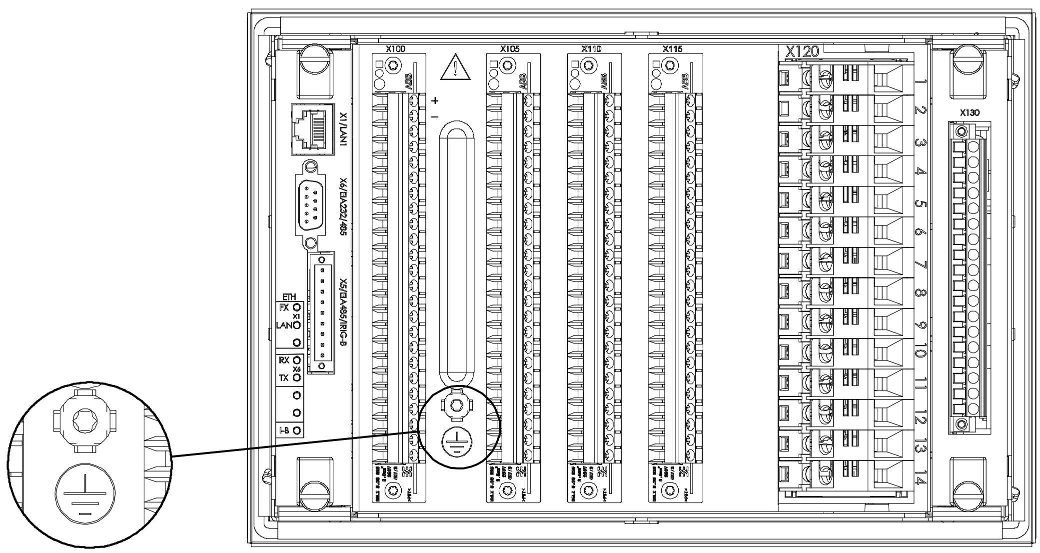


Figure 313: The protective ground screw is located between connectors X100 and X105

The ground lead must be at least 4.0 mm^2 and as short as possible.

12.2 Communication connections

The front communication connection is an RJ-45 type connector used mainly for configuration and setting.

Depending on order code, several rear port communication connections are available.

- Galvanic RJ-45 Ethernet connection
- Optical LC Ethernet connection
- ST-type glass fibre serial connection
- EIA-485 serial connection
- EIA-232 serial connection

12.2.1 Ethernet RJ-45 front connection

The relay is provided with an RJ-45 connector on the LHMI. The connector is mainly for configuration and setting purposes. The interface on the PC side has to be configured in a way that it obtains the IP address automatically. There is a DHCP server inside 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 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.

12.2.2 Ethernet rear connections

The Ethernet communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection depending on the product variant and selected communication interface option. A shielded twisted-pair cable CAT 5e is used with RJ-45, and an optical cable (≤2 km) with LC type connections.

The relay's default IP address through this port is 192.168.2.10 with the TCP/IP protocol. The data transfer rate is 100 Mbps.

The rear and front ethernet ports must be in the different networks.

12.2.3 EIA-232 serial rear connection

The EIA-232 connection follows the TIA/EIA-232 standard and is intended to be used with a point-to-point connection. The connection supports hardware flow control (RTS, CTS, DTR, DSR), full-duplex and half-duplex communication.

12.2.4 EIA-485 serial rear connection

The EIA-485 communication module follows the TIA/EIA-485 standard and is intended to be used in a daisy-chain bus wiring scheme with 2-wire half-duplex or 4-wire full-duplex, multi-point communication.

The maximum number of devices (nodes) connected to the bus where the relay is used is 32, and the maximum length of the bus is 1200 meters.

12.2.5 Optical ST serial rear connection

Serial communication can be used optionally through an optical connection either in loop or star topology. The connection idle state is light on or light off.

12.2.6 Communication interfaces and protocols

The communication protocols supported depend on the optional rear communication module.

Table 428: Supported communication interfaces and protocols

Interfaces/Protocols	Ethernet		Serial	
	100BASE-TX RJ-45	100BASE-FX LC	EIA-232/EIA-485	Fibre-Optic ST
IEC 61850-8-1	●	●	-	-
MODBUS RTU/ASCII	-	-	●	●
MODBUS TCP/IP	●	●	-	-
DNP3, Serial	-	-	●	●
DNP3, TCP/IP	●	●	-	-
PG&E 2179	-	-	●	-

12.2.7 Rear communication modules

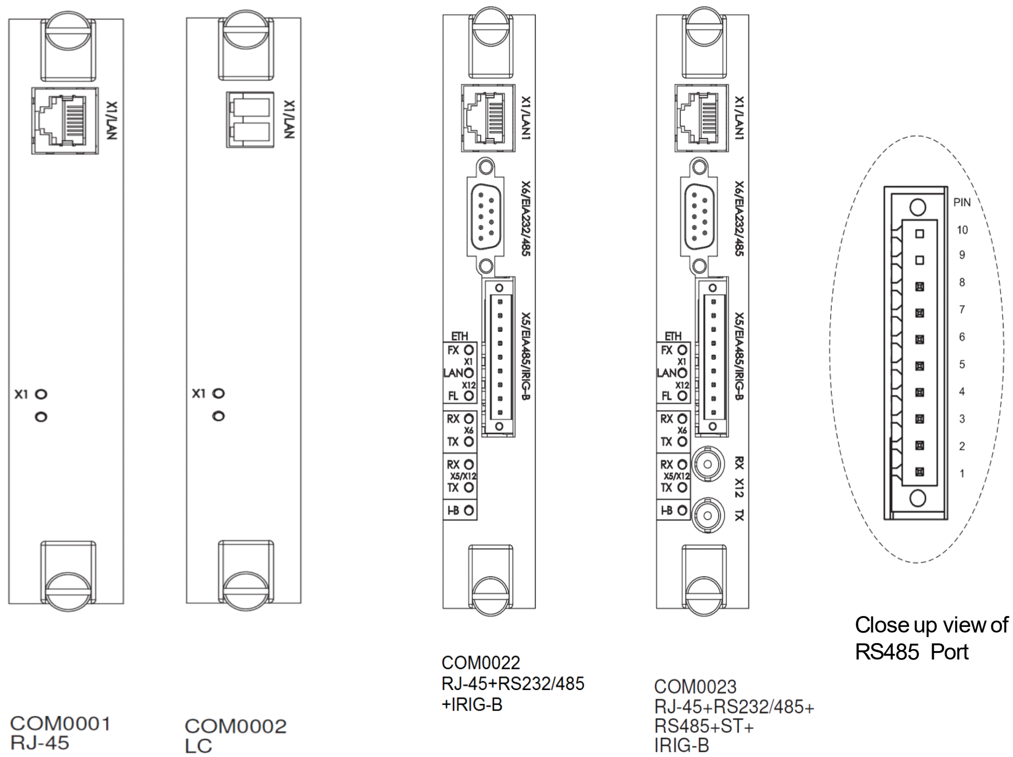


Figure 314: Communication module options

Table 429: Communication interfaces included in communication modules

Module ID	RJ-45	LC	EIA-485/232	EIA-485 / IRIG-B	ST
COMB01A	●	-	-	-	-
COMB02A	-	●	-	-	-
COMB22A	●	-	●	●	-
COMB23A	●	-	●	●	●

Table 430: LED descriptions for COMB01, COMB02

LED	Connector	Description
LAN	X1	LAN link status and activity (RJ-45 and LC)

Table 431: LED descriptions for COMB 22/23A

LED	Connector	Description[1]
FX	X12	Not used
LAN	X1	LAN Link status and activity (RJ-45 and LC)
FL	X12	Not used
RX	X6	COM1 2-wire / 4-wire receive activity
TX	X6	COM1 2-wire / 4-wire transmit activity
RX	X5 / X12	COM2 2-wire / 4-wire or fiber-optic receive activity
TX	X5 / X12	COM2 2-wire / 4-wire or fiber-optic transmit activity
I-B	X5	IRIG-B Signal activity

1. Depending on the jumper configuration

12.2.7.1 COMB022/23A jumper locations and connections

The optional communication module supports EIA-232/EIA-485 serial communication (X6 connector), EIA-485 serial communication (X5 connector) and optical ST serial communication (X12 connector).

Two independent communication ports are supported. The two 2-wire-ports are called COM1 and COM2. Alternatively, if only one 4-wire-port is configured, the port is called COM2. The fibre-optic ST connection uses the COM2 port.

Table 432: Configuration options of the two independent communication ports

COM1 connector X6	COM2 connector X5 or X12
EIA-232	Optical ST (X12)
EIA-485 2-wire	EIA-485 2-wire (X5)
EIA-485 4-wire	EIA-485 4-wire (X5)

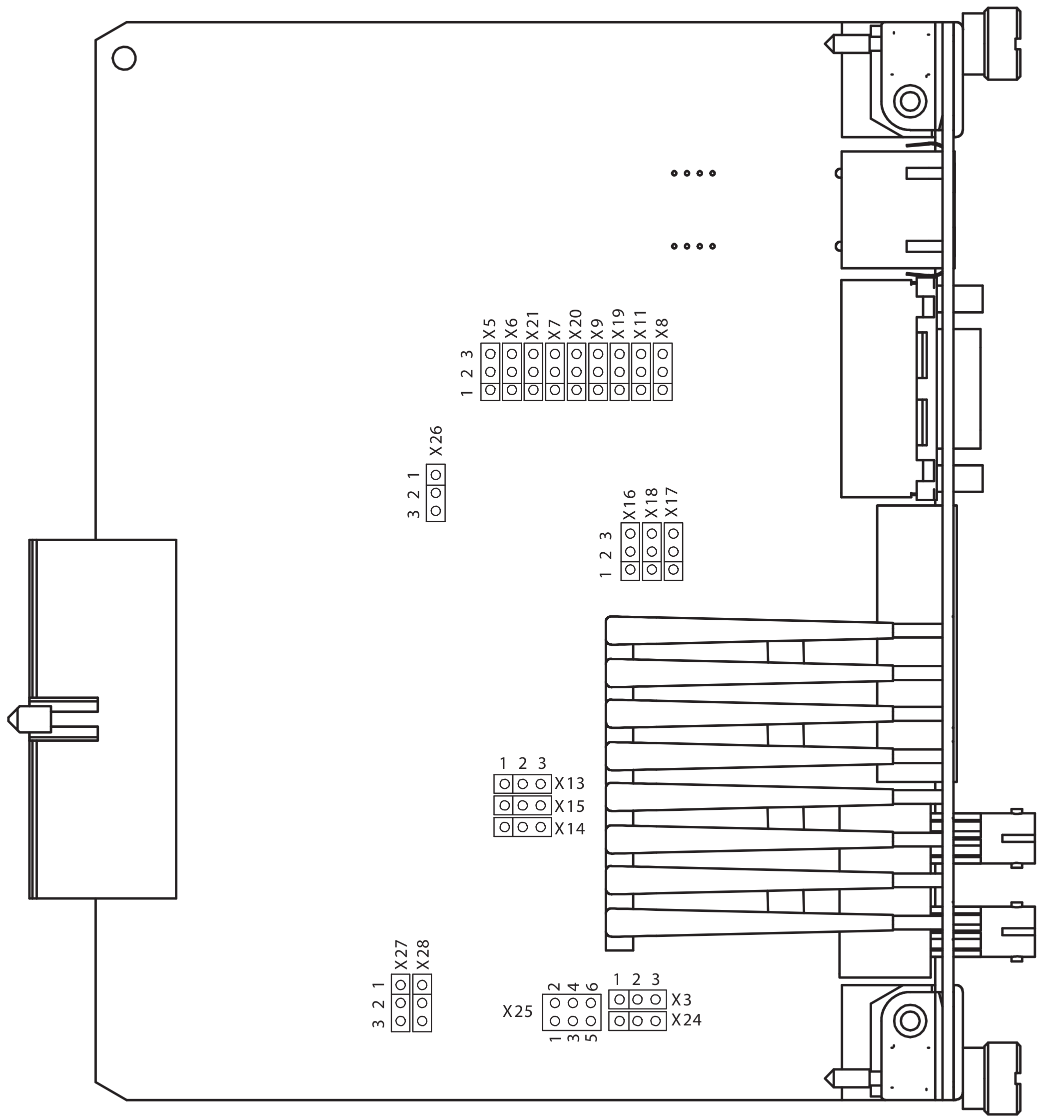


Figure 315: Jumper connections on communication module COMB022/023A

COM1 port connection type can be either EIA-232 or EIA-485. Type is selected by setting jumpers X19, X20, X21, X26.

The jumpers are set to EIA-232 by default.

Table 433: EIA-232 and EIA-485 jumper connectors for COM1

Group	Jumper connection	Description
X19	1-2 2-3	EIA-485 EIA-232
X20	1-2 2-3	EIA-485 EIA-232
X21	1-2 2-3	EIA-485 EIA-232
X26	1-2 2-3	EIA-485 EIA-232

To ensure fail-safe operation, the bus is to be biased at one end using the pull-up and pull-down resistors on the communication module. In the 4-wire connection, the pull-up and pull-down resistors are selected by setting jumpers X5, X6, X8, X9 to enabled position. The bus termination is selected by setting jumpers X7, X11 to enabled position.

The jumpers have been set to no termination and no biasing as default.

Table 434: 2-wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1-2 2-3	A+ bias enabled A+ bias disabled[1]	COM1 Rear connector X6 2-wire connection
X6	1-2 2-3	B- bias enabled B- bias disabled	
X7	1-2 2-3	Bus termination enabled Bus termination disabled	

1. Default setting

Table 435: 4–wire EIA-485 jumper connectors for COM1

Group	Jumper connection	Description	Notes
X5	1-2 2-3	A+ bias enabled A+ bias disabled[1]	COM1 Rear connector X6 4-wire TX channel
X6	1-2 2-3	B- bias enabled B- bias disabled	
X7	1-2 2-3	Bus termination enabled Bus termination disabled	
X9	1-2 2-3	A+ bias enabled A+ bias disabled	4-wire RX channel
X8	1-2 2-3	B- bias enabled B- bias disabled	
X11	1-2 2-3	Bus termination enabled Bus termination disabled	

1. Default setting

COM2 port connection can be either EIA-485 or optical ST. Connection type is selected by setting jumpers X27 and X28.

Table 436: COM2 serial connection X5 EIA-485/ X12 Optical ST

Group	Jumper connection	Description
X27	1-2 2-3	EIA-485 Optical ST
X28	1-2 2-3	EIA-485 Optical ST

Table 437: 2-wire EIA-485 jumper connectors for COM2

Group	Jumper connection	Description
X13	1-2 2-3	A+ bias enabled A+ bias disabled
X14	1-2 2-3	B- bias enabled B- bias disabled
X15	1-2 2-3	Bus termination enabled Bus termination disabled

Table 438: 2-wire EIA-485 jumper connectors for COM2

<table>
<tr><th>Group</th><th>Jumper connection</th><th>Description</th><th>Notes</th></tr>
<tr><td>X13</td><td>1-2
2-3</td><td>A+ bias enabled
A+ bias disabled</td><td rowspan="3">COM2
4-wire TX channel</td></tr>
<tr><td>X14</td><td>1-2
2-3</td><td>B- bias enabled
B- bias disabled</td></tr>
<tr><td>X15</td><td>1-2
2-3</td><td>Bus termination enabled
Bus termination disabled</td></tr>
<tr><td>X17</td><td>1-2
2-3</td><td>A+ bias enabled
A+ bias disabled</td><td rowspan="3">4-wire RX channel</td></tr>
<tr><td>X18</td><td>1-2
2-3</td><td>B- bias enabled
B- bias disabled</td></tr>
<tr><td>X19</td><td>1-2
2-3</td><td>Bus termination enabled
Bus termination disabled</td></tr>
</table>

Table 439: X12 Optical ST connection

Group	Jumper connection	Description
X3	1-2 2-3	Star topology Loop topology
X24	1-2 2-3	Idle state = Light on Idle state = Light off

Table 440: EIA-232 connections (X6)

Pin	EIA-232
1	DCD
2	RxD
3	TxD
4	DTR
5	AGND
6	-
7	RTS
8	CTS

Table 441: EIA-485 connections (X6)

Pin	2-wire mode	4-wire mode
1	-	Rx/+
6	-	Rx/-
7	B/-	Tx/-
8	A/+	Tx/+

Table 442: EIA-485 connections (X5)

Pin	2-wire mode	4-wire mode
9	-	Rx/+
8	-	Rx/-
7	A/+	Tx/+
6	B/-	Tx/-
5	AGND (isolated ground)	
4	IRIG-B +	
3	IRIG-B -	
2	-	
1	GND (case)	

Section 13 Technical data

Table 443: Dimensions

Description	Value	
Width	frame	10.32 inches (262.2 mm)
	case	9.69 inches (246 mm)
Height	frame	6.97 inches (177 mm), 4U
	case	6.30 inches (160 mm)
Depth		7.91 inches (201 mm)
Weight	Complete relay	10.5 lbs (4.8 kg)
	Plug-in unit only	6.0 lbs (2.8 kg)

Table 444: Power supply

Description	Type 2
V nominal (V_n)	60 V DC
V_n variation	50 to 120% of V_n (30 to 72 V DC)
Start-up threshold	48 V DC (60 V DC × 80%)
Burden of auxiliary voltage supply under quiescent (P_q)/operating condition	DC < 6.9 W (nominal)/< 13.3 W (max)
Ripple in the DC auxiliary voltage	Max 12% of the DC value (at frequency of 2 × f_n Hz)
Maximum interruption time in the auxiliary DC voltage without resetting the relay	50 ms at 60 V DC
Fuse type	T4A/250 V

Table 445: Uninterruptible Power Supply (UPS) tests

Test	Type test value	Reference
Control voltage (IEEE C37.90-2005) • UPS0001 • UPS0002	90 to 150 V AC 180 to 280V AC	No influence No influence
Control power interruptions (IEC 60255-11-2008) • UPS0001 and UPS0002	60 VDC	2 seconds (no battery)
IEEE C37.60 - 2003 • UPS0001 and UPS0002	15 kV, 27 kV, 38 kV reclosers	No influence
Power consumption (IEEE C37.90-2005) • UPS0001 • UPS0002	90 to 150 VAC 180 to 280 VAC	25 W (nominal)/~120 W (max)
Auxiliary Power Supply	12 VDC & 24 VDC	20 W (nominal)/~24 W (max)
Battery Charger	48 VDC	35 W max
Battery Run Time	38 hr	48 VDC 12 amp hr. battery with standard load (15 W)
Boost Supply	Programmable 61-250 VDC	80 W max

Table 446: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz ± 5 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	100 V AC/ 110 V AC/ 115 V AC/ 120 V AC (Parametrization)	
	Voltage withstand: • Continuous • For 10 s	 2 x V_n (240 V) 3 x V_n (360 V)	
	Burden at rated voltage	<0.05 VA	

1. Ordering option for ground current input
2. Ground current and/or phase current

Table 447: Binary inputs

Description	Value
Operating range	±20% of the rated voltage
Rated voltage	24...250 V DC
Current drain	1.6...1.9 mA
Power consumption	31.0...570.0 mW
Threshold voltage	18...176 V DC
Reaction time	3 ms

Table 448: 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	100 mA at 24 V AC/DC

Table 449: Double-pole power output relays with TCM function

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC (two contacts connected in series)	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC
Trip-circuit monitoring (TCM):	
• Control voltage range	20...250 V AC/DC
• Current drain through the monitoring circuit	~1.5 mA
• Minimum voltage over the TCS contact	20 V AC/DC (15...20 V)

Table 450: 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, at 48/110/220 V DC	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC

Table 451: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front	TCP/IP protocol	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s
Rear	TCP/IP protocol	Shielded twisted pair CAT 5e cable with RJ-45 connector or fibre-optic cable with LC connector	100 MBits/s

Table 452: Serial rear interface

Type	Counter connector
Serial port (X5)	10-pin counter connector Weidmüller BL 3.5/10/180F AU OR BEDR or 9-pin counter connector Weidmüller BL 3.5/9/180F AU OR BEDR[1]
Serial port (X16)	9-pin D-sub connector DE-9
Serial port (X12)	Optical ST-connector

1. Depending on the optional communication module

Table 453: Fibre-optic communication link

Connector	Fibre type	Wave length	Max. distance	Permitted path attenuation[1]
LC	MM 62.5/125 μm glass fibre core	1300 nm	2 km	<8 dB
ST	MM 62.5/125 μm glass fibre core	820-900 nm	1 km	<11 dB

1. Maximum allowed attenuation caused by connectors and cable together

Table 454: IRIG-B

Description	Value
IRIG time code format	B004,B005[1]
Isolation	500V, 1 Min.
Modulation	Unmodulated
Logic level	TTL Level
Current consumption	2...4 mA
Power consumption	10...20 mW

1. According to 200-04 IRIG -standard

Table 455: Lens sensor and optical fiber for arc flash detector

Description	Value
Fiber-optic cable including lens	1.5 m, 3.0 m or 5.0 m
Normal service temperature range of the lens	-40...+100 °C
Maximum service temperature range of the lens, max 1 h	+140°C
Minimum permissible bending radius of the connection fiber	3.94 inches (100 mm)

Table 456: Degree of protection of flush-mounted relay

Description	Value
Front side	IP 54
Back side	IP 20

Table 457: Environmental conditions

Description	Value
Continuous operating temperature range	-25ºC to +55ºC
Short-term operating temperature range	-40ºC to +85ºC (<12h)[1, 2]
Relative humidity	<93%, non-condensing
Atmospheric pressure	12.47 to 15.37 psi (86 to 106 kPa)
Altitude	Up to 6561.66 feet (2000 m)
Transport and storage temperature range	-40ºC to +85ºC

1. Degradation in MTBF and LHMI performance outside the temperature range of -25ºC to +55ºC
2. For relays with an LC communication interface, the maximum operating temperature is +70ºC

Table 458: Environmental tests

Description	Requirement	Reference
Dry heat test	+85ºC 12h[1, 2]	IEEE C37.90-2005
Dry cold test	-40ºC 12h [2, 3]	IEEE C37.90-2005
Damp heat test	+25ºC Rh = 95%, 96h	IEEE C37.90-2005
Storage test	+85ºC 96h -40ºC 96h	IEEE C37.90-2005

1. For relays with an LC communication interface, the maximum operating temperature is +70ºC.
2. LCD may be unreadable, but relay is operational.
3. For PS_L (24-60 Vdc), the minimum start up voltage is 48Vdc at -40ºC.

Section 14 Relay and functionality tests

Table 459: Electromagnetic compatibility tests

Description	Type test value	Reference
1 MHz/100 kHz burst disturbance test:		IEEE C37.90.1-2002
• Common mode	2.5 kV	
• Differential mode	2.5 kV	
Electrostatic discharge test:		IEEE C37.90.3.2001
• Contact discharge	±8 kV	
• Air discharge	±15 kV	
Radio frequency interference tests:		IEEE C37.90.2-2004
• Frequency step	20V/m, f=80 to 1000 MHz Frequency step 1%, time step 0.5s	
• Keying test	20V/m, f=80 to 1000 MHz, Frequency step 1%, On for 0.5s, off for 0.5s	
• Spot frequencies	20V/m, f=80,160,450,900 MHz	
Fast transient disturbance tests: All ports		IEEE C37.90.1.-2002
• Common mode	±4 kV	
• Differential mode	±4 kV	

Table 460: Mechanical tests

Description	Requirement	Reference
Vibration tests (sinusoidal)	Class 2	IEC 60255-21-1-1998
Shock and bump tests	Class 2	IEC 60255-21-2-1998
Mechanical durability	• 200 withdrawals and insertions of the plug-in unit • 200 adjustments of relay setting controls	IEEE C37.90-2005

Section 15 Applicable standards and regulations

EN 50263

EN 60255-26

EN 60255-27

EMC council directive 2004/108/EC

EU directive 2002/96/EC/175

IEC 60255

IEEE C37.90.1-2002

IEEE C37.90.2-2004

IEEE C37.90.3-2001

Low-voltage directive 2006/95/EC

Section 16 Glossary

615/RER620	Series of numerical relays for basic, inexpensive and simple protection and supervision applications of utility substations, and industrial switchgear and equipment
100BASE-FX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fibre-optic cabling
100BASE-TX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
ANSI	American National Standards Institute
AR	Auto-Recloser
CAT 5	A twisted pair cable type designed for high signal integrity
CAT 5e	An enhanced version of CAT 5 that adds specifications for far end crosstalk
CB	Circuit breaker
CBB	Cycle building block
CPU	Central processing unit
CT	Current transformer
CTS	Clear to send
DFR	Digital fault recorder
DFT	Discrete Fourier Transform
DHCP	Dynamic Host Configuration Protocol
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DSR	Data set ready
DT	Definite time
DTR	Data terminal ready
EEPROM	Electrically erasable programmable read-only memory
EIA-232	Serial communication standard according to Electronics Industries Association
EIA-485	Serial communication standard according to Electronics Industries Association
EMC	Electromagnetic compatibility
FPGA	Field programmable gate array
GOOSE	Generic Object Oriented Substation Event

HMI	Human-machine interface
HW	Hardware
IDMT	Inverse definite minimum time
IEC 61850	International standard for substation communication and modelling
Relay	Intelligent electronic device
IP	Internet protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
NPS	Negative Phase Sequence
PC	Personal computer; Polycarbonate
PCM600	Protection and Control Relay Manager
Peak-to-peak	The amplitude of a waveform between its maximum positive value and its maximum negative value; A measurement principle, where the measurement quantity is made by calculating the average from the positive and negative peak values without including the DC component. The peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.
Peak-to-peak with peak backup	A measurement principle similar to the peak-to-peak mode but with the function picking up on two conditions: the peak-to-peak value is above the set pickup current or the peak value is above two times the set pickup value
RAM	Random access memory
RCA	Also known as MTA or base angle. Characteristic angle.
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
ROM	Read-only memory
RTC	Real-time clock
RTS	Ready to send

SBO	Select-before-operate
SCL	Substation configuration language
SMT	Signal Matrix Tool in PCM600
SNTP	Simple Network Time Protocol
SOTF	Switch on to fault
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
TRMS	True root-mean-square (value)
UTC	Coordinated universal time
WAN	Wide area network
WHMI	Web human-machine interface

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