



Relion® 615 series

Line Differential Protection and Control RED615 Application Manual

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Section 1 Introduction

1.1 This manual

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.

1.2 Intended audience

This manual addresses the protection and control engineer responsible for planning, pre-engineering and engineering.

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as protection schemes and principles.

1.3 Product documentation

1.3.1 Product documentation set

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 communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

The engineering guide provides information for IEC 61850 engineering of the 615 series protection IEDs with PCM600 and IET600. This guide concentrates especially on the configuration of GOOSE communication with these tools. The guide can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. For more details on tool usage, see the PCM600 documentation.

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs 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 other supported protocols.

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

The operation manual contains instructions on how to operate the IED once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the IED. 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 point list manual describes the outlook and properties of the data points specific to the IED. The manual should be used in conjunction with the corresponding communication protocol 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.

1.3.2

Document revision history

Document revision/date	Product version	History
A/2008-10-03	1.1	First release
B/2009-07-03	2.0	Content updated to correspond to the product version
C/2010-06-11	3.0	Content updated to correspond to the product version
D/2010-06-29	3.0	Terminology updated
E/2010-09-24	3.0	Content updated
F/2012-05-11	4.0	Content updated to correspond to the product version



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1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS756468
DNP3 Communication Protocol Manual	1MRS756709
IEC 60870-5-103 Communication Protocol Manual	1MRS756710
IEC 61850 Engineering Guide	1MRS756475
Engineering Manual	1MRS757121
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887
CT dimensioning, Application Note and Setting Guide	1MRS756683

1.4 Symbols and conventions

1.4.1 Symbols



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



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



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



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



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

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged

equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms 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.
To navigate between the options, use  and .
- HMI menu paths are presented in bold.
Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
To save the changes in non-volatile memory, select Yes and press .
- Parameter names are shown in italics.
The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
The corresponding parameter values are "On" and "Off".
- IED input/output messages and monitored data names are shown in Courier font.
When the function starts, the START output is set to TRUE.

1.4.3 Functions, codes and symbols

Table 1: *RED615 functions, codes and symbols*

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Admittance based earth-fault protection	EFPADM1	Yo> -> (1)	21YN (1)
	EFPADM2	Yo> -> (2)	21YN (2)
	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection	WPWDE1	Po> -> (1)	32N (1)
	WPWDE2	Po> -> (2)	32N (2)
	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Binary signal transfer	BSTGGIO1	BST	BST
Line differential protection and related measurements, stabilized and instantaneous stages	LNPLDF1	3dI>L	87L
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnecter control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnecter position indication	DCSXSXI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSXI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSXI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSXI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSXI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Protection communication supervision	PCSRTPC1	PCS	PCS
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement	RESCMMXU1	Io	In
Residual voltage measurement	RESVMMXU1	Uo	Vn

Section 2 RED615 overview

2.1 Overview

RED615 is a phase-segregated two-end line differential protection and control IED (intelligent electronic device) designed for utility and industrial power systems, including radial, looped and meshed distribution networks with or without distributed power generation. The RED615s communicate between substations over a fibre-optic link or a galvanic pilot wire connection. RED615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series IEDs are characterized by their compactness and withdrawable-unit design. Re-engineered from the ground up, the 615 series has been guided by the IEC 61850 standard for communication and interoperability of substation automation equipment.

The IED provides unit type main protection for overhead lines and cable feeders in distribution networks. The IED also features current-based protection functions for remote back-up for down-stream protection IEDs and local back-up for the line differential main protection. Further, standard configurations B and C also include earth-fault protection.

The IED is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance earthed, compensated (impedance earthed) and solidly earthed networks. Once the IED has been given the application-specific settings, it can directly be put into service.

The 615 series IEDs support a range of communication protocols including IEC 61850 with GOOSE messaging, IEC 60870-5-103, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
1.1	Product released
2.0	• Support for DNP3 serial or TCP/IP • Support for IEC 60870-5-103 • New standard configurations B and C • Disturbance recorder upload via WHMI
3.0	• Additions to configuration B • Application configurability support • Analog GOOSE support • Large display with single line diagram • Enhanced mechanical design • Increased maximum amount of events and fault records • Admittance-based earth-fault protection • Residual overvoltage protection • Low voltage power supply option • Pilot wire modem support
4.0	• Additions/changes for configurations A-C • Dual fibre optic Ethernet communication option (COM0032) • Generic control point (SPCGGIO) function blocks • Additional logic blocks • Button object for SLD • Controllable disconnecter and earth switch objects for SLD • Wattmetric based E/F • Harmonics based E/F • Increased maximum amount of events and fault records

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.4 SP1 or later
- RED615 Connectivity Package Ver. 4.0 or later
 - Parameter Setting
 - Firmware Update
 - Disturbance Handling
 - Signal Monitoring
 - Lifecycle Traceability
 - Signal Matrix
 - Communication Management
 - Configuration Wizard
 - Label Printing
 - IED User Management
 - Application Configuration
 - Graphical Display Editor
 - Differential Characteristics Tool
 - Event Viewer



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

2.2 Operation functionality

2.2.1 Optional functions

- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Admittance based earth-fault (configuration B only)
- Watt-metric based earth-fault (configuration B only)
- Harmonics based earth-fault (configuration B and C only)

2.3 Physical hardware

The IED consists of two main parts: plug-in unit and case. The content depends on the ordered functionality.

Table 2: *Plug-in unit and case*

Main	Slot ID	Content options	
Plug-in unit	-	HMI	Small (4 lines, 16 characters) Large (8 lines, 16 characters)
	X100	Auxiliary power/BO module	48-250V DC/100-240 V AC; or 24-60 V DC 2 normally-open PO contacts 1 change-over SO contacts 1 normally open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BIO module	8 binary inputs 4 signal output contacts
	X120	AI/BI module	Only with configuration B: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A) ¹⁾ 1 residual voltage input (60-210 V) 3 binary inputs
		AI/BI module	Only with configurations A and C: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A) 4 binary inputs
Case	X130	Optional BIO module	6 binary inputs 3 signal output contacts
	X000	Optional communication module	See technical manual for details about different type of communication modules.

1) The 0.2/1 A input is normally used in applications requiring sensitive earth-fault protection and featuring core-balance current transformers.

Rated values of the current and voltage inputs are basic setting parameters of the IED. The binary input thresholds are selectable within the range 18...176 V DC by adjusting the binary input setting parameters.



See the installation manual for more information about the case and the plug-in unit.

The connection diagrams of different hardware modules are presented in this manual.

Table 3: *Number of physical connections in standard configurations*

Conf.	Analog channels		Binary channels	
	CT	VT	BI	BO
A	4	-	12 (18) ¹⁾	10 (13) ¹⁾
B	4	1	11 (17) ¹⁾	10 (13) ¹⁾
C	4	-	12 (18) ¹⁾	10 (13) ¹⁾

1) With optional BIO module

2.4 Local HMI

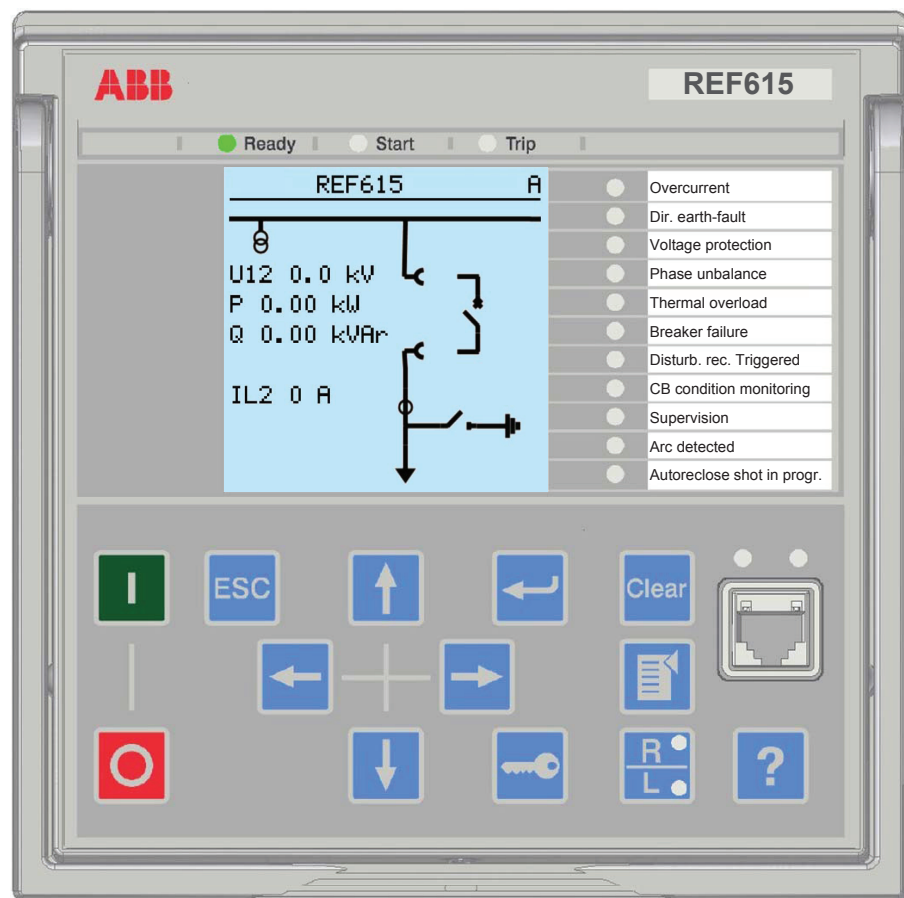


Figure 1: Example of 615 series LHMI

The LHMI of the IED contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

2.4.1 Display

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

Table 4: Characters and rows on the view

Character size	Rows in view	Characters on row
Small, mono-spaced (6x12 pixels)	5 rows 10 rows with large screen	20
Large, variable width (13x14 pixels)	4 rows 8 rows with large screen	min 8

The display view is divided into four basic areas.

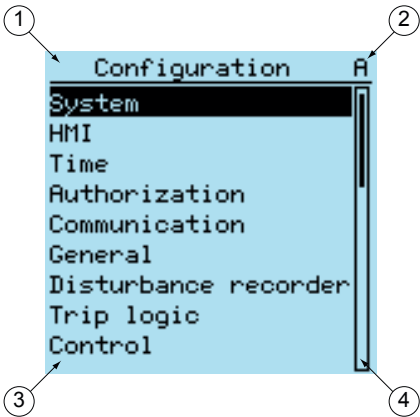


Figure 2: Display layout

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

2.4.2 LEDs

The LHMI includes three protection indicators above the display: Ready, Start and Trip.

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

2.4.3 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 objects in the primary circuit, for example, a circuit breaker, a contactor or a

disconnecter. The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

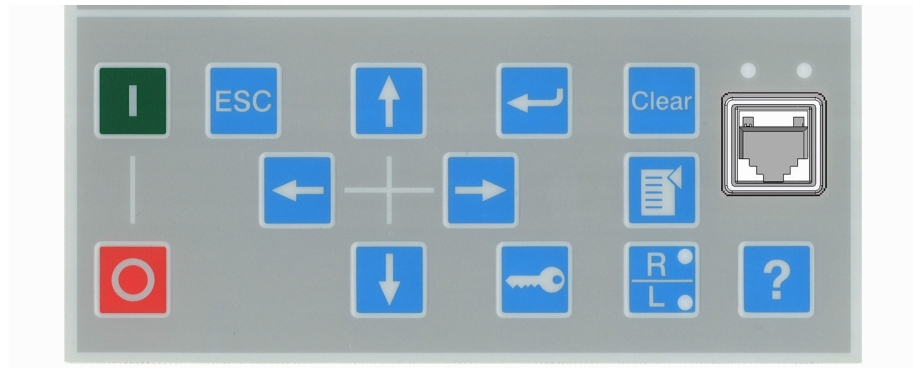


Figure 3: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.5

Web HMI

The WHMI enables the user to access the IED via a Web browser. The supported Web browser versions are Internet Explorer 7.0, 8.0 or 9.0.



WHMI is disabled by default.

WHMI offers several functions.

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

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

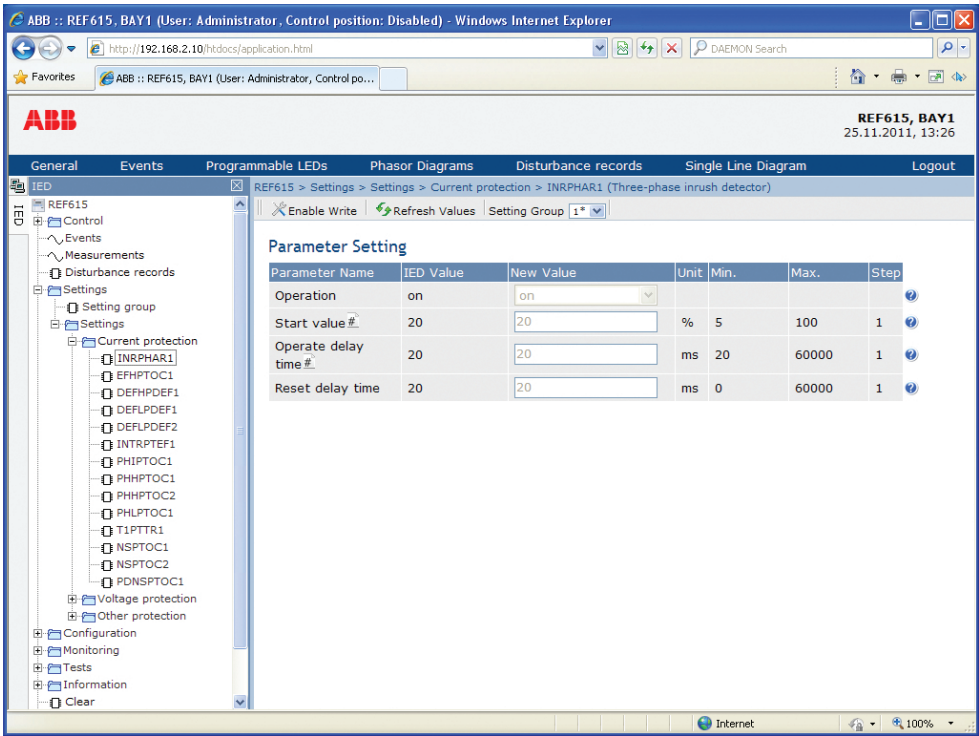


Figure 4: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 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 5: *Predefined user categories*

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



For user authorization for PCM600, see PCM600 documentation.

2.6.1

Audit trail

615 series IEDs offer a large set of event logging functions. Normal process related events can be viewed by the normal user with Event Viewer in PCM600. Critical system and IED security related events are logged to a separate non-volatile audit trail for the administrator.

Audit trail is a chronological record of system activities that enable the reconstruction and examination of the sequence of events and/or changes in an event. Past user and process events can be examined and analyzed in a consistent method with the help of Event List and Event Viewer in PCM600. The IED stores 2048 system events to non-volatile audit trail. Additionally, 1024 process events are stored in non-volatile event list. Both audit trail and event list work according to the FIFO principle.

User audit trail is defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined usernames or user categories. The user audit trail events are supported in IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 6: *Audit trail events*

Enum	Explanation/note
Configuration change	Configuration files changed
Firmware change	
Setting group remote	User changed setting group remotely
Table continues on next page	

Enum	Explanation/note
Setting group local	User changed setting group locally
Control remote	DPC object control remote
Control local	DPC object control local
Test on	Test mode on
Test off	Test mode off
Setting commit	Settings has been changed
Time change	
View audit log	Administrator accessed audit trail
Login	
Logout	
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period

PCM600 Event Viewer can be used to view the audit trail events together with normal events. Since only the administrator has the right to read audit trail, authorization must be properly configured in PCM600. The audit trail cannot be reset but PCM600 Event Viewer can filter data. Some of the audit trail events are interesting also as normal process events.



To expose the audit trail events also as normal process events, define the level parameter via **Configuration/Authorization/Authority logging**.

Table 7: *Audit trail events*

Audit trail event	Authority logging				
	None	Configuration change	Setting group	Setting group, control	Settings edit
Configuration change		x	x	x	x
Firmware change		x	x	x	x
Setting group remote			x	x	x
Setting group local			x	x	x
Control remote				x	x
Control local				x	x
Test on				x	x
Test off				x	x
Setting commit					x
Time change					
View audit log					
Login					
Table continues on next page					

Audit trail event	Authority logging				
Logout					
Firmware reset					
Audit overflow					

2.7 Communication

The IED supports a range of communication protocols including IEC 61850, IEC 60870-5-103, Modbus® and DNP3. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the IEDs, is only enabled by the IEC 61850 communication protocol.

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

The IED can support five simultaneous clients. If PCM600 reserves one client connection, only four client connections are left, for example, for IEC 61850 and Modbus.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The IED can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX). If connection to a RS-485 network is required, a 9-pin screw-terminal connector, an optional 9-pin D-sub connector or an optional ST-type glass-fibre connector can be used.

Remote-end station time reference:

- Line differential

For the correct operation of redundant loop topology, it is essential that the external switches in the network support the RSTP protocol and that it is enabled in the switches. Otherwise, connecting the loop topology can cause problems to the network. The IED itself does not support link-down detection or RSTP. The ring recovery process is based on the aging of MAC addresses and link-up/link-down events can cause temporary breaks in communication. For better performance of the self-healing loop, it is recommended that the external switch furthest from the

615 IED loop is assigned as the root switch (bridge priority = 0) and the bridge priority increases towards the IED loop. The end links of the IED loop can be attached to the same external switch or to two adjacent external switches. Self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all IEDs.

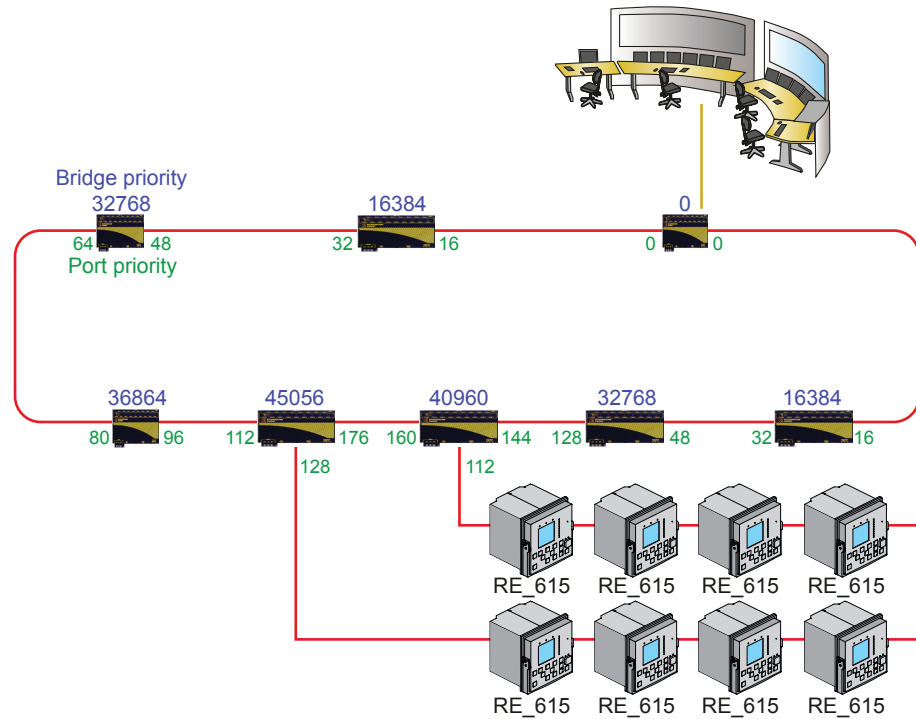


Figure 5: Self-healing Ethernet ring solution



The Ethernet ring solution supports the connection of up to thirty 615 series IEDs. If more than 30 IEDs are to be connected, it is recommended that the network is split into several rings with no more than 30 IEDs per ring.

Section 3 RED615 standard configurations

3.1 Standard configurations

RED615 is available in three alternative standard configurations. The standard signal configuration can be altered by means of the graphical signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions utilizing various logical elements including timers and flip-flops. By combining protection functions with logic function blocks the IED configuration can be adapted to user specific application requirements.

Table 8: *Standard configurations*

Description	Std. conf.
Line differential protection	A
Line differential protection with directional earth-fault protection	B
Line differential protection with non-directional earth-fault protection	C

Table 9: *Supported functions*

Functionality	A	B	C
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	•	•	•
Three-phase non-directional overcurrent protection, high stage, instance 1	•	•	•
Three-phase non-directional overcurrent protection, high stage, instance 2	•	•	•
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	•	•	•
Non-directional earth-fault protection, low stage, instance 1	-	-	● ²⁾
Non-directional earth-fault protection, low stage, instance 2	-	-	● ²⁾
Non-directional earth-fault protection, high stage, instance 1	-	-	● ²⁾
Non-directional earth-fault protection, instantaneous stage	-	-	● ²⁾
Directional earth-fault protection, low stage, instance 1	-	● ¹⁾²⁾³⁾	-
Directional earth-fault protection, low stage, instance 2	-	● ¹⁾²⁾³⁾	-
Directional earth-fault protection, high stage	-	● ¹⁾²⁾³⁾	-
Admittance based earth-fault protection, instance 1	-	○ ¹⁾²⁾³⁾	-
Admittance based earth-fault protection, instance 2	-	○ ¹⁾²⁾³⁾	-
Admittance based earth-fault protection, instance 3	-	○ ¹⁾²⁾³⁾	-
Table continues on next page			

Functionality	A	B	C
Wattmetric based earth-fault protection, instance 1		0 ¹⁾²⁾³⁾	-
Wattmetric based earth-fault protection, instance 2		0 ¹⁾²⁾³⁾	-
Wattmetric based earth-fault protection, instance 3		0 ¹⁾²⁾³⁾	-
Transient / intermittent earth-fault protection	-	● ³⁾⁴⁾	-
Harmonics based earth-fault protection		0 ¹⁾⁴⁾⁵⁾	0 ¹⁾⁴⁾⁵⁾
Non-directional (cross-country) earth fault protection, using calculated I _o	-	● ⁶⁾	-
Negative-sequence overcurrent protection, instance 1	●	●	●
Negative-sequence overcurrent protection, instance 2	●	●	●
Phase discontinuity protection	-	●	●
Residual overvoltage protection, instance 1	-	● ³⁾	-
Residual overvoltage protection, instance 2	-	● ³⁾	-
Residual overvoltage protection, instance 3	-	● ³⁾	-
Three-phase thermal protection for feeders, cables and distribution transformers	-	●	●
Binary signal transfer	●	●	●
Line differential protection and related measurements, stabilized and instantaneous stages	●	●	●
Circuit breaker failure protection	● ⁷⁾	●	●
Three-phase inrush detector	●	●	●
Master trip, instance 1	●	●	●
Master trip, instance 2	●	●	●
Control			
Circuit-breaker control	●	●	●
Disconnecter control, instance 1	● ⁵⁾	● ⁵⁾	● ⁵⁾
Disconnecter control, instance 2	● ⁵⁾	● ⁵⁾	● ⁵⁾
Earthing switch control	● ⁵⁾	● ⁵⁾	● ⁵⁾
Disconnecter position indication, instance 1	●	●	●
Disconnecter position indication, instance 2	● ⁵⁾	● ⁵⁾	● ⁵⁾
Disconnecter position indication, instance 3	● ⁵⁾	● ⁵⁾	● ⁵⁾
Earthing switch indication, instance 1	●	●	●
Earthing switch indication, instance 2	● ⁵⁾	● ⁵⁾	● ⁵⁾
Auto-reclosing	-	0	0
Condition Monitoring			
Circuit-breaker condition monitoring	-	●	●
Trip circuit supervision, instance 1	●	●	●
Trip circuit supervision, instance 2	●	●	●
Current circuit supervision	●	●	●
Protection communication supervision	●	●	●
Measurement			
Table continues on next page			

Functionality	A	B	C
Disturbance recorder	•	•	•
Three-phase current measurement, instance 1	•	•	•
Sequence current measurement	•	•	•
Residual current measurement, instance 1	-	•	•
Residual voltage measurement	-	•	-
• = included, o = optional at the time of order			

- 1) One of the following can be ordered as an option; Admittance based E/F, Wattmetric based E/F or Harmonics based E/F. The option is an addition to the existing E/F of the original configuration. The Admittance based and Wattmetric based optional E/F has also a predefined configuration in the relay. The optional E/F can be set on or off.
- 2) Io selectable by parameter, Io measured as default.
- 3) Uo measured is always used.
- 4) Io measured is always used.
- 5) Available in IED and SMT but not connected to anything in logic.
- 6) Io selectable by parameter, Io calculated as default.
- 7) Io calculated is always used.

3.1.1

Addition of control functions for primary devices and the use of binary inputs and outputs

If extra control functions intended for controllable primary devices are added to the configuration, additional binary inputs and/or outputs are needed to complement the standard configuration.

If the number of inputs and/or outputs in a standard configuration is not sufficient, it is possible either to modify the chosen IED standard configuration in order to release some binary inputs or binary outputs which have originally been configured for other purposes, or to integrate an external input/output module, for example RIO600, to the IED.

The external I/O module's binary inputs and outputs can be used for the less time-critical binary signals of the application. The integration enables releasing some initially reserved binary inputs and outputs of the IED's standard configuration.

The suitability of the IED's binary outputs which have been selected for primary device control should be carefully verified, for example make and carry and breaking capacity. If the requirements for the primary device control circuit are not met, using external auxiliary relays should be considered.

3.2 Connection diagrams

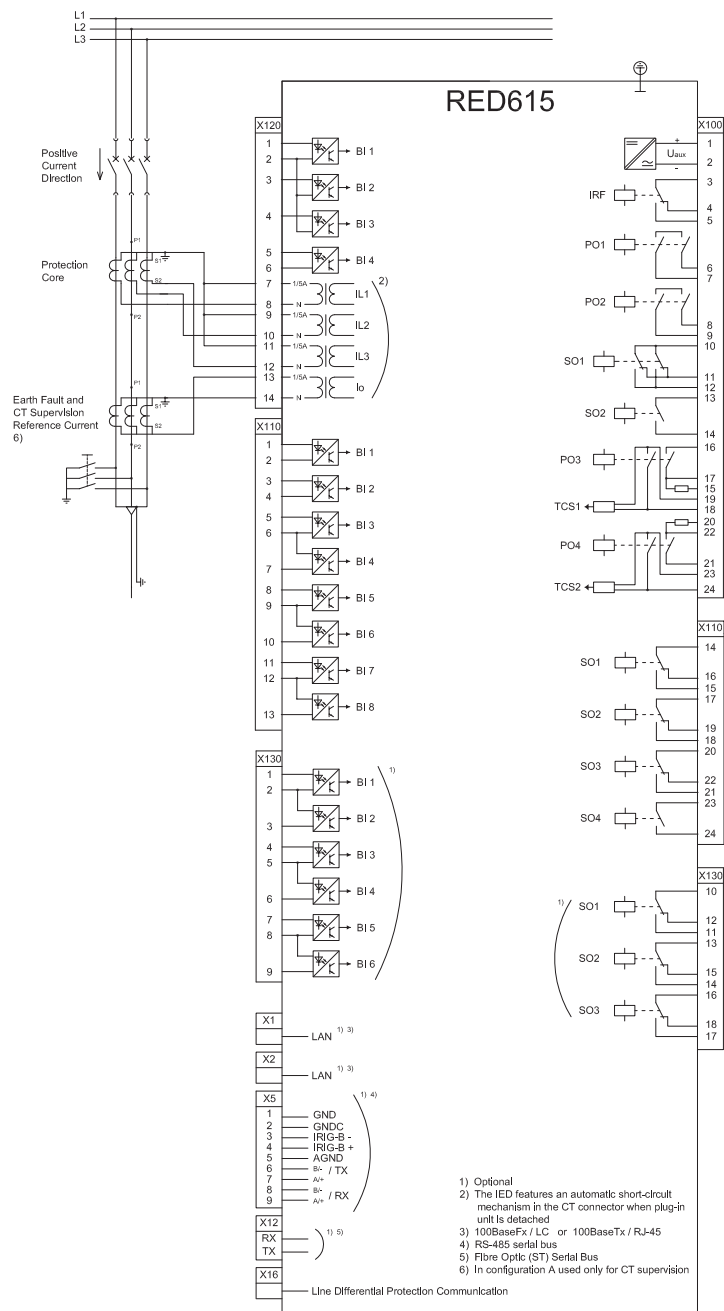


Figure 6: Connection diagram for the A and C configurations

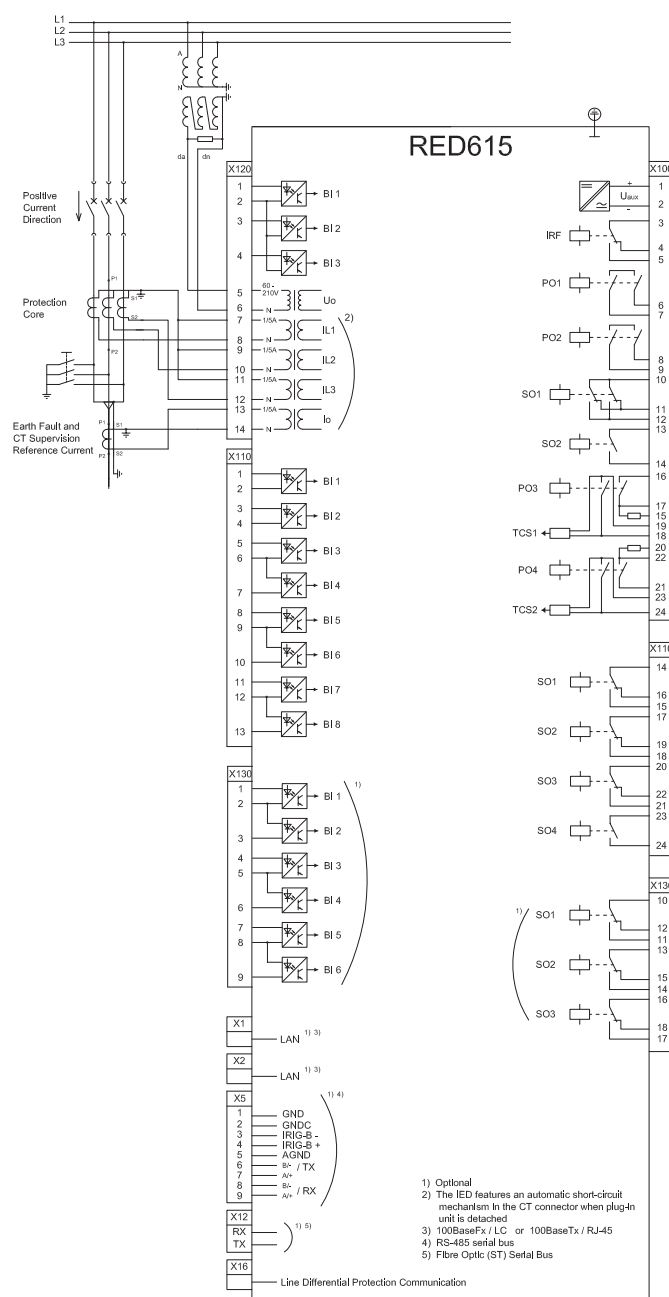


Figure 7: Connection diagram for the B configuration

3.3

Presentation of standard configurations

Functional diagrams

The functional diagrams describe the IED's functionality from the protection, measuring, condition monitoring, disturbance recording, control and interlocking perspective. Diagrams show the default functionality with simple symbol logics

forming principle diagrams. The external connections to primary devices are also shown, stating the default connections to measuring transformers. The positive measuring direction of directional protection functions is towards the outgoing feeder.

The functional diagrams are divided into sections with each section constituting one functional entity. The external connections are also divided into sections. Only the relevant connections for a particular functional entity are presented in each section.

Protection function blocks are part of the functional diagram. They are identified based on their IEC 61850 name but the IEC based symbol and the ANSI function number are also included. Some function blocks, such as PHHPTOC, are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name, IEC symbol and ANSI function number are appended with a running number, that is an instance number, from one upwards. If the block has no suffix after the IEC or ANSI symbol, the function block has been used, that is, instantiated, only once. The IED's internal functionality and the external connections are separated with a dashed line presenting the IED's physical casing.

Signal Matrix and Application Configuration

With Signal Matrix and Application Configuration in PCM600, it is possible to modify the standard configuration according to the actual needs. The IED is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. The Signal Matrix is used for GOOSE signal input engineering and for making cross-references between the physical I/O signals and the function blocks. The Signal Matrix tool cannot be used for adding or removing function blocks, for example, GOOSE receive function blocks. The Application Configuration tool is used for these kind of operations. If a function block is removed with Application Configuration, the function related data disappears from the menus as well as from the 61850 data model, with the exception of some basic function blocks, which are mandatory and thus cannot be removed from the IED configuration by removing them from the Application Configuration.

3.4 Standard configuration A

3.4.1 Applications

The standard configuration for line current differential protection is mainly intended for cable feeder applications in distribution networks.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.4.2 Functions

Table 10: *Functions included in the standard configuration A*

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Binary signal transfer	BSTGGIO1	BST	BST
Line differential protection and related measurements, stabilized and instantaneous stages	LNPLDF1	3dI>L	87L
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnecter control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnecter control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Disconnecter position indication, instance 1	DCSXSXI1	I <-> O DC (1)	I <-> O DC (1)
Disconnecter position indication, instance 2	DCSXSXI2	I <-> O DC (2)	I <-> O DC (2)
Disconnecter position indication, instance 3	DCSXSXI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Condition monitoring			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Protection communication supervision	PCSRTPC1	PCS	PCS
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0

3.4.2.1 Default I/O connections

Table 11: *Default connections for binary inputs*

Binary input	Description	Connector pins
X110-BI2	External start of breaker failure protection	X110-3,4
X110-BI3	Setting group change	X110-5,6
X110-BI4	Binary signal transfer input	X110-7,6
X110-BI5	Disconnecter close/truck in	X110-8,9
X110-BI6	Disconnecter open/truck out	X110-10,9
X110-BI7	Earth switch close	X110-11,12
X110-BI8	Earth switch open	X110-13,12
X120-BI1	Blocking input for general use	X120-1,2
X120-BI2	Circuit breaker close	X120-3,2
X120-BI3	Circuit breaker open	X120-4,2
X120-BI4	Lockout reset	X120-5,2

Table 12: *Default connections for binary outputs*

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Line differential protection trip alarm	X100-10,11,(12)
X100-SO2	Protection communication failure or differential protection not available	X100-13,14
X100-PO3	Open circuit breaker/trip 1	X100-15-19
X100-PO4	Open circuit breaker/trip 2	X100-20-24
X110-SO1	Start indication	X110-14,15
X110-SO2	Operate indication	X110-17,18
X110-SO3	Binary transfer signal	X110-20,21

Table 13: *Default connections for LEDs*

LED	Description
1	Line differential protection biased stage operate
2	Line differential protection instantaneous stage operate
3	Line differential protection is not available
4	Protection communication failure
5	Current transformer failure detected
6	Phase or negative sequence component over current
7	Breaker failure operate
8	Disturbance recorder triggered
Table continues on next page	

LED	Description
9	Trip circuit supervision alarm
10	Binary signal transfer receive
11	Binary signal transfer send

3.4.2.2

Default disturbance recorder settings

Table 14: *Default analog channel selection and text settings*

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.4.3

Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the eight analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io

represents the measured residual current, via a sum connection of second CT cores of the phase current transformers.

3.4.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

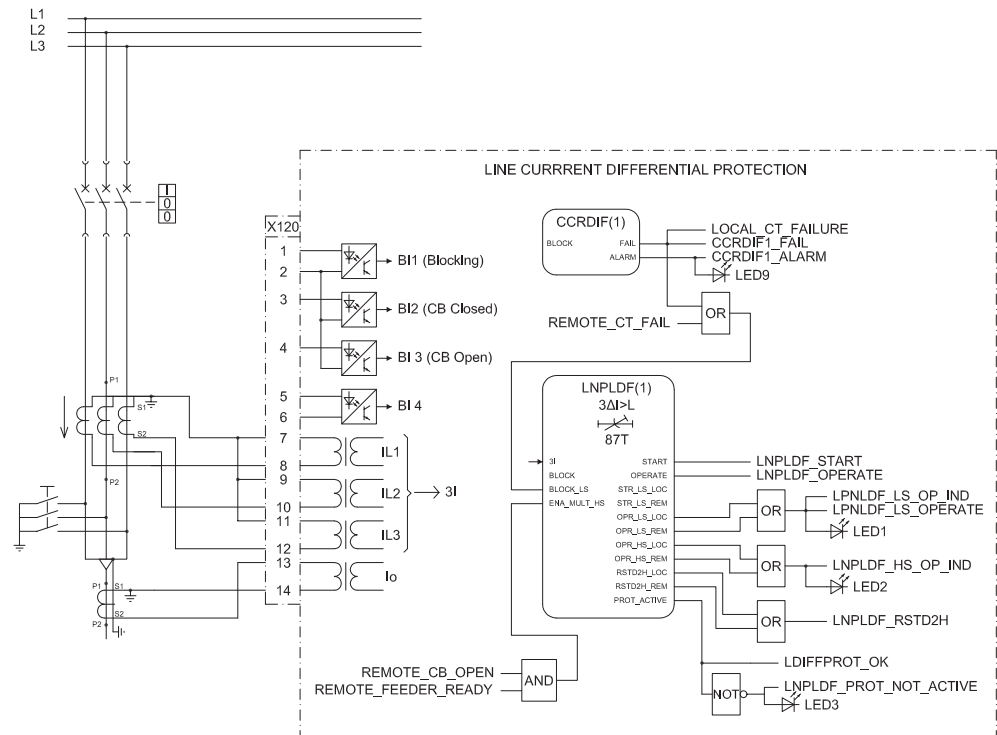


Figure 8: Line differential protection

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined settings if the ENA_MULT_HS input is activated. In this configuration it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnecter is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12). LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

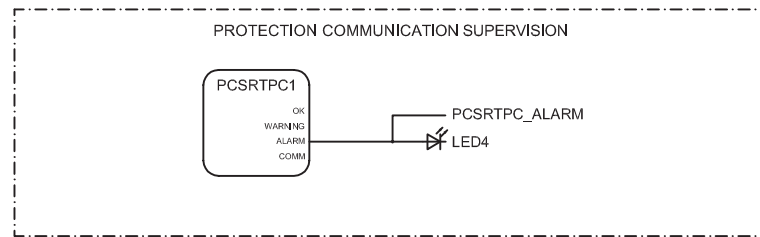


Figure 9: Protection communication supervision

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14-15).

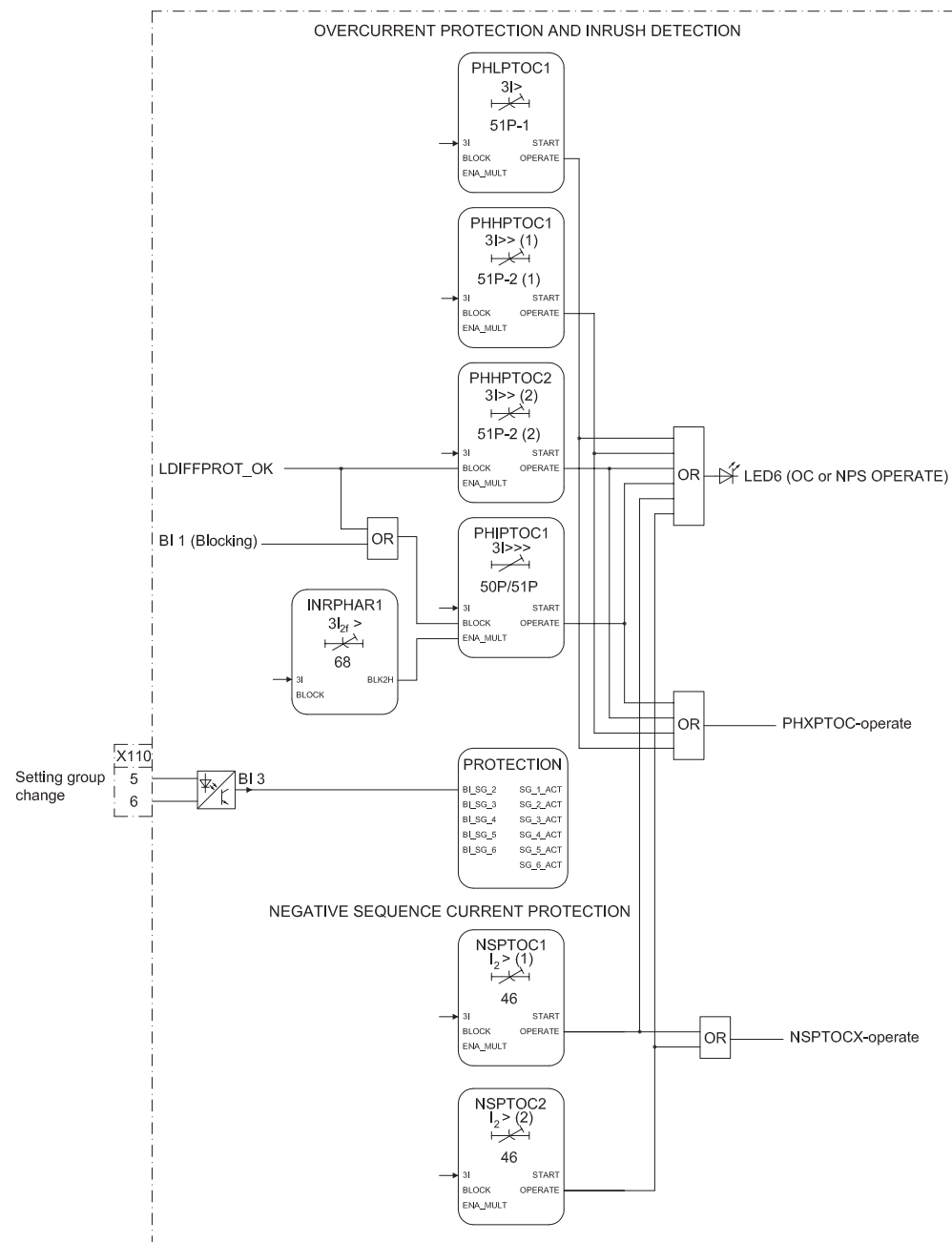


Figure 10: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRP HAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

Depending on the selected operation mode, the active setting group can be changed either with a parameter or via binary input.

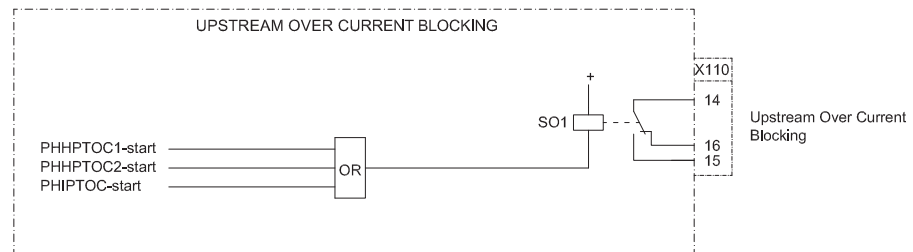


Figure 11: Blocking of the upstream overcurrent relay

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

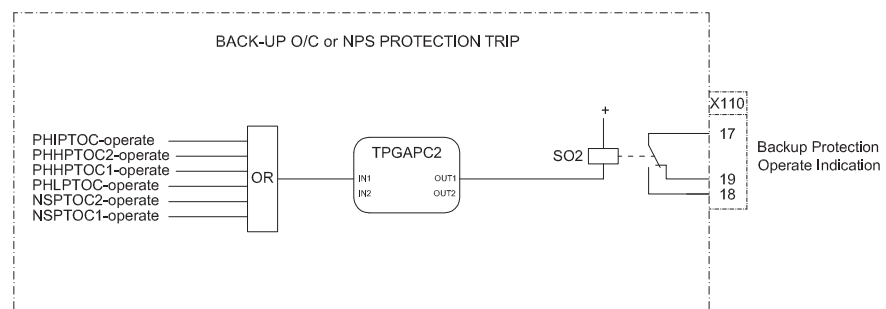


Figure 12: Indication of overcurrent or NPS overcurrent operation

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

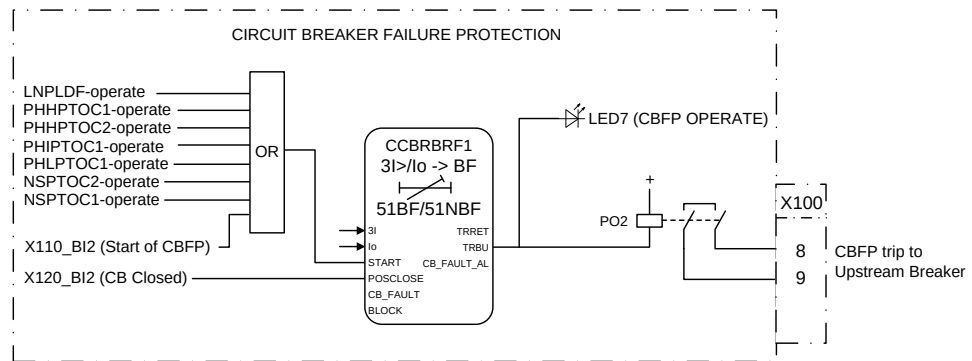


Figure 13: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip Logic 2. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

3.4.3.2

Functional diagrams for disturbance recorder and trip circuit supervision

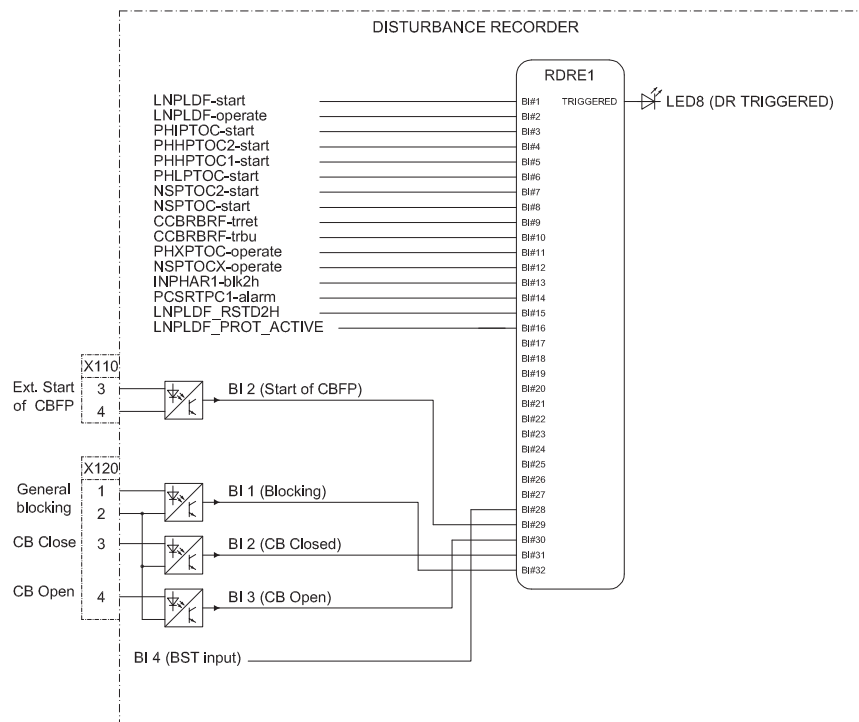


Figure 14: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the five binary inputs are also connected.

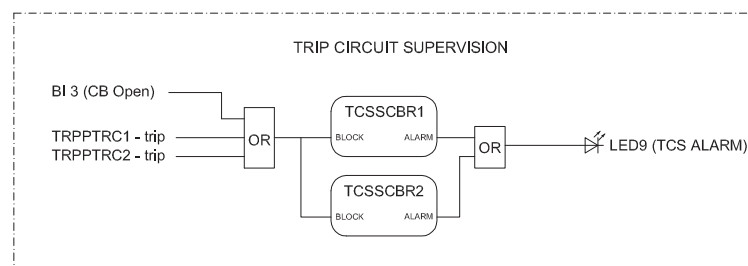


Figure 15: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.



By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.4.3.3

Functional diagrams for control and interlocking

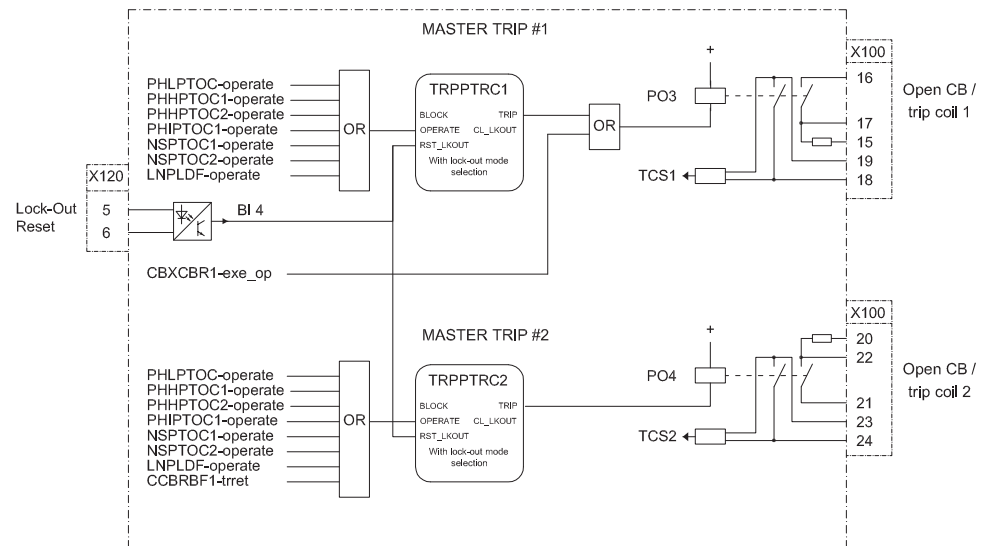


Figure 16: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op is connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

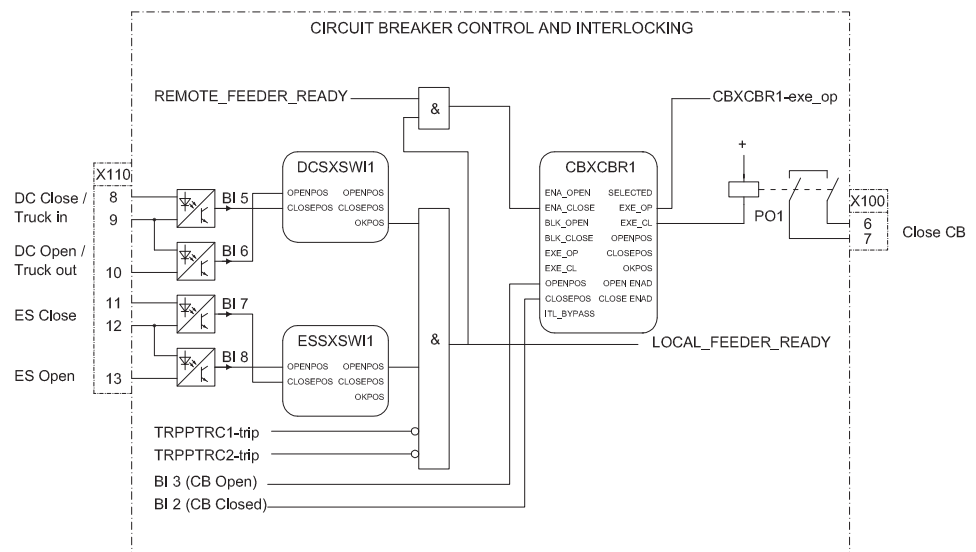


Figure 17: Circuit breaker control and interlocking

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

ENA_CLOSE input enables the closing of the circuit breaker. In the circuit-breaker control function CBXCBR is a combination of the statuses of the Master Trip logics, disconnector and earth-switch position indications and remote feeder position indications. Master trip logic, disconnector and earth-switch statuses are local feeder ready information to be sent for the remote end. Opening is always enabled.



If the ENA_CLOSE signal is completely removed from CBXCBR with PCM600, the function assumes that the circuit breaker close commands are allowed continuously.



If REMOTE_FEEDER_READY information is missing, for example, in case of protection communication not connected, it disables the breaker closing in the local IED.

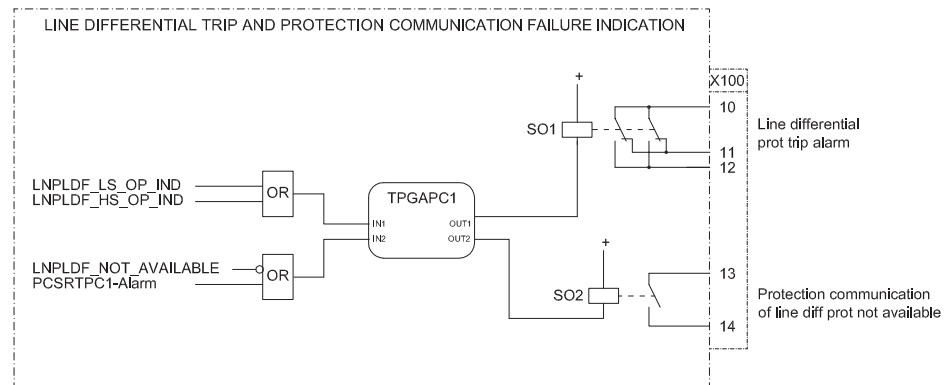


Figure 18: Line differential trip and protection communication failure indication

The signal outputs from the IED are connected to give dedicated information on:

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)

TPGAPC1 is used for setting the minimum pulse length for the outputs.

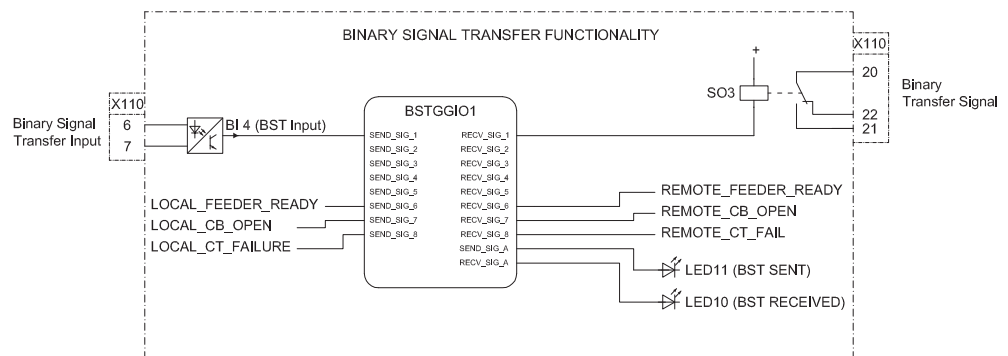


Figure 19: Binary signal transfer

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI4 (X110:6-7) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

3.5 Standard configuration B

3.5.1 Applications

The standard configuration for line current differential protection including directional earth-fault protection and autoreclosing is mainly intended for cable feeder applications in distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance, wattmetric or harmonic principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.5.2 Functions

Table 15: Functions included in the standard configuration B

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Table continues on next page			

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Binary signal transfer	BSTGGIO1	BST	BST
Line differential protection and related measurements, stabilized and instantaneous stages	LNPLDF1	3dI>L	87L
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnecter control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnecter control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnecter position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnecter position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnecter position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Table continues on next page			

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Protection communication supervision	PCSRTPC1	PCS	PCS
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Residual voltage measurement	RESVMMXU1	Uo	Vn

3.5.2.1

Default I/O connections

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	Lockout reset	X110-1,2
X110-BI2	Binary signal transfer input	X110-3,4
X110-BI3	Circuit breaker low gas pressure alarm	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking input for general use	X120-1,2
X120-BI2	Circuit breaker close	X120-3,2
X120-BI3	Circuit breaker open	X120-4,2

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Line differential protection trip alarm	X100-10,11,(12)
X100-SO2	Protection communication failure or differential protection not available	X100-13,14
X100-PO3	Open circuit breaker/trip 1	X100-15-19
X100-PO4	Open circuit breaker/trip 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15
X110-SO2	Backup protection operate indication	X110-17,18
X110-SO3	Binary transfer signal	X110-20,21
X110-SO4		X110-20,21

Table 18: *Default connections for LEDs*

LED	Description
1	Line differential protection biased stage operated
2	Line differential protection instantaneous stage operated
3	Line differential protection is not available
4	Protection communication failure
5	Auto reclose in progress
6	Backup protection operated
7	Circuit breaker failure protection backup trip operated
8	Disturbance recorder triggered
9	Current transformer failure or trip circuit or circuit breaker supervision alarm
10	Binary signal transfer receive
11	Binary signal transfer send

3.5.2.2

Default disturbance recorder settings

Table 19: *Default analog channel selection and text settings*

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.5.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the eight analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with I_o represents the measured residual current, via a sum connection of second CT cores of the phase current transformers. The signal marked with U_o represents the measured residual voltage from voltage transformers.

3.5.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

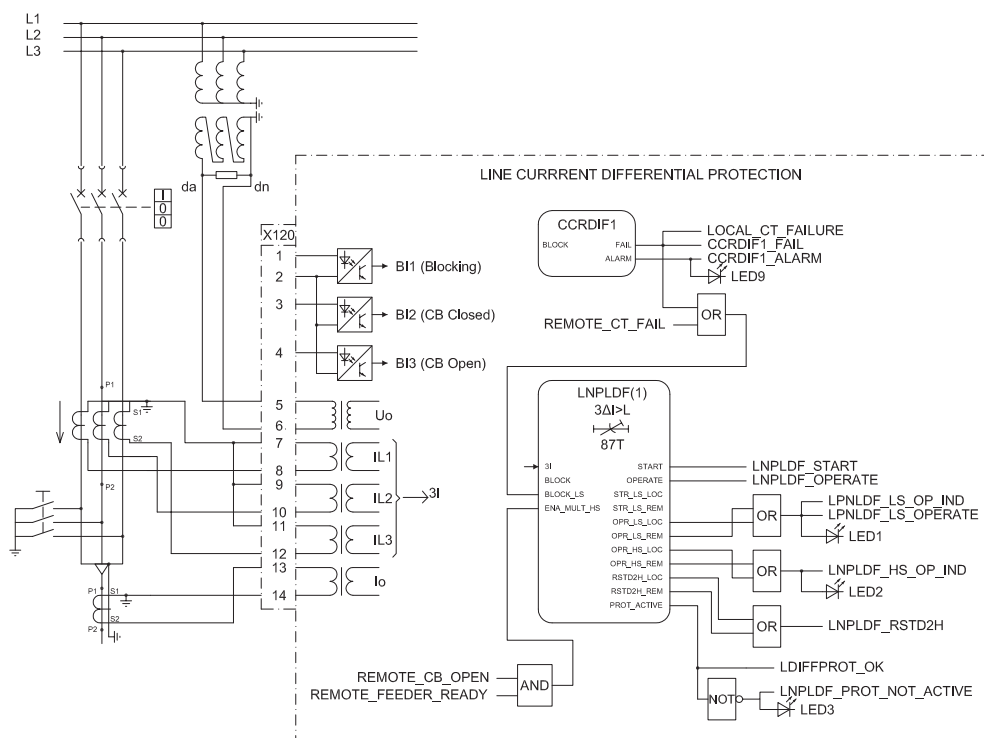


Figure 20: Line current differential protection

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined settings if the ENA_MULT_HS input is activated. In this configuration it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnecter is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12). LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

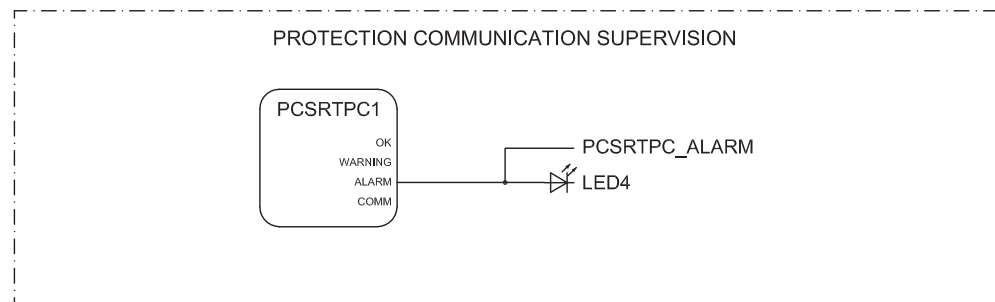


Figure 21: Protection communication supervision function

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14).

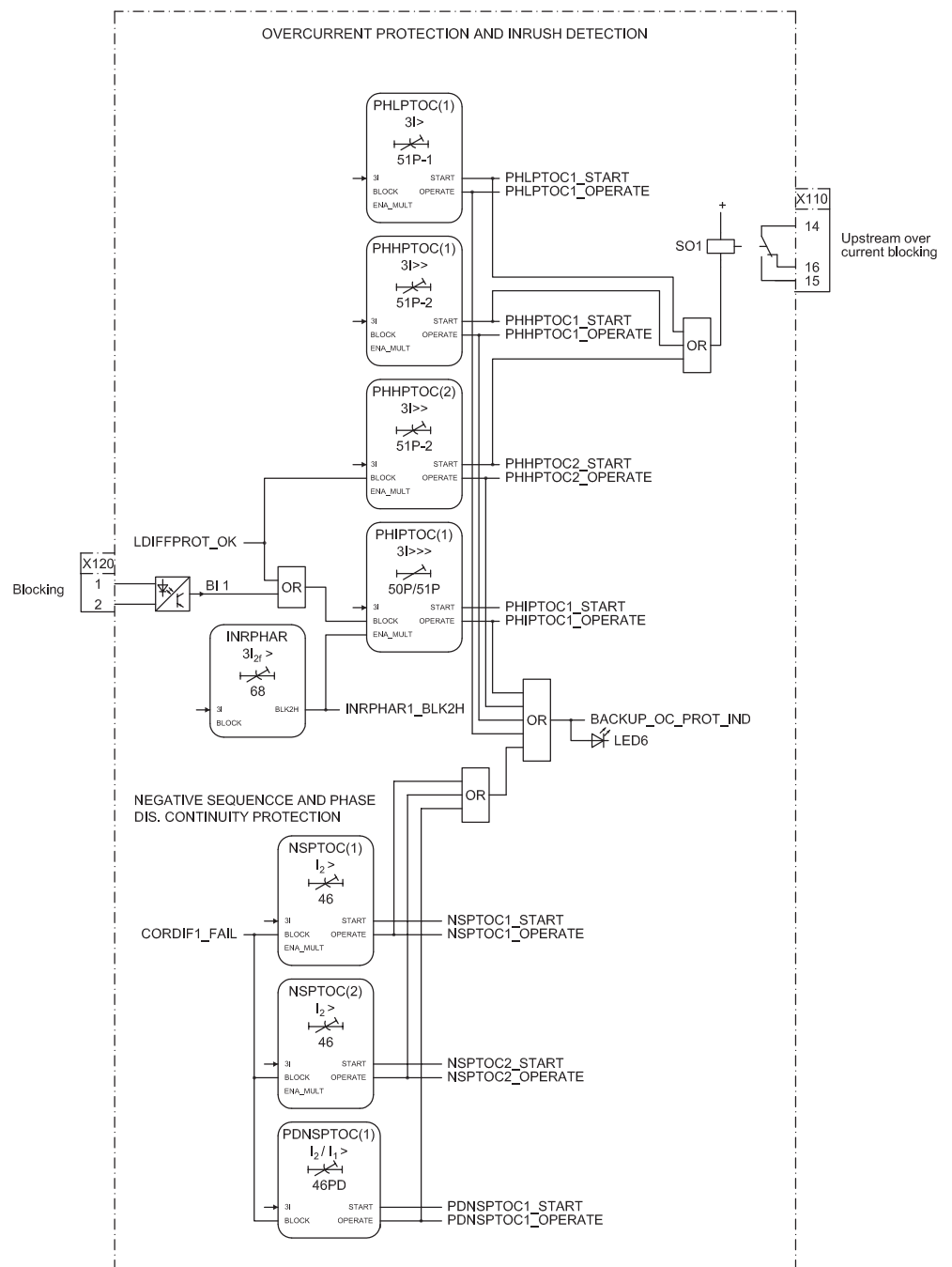


Figure 22: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The phase discontinuity protection (PDNSPTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The inrush

detection block's (INRPHAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

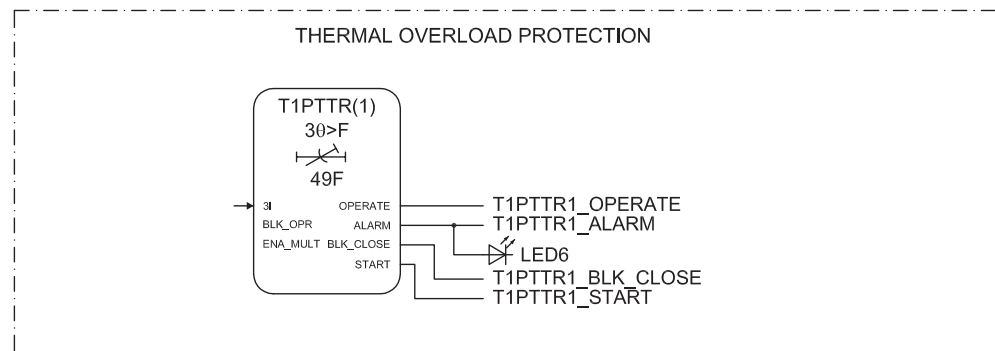


Figure 23: Thermal overload protection

The thermal overload protection (T1PTTR1) provides indication on overload situations. Active BLK_CLOSE signal blocks the closing of the circuit breaker. LED 6 is used also for the thermal overload protection alarm indication.

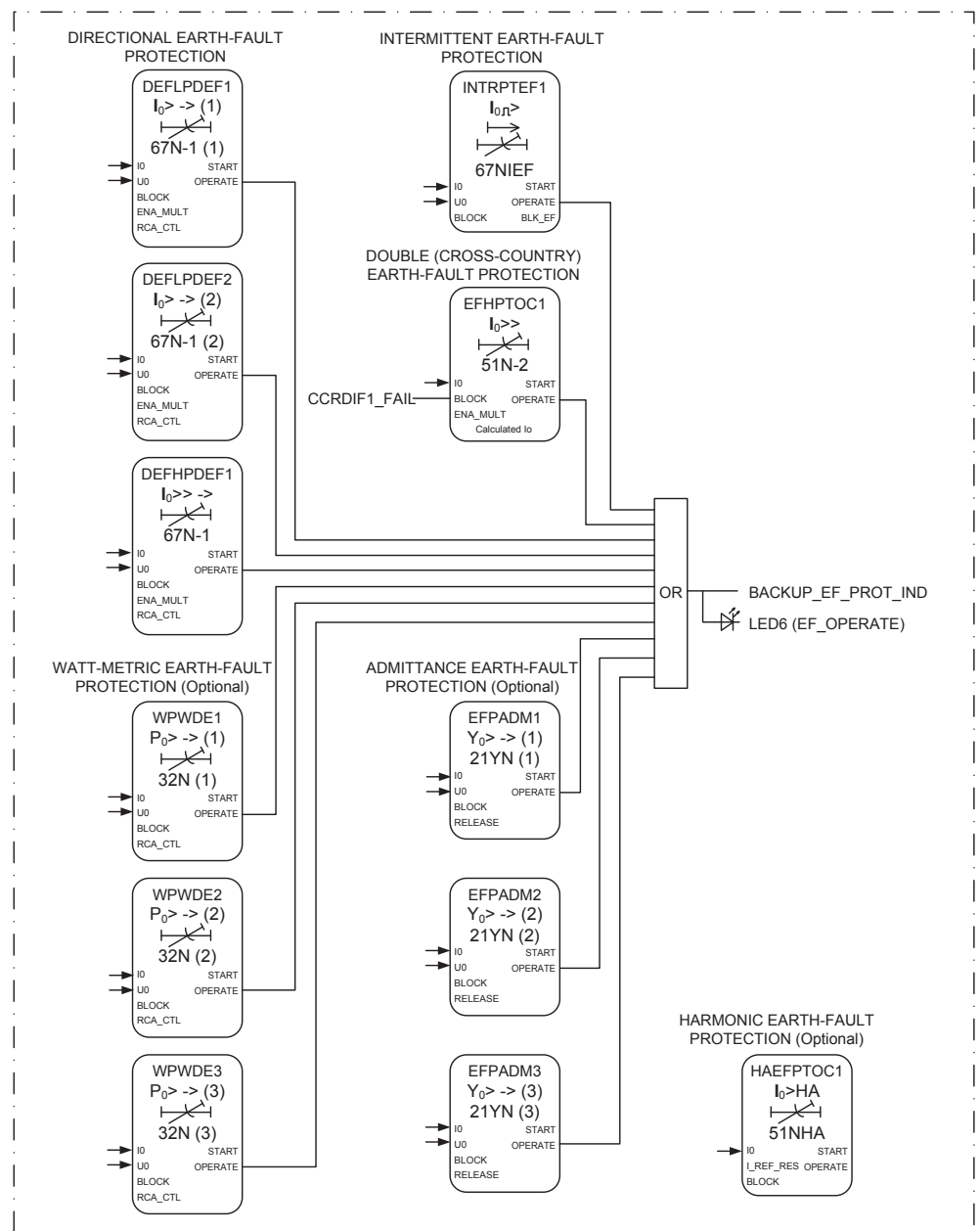


Figure 24: Earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only, or alternatively together with admittance (EFPADM), wattmetric (WPWDE) or harmonics (HAEFPTOC) based earth-fault protection. In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated

networks. This protection function uses the calculated residual current originating from the phase currents.

All operate signals are connected to the Master Trip as well as to the alarm LED 6.

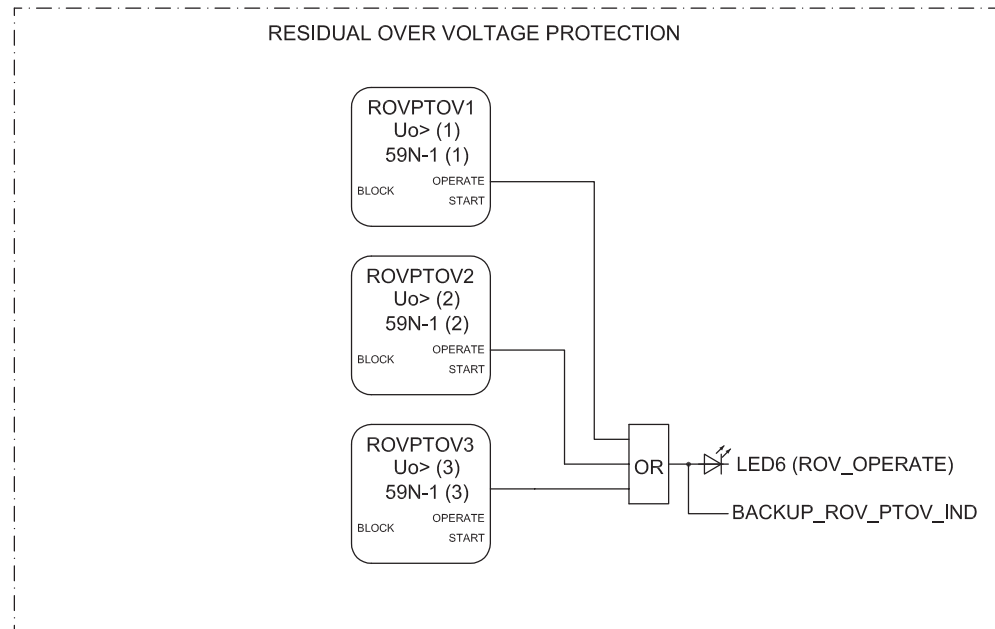


Figure 25: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 6.

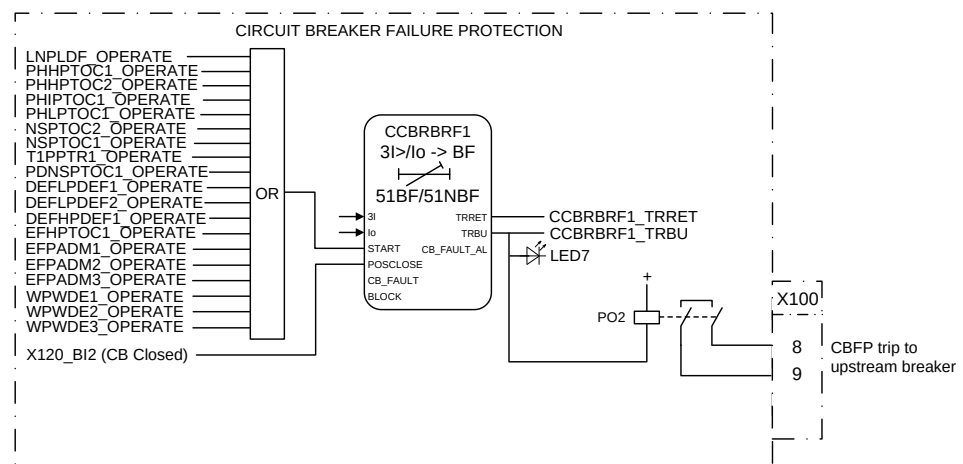


Figure 26: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different

operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip Logic 2. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

3.5.3.2

Functional diagrams for disturbance recorder and supervision functions

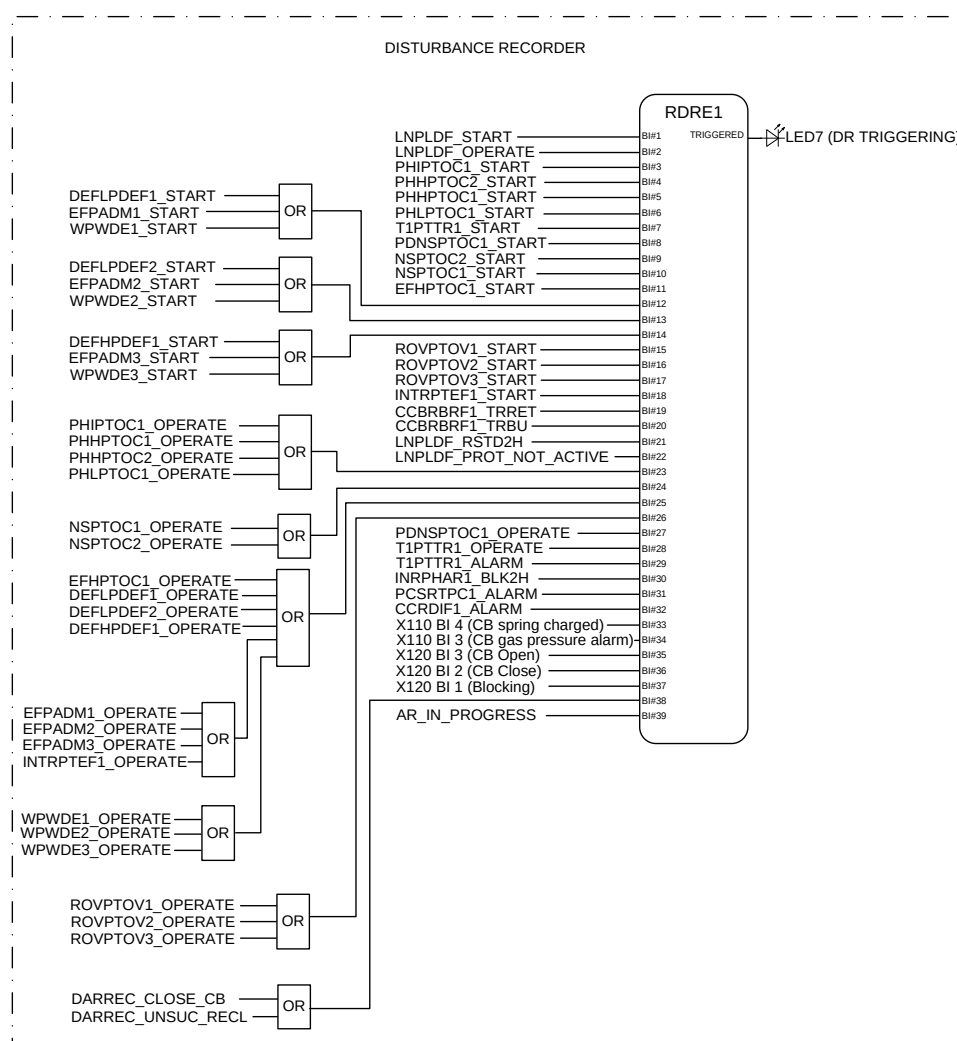


Figure 27: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance

recorder depending on the parameter settings. Additionally, the five binary inputs are also connected.

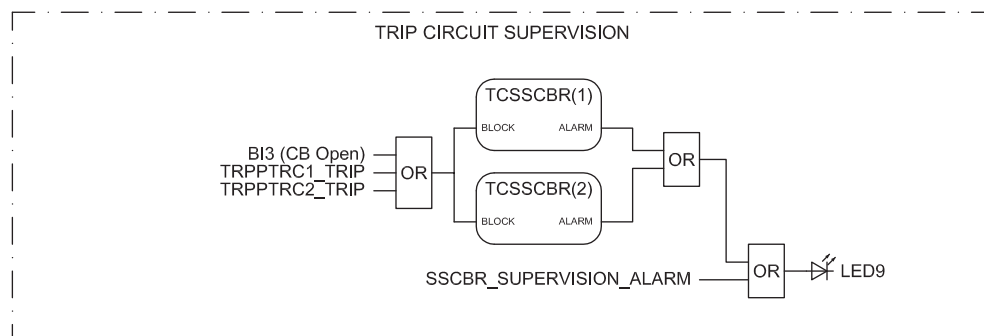


Figure 28: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.



By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.5.3.3

Functional diagrams for control and interlocking

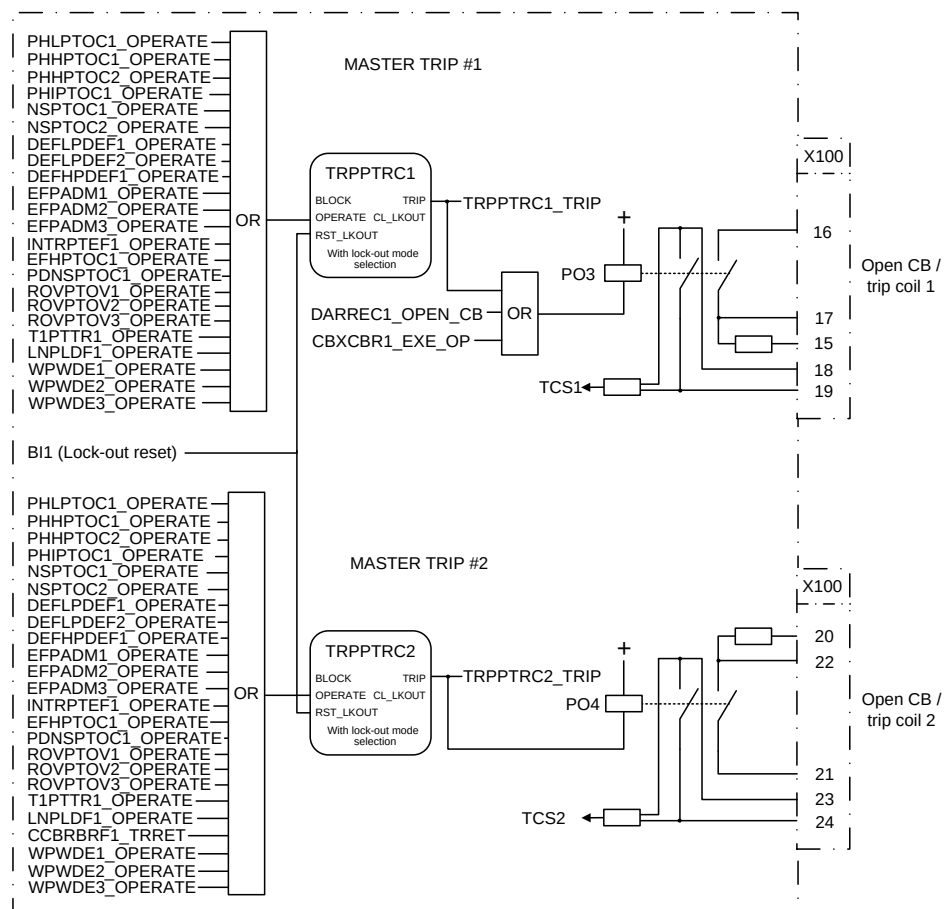


Figure 29: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR_EXE_OP is connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

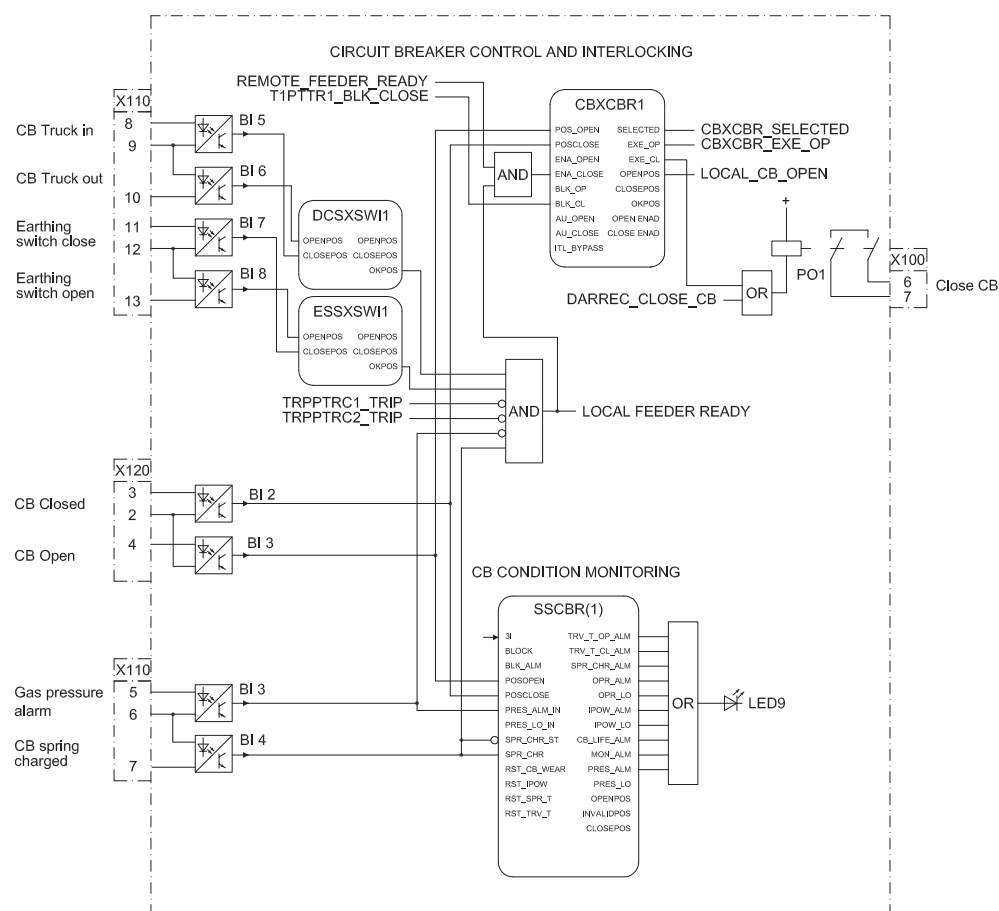


Figure 30: Circuit breaker control and interlocking

There are two types of disconnector and earthing switch blocks available. DCSXSXW1...3 and ESSXSXW1...2 are status only type, and DCXSXW1...2 and ESXSXW1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSXW1) or circuit-breaker truck position indication.

Table 20: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnect or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. This combination of interlocking conditions is called LOCAL_FEEDER_READY and is transferred also to the remote end via binary signal transfer. The OKPOS output from DCSXSWI defines if the disconnect or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.



If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.



If REMOTE_FEEDER_READY information is missing, for example in case of protection communication not connected, it disables the circuit breaker closing in the local IED.

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 9.

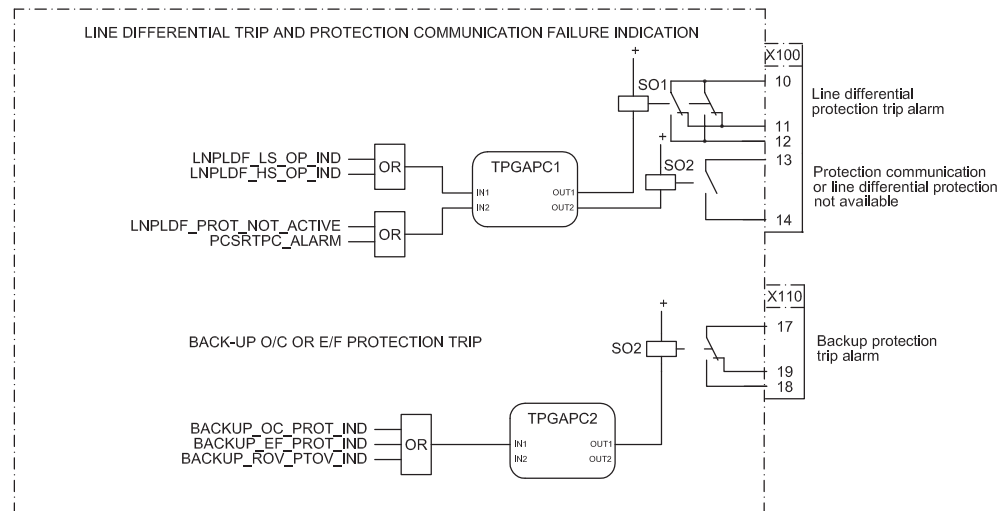


Figure 31: Line differential trip and protection communication failure indication

The signal outputs from the IED are connected to give dedicated information on:

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)
- Back-up overcurrent or earth-fault protection trip alarm SO2 (X110:17-19)

TPGAPC1 is used for setting the minimum pulse length for the outputs.

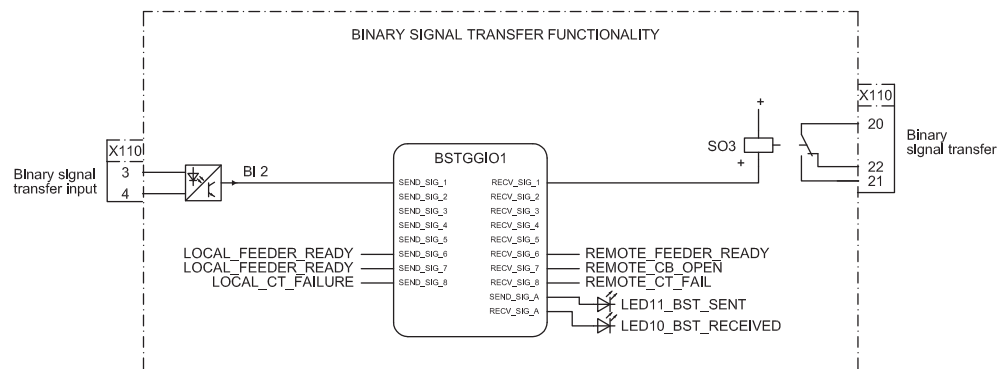


Figure 32: Binary signal transfer

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI2 (X110:3-4) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

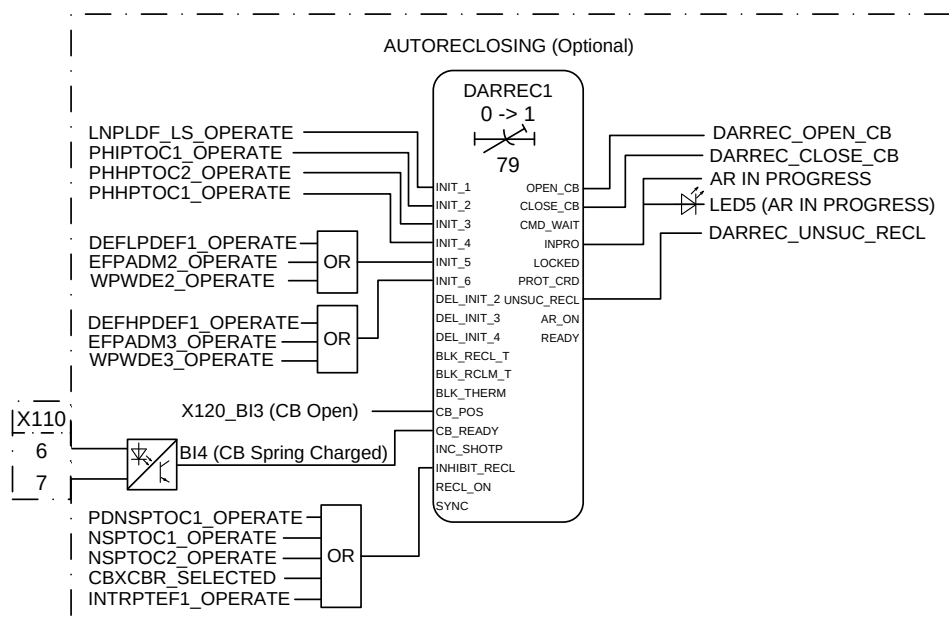


Figure 33: Autoreclose

The autoreclose function (DARREC1) is configured to be initiated by operate signals from a number of protection stages through the INIT1...6 inputs. It is possible to create individual autoreclose sequences for each input. DARREC1 can be blocked with the INHIBIT_RECL input. As a default, the operation of some selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks DARREC1 via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclose sequence is expressed with the binary input 4 (X110:6-7) by connecting the input signal to the CB_READY input. In case this signal is completely removed from DARREC1 with PCM600, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to alarm LED 5.

3.6 Standard configuration C

3.6.1 Applications

The standard configuration for line current differential protection including non-directional earth-fault protection and autoreclosing is mainly intended for cable feeder applications in distribution networks.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.6.2 Functions

Table 21: Functions included in the standard configuration C

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Binary signal transfer	BSTGGIO1	BST	BST
Table continues on next page			

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Line differential protection and related measurements, stabilized and instantaneous stages	LNPLDF1	3dI>L	87L
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnecter control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnecter control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnecter position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnecter position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnecter position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Protection communication supervision	PCSRTPC1	PCS	PCS
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In

3.6.2.1

Default I/O connections

Table 22: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	External start of breaker failure protection	X110-1,2
X110-BI2	Binary signal transfer input	X110-3,4
X110-BI3	Circuit breaker low gas pressure alarm	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
Table continues on next page		

Binary input	Description	Connector pins
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking input for general use	X120-1,2
X120-BI2	Circuit breaker close	X120-3,2
X120-BI3	Circuit breaker open	X120-4,2
X120-BI4	Lockout reset	X120-5,6

Table 23: *Default connections for binary outputs*

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Line differential protection trip alarm	X100-10,11,(12)
X100-SO2	Protection communication failure or differential protection not available	X100-13,14
X100-PO3	Open circuit breaker/trip 1	X100-15-19
X100-PO4	Open circuit breaker/trip 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15
X110-SO2	Backup protection operate indication	X110-17,18
X110-SO3	Binary transfer signal	X110-20,21
X110-SO4		X110-20,21

Table 24: *Default connections for LEDs*

LED	Description
1	Line differential protection biased stage operated
2	Line differential protection instantaneous stage operated
3	Line differential protection is not available
4	Protection communication failure
5	Autoreclose in progress
6	Backup protection operated
7	Circuit failure protection backup trip operated
8	Disturbance recorder triggered
9	Current transformer failure or trip circuit or circuit breaker supervision alarm
10	Binary signal transfer receive
11	Binary signal transfer send

3.6.2.2 Default disturbance recorder settings

Table 25: *Default analog channel selection and text settings*

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.6.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the eight analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current, via a sum connection of second CT cores of the phase current transformers.

3.6.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

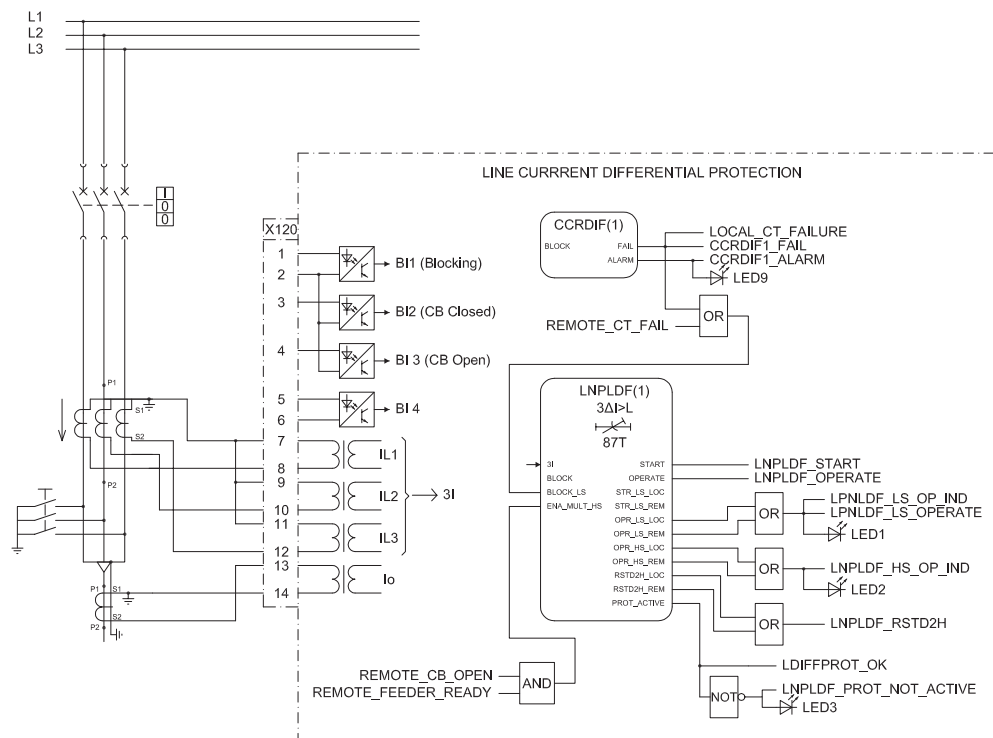


Figure 34: Line current differential protection

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined settings if the ENA_MULT_HS input is activated. In this configuration it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnector is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12). LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

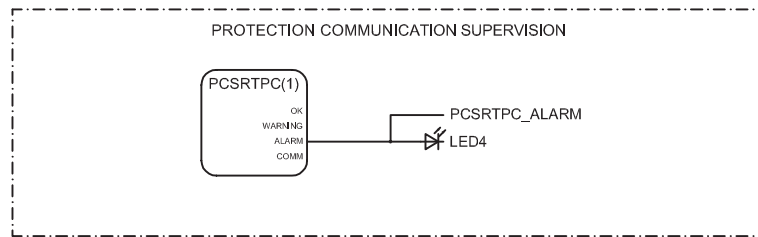


Figure 35: Protection communication supervision function

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14).

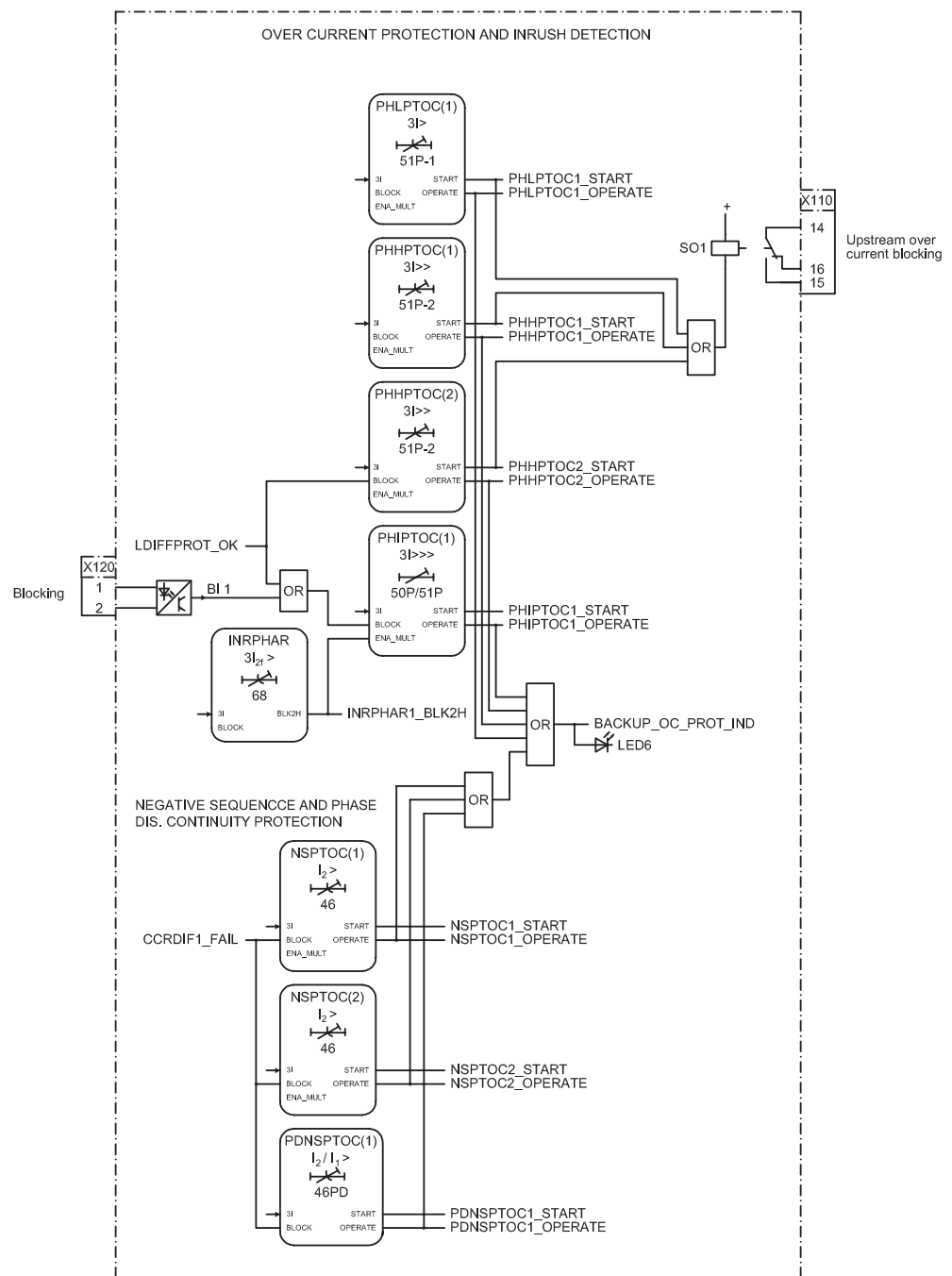


Figure 36: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The phase discontinuity protection (PDNSPTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The inrush

detection block's (INRP HAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

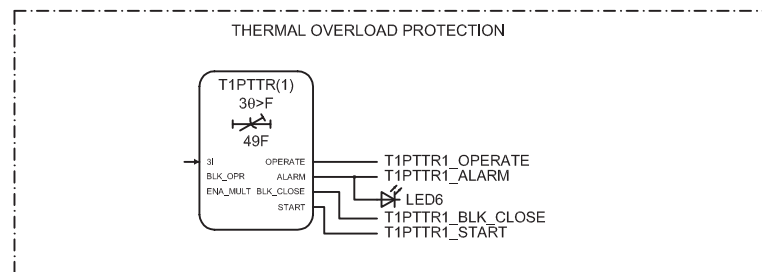


Figure 37: Thermal overload protection

The thermal overload protection (T1PTTR1) provides indication on overload situations. Active BLK_CLOSE signal blocks the closing of the circuit breaker. LED 6 is used also for the thermal overload protection alarm indication.

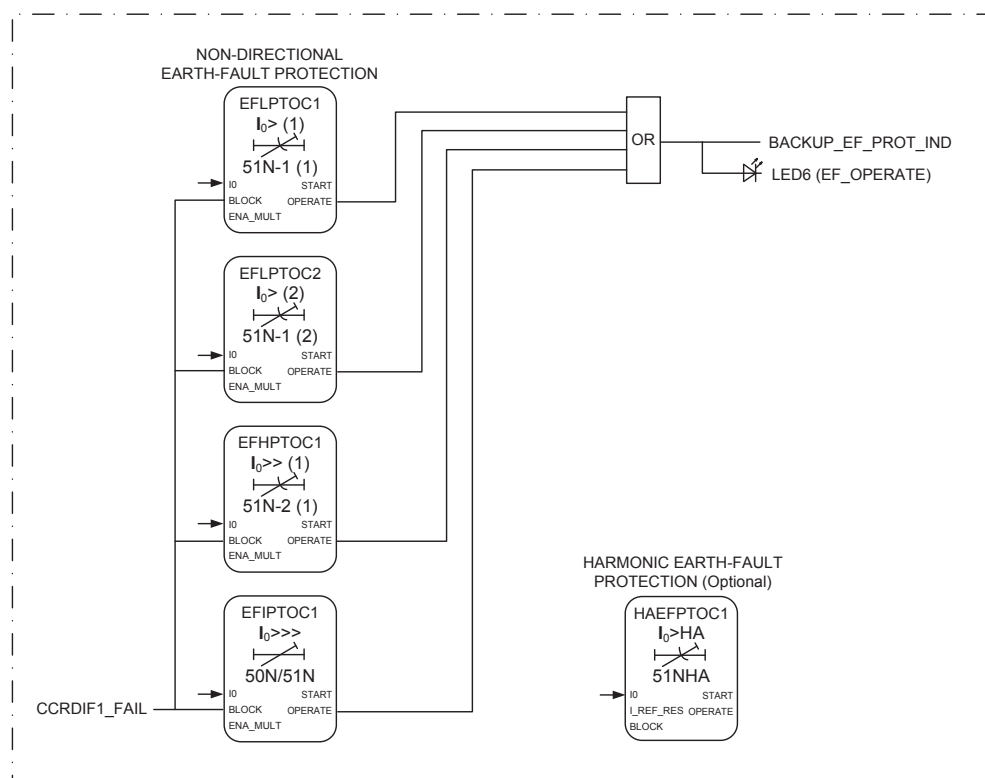


Figure 38: Earth-fault protection

Four stages are offered for non-directional earth-fault protection. The earth-fault protection uses measured residual currents. When current circuit failure is detected by CCRDIF1, all earth-fault functions are blocked to inhibit unwanted operation, which can occur due to apparent residual current. Based on the order code, the configuration can also include optional harmonic based earth-fault (HAEFPTOC) protection.

The functionality of CCRDIF1 should be disabled in case the earth-fault protections current signal originates from the phase current transformers via external summation instead of separate balanced-core current transformer.

All operate signals are connected to the Master Trip as well as to the alarm LED 6.

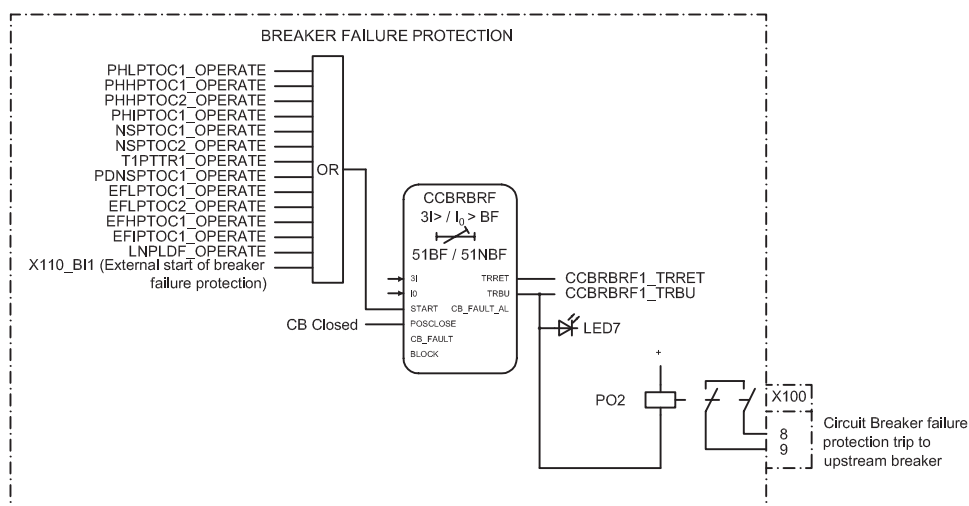


Figure 39: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip Logic 2. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

3.6.3.2

Functional diagrams for disturbance recorder and supervision functions

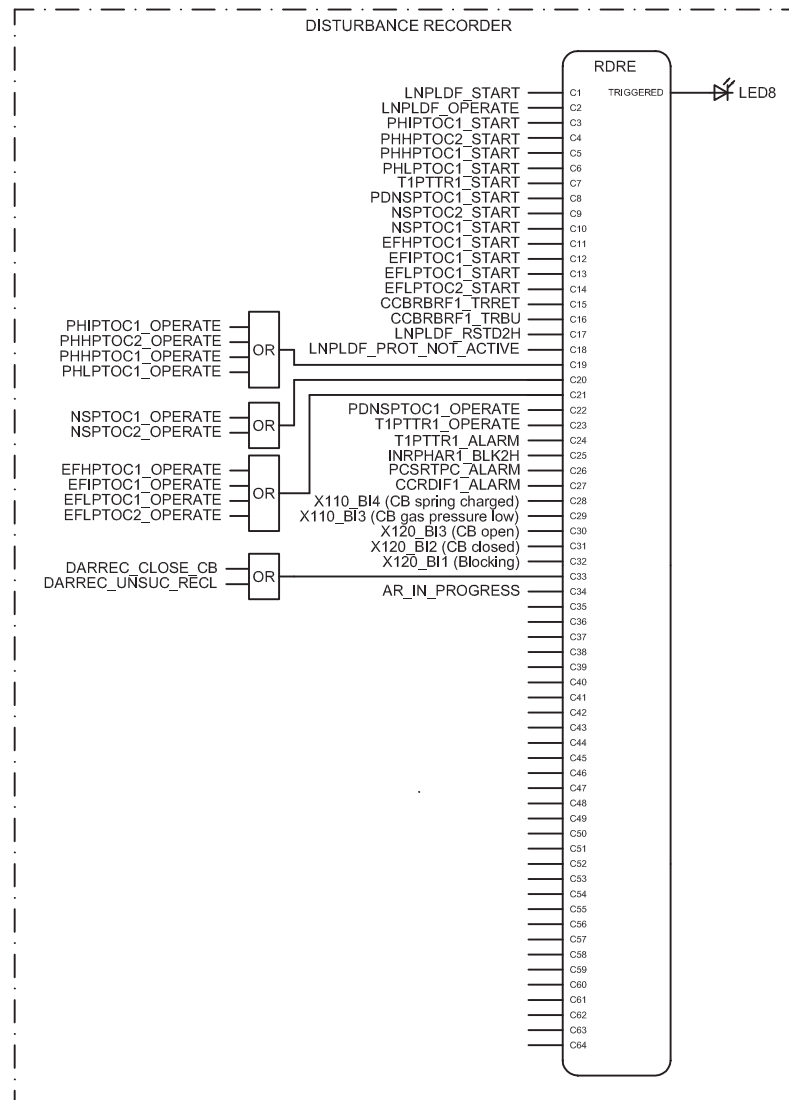


Figure 40: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the five binary inputs are also connected.

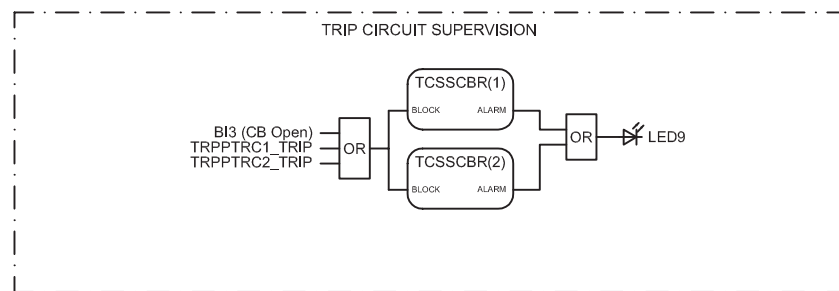


Figure 41: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.



By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.6.3.3

Functional diagrams for control and interlocking

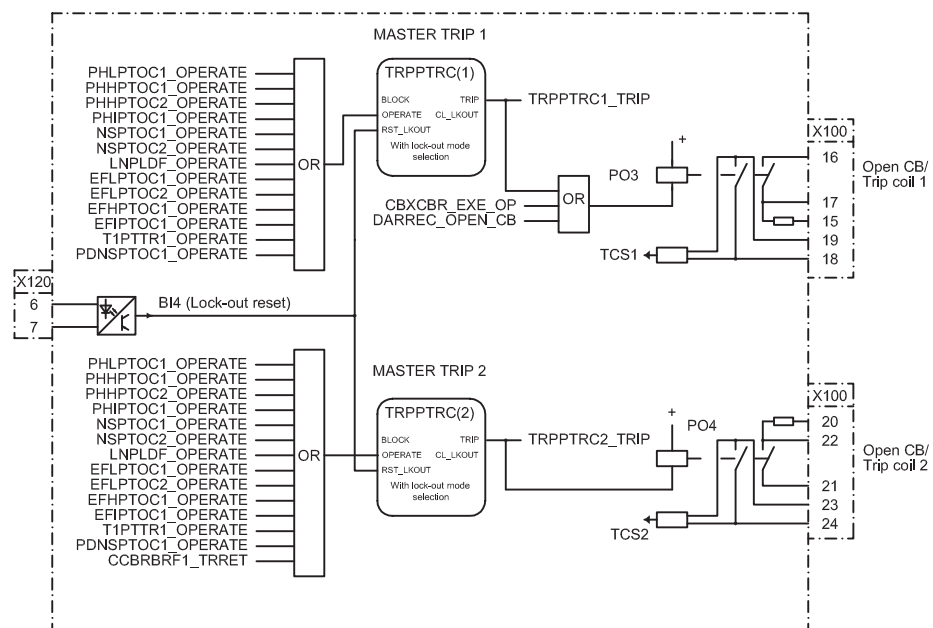


Figure 42: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker

from local or remote CBXCBR_EXE_OP is connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

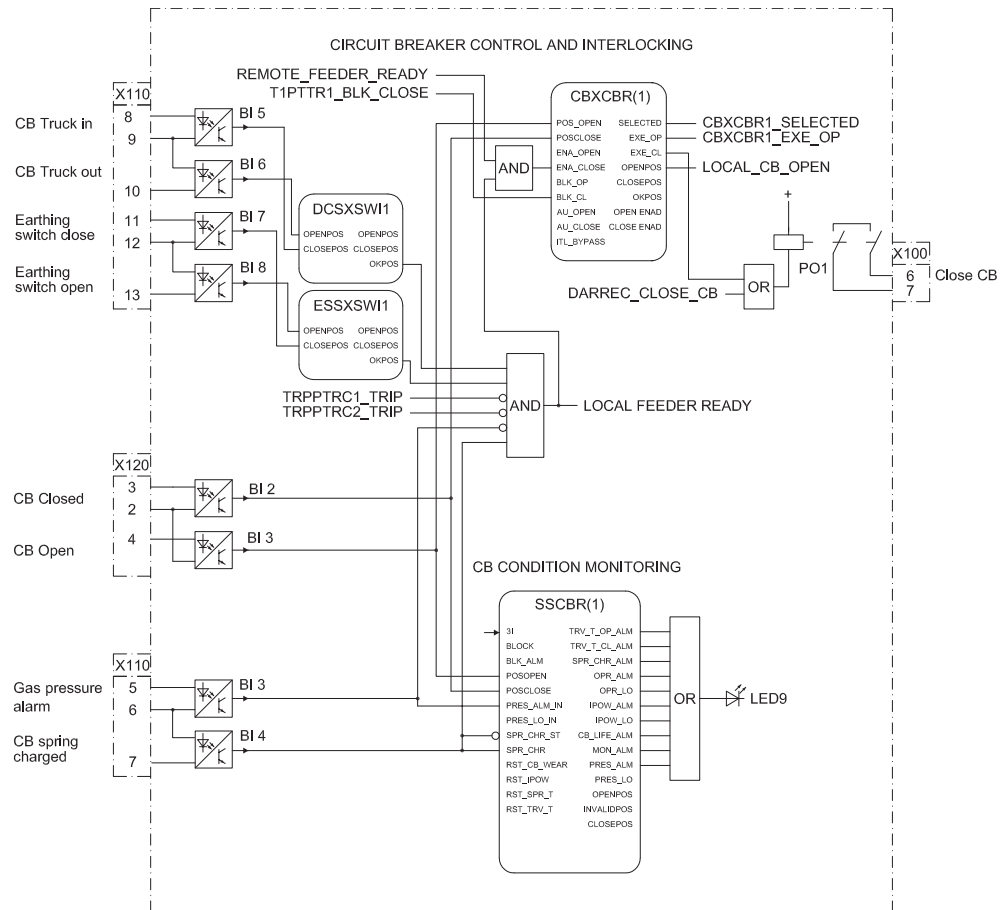


Figure 43: Circuit breaker control and interlocking

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 26: *Device positions indicated by binary inputs 5 and 6*

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnecter closed	x	
Busbar disconnecter open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnecter or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. This combination of interlocking conditions is called LOCAL_FEEDER_READY and is transferred also to the remote end via binary signal transfer. The OKPOS output from DCSXSWI defines if the disconnecter or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.



If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.



If REMOTE_FEEDER_READY information is missing, for example in case of protection communication not connected, it disables the circuit breaker closing in the local IED.

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 9.

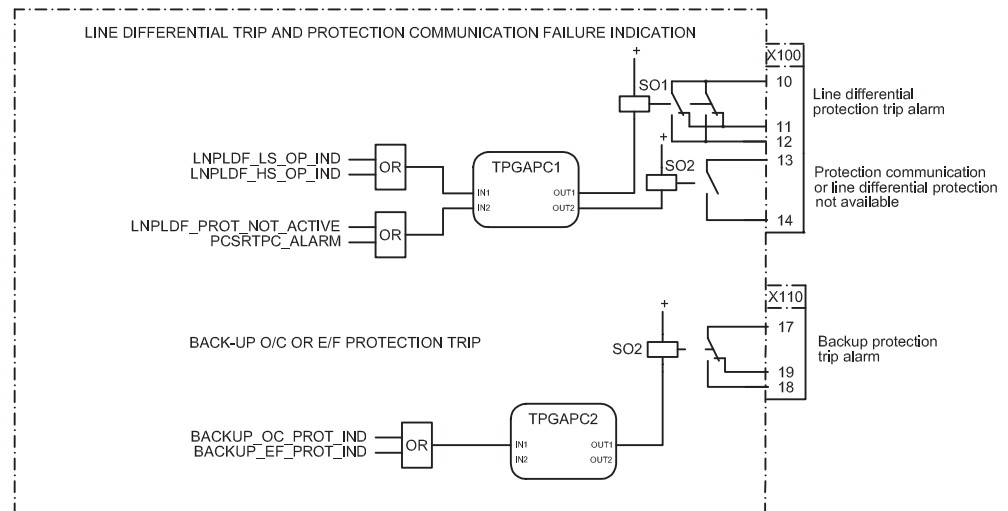


Figure 44: Line differential trip and protection communication failure indication

The signal outputs from the IED are connected to give dedicated information on:

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)
- Back-up overcurrent or earth-fault protection trip alarm SO2 (X110:17-19)

TPGAPC1 is used for setting the minimum pulse length for the outputs.

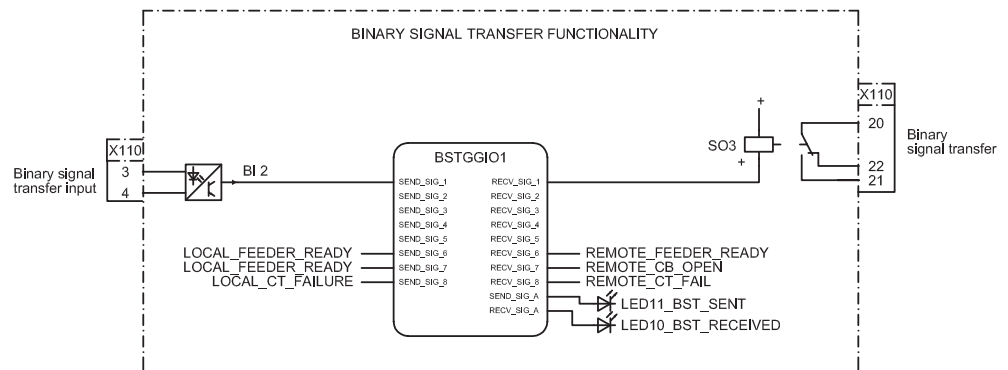


Figure 45: Binary signal transfer

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI2 (X110:3-4) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

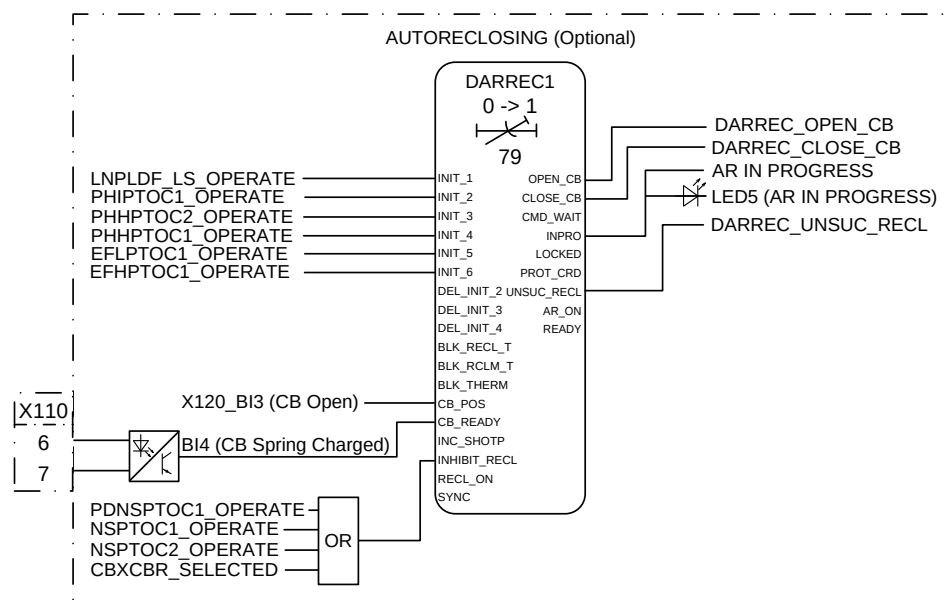


Figure 46: Autoreclose

The autoreclose function (DARREC1) is configured to be initiated by operate signals from a number of protection stages through the INIT1...6 inputs. It is possible to create individual autoreclose sequences for each input. DARREC1 can be blocked with the INHIBIT_RECL input. As a default, the operation of some selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks DARREC1 via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclose sequence is expressed with the binary input 4 (X110:6-7) by connecting the input signal to the CB_READY input. In case this signal is completely removed from DARREC1 with PCM600, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to alarm LED 5.

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 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 IED should be defined in accordance with the CT performance as well as other factors.

4.1.1.1 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 27: 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 IED.

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 IED.

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

4.1.1.2

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 IED 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 IED. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to operate, the start current should be set using the formula:

$$\text{Current start value} < 0.7 \times (I_{kmin} / I_{1n})$$

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection IED inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The operate time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a .

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the start current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed IED operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive IEDs.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time the constant of the DC component of the fault current, when the current is only slightly higher than the starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the operate time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

$$F_a > 20 * \text{Current start value} / I_{1n}$$

The *Current start value* is the primary pickup current setting of the IED.

4.1.1.3

Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three-stage definite time non-directional overcurrent protection.

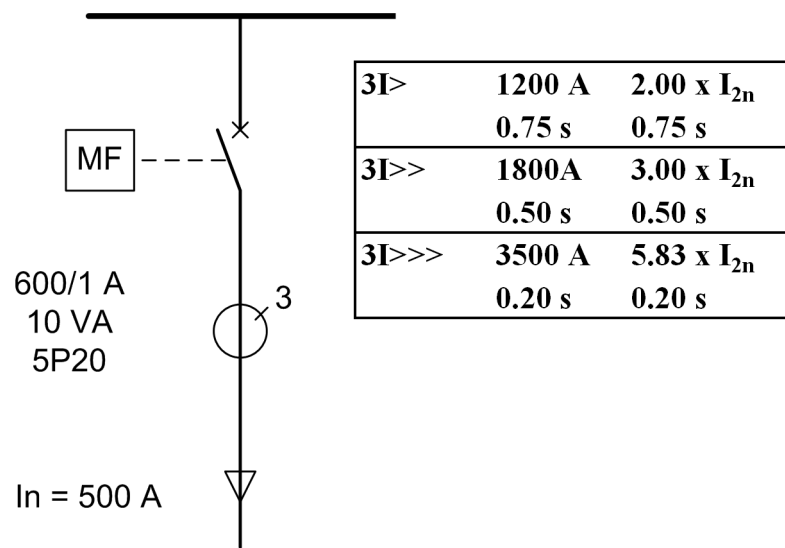


Figure 47: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next IED (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 start current settings have to be defined so that the IED operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in the figure above.

For the application point of view, the suitable setting for instantaneous stage (I>>>) 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 IED 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 5 IED physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents



The IED can also be used in single or two-phase applications by leaving one or two energizing inputs unoccupied. However, at least terminals X120/7-8 must be connected.

Table 28: *Phase currents*

Terminal	Description
X120-7, 8	IL1
X120-9, 10	IL2
X120-11, 12	IL3

5.1.1.2 Residual current

Table 29: *Residual current input*

Terminal	Description
X120-13, 14	Io

5.1.1.3 Residual voltage

Table 30: *Additional residual voltage input included in configuration B*

Terminal	Description
X120-5, 6	Uo

5.1.2 Auxiliary supply voltage input

The auxiliary voltage of the IED is connected to terminals X100/1-2. At DC supply, the positive lead is connected to terminal X100-1. The permitted auxiliary voltage range (AC/DC or DC) is marked on the top of the LHMI of the IED.

Table 31: *Auxiliary voltage supply*

Terminal	Description
X100-1	+ Input
X100-2	- Input

5.1.3

Binary inputs

The binary inputs can be used, for example, to generate a blocking signal, to unlatch output contacts, to trigger the disturbance recorder or for remote control of IED settings.

Table 32: *Binary input terminals X110-1...13*

Terminal	Description
X110-1	BI1, +
X110-2	BI1, -
X110-3	BI2, +
X110-4	BI2, -
X110-5	BI3, +
X110-6	BI3, -
X110-6	BI4, -
X110-7	BI4, +
X110-8	BI5, +
X110-9	BI5, -
X110-9	BI6, -
X110-10	BI6, +
X110-11	BI7, +
X110-12	BI7, -
X110-12	BI8, -
X110-13	BI8, +

Binary inputs of slot X120 are available with configurations A and C.

Table 33: *Binary input terminals X120-1...6*

Terminal	Description
X120-1	BI1, +
X120-2	BI1, -
X120-3	BI2, +
X120-2	BI2, -
X120-4	BI3, +
X120-2	BI3, -
X120-5	BI4, +
X120-6	BI4, -

Binary inputs of slot X120 are available with configuration B.

Table 34: *Binary input terminals X120-1...4*

Terminal	Description
X120-1	BI1, +
X120-2	BI1, -
X120-3	BI2, +
X120-2	BI2, -
X120-4	BI3, +
X120-2	BI3, -

Binary inputs of slot X130 are optional for configurations A, B and C.

Table 35: *Binary input terminals X130-1...9*

Terminal	Description
X130-1	BI1, +
X130-2	BI1, -
X130-2	BI2, -
X130-3	BI2, +
X130-4	BI3, +
X130-5	BI3, -
X130-5	BI4, -
X130-6	BI4, +
X130-7	BI5, +
X130-8	BI5, -
X130-8	BI6, -
X130-9	BI6, +

5.2 Outputs

5.2.1 Outputs for tripping and controlling

Output contacts PO1, PO2, PO3 and PO4 are heavy-duty trip contacts capable of controlling most circuit breakers. On delivery from the factory, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 36: *Output contacts*

Terminal	Description
X100-6	PO1, NO
X100-7	PO1, NO
X100-8	PO2, NO
Table continues on next page	

Terminal	Description
X100-9	PO2, NO
X100-15	PO3, NO (TCS resistor)
X100-16	PO3, NO
X100-17	PO3, NO
X100-18	PO3 (TCS1 input), NO
X100-19	PO3 (TCS1 input), NO
X100-20	PO4, NO (TCS resistor)
X100-21	PO4, NO
X100-22	PO4, NO
X100-23	PO4 (TCS2 input), NO
X100-24	PO4 (TCS2 input), NO

5.2.2 Outputs for signalling

Output contacts SO1 and SO2 in slot X100 or SO1, SO2, SO3 and SO4 in slot X110 or SO1, SO2 and SO3 in slot X130 (optional) can be used for signalling on start and tripping of the IED. On delivery from the factory, the start and alarm signals from all the protection stages are routed to signalling outputs.

Table 37: *Output contacts X100-10...14*

Terminal	Description
X100-10	SO1, common
X100-11	SO1, NC
X100-12	SO1, NO
X100-13	SO2, NO
X100-14	SO2, NO

Table 38: *Output contacts X110-14...24*

Terminal	Description
X110-14	SO1, common
X110-15	SO1, NO
X110-16	SO1, NC
X110-17	SO2, common
X110-18	SO2, NO
X110-19	SO2, NC
X110-20	SO3, common
X110-21	SO3, NO
X110-22	SO3, NC
X110-23	SO4, common
X110-24	SO4, NO

Output contacts of slot X130 are available in the optional BIO module (BIOB02A).

Table 39: *Output contacts X130-10...18*

Terminal	Description
X130-10	SO1, common
X130-11	SO1, NO
X130-12	SO1, NC
X130-13	SO2, common
X130-14	SO2, NO
X130-15	SO2, NC
X130-16	SO3, common
X130-17	SO3, NO
X130-18	SO3, NC

5.2.3

IRF

The IRF contact functions as an output contact for the self-supervision system of the protection IED. Under normal operating conditions, the IED is energized and the contact is closed (X100/3-5). When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the output contact drops off and the contact closes (X100/3-4).

Table 40: *IRF contact*

Terminal	Description
X100-3	IRF, common
X100-4	Closed; IRF, or U_{aux} disconnected
X100-5	Closed; no IRF, and U_{aux} connected

5.3

Protection communication options

Two different protection communication options are available for the IED, that is, a fibre optic link and a galvanic pilot wire link.

Multi-mode or single-mode glass fibre can be used in a fibre optic link. Select the required glass fibre mode when ordering the IED. Link lengths up to 2 km with multi-mode fibre and link lengths up to 20 km with single-mode fibre can be achieved. The fibre optic cable used for protection communication is connected to the X16/LD connector in the IED. See 615 series technical manual for more information.

If a galvanic pilot wire is used as a protection communication link, the pilot wire modem RPW600 is required. Select the pilot wire option when ordering the IED. The protection communication link always requires two modems in a protection

scheme, thus delivered in pairs of master (RPW600M) and follower (RPW600F) units. The IED is connected to the pilot wire modem using a single-mode fibre optic cable. Thus a single-mode version of IED is required if the pilot wire link is used. The fibre optic cable is connected to the X16/LD connector in the IED and in Ethernet FX connector in the pilot wire modem.

Setting or configuration is not needed with either of the pilot wire modem variants or with the IED. Pilot wire link lengths up to 8 km with 0.8 mm² twisted pair cables can be applied. Even higher distances can be achieved with good quality twisted pair cables in the pilot wire link. The achieved link length also depends on the noise levels in the installations.

The pilot wire modem has QoS (quality of service) LEDs in the front panel for easy diagnostics of the pilot wire link quality. The diagnostics feature does not depend on the payload over the pilot wire link and can be used for checking the quality of the intended pilot wire link even without installing the IEDs. In addition, a diagnostic kit is available as an ordering option for more advanced diagnostic and logging of diagnostic parameters of the pilot wire link. The kit consists of a CD-ROM with the RPW600 Diagnostic Tool software with a built-in help, required drivers and a special serial diagnostic cable to be connected to the console port of the modem.

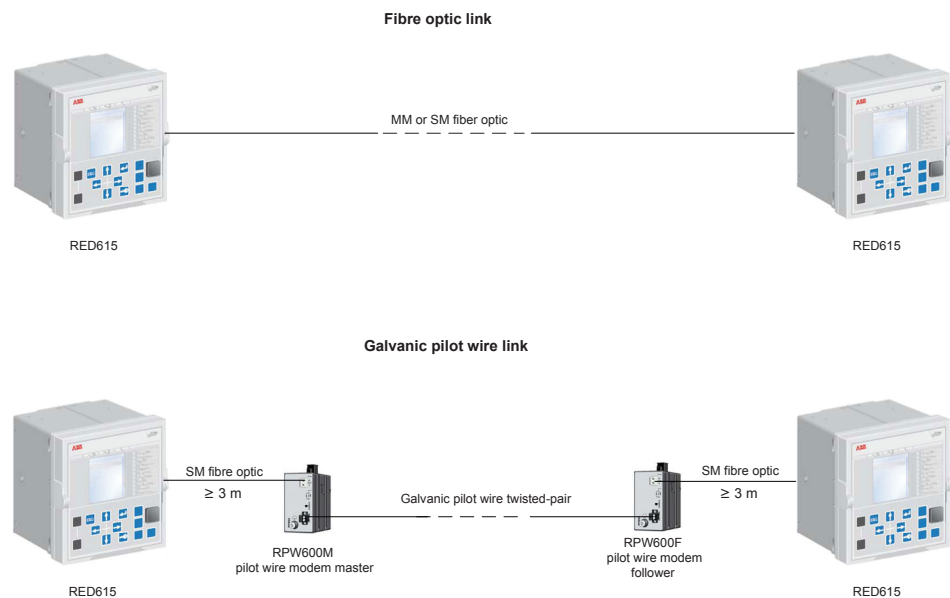


Figure 48: Protection communication options



See RPW600 user guide for more information.

Section 6

Glossary

615 series	Series of numerical IEDs for low-end protection and supervision applications of utility substations, and industrial switchgear and equipment
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
CT	Current transformer
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.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
I/O	Input/output
IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IED	Intelligent electronic device
IET600	Integrated Engineering Toolbox in PCM600
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.
LAN	Local area network

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.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
NPS	Negative phase sequence
PCM600	Protection and Control IED Manager
PO	Power output
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTU	Remote terminal unit
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SO	Signal output
TCP/IP	Transmission Control Protocol/Internet Protocol
WAN	Wide area network
WHMI	Web human-machine interface

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