RELION® 615 SERIES

Line Differential Protection and Control
RED615 ANSI

Application Manual

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Warranty

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

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

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series and ANSI C37.90. This product complies with the UL 508 certification.

Table of contents

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

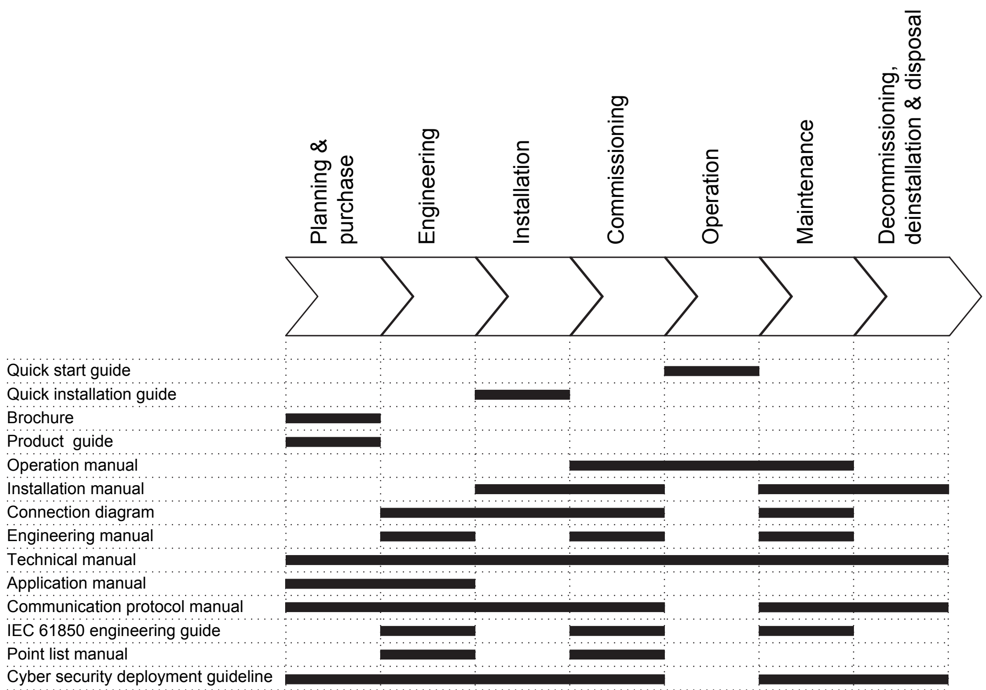


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2018-02-26	5.0 FP1	First release

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MAC057386-MB
DNP3 Communication Protocol Manual	1MAC052479-MB
IEC 61850 Engineering Guide	1MAC053584-RG
Engineering Manual	1MAC108982-MB
Installation Manual	1MAC051065-MB
Operation Manual	1MAC054853-MB
Technical Manual	1MAC059074-MB
Cyber Security Deployment Guideline	1MAC052704-HT

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

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

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Protection			
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P-3
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67/51P-1
	DPHLPDOC2	3I> -> (2)	67/51P-2
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67/50P-1
Non-directional ground-fault protection, high stage	EFHPTOC1	Io>> (1)	50G-1
Table continues on next page			

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Directional ground-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67/51N-1
	DEFLPDEF2	Io> -> (2)	67/51N-2
Directional ground-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67/50N-1
Admittance-based ground-fault protection	EFPADM1	Yo> -> (1)	21YN-1
	EFPADM2	Yo> -> (2)	21YN-2
	EFPADM3	Yo> -> (3)	21YN-3
Wattmetric-based ground-fault protection	WPWDE1	Po> -> (1)	32N-1
	WPWDE2	Po> -> (2)	32N-2
	WPWDE3	Po> -> (3)	32N-3
Transient/intermittent ground-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF
Harmonics-based ground-fault protection	HAEFPTOC1	Io>HA (1)	51NHA
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46-1
	NSPTOC2	I2> (2)	46-2
Phase discontinuity protection	PDNSPTOC1	I2/I1> (1)	46PD
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G
	ROVPTOV2	Uo> (2)	59N-1
	ROVPTOV3	Uo> (3)	59N-2
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27-1
	PHPTUV2	3U< (2)	27-2
	PHPTUV3	3U< (3)	27-3
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59-1
	PHPTOV2	3U> (2)	59-2
	PHPTOV3	3U> (3)	59-3
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U-1
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47-1
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81-1
	FRPFRQ2	f>/f<,df/dt (2)	81-2
	FRPFRQ3	f>/f<,df/dt (3)	81-3
	FRPFRQ4	f>/f<,df/dt (4)	81-4
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F (1)	49F-1
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T-1
Binary signal transfer	BSTGGIO1	BST (1)	BST-1
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	50BF-1
Three-phase inrush detector	INRPHAR1	3I2f> (1)	INR-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Switch onto fault	CBPSOF1	SOTF (1)	SOTF-1
Master trip	TRPPTRC1	Master Trip (1)	86/94-1
	TRPPTRC2	Master Trip (2)	86/94-2
Multipurpose protection	MAPGAPC1	MAP (1)	MAP-1
	MAPGAPC2	MAP (2)	MAP-2
	MAPGAPC3	MAP (3)	MAP-3
	MAPGAPC4	MAP (4)	MAP-4
	MAPGAPC5	MAP (5)	MAP-5
	MAPGAPC6	MAP (6)	MAP-6
	MAPGAPC7	MAP (7)	MAP-7
	MAPGAPC8	MAP (8)	MAP-8
	MAPGAPC9	MAP (9)	MAP-9
	MAPGAPC10	MAP (10)	MAP-10
	MAPGAPC11	MAP (11)	MAP-11
	MAPGAPC12	MAP (12)	MAP-12
	MAPGAPC13	MAP (13)	MAP-13
	MAPGAPC14	MAP (14)	MAP-14
	MAPGAPC15	MAP (15)	MAP-15
	MAPGAPC16	MAP (16)	MAP-16
	MAPGAPC17	MAP (17)	MAP-17
	MAPGAPC18	MAP (18)	MAP-18
Fault locator	SCEFRFLO1	FLOC (1)	21FL-1
Line differential protection with in-zone power transformer	LNPLDF1	3Id/I> (1)	87L-1
High-impedance fault detection	PHIZ1	HIF (1)	HIZ-1
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQI-1
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQVPH-1
Voltage variation	PHQVVR1	PQMU (1)	PQSS-1
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB-1
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	52-1
Disconnector control	DCXSWI1	I <-> O DCC (1)	29DS-1
	DCXSWI2	I <-> O DCC (2)	29DS-2
Grounding switch control	ESXSWI1	I <-> O ESC (1)	29GS-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	52-TOC
	DCSXSWI2	I <-> O DC (2)	29DS-1
	DCSXSWI3	I <-> O DC (3)	29DS-2
Grounding switch indication	ESSXSWI1	I <-> O ES (1)	29GS-1
	ESSXSWI2	I <-> O ES (2)	29GS-2
Autoreclosing	DARREC1	O -> I (1)	79
Synchronism and energizing check	SECRSYN1	SYNC (1)	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	52CM-1
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM-1
	TCSSCBR2	TCS (2)	TCM-2
Current circuit supervision	CCSPVC1	MCS 3I (1)	CCM
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60-1
Protection communication supervision	PCSITPC1	PCS (1)	PCS-1
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM-1
Measurement			
Load profile record	LDPRLRC1	LOADPROF (1)	LoadProf
Three-phase current measurement	CMMXU1	3I (1)	IA, IB, IC
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0
Residual current measurement	RESCMMXU1	Io (1)	IG
Three-phase voltage measurement	VMMXU1	3U (1)	VA, VB, VC
	VMMXU2	3U (2)	VA, VB, VC (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	VG-1
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0
Single-phase power and energy measurement	SPEMMXU1	SP, SE	SP, SE-1
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E-1
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRECEIVER	SMVRECEIVER	SMVRECEIVER
Other			
Table continues on next page			

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Minimum pulse timer	TPGAPC1	TP (1)	62TP-1
	TPGAPC2	TP (2)	62TP-2
	TPGAPC3	TP (3)	62TP-3
	TPGAPC4	TP (4)	62TP-4
Minimum pulse timer (second resolution)	TPSGAPC1	TPS (1)	62TPS-1
Minimum pulse timer (minute resolution)	TPMGAPC1	TPM (1)	62TPM-1
Pulse timer	PTGAPC1	PT (1)	62PT-1
	PTGAPC2	PT (2)	62PT-2
Time delay off	TOFGAPC1	TOF (1)	62TOF-1
	TOFGAPC2	TOF (2)	62TOF-2
	TOFGAPC3	TOF (3)	62TOF-3
	TOFGAPC4	TOF (4)	62TOF-4
Time delay on	TONGAPC1	TON (1)	62TON-1
	TONGAPC2	TON (2)	62TON-2
	TONGAPC3	TON (3)	62TON-3
	TONGAPC4	TON (4)	62TON-4
Set-reset	SRGAPC1	SR (1)	SR-1
	SRGAPC2	SR (2)	SR-2
	SRGAPC3	SR (3)	SR-3
	SRGAPC4	SR (4)	SR-4
Move	MVGAPC1	MV (1)	MV-1
	MVGAPC2	MV (2)	MV-2
Generic control point	SPCGAPC1	SPC (1)	SPC-1
	SPCGAPC2	SPC (2)	SPC-2
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4-1
	SCA4GAPC2	SCA4 (2)	SCA4-2
	SCA4GAPC3	SCA4 (3)	SCA4-3
	SCA4GAPC4	SCA4 (4)	SCA4-4
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4-1
Generic up-down counters	UDFCNT1	UDCNT (1)	CTR-1
	UDFCNT2	UDCNT (2)	CTR-2
	UDFCNT3	UDCNT (3)	CTR-3
	UDFCNT4	UDCNT (4)	CTR-4

Section 2 RED615 overview

2.1 Overview

RED615 is a phase-segregated two-end line differential protection and control relay designed for utility and industrial power systems, including radial, looped and meshed distribution networks with or without distributed power generation. RED615 is also designed for the protection of line differential applications with a transformer within the protection zone. RED615 relays communicate between substations over a fiber 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 relays 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 relay provides unit type main protection for overhead lines and cable feeders in distribution networks. The relay also features current-based protection functions for remote back-up for down-stream protection relays and local back-up for the line differential main protection. Standard configurations D and E include directional overcurrent and voltage based protection functions.

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

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
5.0 FP1	Product released

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.8 or later
- RED615 Connectivity Package Ver.5.1 or later

- Parameter Setting
- Signal Monitoring
- Event Viewer
- Disturbance Handling
- Application Configuration
- Signal Matrix
- Graphical Display Editor
- Communication Management
- IED User Management
- IED Compare
- Firmware Update
- Fault Record tool
- Load Record Profile
- Lifecycle Traceability
- Configuration Wizard
- AR Sequence Visualizer
- Label Printing
- IEC 61850 Configuration
- IED Configuration Migration
- Differential Characteristics Tool

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

2.2 Operation functionality

2.2.1 Optional features

- Autoreclosing
- Modbus TCP/IP or RTU/ASCII
- DNP3 TCP/IP or serial
- Admittance-based ground-fault protection
- Wattmetric-based ground-fault protection
- Harmonics-based ground-fault protection
- Power quality functions
- Fault locator
- RTD/mA measurement (configuration D only)
- IEC 61850-9-2 LE (with 2 × LC only)
- IEEE 1588 v2 time synchronization (with 2 × LC only)

2.3 Physical hardware

The protection relay 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 unit	Slot ID	Content	Details
Plug-in unit	-	HMI	Large (10 lines, 20 characters) with SLD
	X100	Auxiliary power/BO module	48...250 V DC/100...240 V AC or 24...60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	Optional BIO module	Only with configurations D and E: 8 binary inputs 4 SO contacts
	X120	Order alternatively options AI/BI module	Only with configuration D: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A) 3 binary inputs
			Only with configuration D: 3 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)] 3 binary inputs
Case	X130	Order alternatively options AI/BI or AI/RTD/mA module	Only with configuration D: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
			Only with configuration D: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA input 2 RTD sensor inputs
		Sensor input module	Only with configuration E: 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)[1)]
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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

Rated values of the current and voltage inputs are basic setting parameters of the protection relay. The binary input thresholds are selectable within the range 16…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: Input/output overview

Std. conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
D	FE/FF	AD	4	5	-	12	4 PO + 6 SO	2	1
	AE/AF	AG	4	5	-	16	4 PO + 6 SO	-	-
E	DA	AH	1	-	3	8	4 PO + 6 SO	-	-

2.4 Local HMI

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

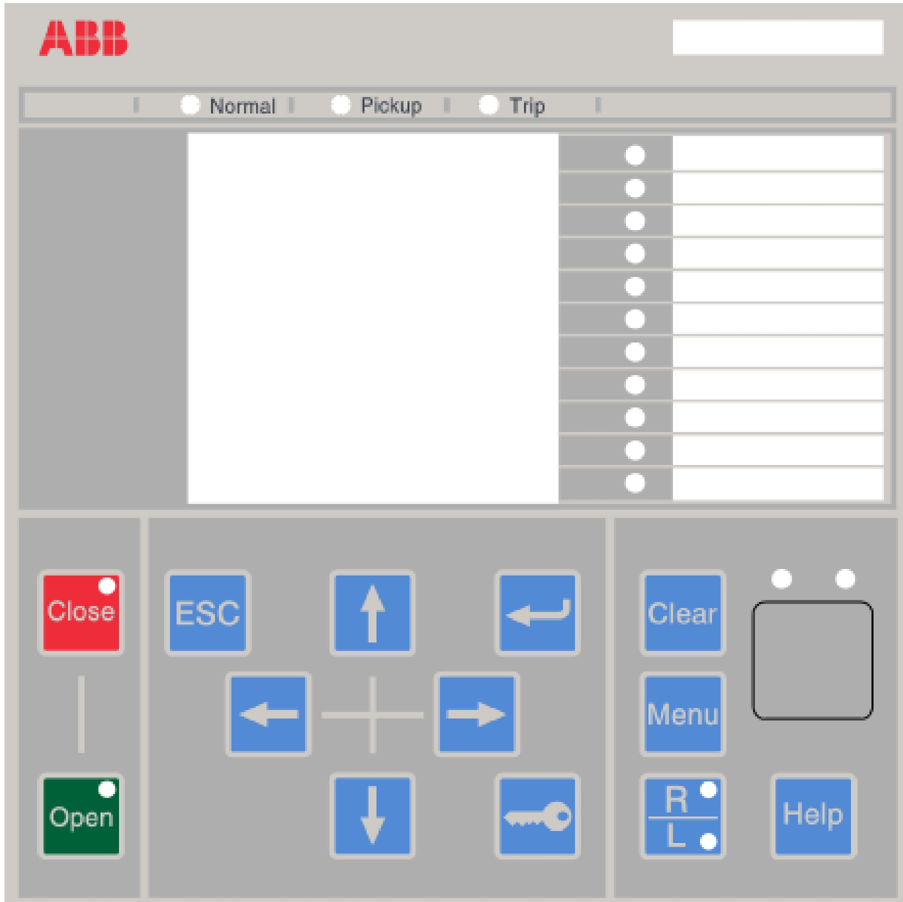


Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Large display

Character size[1)]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20

1) Depending on the selected language

The display view is divided into four basic areas.

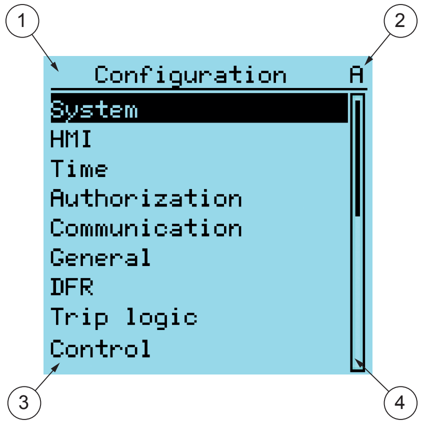


Figure 3: Display layout

1 Header

2 Icon

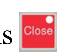
3 Content

4 Scroll bar (displayed when needed)

2.4.2 LEDs

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

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

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

and 

. They represent the status of breaker 1 (CBXCBR1).

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

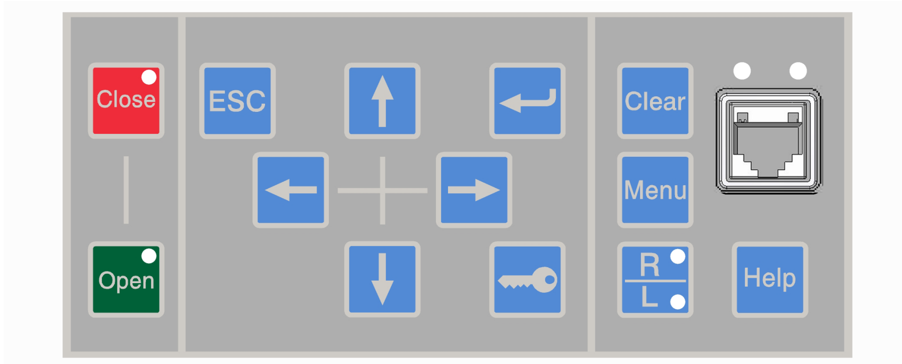


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

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

WHMI is disabled by default.WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- DFR records
- Fault records
- Load profile record
- Phasor diagram
- Single-line diagram
- Importing/Exporting parameters
- Report summary

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

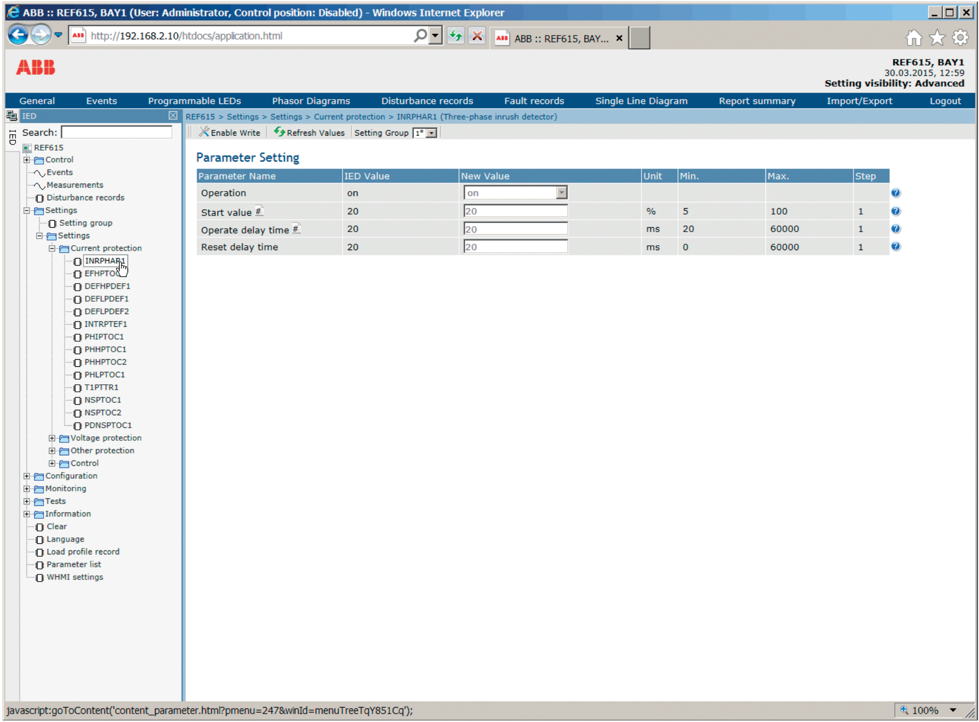


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

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

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

Table 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 DFRs and load profile record • Changing system settings such as IP address, serial baud rate or DFR settings • Setting the protection relay to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850, IEC 61850-9-2 LE, Modbus® and DNP3. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

The protection relay utilizes Ethernet communication extensively for different purposes. The exact services depend on the ordered product variant and enabled functionality. HSR/PRP is available in 615 series Ver.5.0 FP1 ANSI.

HSR/PRP availability depends on the product ordering information. See the Rear communication modules chapter for information on HSR/PRP supported COM cards.

Table 6: TCP and UDP ports used for different services

Service	Port
File Transfer Protocol (FTP and FTPS)	20, 21
IEC 61850	102
Web Server HTTP	80
Web Server HTTPS	443
Simple Network Time Protocol (SNTP)	123
Modbus TCP	502
DNP TCP	20000

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

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

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

2.7.1 Self-healing Ethernet ring

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

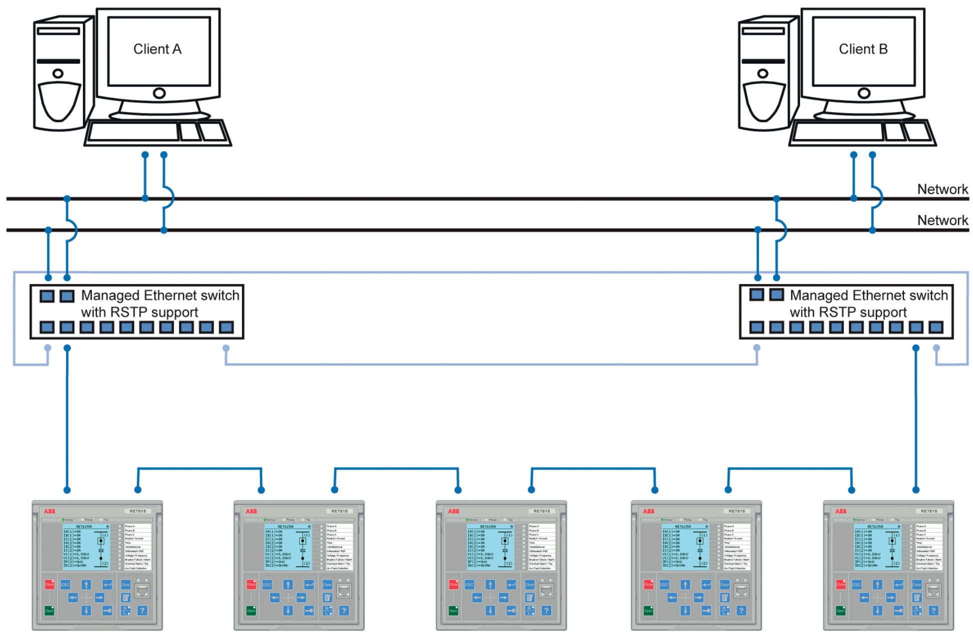


Figure 6: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to 30 protection relays. If more than 30 protection relays are to be connected, it is recommended that the network is split into several rings with no more than 30 protection relays per ring. Each protection relay has a 50-μs store-and-forward delay, and to fulfil the performance requirements for fast horizontal communication, the ring size is limited to 30 protection relays.

2.7.2 Ethernet redundancy

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

PRP specifies that each device is connected in parallel to two local area networks. HSR applies the PRP principle to rings and to the rings of rings to achieve cost-effective redundancy. Thus, each device incorporates a switch element that forwards frames from port to port. The HSR/PRP option is available for all 615 series protection relays. However, RED615 supports this option only over fiber optics.

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

PRP

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

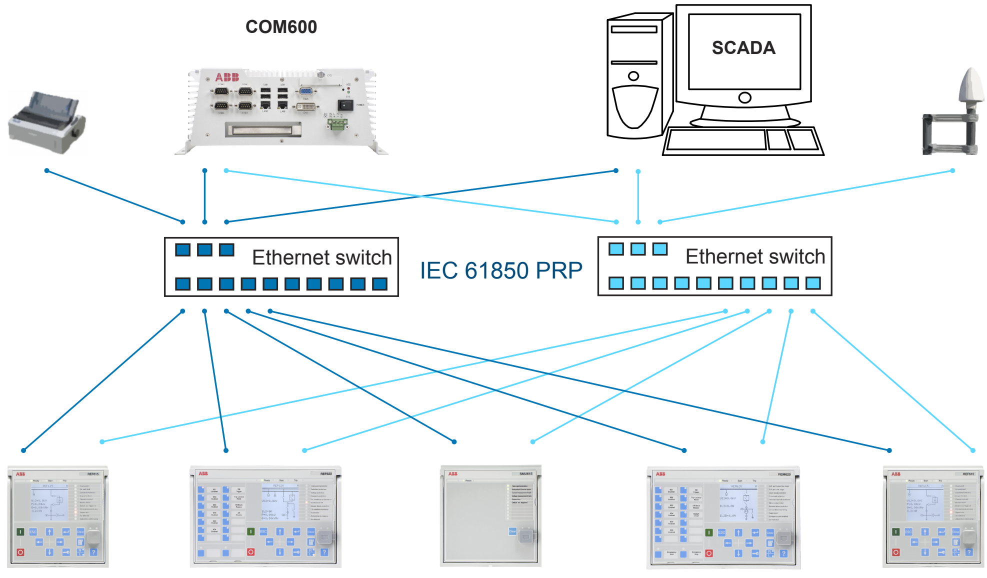


Figure 7: PRP solution

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

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

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

HSR

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

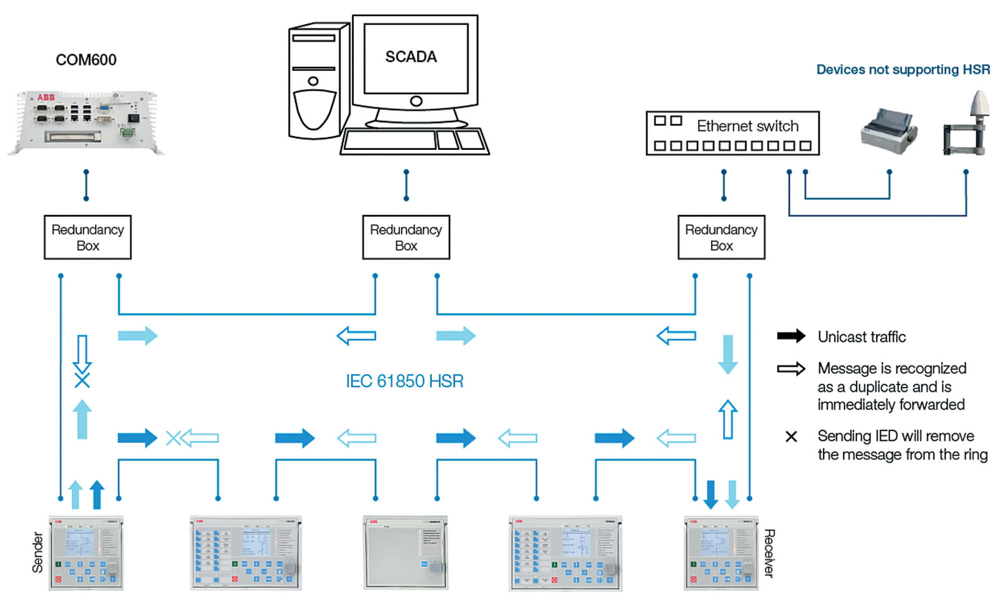


Figure 8: HSR solution

2.7.3 Protection communication and supervision

The communication between the relays is enabled by means of a dedicated fiber optic communication channel. 1310 nm multi-mode or single-mode fibers with LC connectors are used for line differential communication. The channel is used for transferring the phase segregated current value data between the relays. The current phasors from the two relays, geographically located apart from each other, must be time coordinated so that the current differential algorithm can be executed correctly. The so called echo method is used for time synchronization. No external devices such as GPS clocks are thereby needed for the line differential protection communication.

Apart from the continued protection communication, the communication channel can also be used for binary signal transfer (BST) that is, transferring of user configurable binary information between the relays. There are a total of eight BST signals available for user definable purposes. The BST signals can originate from the relay's binary inputs or internal logics, and be assigned to the remote relay's binary outputs or internal logics.

The protection communication supervision continuously monitors the protection communication link. The relay immediately blocks the line differential protection function in case that severe interference in the communication link, risking the correct operation of the function, is detected. An alarm signal will eventually be issued if the interference, indicating permanent failure in the protection communication, persists. The two high-set stages of the overcurrent protection are further by default released.

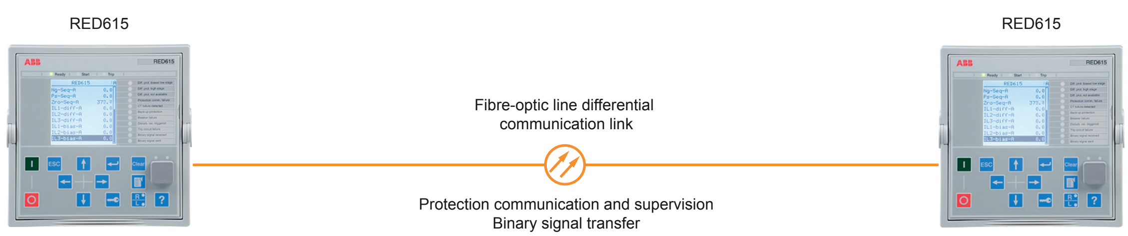


Figure 9: Fiber optic protection communication link

Section 3 RED615 standard configurations

3.1 Standard configurations

RED615 is available with two alternative standard configurations. The standard signal configuration can be altered by means of the 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 relay configuration can be adapted to user specific application requirements.

The relay 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. Some of the supported functions in RED615 must be added with the Application Configuration tool to be available in the Signal Matrix tool and in the relay. The positive measuring direction of directional protection functions is towards the outgoing feeder.

Table 7: Standard configurations

Description	Std. conf.
Line differential protection with directional overcurrent and ground-fault protection, voltage and frequency based protection and measurements, synchro-check and circuit-breaker condition monitoring (RTD option, optional power quality and fault locator)	D
Line differential protection with directional overcurrent and ground-fault protection, voltage and frequency based protection and measurements, and circuit-breaker condition monitoring (sensor inputs, optional power quality, fault locator and synchro-check with IEC 61850-9-2 LE)	E

Table 8: Supported functions

Function	IEC 61850	ANSI	D	E
Protection				
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P	2	2
Three-phase directional overcurrent protection, high stage	DPHHPDOC	67/50P	1	1
Table continues on next page				

Function	IEC 61850	ANSI	D	E
Non-directional ground-fault protection, high stage	EFHPTOC	50G	1	1
Directional ground-fault protection, low stage	DEFLPDEF	67/51N	2	2
Directional ground-fault protection, high stage	DEFHPDEF	67/50N	1	1
Admittance-based ground-fault protection[1]	EFPADM	21YN	(3)[1]	(3)[1][2]
Wattmetric-based ground-fault protection[1]	WPWDE	32N	(3)[1]	(3)[1][2]
Transient/intermittent ground-fault protection	INTRPTEF	67NIEF	1[3]	1[2][3]
Harmonics-based ground-fault protection[1]	HAEFPTOC	51NHA	(1)[1][3]	(1)[1][3]
Negative-sequence overcurrent protection	NSPTOC	46	2	2
Phase discontinuity protection	PDNSPTOC	46PD	1	1
Residual overvoltage protection	ROVPTOV	59G	1	1
		59N	2	2
Three-phase undervoltage protection	PHPTUV	27	3	3
Three-phase overvoltage protection	PHPTOV	59	3	3
Positive-sequence undervoltage protection	PSPTUV	47U	1	1
Negative-sequence overvoltage protection	NSPTOV	47	1	1
Frequency protection	FRPFRQ	81	4	4
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	49F	1	1
Three-phase thermal overload protection, two time constants	T2PTTR	49T	1	1
Binary signal transfer	BSTGGIO	BST	1	1
Circuit breaker failure protection	CCBRBRF	50BF	1	1
Three-phase inrush detector	INRPHAR	INR	1	1
Switch onto fault	CBPSOF	SOTF	1	1
Master trip	TRPPTRC	86/94	2	2
Multipurpose protection	MAPGAPC	MAP	18	18
Fault locator	SCEFRFLO	21FL	(1)	(1)
Line differential protection with in-zone power transformer	LNPLDF	87L	1	1
High-impedance fault detection	PHIZ	HIZ	1	
Table continues on next page				

Function	IEC 61850	ANSI	D	E
Power quality				
Current total demand distortion	CMHAI	PQI	(1)[4)]	(1)[4)]
Voltage total harmonic distortion	VMHAI	PQVPH	(1)[4)]	(1)[4)]
Voltage variation	PHQVVR	PQSS	(1)[4)]	(1)[4)]
Voltage unbalance	VSQVUB	PQVUB	(1)[4)]	(1)[4)]
Control				
Circuit-breaker control	CBXCBR	52	1	1
Disconnector control	DCXSWI	29DS	2	2
Grounding switch control	ESXSWI	29GS	1	1
Disconnector position indication	DCSXSWI	52	3	3
Grounding switch indication	ESSXSWI	29GS	2	2
Autoreclosing	DARREC	79	(1)	(1)
Synchronism and energizing check	SECRSYN	25	1	(1)[5)]
Condition monitoring				
Circuit-breaker condition monitoring	SSCBR	52CM	1	1
Trip circuit supervision	TCSSCBR	TCM	2	2
Current circuit supervision	CCSPVC	CCM	1	1
Fuse failure supervision	SEQSPVC	60	1	1
Protection communication supervision	PCSITPC	PCS	1	1
Runtime counter for machines and devices	MDSOPT	OPTM	1	1
Measurement				
Load profile record	LDPRLRC	LoadProf	1	1
Three-phase current measurement	CMMXU	IA, IB, IC	1	1
Sequence current measurement	CSMSQI	I1, I2, I0	1	1
Residual current measurement	RESCMMXU	IG	1	1
Three-phase voltage measurement	VMMXU	VA, VB, VC	2	1 (1)[4)]
Residual voltage measurement	RESVMMXU	VG	1	
Sequence voltage measurement	VSMSQI	V1, V2, V0	1	1
Single-phase power and energy measurement	SPEMMXU	SP, SE	1	1
Three-phase power and energy measurement	PEMMXU	P, E	1	1
RTD/mA measurement	XRGGIO130	X130 (RTD)	(1)	
Frequency measurement	FMMXU	f	1	1
IEC 61850-9-2 LE sampled value sending[6)]	SMVSENDER	SMVSENDER	(1)	(1)

Table continues on next page

Function	IEC 61850	ANSI	D	E
IEC 61850-9-2 LE sampled value receiving (voltage sharing)[6)]	SMVRECEIVER	SMVRECEIVER	(1)	(1)
Other				
Minimum pulse timer (2 pcs)	TPGAPC	62TP	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1	1
Pulse timer (8 pcs)	PTGAPC	62PT	2	2
Time delay off (8 pcs)	TOFGAPC	62TOF	4	4
Time delay on (8 pcs)	TONGAPC	62TON	4	4
Set-reset (8 pcs)	SRGAPC	SR	4	4
Move (8 pcs)	MVGAPC	MV	2	2
Generic control point (16 pcs)	SPCGAPC	SPC	2	2
Analog value scaling	SCA4GAPC	SCA4	4	4
Integer value move	MVI4GAPC	MVI4	1	1
Generic up-down counters	UDFCNT	CTR	4	4
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = Optional				

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 optional ground-fault protection has a predefined configuration in the relay. The optional ground-fault protection can be set on or off.
2) "Calculated V0" is always used
3) "Measured IG" is always used
4) Power quality option includes Current total demand distortion, Voltage total harmonic distortion and Voltage variation.
5) Only available with IEC 61850-9-2
6) Only available with COM0031...0037

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 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 protection relay.

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 protection relay's standard configuration.

The suitability of the protection relay'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

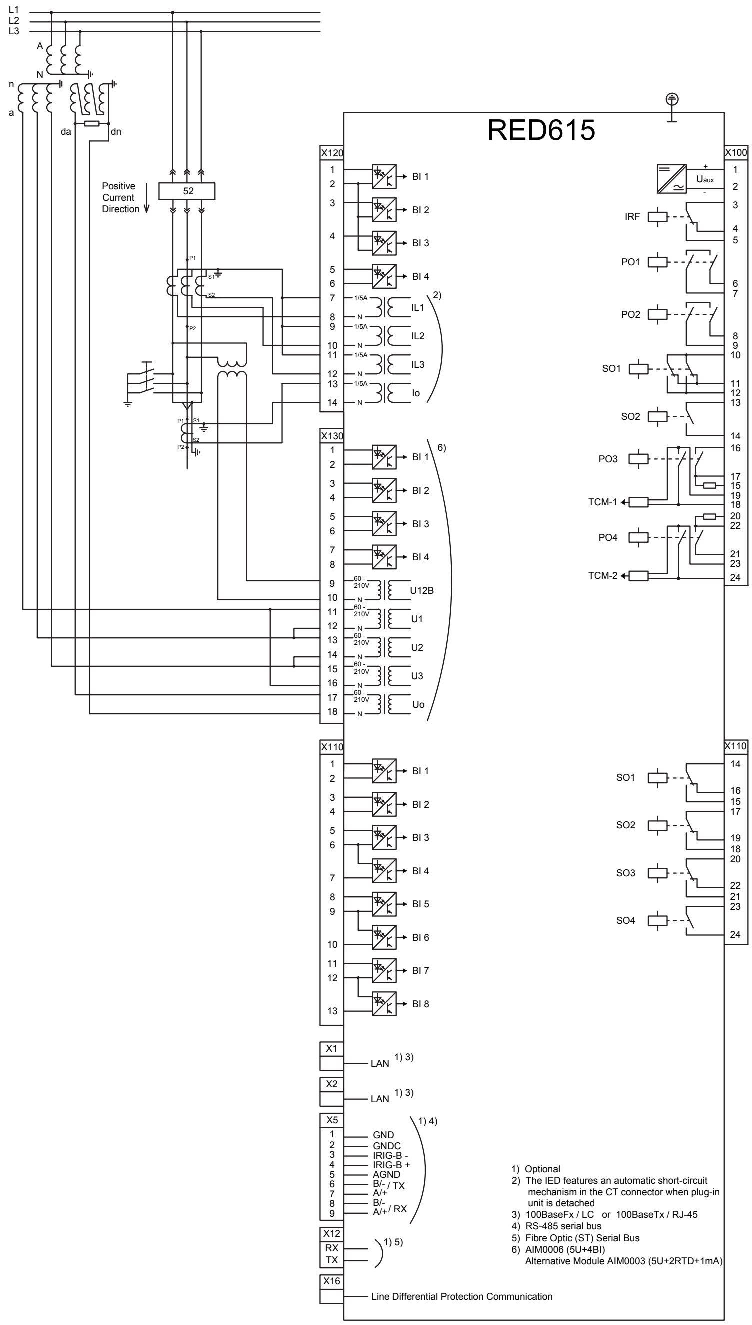


Figure 10: Connection diagram for the D configuration

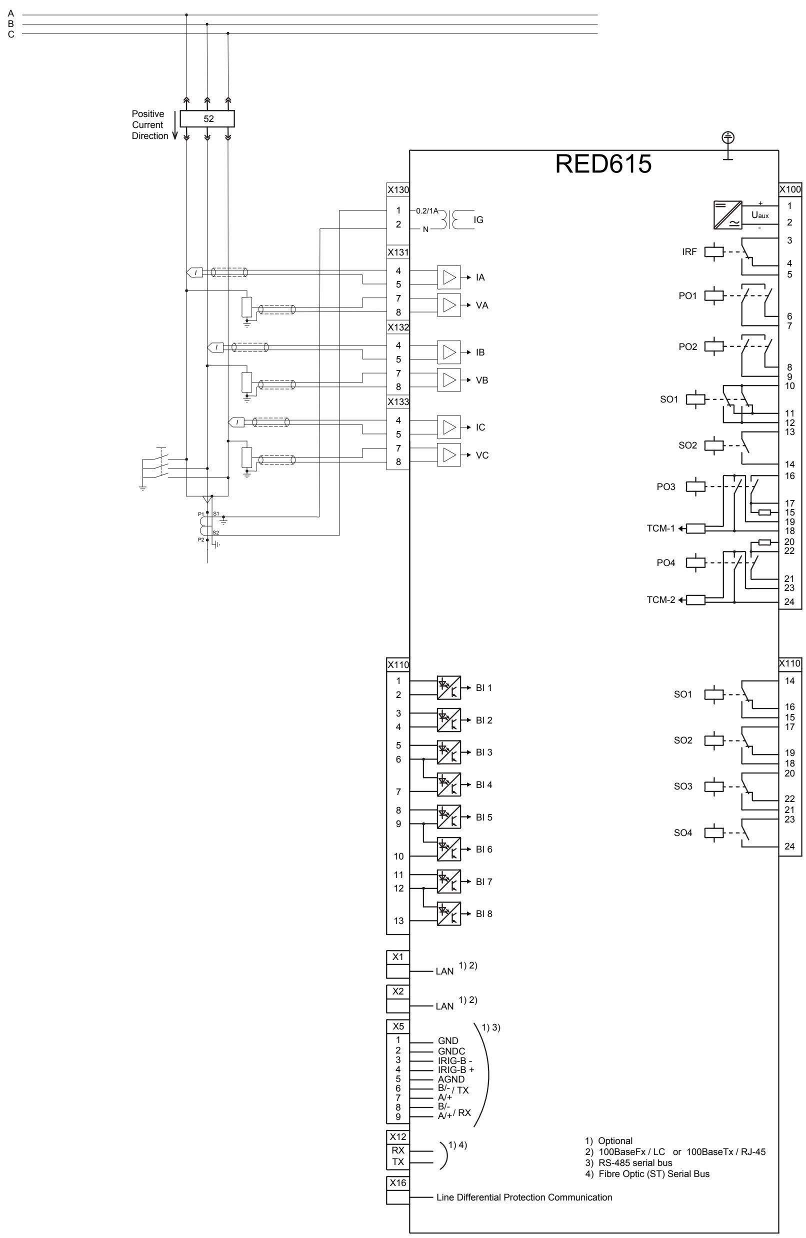


Figure 11: Connection diagram for the E configuration

3.3 Standard configuration D

3.3.1 Applications

The standard configuration with directional overcurrent and directional ground-fault protection, phase-voltage and frequency based protection is mainly intended for cable feeder applications in distribution networks. The standard configuration for line current differential protection includes support for in-zone transformers. The configuration also includes additional options to select ground-fault protection based on admittance, wattmetric or harmonic principle.

Standard configuration D is not designed for using all the available functionality content in one relay at the same time. Frequency protection functions and third instances of voltage protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user-specific configuration load is verified with the Application Configuration tool in PCM600.

The protection relay 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 protection relay enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.3.2 Functions

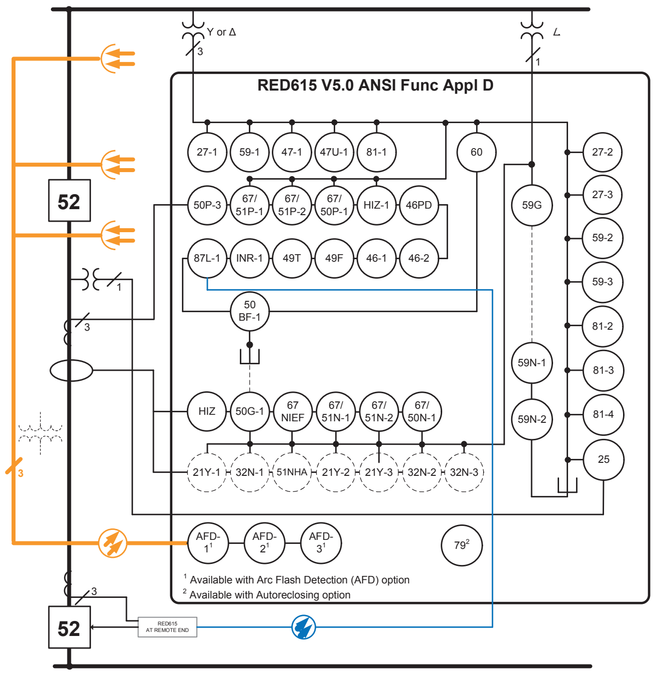


Figure 12: Functionality overview for standard configuration D

3.3.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Description	Connector pins
IL1	Phase A current	X120:7-8
IL2	Phase B current	X120:9-10
IL3	Phase C current	X120:11-12
Io	Residual current IG	X120:13-14
U12B	Phase-to-phase voltage VAB(2)	X130:9-10
U1	Phase voltage VA	X130:11-12
U2	Phase voltage VB	X130:13-14
U3	Phase voltage VC	X130:15-16
Uo	Residual voltage VG	X130:17-18

Table 10: 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	-	X110:5-6
X110-BI4	-	X110:7-6
X110-BI5	-	X110:8-9
X110-BI6	-	X110:10-9
X110-BI7	-	X110:11-12
X110-BI8	-	X110:13-12
X120-BI1	Blocking input for general use	X120:1-2
X120-BI2	Circuit breaker closed position indication	X120:3-2
X120-BI3	Circuit breaker open position indication	X120:4-2
X120-BI4	-	X120:5-6
X130-BI1	-	X130:1-2
X130-BI2	-	X130:3-2
X130-BI3	-	X130:4-5
X130-BI4	-	X130:6-5
X130-BI5	-	X130:7-8
X130-BI6	-	X130:9-8

Table 11: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection 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 coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Upstream overcurrent blocking	X110:14-16
X110-SO2	Backup protection trip	X110:17-19
X110-SO3	Binary transfer signal	X110:20-22
X110-SO4	-	X110:23-24
X130-SO1	-	X130:10-12
X130-SO2	-	X130:13-15
X130-SO3	-	X130:16-18

Table 12: Default connections for LEDs

LED	Default usage	ID	Label description
1	Line differential protection biased stage trip	LED_DiffProtBiasedLowStage_1	Diff. prot. biased low stage
2	Line differential protection instantaneous stage trip	LED_DiffProtHighStage_1	Diff. prot. high stage
3	Line differential protection is not available	LED_DiffProtNotAvailable_1	Diff. prot. not available
4	Protection communication failure	LED_ProtectionCommFailure_1	Protection comm. failure
5	Autoreclose in progress	LED_AutorecloseInProgress_1	Autoreclose shot in progr.
6	Backup protection trip	LED_BackUpProtection_1	Back-up protection
7	Breaker failure trip	LED_BreakerFailure_1	Breaker failure
8	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
9	Supervision alarm	LED_Supervision_1	Supervision
10	Binary signal transfer receive	LED_BinarySignalReceived_1	Binary signal received
11	Binary signal transfer send	LED_BinarySignalSent_1	Binary signal sent

3.3.2.2 Default disturbance recorder settings

Table 13: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	U12B
10	-
11	-
12	-

Table 14: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - pickup	Positive or Rising
2	LNPLDF1 - trip	Positive or Rising
3	PHIPTOC1 - pickup	Positive or Rising
4	DPHHPDOC1 - pickup	Positive or Rising
5	DPHLPDOC1 - pickup	Positive or Rising
6	DPHLPDOC2 - pickup	Positive or Rising
7	NSPTOC1 - pickup	Positive or Rising
8	NSPTOC2 - pickup	Positive or Rising
9	INRPHAR1 - blk2h	Positive or Rising
10	EFHPTOC1 - pickup	Positive or Rising
11	DEFLPDEF1/WPWDE1/EFPADM1 - pickup	Positive or Rising
12	DEFLPDEF2/WPWDE2/EFPADM2 - pickup	Positive or Rising
13	DEFHPDEF1/WPWDE3/EFPADM3 - pickup	Positive or Rising
14	PDNSPTOC1 - pickup	Positive or Rising
15	T1PTTR1 - pickup	Positive or Rising
16	T2PTTR1 - pickup	Positive or Rising
17	PHPTOV1 - pickup	Positive or Rising
18	PHPTOV2 - pickup	Positive or Rising
19	-	-
20	ROVPTOV1 - pickup	Positive or Rising
21	ROVPTOV2 - pickup	Positive or Rising
22	-	-
23	PSPTUV1 - pickup	Positive or Rising
24	NSPTOV1 - pickup	Positive or Rising
25	PHPTUV1 - pickup	Positive or Rising
26	PHPTUV2 - pickup	Positive or Rising
27	-	-
28	-	-
29	-	-
30	-	-
31	-	-
32	CCBRBRF1 - trret	Level trigger off
33	CCBRBRF1 - trbu	Level trigger off
34	LNPLDF1 - rstd2h	Level trigger off
35	LNPLDF1 - prot not active	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
36	PHxPTOC - trip	Level trigger off
37	NSPTOC - trip	Level trigger off
38	INTRPTEF1 - trip	Level trigger off
39	EFHPTOC1 - trip	Level trigger off
40	DEFxPDEF/WPWDE/EFPADM - trip	Level trigger off
41	PDNSPTOC1 - trip	Level trigger off
42	T1PTTR1 - alarm	Level trigger off
43	T2PTTR2 - alarm	Level trigger off
44	PHPTOV - trip	Level trigger off
45	ROVPTOV/PSPTUV1/NSPTOV1 - trip	Level trigger off
46	T1PTTR1/T2PTTR2 - trip	Level trigger off
47	PHPTUV - trip	Level trigger off
48	-	-
49	INRPHAR1 - blk2h	Level trigger off
50	PCSITPC1 - alarm	Level trigger off
51	CCSPVC1 - alarm	Level trigger off
52	SEQSPVC - fusef 3ph	Level trigger off
53	SEQSPVC - fusef u	Level trigger off
54	-	-
55	-	-
56	X120BI3 - CB open	Level trigger off
57	X120BI2 - CB closed	Level trigger off
58	X120BI1 - ext OC blocking	Level trigger off
59	DARREC1 - unsuc recl/close CB	Level trigger off
60	DARREC1 - inpro	Level trigger off
61	-	-
62	-	-
63	-	-
64	-	-

3.3.3 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.

The analog channels have fixed connections to the different function blocks inside the protection relay’s standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder’s parameter settings.

The phase currents to the protection relay are fed from a current transformer. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages. The signal VG represents the measured ground voltage.

The protection relay offers six different setting groups which can be set based on individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.3.3.1 Functional diagrams for protection

The functional diagrams describe the relay's protection functionality in detail and according to the factory set default connections.

Line differential protection with in-zone power transformer LNPLDF1_87L-1 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 trip value of the instantaneous high stage can be multiplied by 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 ground 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.

Alarm LED3 informs when the line differential is not available possibly due to a failure in protection communication, or if the function is set in a test mode.

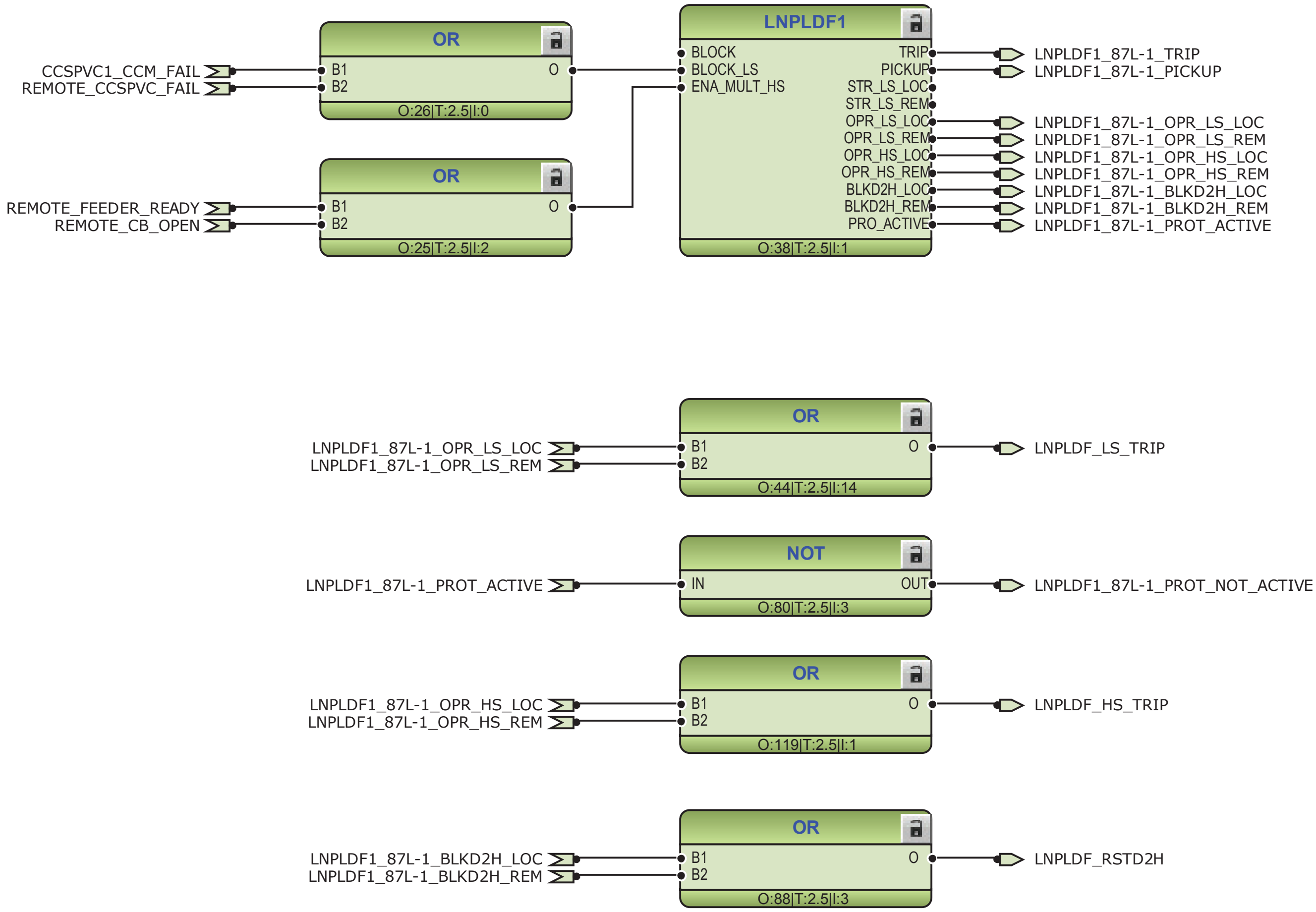


Figure 13: *Line differential protection functions*

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC_67/5xP. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1_50P-3 can be blocked by energizing the binary input X120:BI1.

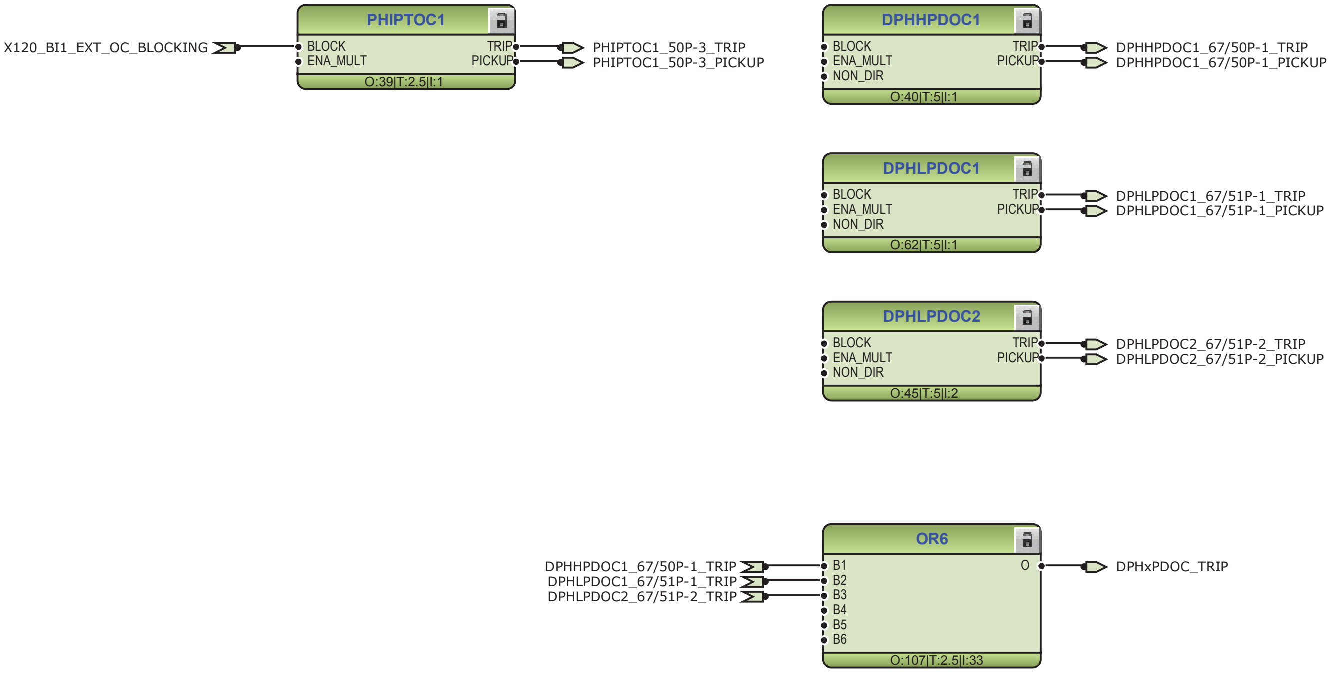


Figure 14: Overcurrent protection functions

The upstream blocking from the pickup of the instantaneous as well as the high stage overcurrent protection function is connected to the binary output X110:SO1. This output can be used to send a blocking signal to the relevant overcurrent protection stage of the relay at the upstream bay.

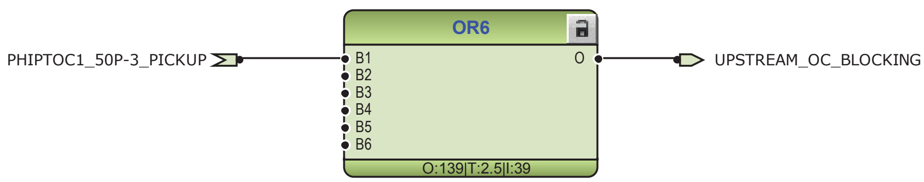


Figure 15: Upstream blocking logic

Three stages are provided for directional ground-fault protection. According to the order code, the directional ground-fault protection method can be based on conventional directional ground-fault DEFxPDEF_67/51N only or alternatively together with admittance-based ground-fault protection EFPADM_21YN, wattmetric-based ground-fault protection WPWDE_32N. In addition, there is a dedicated protection stage INTRPTEF_67NIEF either for transient-based ground-fault protection or for cable intermittent ground-fault protection in compensated networks.

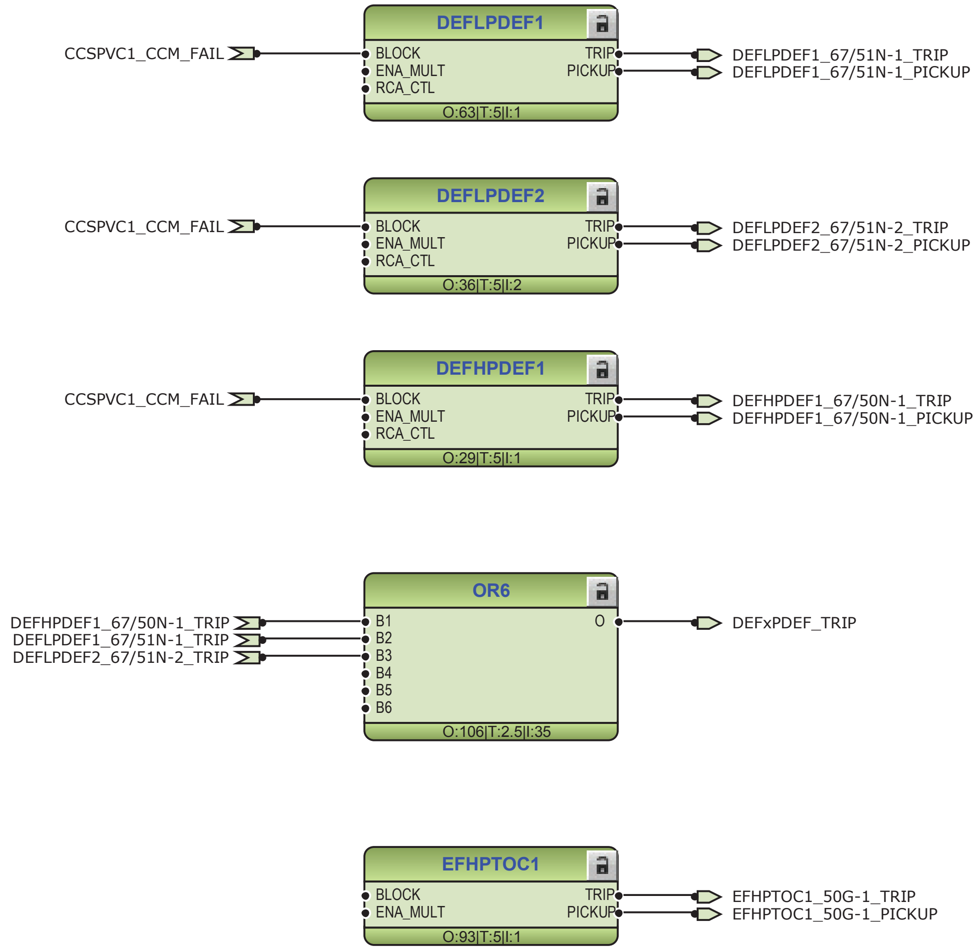


Figure 16: Directional ground-fault protection function

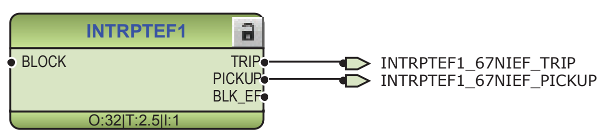


Figure 17: Transient or intermittent ground-fault protection function

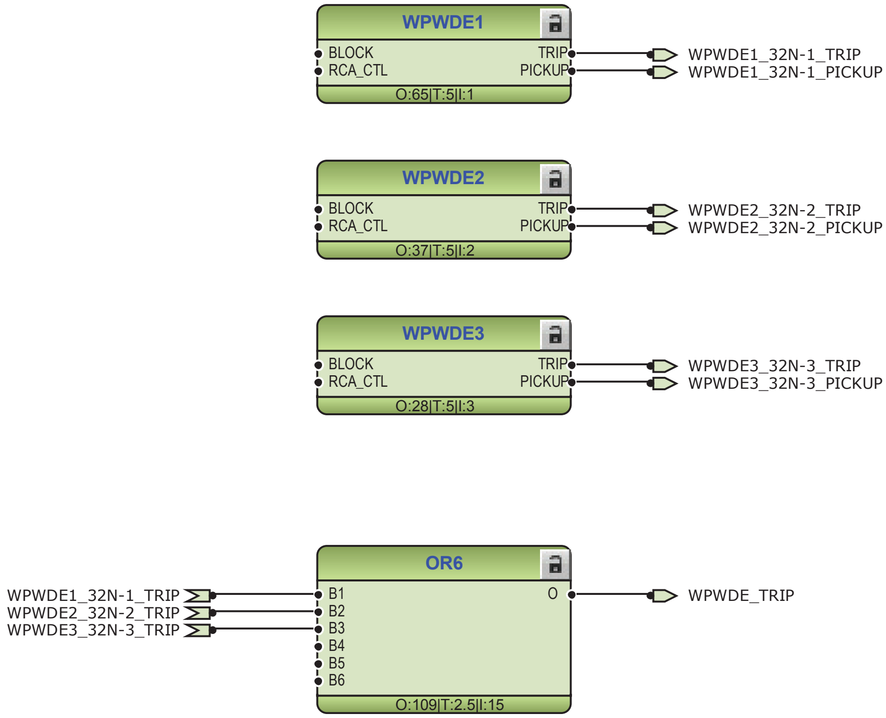


Figure 18: Wattmetric protection function

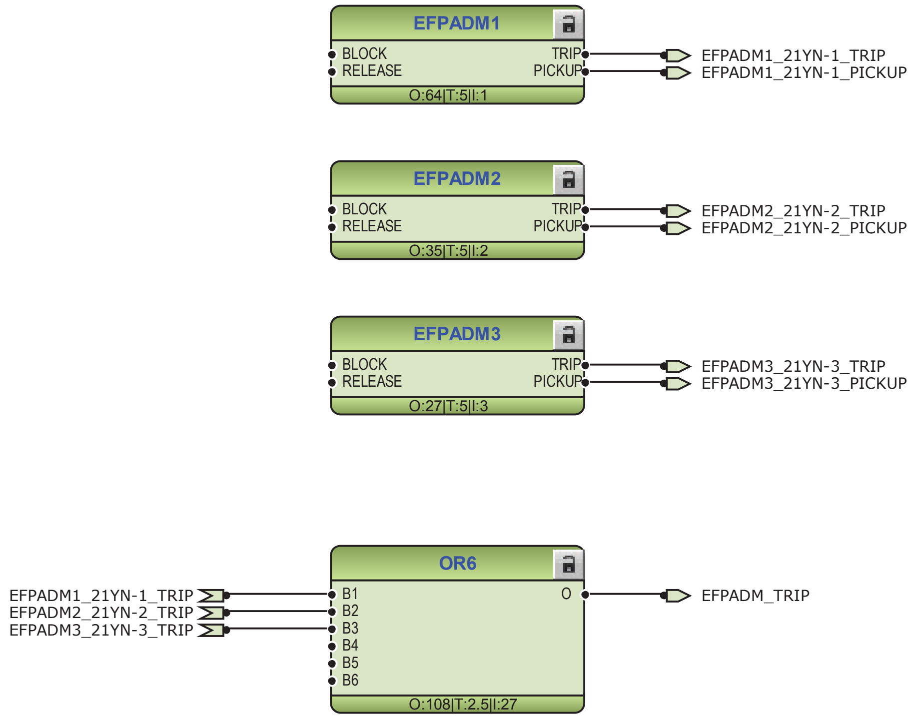


Figure 19: Admittance-based ground-fault protection function

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

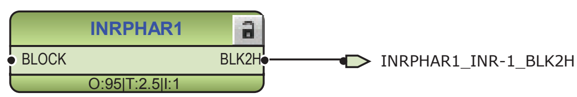


Figure 20: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1_46-1 and NSPTOC2_46-2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance.

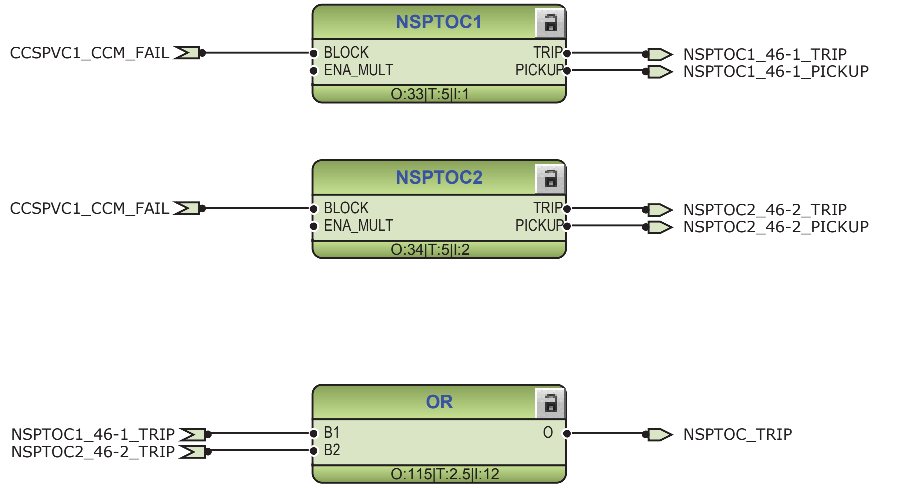


Figure 21: Negative-sequence overcurrent protection function

Phase discontinuity protection PDNSPTOC1_46PD protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

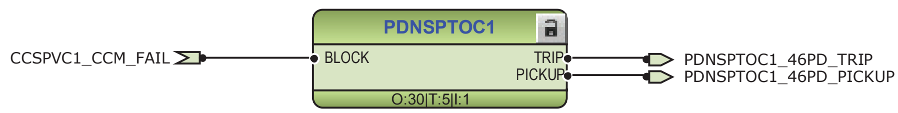


Figure 22: Phase discontinuity protection

Two thermal overload protection functions are incorporated, one with one time constant T1PTTR1_49F-1 and other with two time constants T2PTTR1_49T-1 for detecting overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

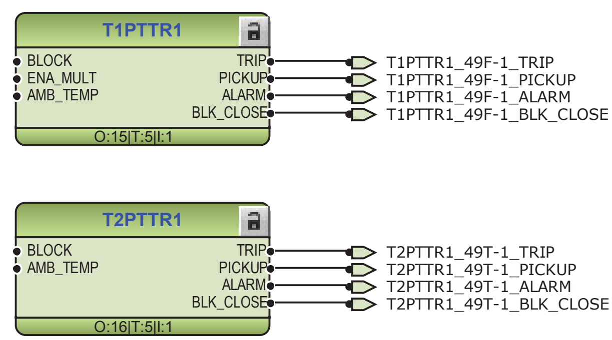


Figure 23: Thermal overcurrent protection function

Four overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage PSPTUV1_47U-1 and negative-sequence overvoltage NSPTOV1_47-1 protection functions enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

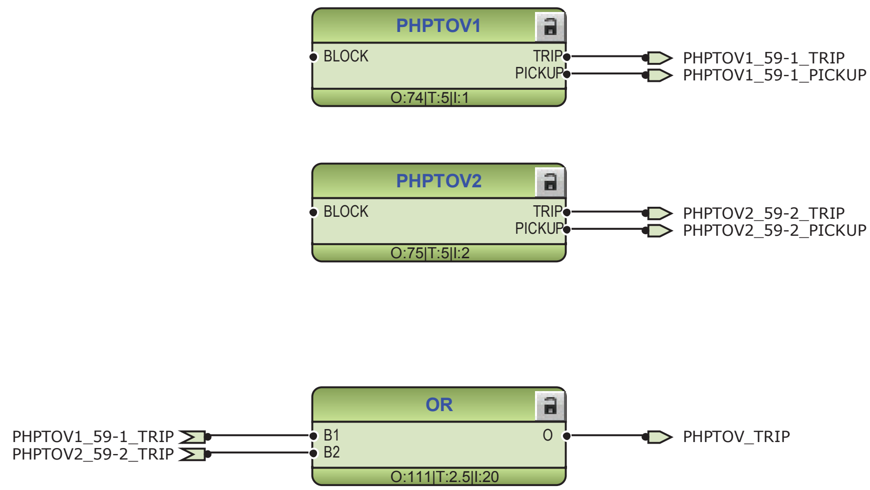


Figure 24: Overvoltage protection function

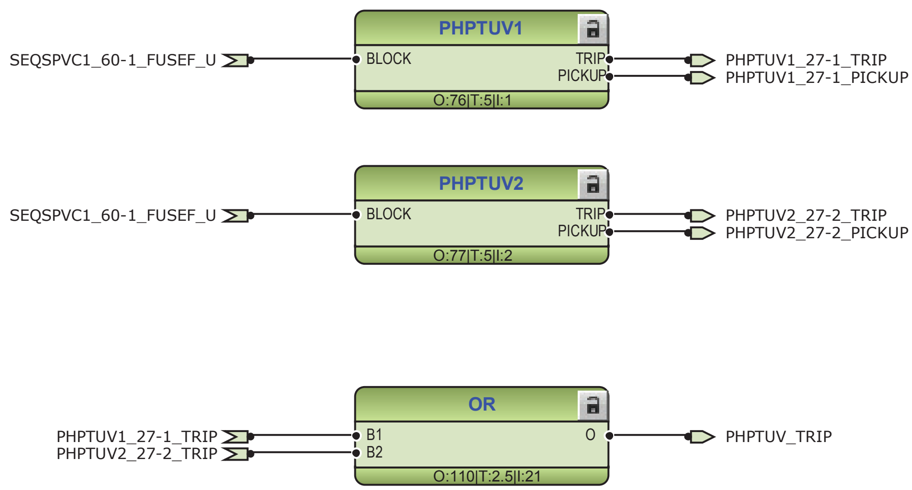


Figure 25: Undervoltage protection function

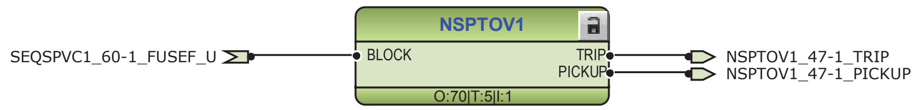


Figure 26: Negative-sequence overvoltage protection function

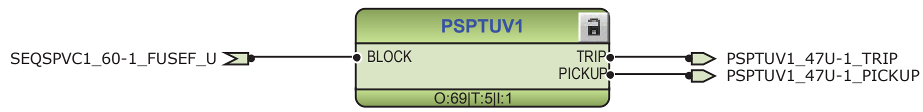


Figure 27: Positive-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV_59G/N provides ground-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

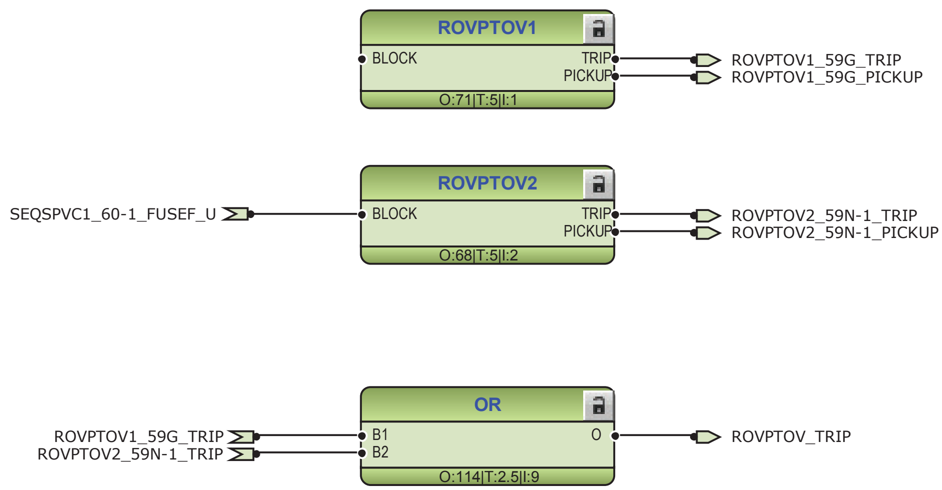


Figure 28: Residual voltage protection function

The overcurrent protection, negative-sequence overcurrent protection, phase discontinuity, ground-fault protection, residual overvoltage protection, phase overvoltage and undervoltage protection are all used as backup protection against line differential protection.

The backup protection tripped information is available at binary output X110:SO2 which can be used for external alarm purpose.

The optional autoreclosing function is configured to be initiated by trip signals from a number of protection stages through the INIT_1...6 inputs. It is possible to create individual autoreclosing sequences for each input.

The autoreclosing function can be inhibited with the INHIBIT_RECL input. By default, few selected protection function operations are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclosing function via the CBXCBR1_52-1_SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the CB_READY input in DARREC1_79. The signal, and other required signals, are connected to the CB spring charged binary inputs in this configuration. The open command from the autorecloser is connected directly to binary output X100:PO3, whereas close command is connected directly to binary output X100:PO1.

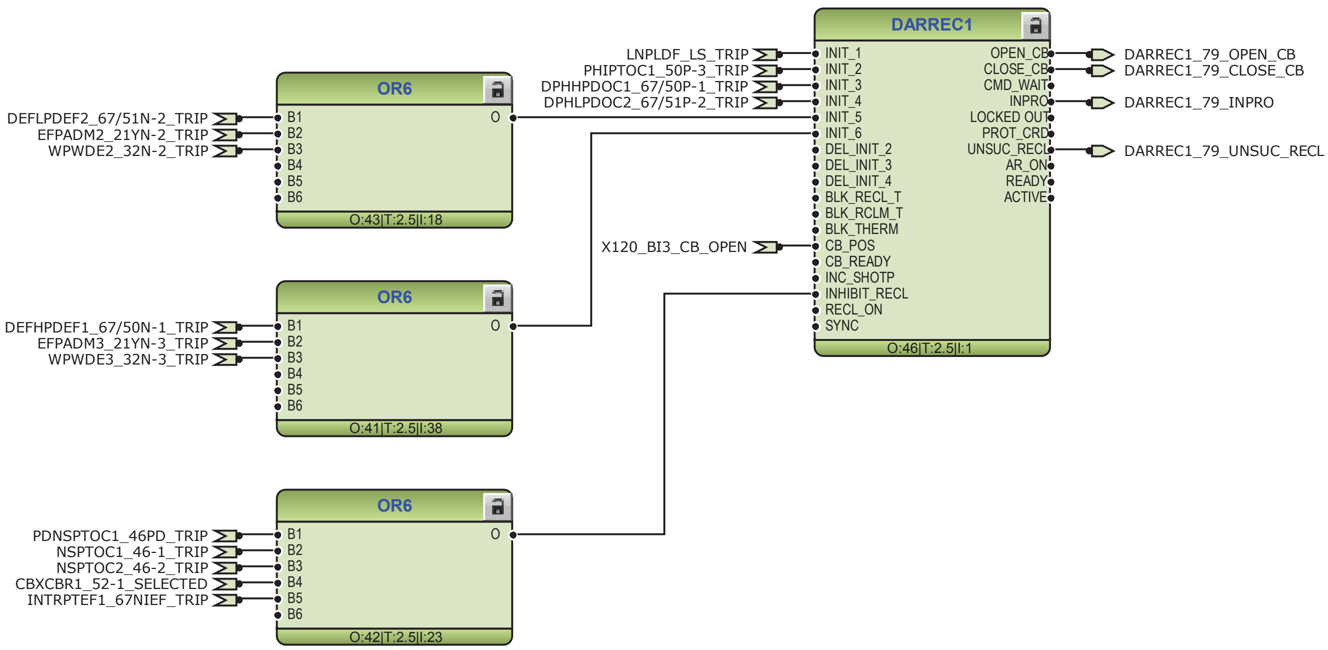


Figure 29: Autoreclosing function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by a number of different protection functions available in the relay. The circuit breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET trip output is used for retripping its own breaker through TRPPTRC2_86/94-1_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the binary output X100:PO2.

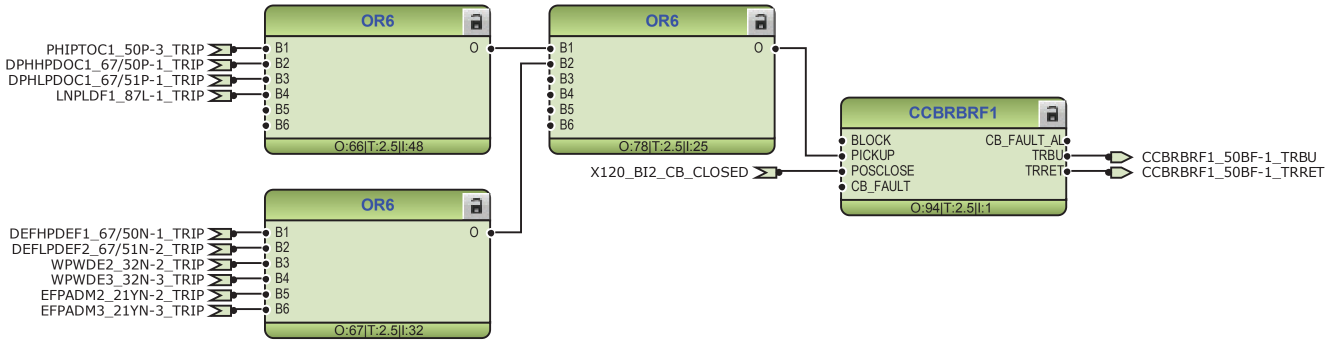


Figure 30: Circuit breaker failure protection function

The trip signals from the protection functions are connected to the two trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO4. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X110:BI1 can be assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

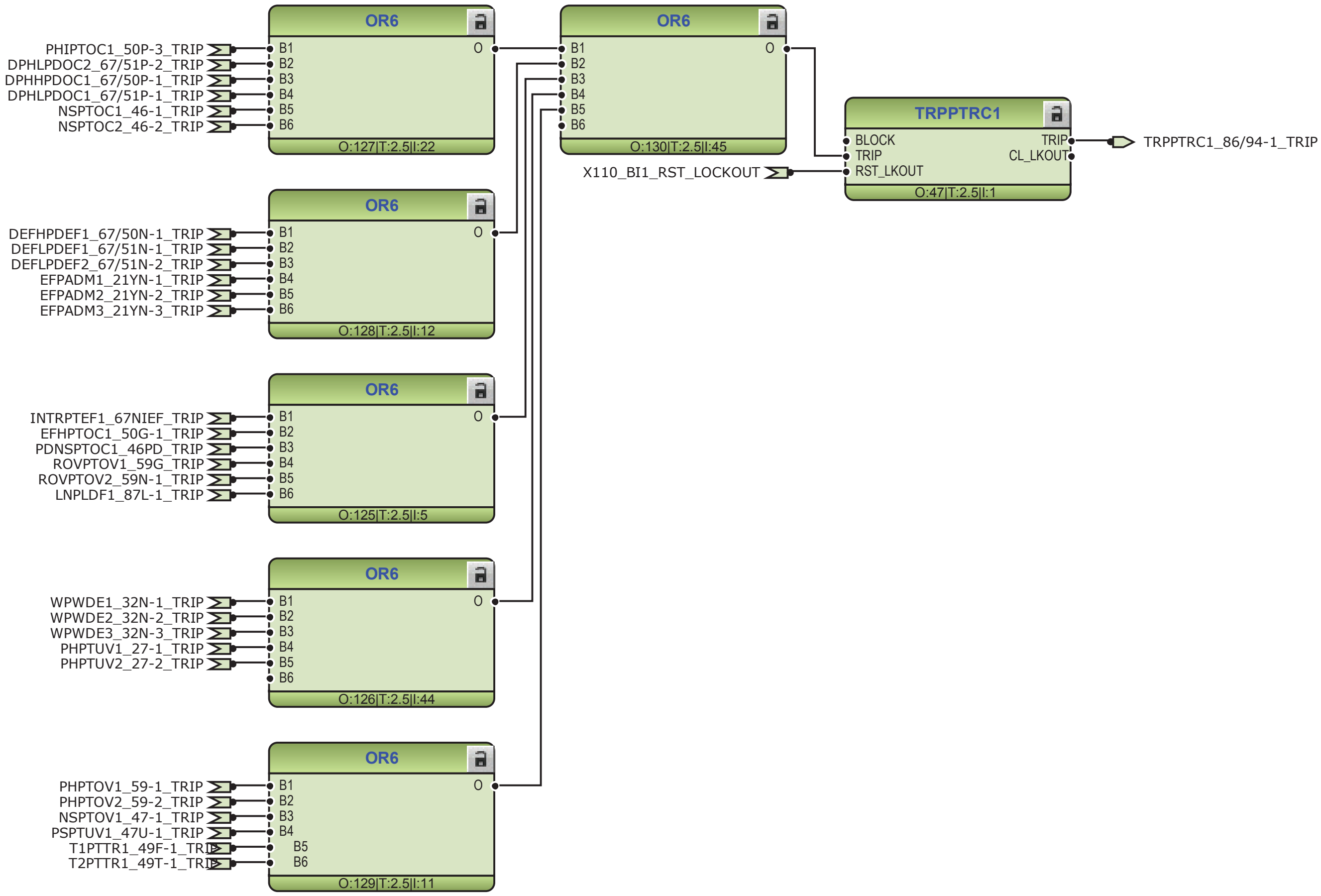


Figure 31: Trip logic TRPPTRC1

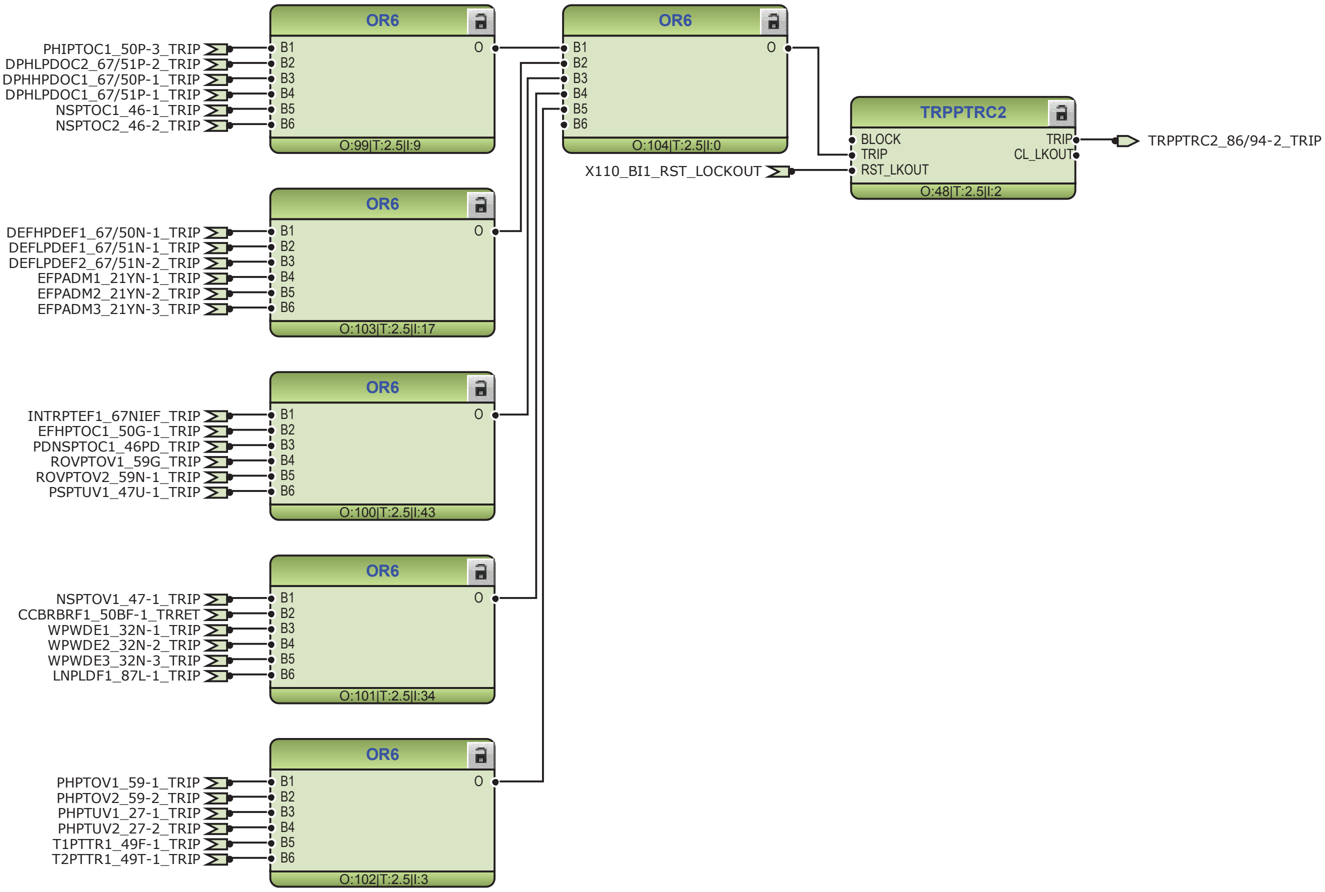


Figure 32: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

The `PICKUP` and `TRIP` outputs 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 selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

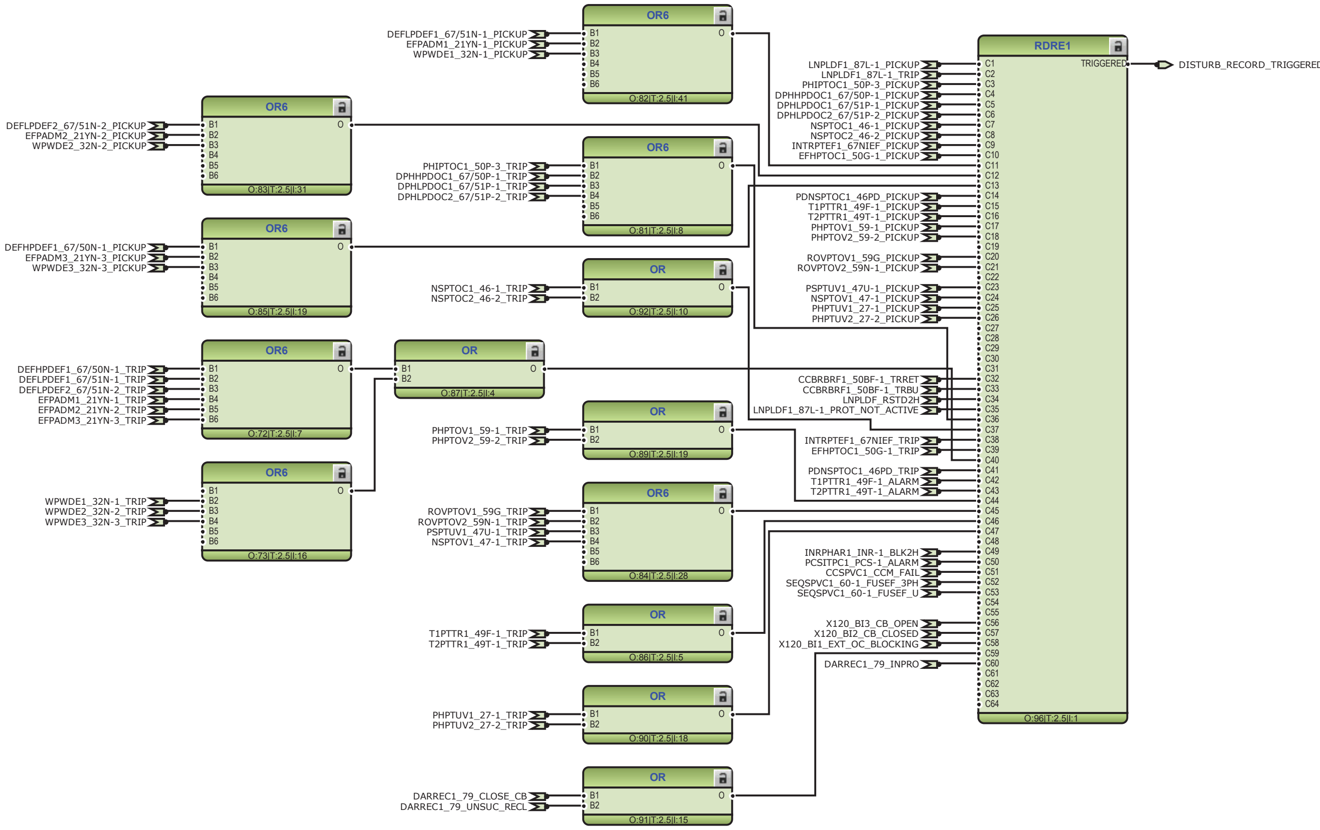


Figure 33: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

Failures in current measuring circuits are detected by CCSPVC1_CCM. When a failure is detected, it can be used to block the current protection functions that are measuring the calculated sequence component currents or residual current to avoid unnecessary operation.

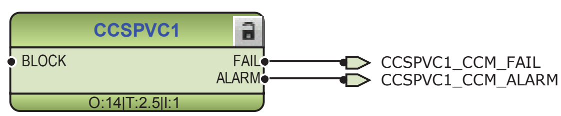


Figure 34: Current circuit supervision function

The fuse failure supervision SEQSPVC1_60-1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

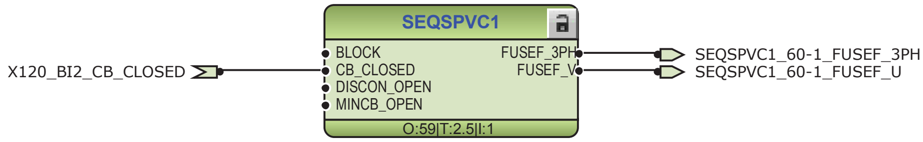


Figure 35: Fuse failure supervision function

Circuit-breaker condition monitoring SSCBR1_52CM-1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM-1 introduces various supervision methods.

Set the parameters for SSCBR1_52CM-1 properly.

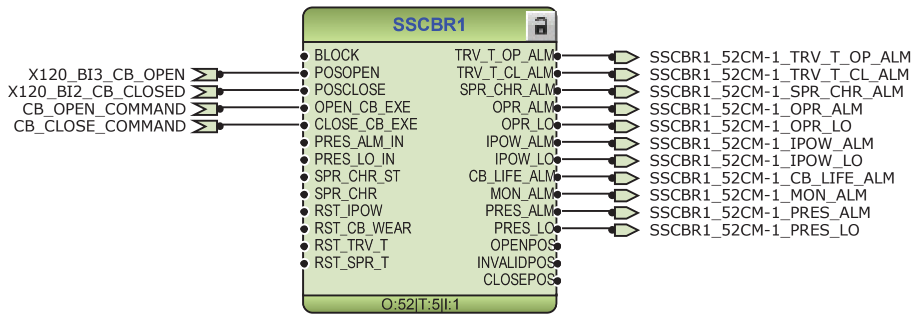


Figure 36: Circuit-breaker condition monitoring function

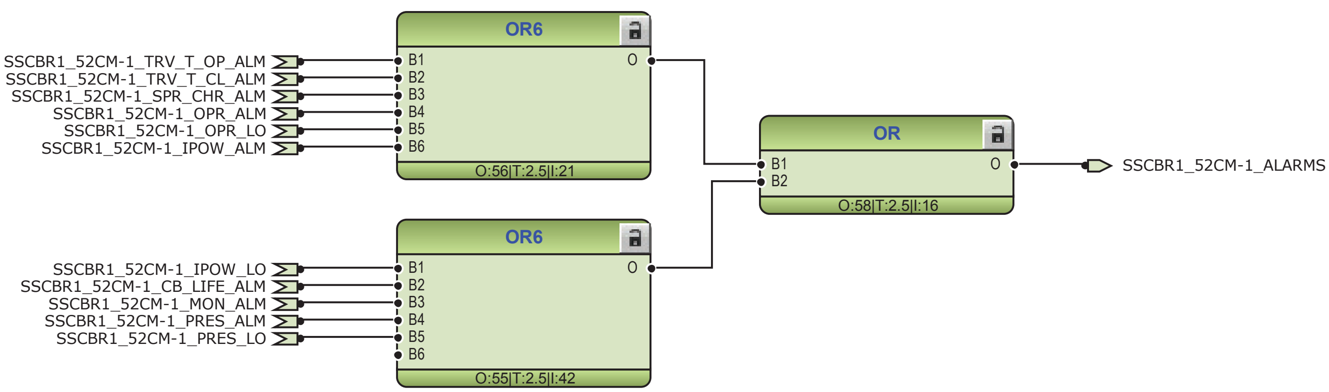


Figure 37: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. Both the functions are blocked by the master trip TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 and the circuit breaker open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR _TCM properly.

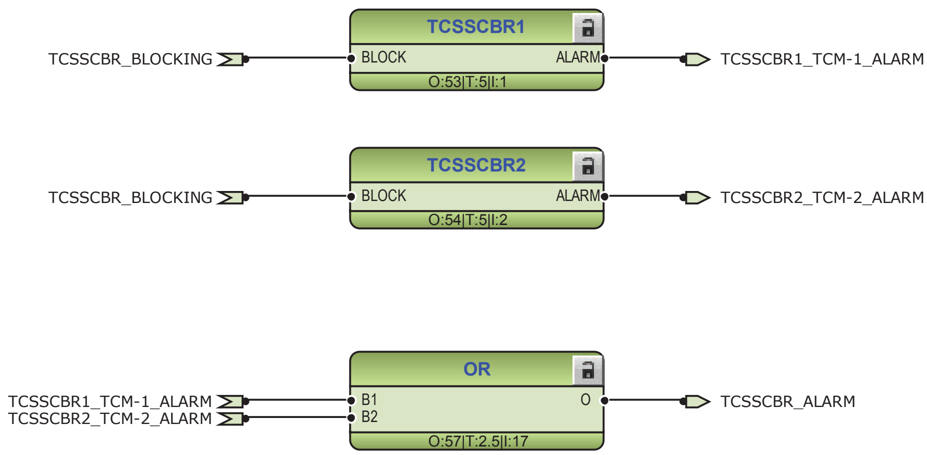


Figure 38: Trip circuit supervision function

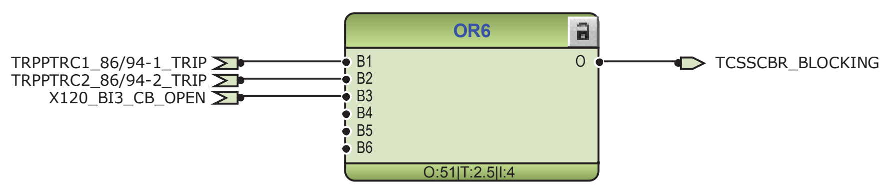


Figure 39: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC_PCS-1 is used in the configuration to block the operation of the line differential function. This way, the malfunction of the line differential is prevented. The activation of binary signal transfer outputs during the protection communication failure is also blocked. These are done internally without connections in the configurations. The protection communication supervision alarm is connected to the alarm LED 4, disturbance recorder and binary output X100:SO2.

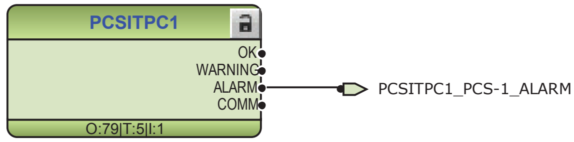


Figure 40: Protection communication supervision function

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 X110:BI2 is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to the BSTGGIO inputs 6 and 7. This is 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 the binary signal transfer function outputs. The remote binary transfer output signal is connected to the binary output X110:SO3.

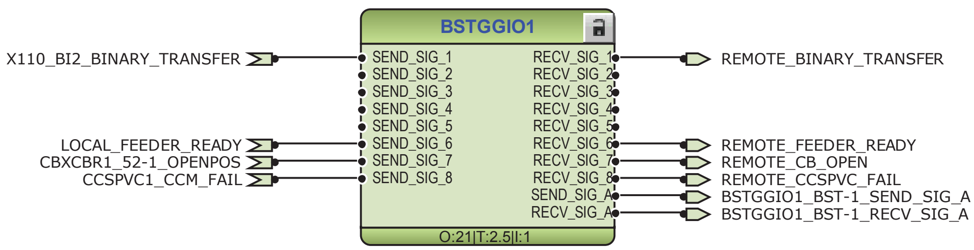


Figure 41: Binary signal transfer function

3.3.3.4 Functional diagrams for control and interlocking

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 disconnector or circuit breaker truck and ground switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and ground switch statuses are local feeder ready information to be sent for the remote end.

The `OKPOS` output from DCSXSWI defines if the disconnector or circuit breaker truck is either open (in test position) or close (in service position). This, together with the open ground switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for circuit breaker is always enabled.

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

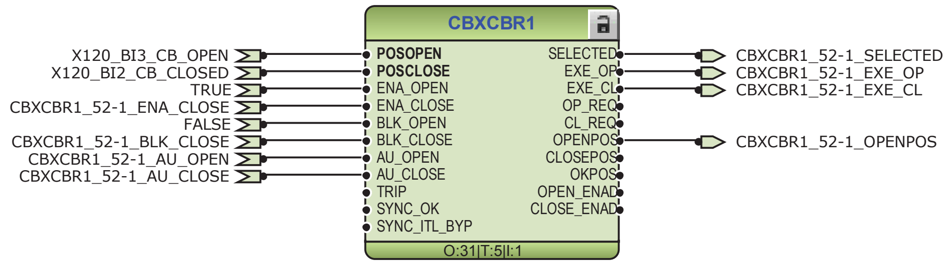


Figure 42: *Circuit breaker 1 control logic*

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

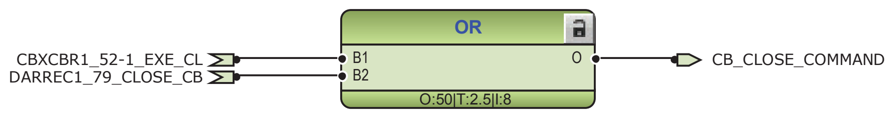


Figure 43: *Circuit breaker control logic: Signals for the closing coil of circuit breaker 1*

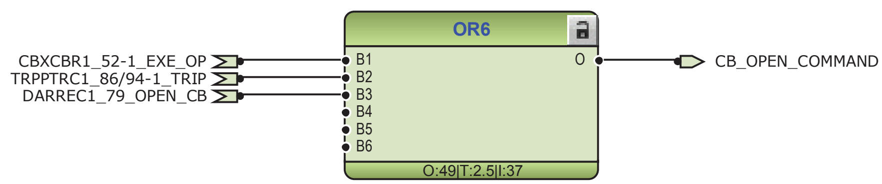


Figure 44: *Circuit breaker control logic: Signals for the opening coil of circuit breaker 1*

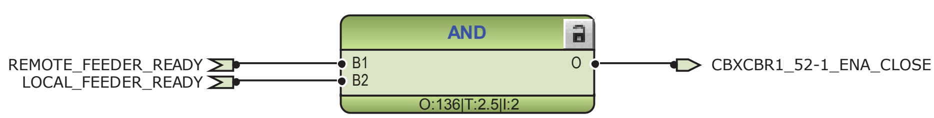


Figure 45: *Circuit breaker close enable logic*

The configuration includes the logic for generating circuit breaker external closing and opening command with the relay in local or remote mode.

Check the logic for the external circuit breaker closing command and modify it according to the application.

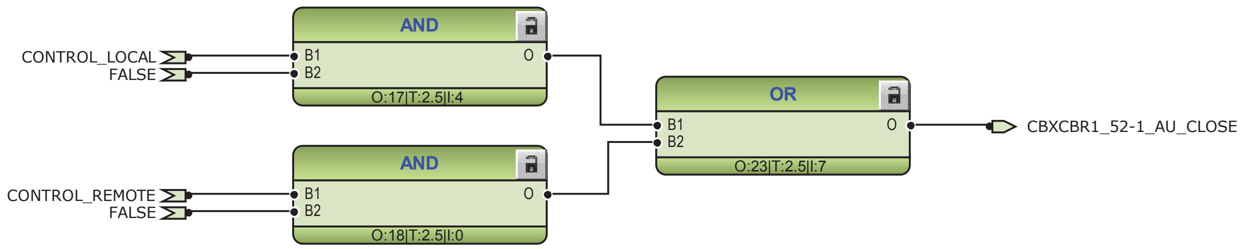


Figure 46: External closing command for circuit breaker

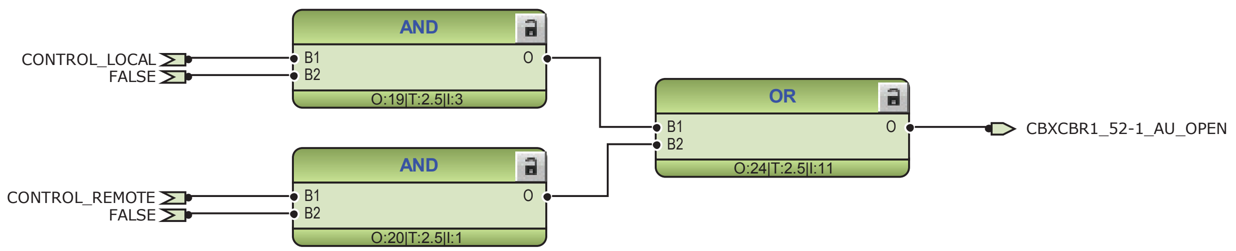


Figure 47: External opening command for circuit breaker

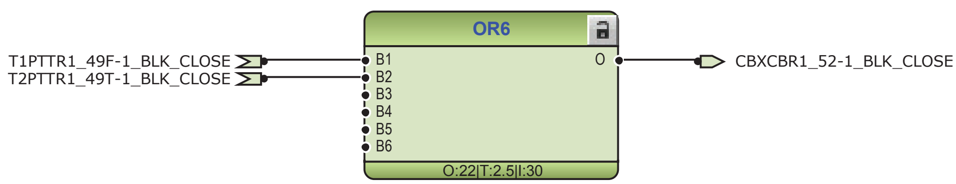


Figure 48: Circuit breaker 1 close blocking logic

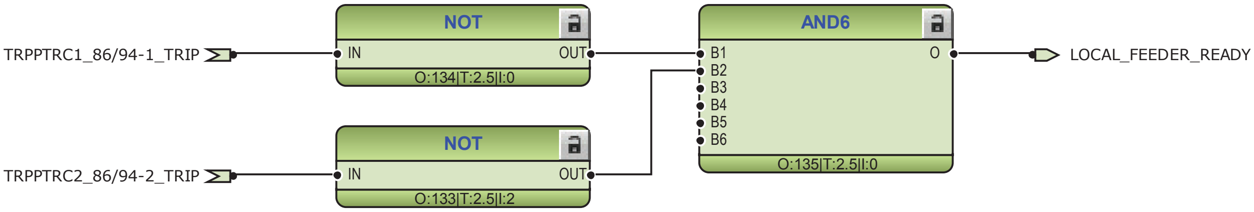


Figure 49: Logic for local feeder ready

3.3.3.5 Functional diagrams for measurement functions

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. Similarly, the sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase voltage inputs to the relay are measured by three-phase voltage measurement VMMXU1.The three-phase bus side phase voltage inputs to the relay are measured by three-phase voltage measurement VMMXU2. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESVMMXU1 measures the residual voltage.

The measurements can be seen from the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

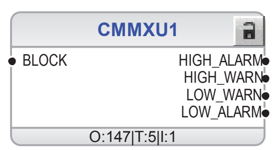


Figure 50: Three-phase current measurement

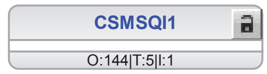


Figure 51: Sequence current measurements

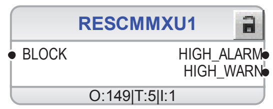


Figure 52: Ground current measurements

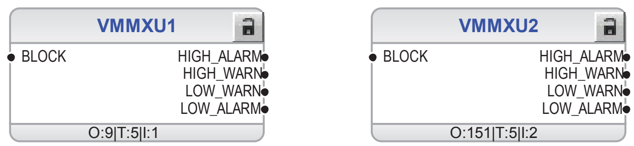


Figure 53: Three-phase voltage measurement

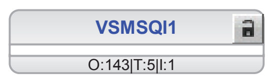


Figure 54: Sequence voltage measurements

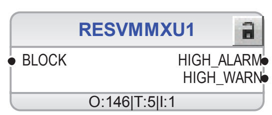


Figure 55: Ground voltage measurements

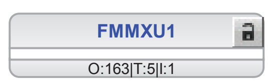


Figure 56: Frequency measurement

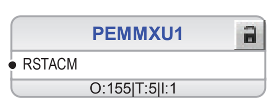


Figure 57: Three-phase power and energy measurement

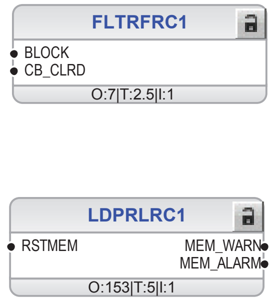


Figure 58: Data monitoring and load profile record

3.3.3.6 Functional diagrams for IO and alarm LEDs

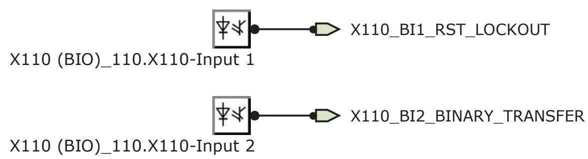


Figure 59: Default binary inputs - X110

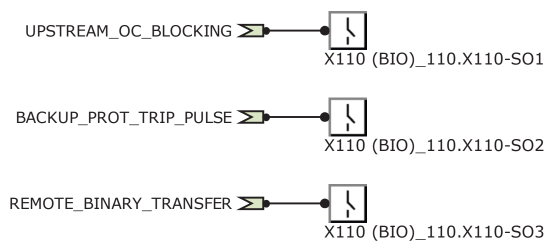


Figure 60: Default binary outputs - X110

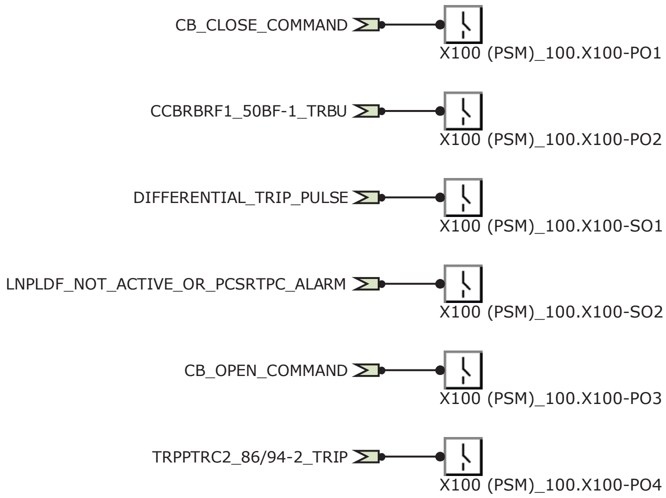


Figure 61: Default binary outputs - X100

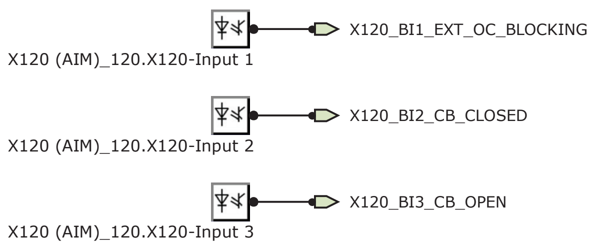


Figure 62: Default binary inputs - X120

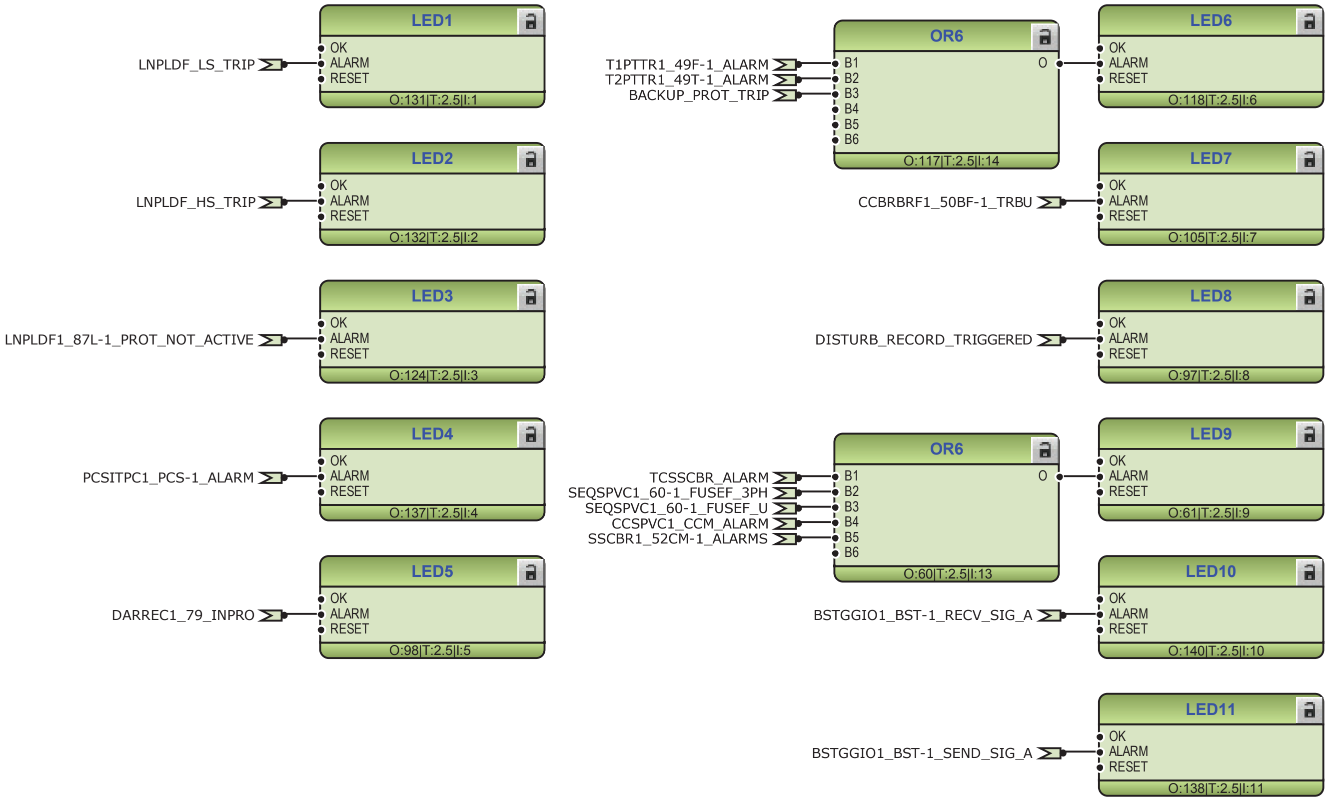


Figure 63: Default LED connection

3.3.3.7 Functional diagrams for other functions

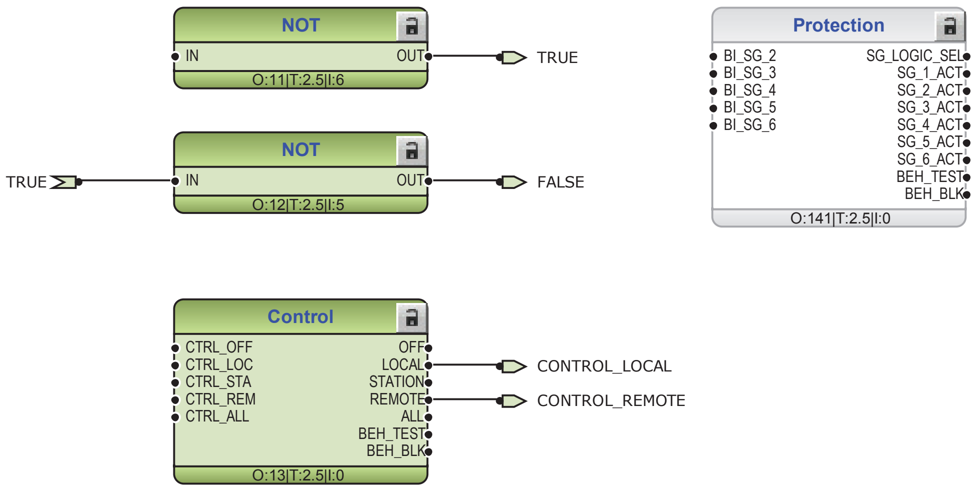


Figure 64: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.3.3.8 Functional diagrams for other timer logics

The configuration also includes line differential trip, inactive communication and backup protection trip logic. The trip logics are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to the binary outputs.

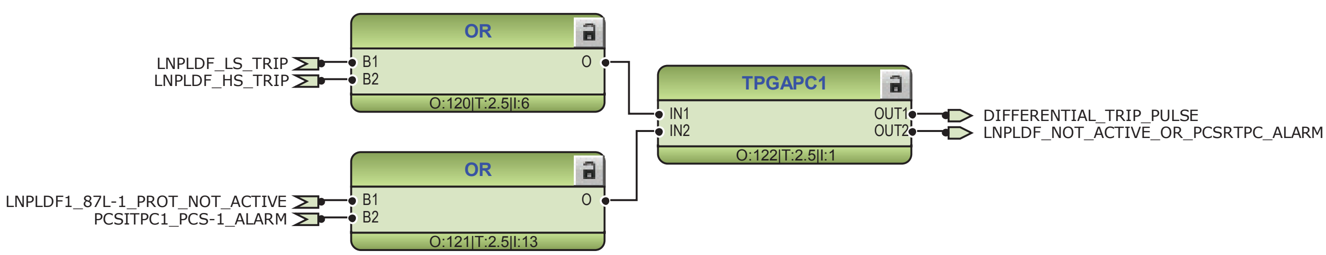


Figure 65: Timer logic for differential trip and communication not active

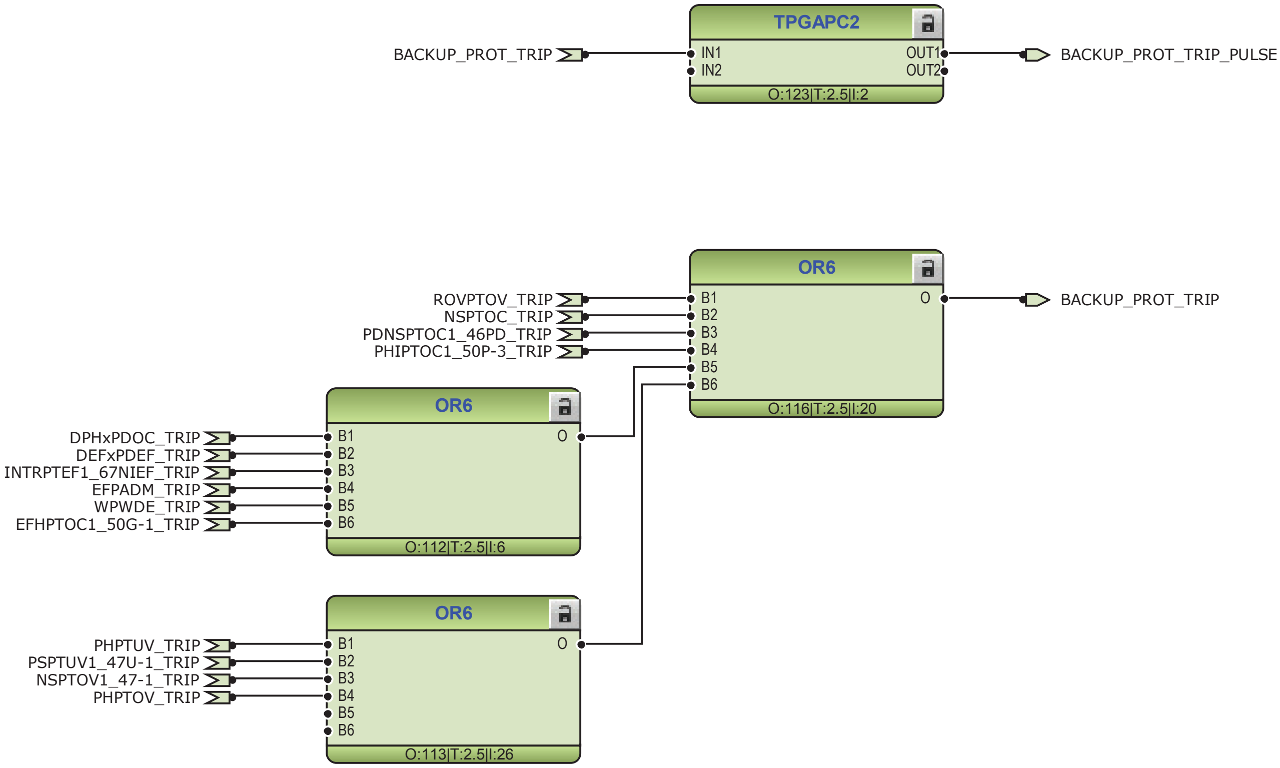


Figure 66: Timer logic for backup protection trip pulse

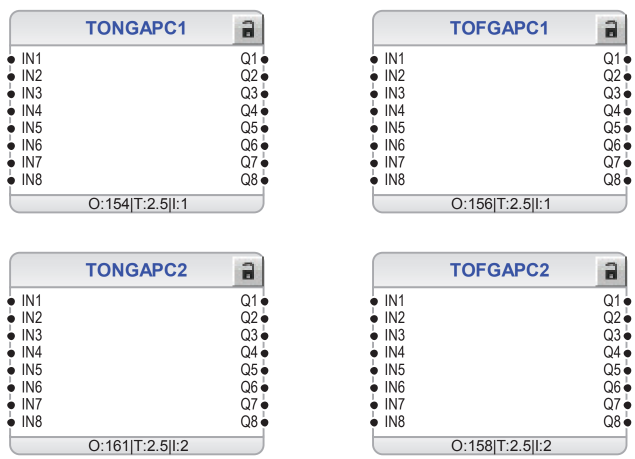


Figure 67: Programmable timers

3.3.3.9 Functional diagrams for communication

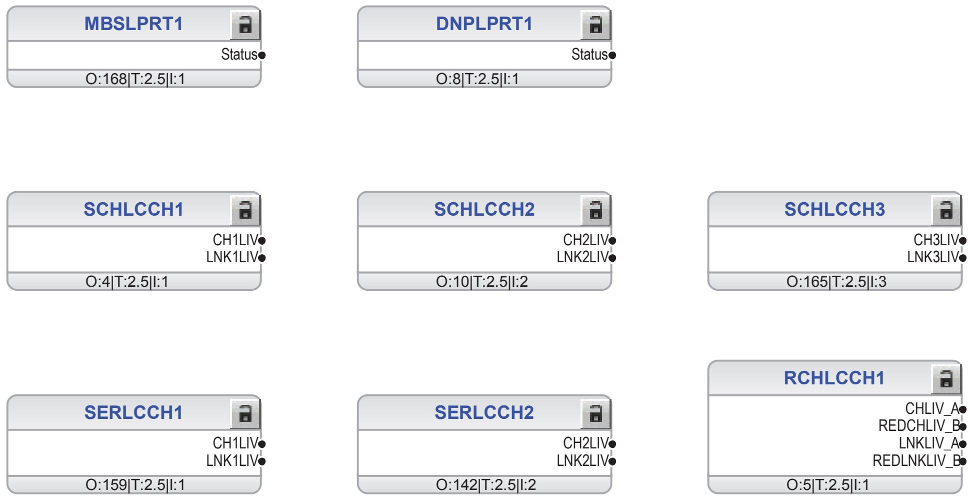


Figure 68: Default communication function connection

3.4 Standard configuration E

3.4.1 Applications

The standard configuration with directional overcurrent and directional ground-fault protection, phase-voltage and frequency based protection is mainly intended for cable feeder applications in distribution networks. The standard configuration for line current differential protection includes support for in-zone transformers. The configuration also includes additional options to select ground-fault protection based on admittance, wattmetric or harmonic principle.

Standard configuration E is not designed for using all the available functionality content in one relay at the same time. Frequency protection functions and third instances of voltage protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user-specific configuration load is verified with the Application Configuration tool in PCM600.

The protection relay 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 protection relay 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

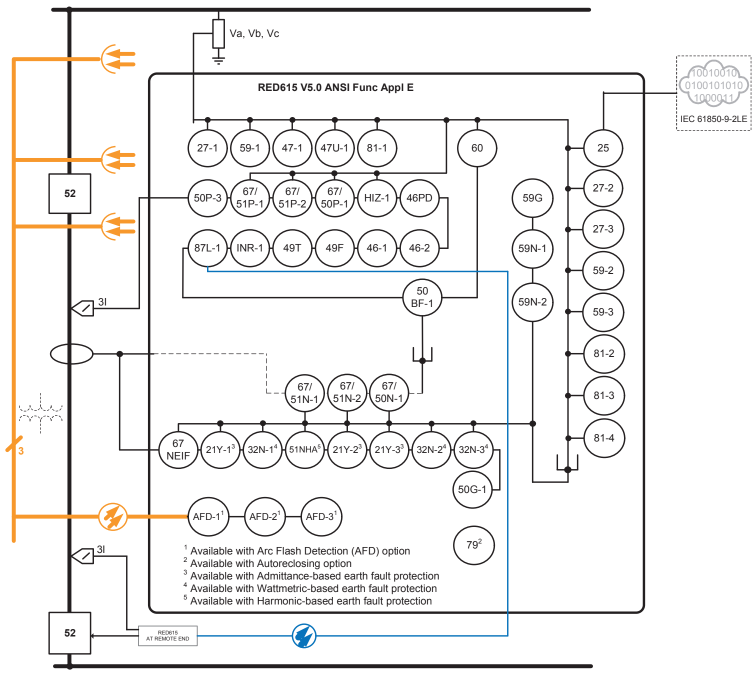


Figure 69: Functionality overview for standard configuration E

3.4.2.1 Default I/O connections

Table 15: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X131:4-5
IB	Phase B current	X132:4-,5
IC	Phase C current	X133:4-5
IG	Residual current IG	X130:1-2
VA	Phase voltage VA	X131:7-8
VB	Phase voltage VB	X132:7-8
VC	Phase voltage VC	X133:7-8

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	-	X110:1-2
X110-BI2	-	X110:3-4
X110-BI3	Circuit breaker open position indication	X110:5-6
X110-BI4	Circuit breaker closed position indication	X110:7-6
X110-BI5	-	X110:8-9
X110-BI6	-	X110:10-9
X110-BI7	-	X110:11-12
X110-BI8	-	X110:13-12

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Release for circuit breaker closing	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	-	X100:10-11,(12)
X100-SO2	-	X100:13-14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X110-SO1	-	X110:14-16
X110-SO2	-	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	X110:23-24

Table 18: Default connections for LEDs

LED	Default usage	ID	Label description
1	Circuit breaker close enabled	LED_CBcloseenabled_1	CB close enabled
2	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
3	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
4	Line differential protection instantaneous stage trip	LED_DiffProtHighStage_1	Diff. prot. high stage
5	Line differential protection biased stage trip	LED_DiffProtBiasedLowStage_1	Diff. prot. biased low stage
6	Thermal protection	LED_ThermalOverload_1	Thermal overload
7	Line differential protection not active	LED_DiffProtNotAvailable_1	Diff. prot. not available
Table continues on next page			

LED	Default usage	ID	Label description
8	Protection communication supervision alarm	LED_ProtectionCommFailure_1	Protection comm. failure
9	Supervision alarm	LED_Supervision_1	Supervision
10	Circuit breaker monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
11	-	-	-

3.4.2.2 Default disturbance recorder settings

Table 19: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	U1
6	U2
7	U3
8	-
9	-
10	-
11	-
12	-

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - pickup	Positive or Rising
2	LNPLDF1 - trip	Positive or Rising
3	PHIPTOC1 - pickup	Positive or Rising
4	DPHHPDOC1 - pickup	Positive or Rising
5	DPHLPDOC1 - pickup	Positive or Rising
6	DPHLPDOC2 - pickup	Positive or Rising
7	NSPTOC1 - pickup	Positive or Rising
8	NSPTOC2 - pickup	Positive or Rising
9	INRPHAR1 - blk2h	Positive or Rising
10	EFHPTOC1 - pickup	Positive or Rising
Table continues on next page		

Channel	ID text	Level trigger mode
11	DEFLPDEF1/WPWDE1/EFPADM1 - pickup	Positive or Rising
12	DEFLPDEF2/WPWDE2/EFPADM2 - pickup	Positive or Rising
13	DEFHPDEF1/WPWDE3/EFPADM3 - pickup	Positive or Rising
14	PDNSPTOC1 - pickup	Positive or Rising
15	T1PTTR1 - pickup	Positive or Rising
16	T2PTTR1 - pickup	Positive or Rising
17	PHPTOV1 - pickup	Positive or Rising
18	PHPTOV2 - pickup	Positive or Rising
19	-	-
20	ROVPTOV1 - pickup	Positive or Rising
21	ROVPTOV2 - pickup	Positive or Rising
22	-	-
23	PSPTUV1 - pickup	Positive or Rising
24	NSPTOV1 - pickup	Positive or Rising
25	PHPTUV1 - pickup	Positive or Rising
26	PHPTUV2 - pickup	Positive or Rising
27	-	-
28	-	-
29	-	-
30	-	-
31	-	-
32	CCBRBRF1 - trret	Level trigger off
33	CCBRBRF1 - trbu	Level trigger off
34	LNPLDF1 - rstd2h	Level trigger off
35	LNPLDF1 - prot not active	Level trigger off
36	PHxPTOC - trip	Level trigger off
37	NSPTOC - trip	Level trigger off
38	INTRPTEF1 - trip	Level trigger off
39	EFHPTOC1 - trip	Level trigger off
40	DEFxPDEF/WPWDE/EFPADM - trip	Level trigger off
41	PDNSPTOC1 - trip	Level trigger off
42	T1PTTR1 - alarm	Level trigger off
43	T2PTTR2 - alarm	Level trigger off
44	PHPTOV - trip	Level trigger off
45	ROVPTOV/PSPTUV1/NSPTOV1 - trip	Level trigger off
46	T1PTTR1/T2PTTR2 - trip	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
47	PHPTUV - trip	Level trigger off
48	-	-
49	INRPHAR1 - blk2h	Level trigger off
50	PCSITPC1 - alarm	Level trigger off
51	CCSPVC1 - alarm	Level trigger off
52	-	-
53	X110BI3 - CB open	Level trigger off
54	X110BI4 - CB closed	Level trigger off
55	DARREC1 - unsuc recl/close CB	Level trigger off
56	DARREC1 - inpro	Level trigger off
57	General pickup pulse	Level trigger off
58	General trip pulse	Level trigger off
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

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.

The analog channels have fixed connections to the different function blocks inside the protection relay’s standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder’s parameter settings.

The phase currents to the protection relay are fed from Rogowski or Combi sensors. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The phase voltages to the protection relay are fed from Combi sensors. The residual voltage is calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages.

The protection relay offers six different setting groups which can be set based on individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.4.3.1 Functional diagrams for protection

The functional diagrams describe the relay's protection functionality in detail and according to the factory set default connections.

Line differential protection with in-zone power transformer LNPLDF1_87L-1 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 trip value of the instantaneous high stage can be multiplied by 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 ground 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.

Alarm LED3 informs when the line differential is not available possibly due to a failure in protection communication, or if the function is set in a test mode.

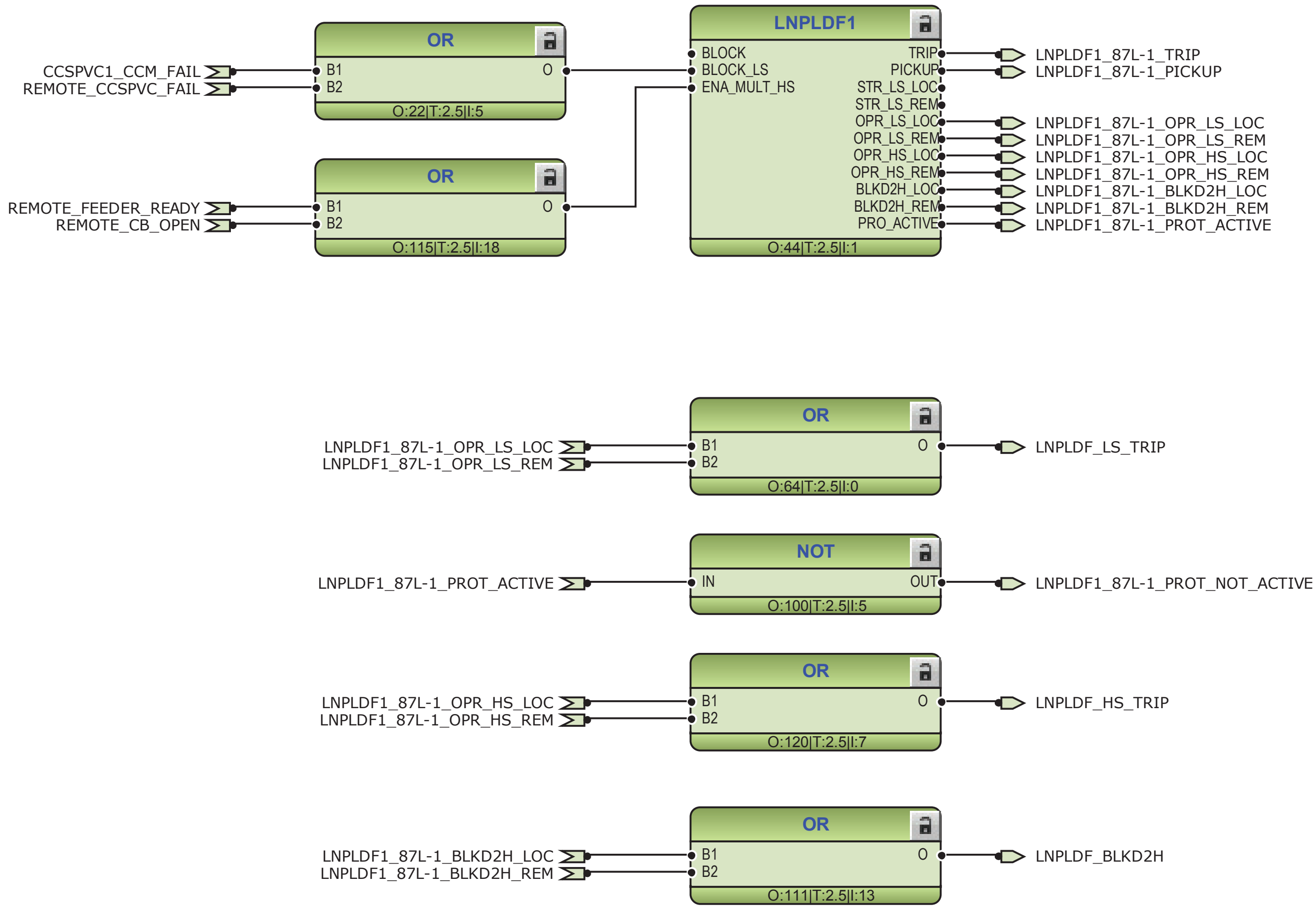


Figure 70: Line differential protection functions

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC_67/5xP. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1_50P-3 can be blocked by energizing the binary input X120:BI1.

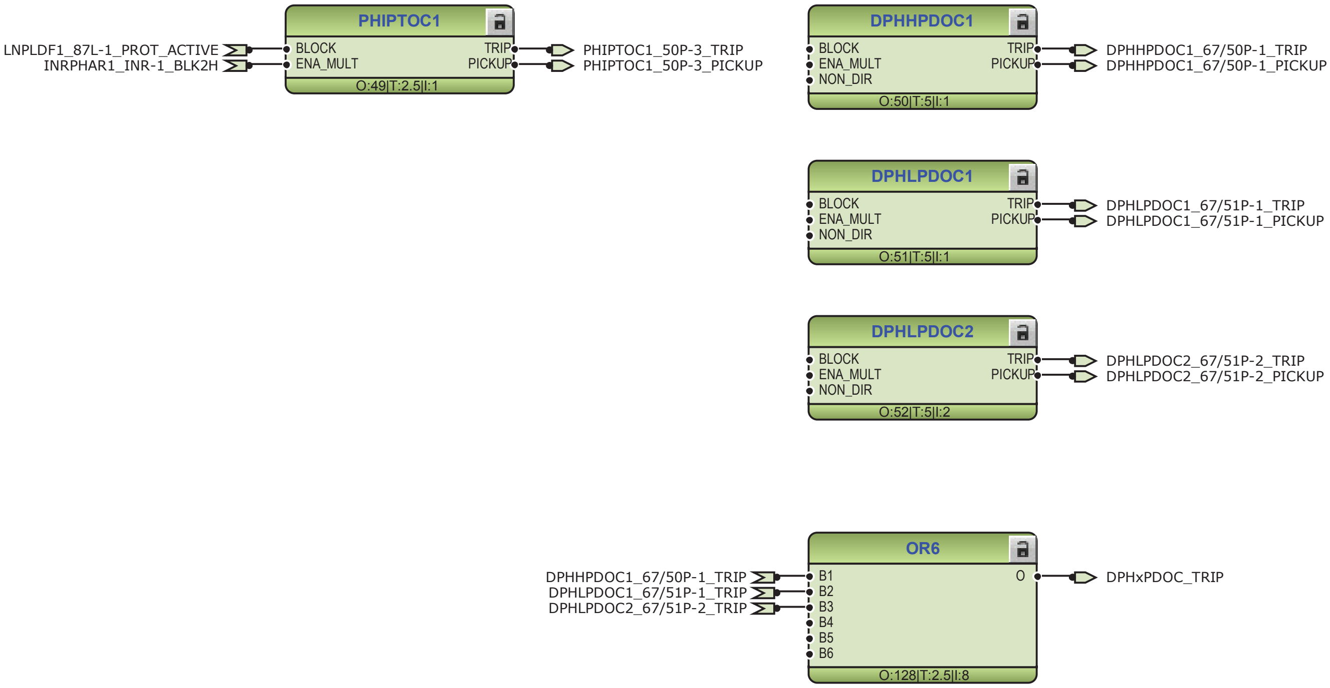


Figure 71: Overcurrent protection functions

Three stages are provided for directional ground-fault protection. According to the order code, the directional ground-fault protection method can be based on conventional directional ground-fault DEFxPDEF_67/51N only or alternatively together with admittance-based ground-fault protection EFPADM_21YN, wattmetric-based ground-fault protection WPWDE_32N. In addition, there is a dedicated protection stage INTRPTEF_67NIEF either for transient-based ground-fault protection or for cable intermittent ground-fault protection in compensated networks.

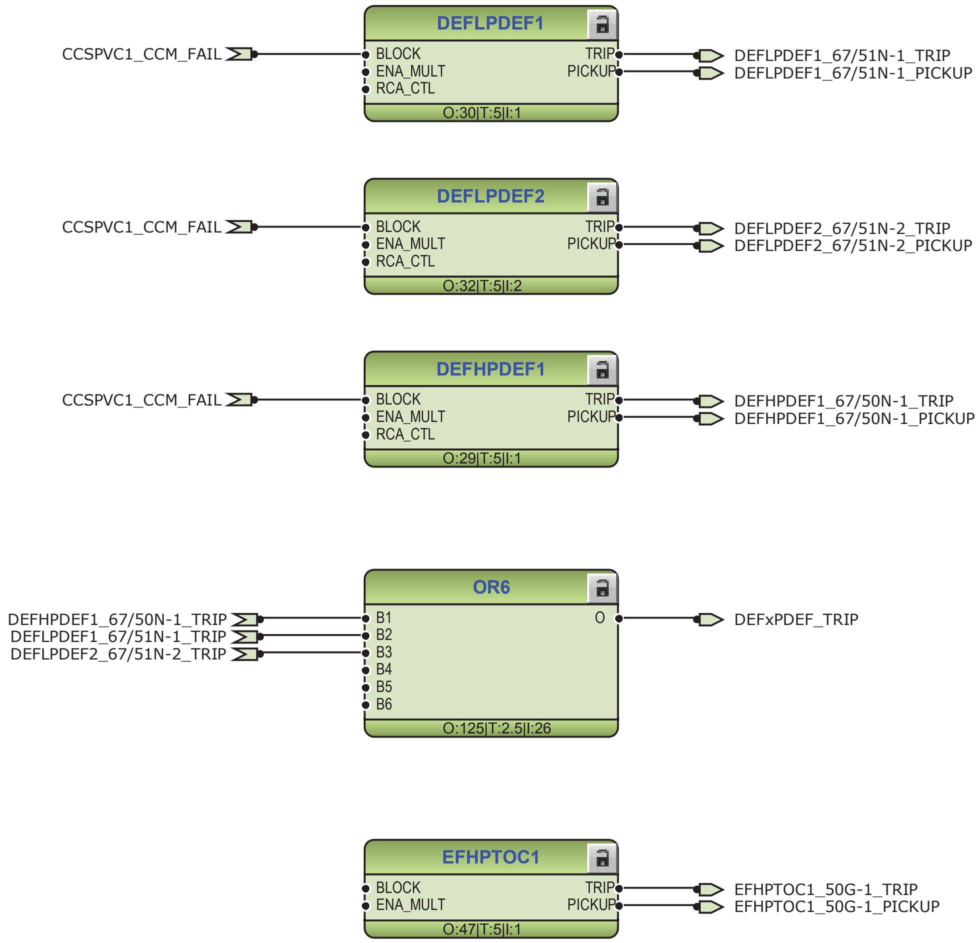


Figure 72: Directional ground-fault protection function

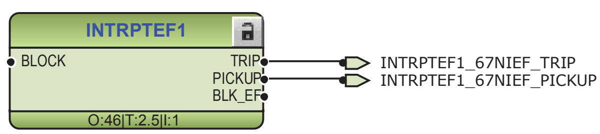


Figure 73: Transient or intermittent ground-fault protection function

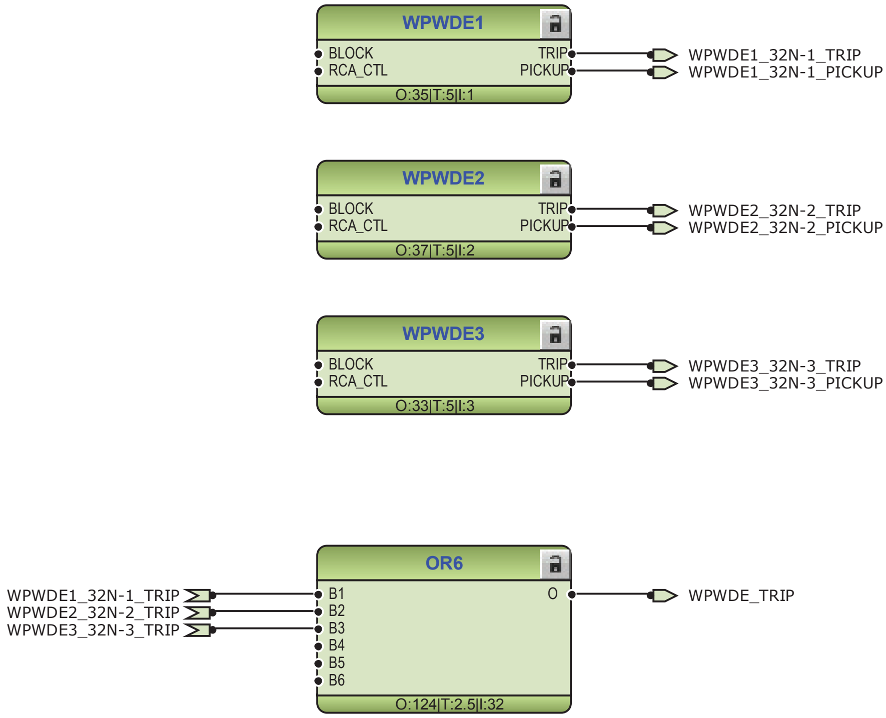


Figure 74: Wattmetric protection function

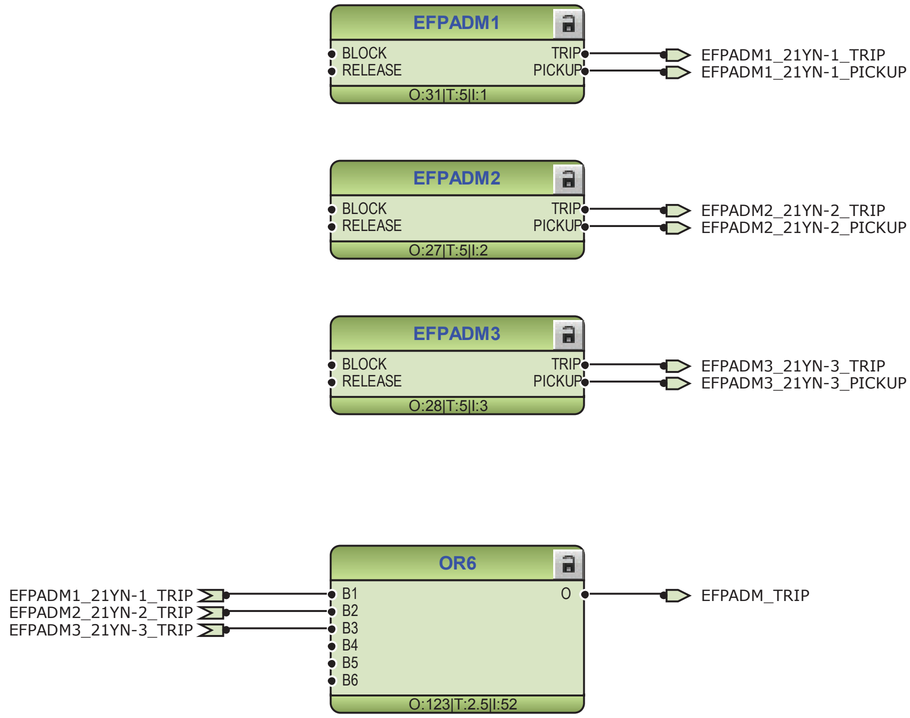


Figure 75: Admittance-based ground-fault protection function

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

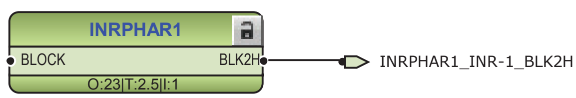


Figure 76: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1_46-1 and NSPTOC2_46-2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance.

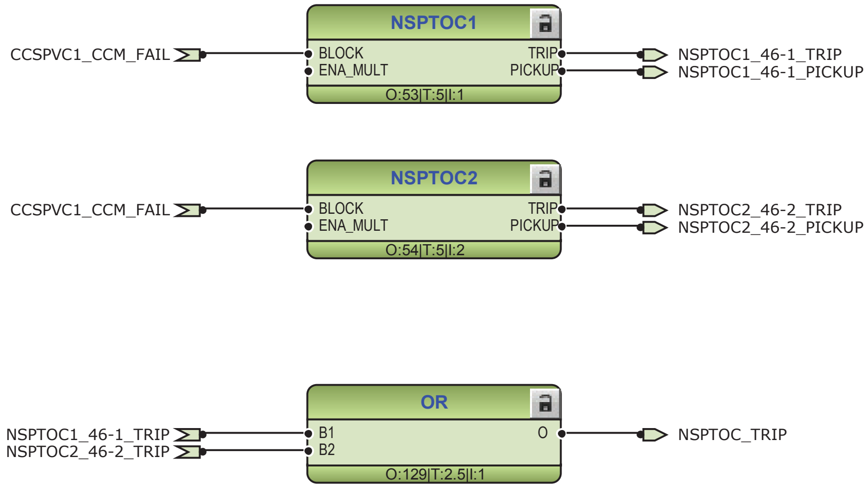


Figure 77: Negative-sequence overcurrent protection function

Phase discontinuity protection PDNSPTOC1_46PD protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

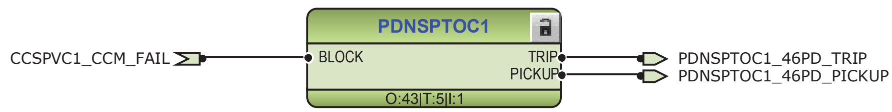


Figure 78: Phase discontinuity protection

Two thermal overload protection functions are incorporated, one with one time constant T1PTTR1_49F-1 and other with two time constants T2PTTR1_49T-1 for detecting overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

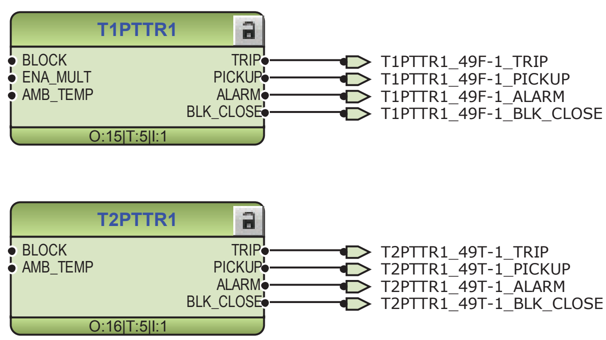


Figure 79: Thermal overcurrent protection function

Four overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage PSPTUV1_47U-1 and negative-sequence overvoltage NSPTOV1_47-1 protection functions enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

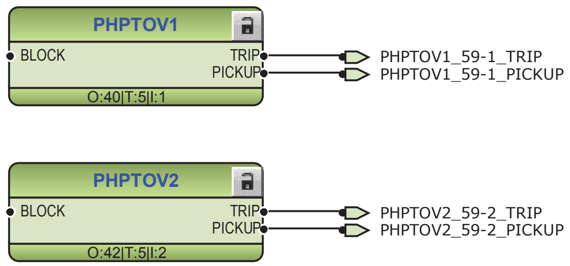


Figure 80: Overvoltage protection function

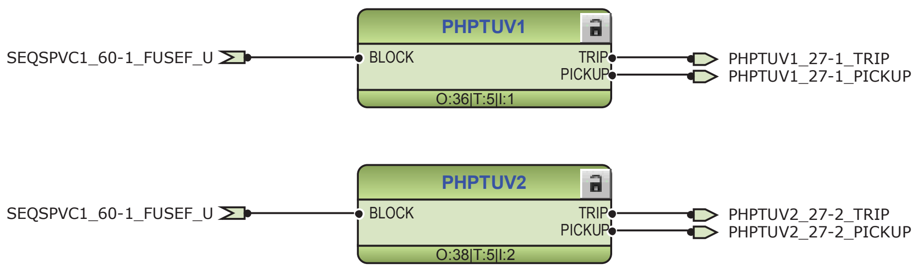


Figure 81: Undervoltage protection function

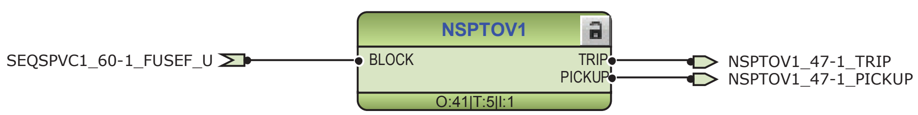


Figure 82: Negative-sequence overvoltage protection function

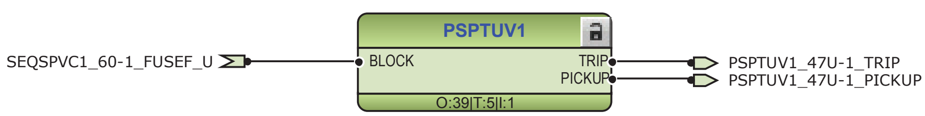


Figure 83: Positive-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV_59G/N provides ground-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

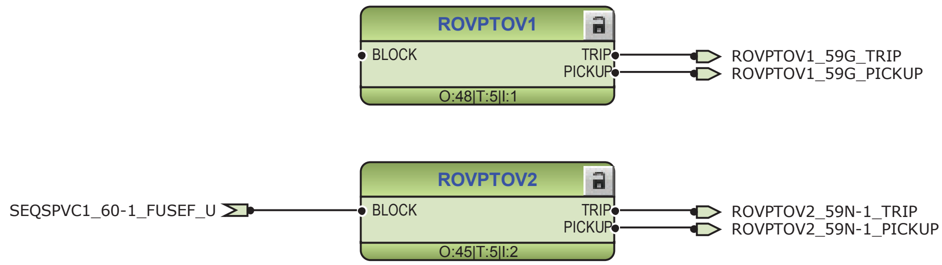


Figure 84: Residual voltage protection function

The overcurrent protection, negative-sequence overcurrent protection, phase discontinuity, ground-fault protection, residual overvoltage protection, phase overvoltage and undervoltage protection are all used as backup protection against line differential protection.

The backup protection tripped information is available at binary output X110:SO2 which can be used for external alarm purpose.

The optional autoreclosing function is configured to be initiated by trip signals from a number of protection stages through the INIT_1...6 inputs. It is possible to create individual autoreclosing sequences for each input.

The autoreclosing function can be inhibited with the `INHIBIT_RECL` input. By default, few selected protection function operations are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclosing function via the CBXCBR1_52-1_SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1_79. The signal, and other required signals, are connected to the CB spring charged binary inputs in this configuration. The open command from the autorecloser is connected directly to binary output X100:PO3, whereas close command is connected directly to binary output X100:PO1.

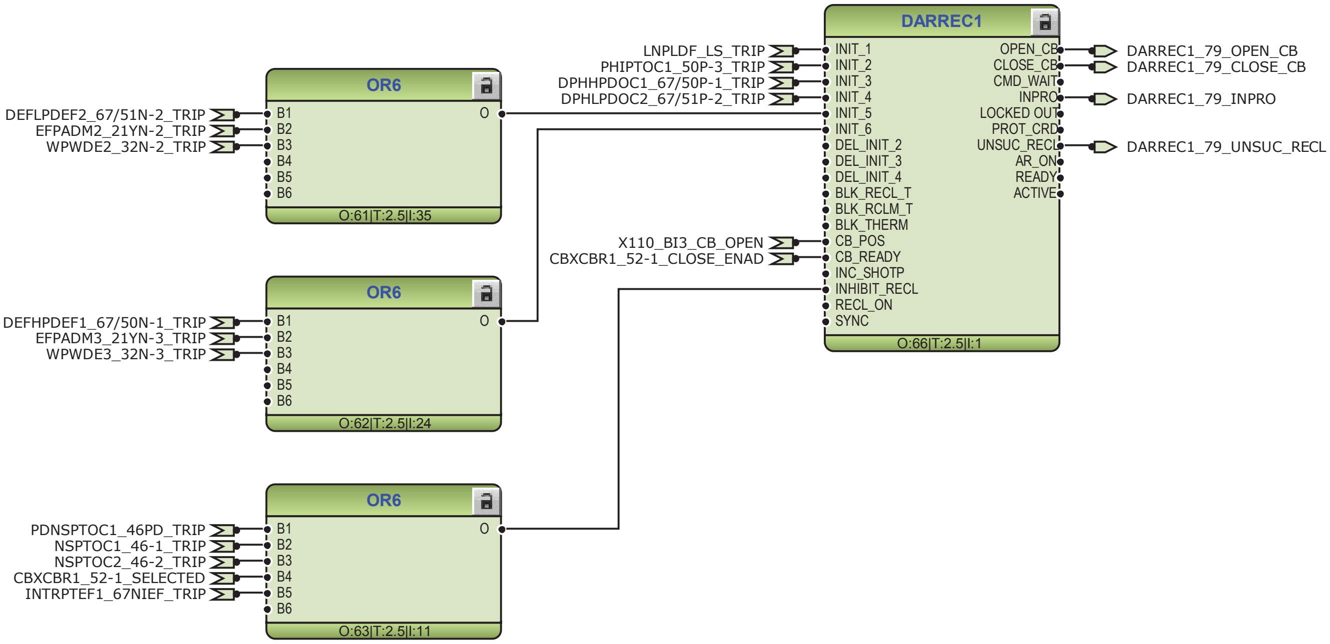


Figure 85: Autoreclosing function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by a number of different protection functions available in the relay. The circuit breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET trip output is used for retripping its own breaker through TRPPTRC2_86/94-1_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the binary output X100:PO2.

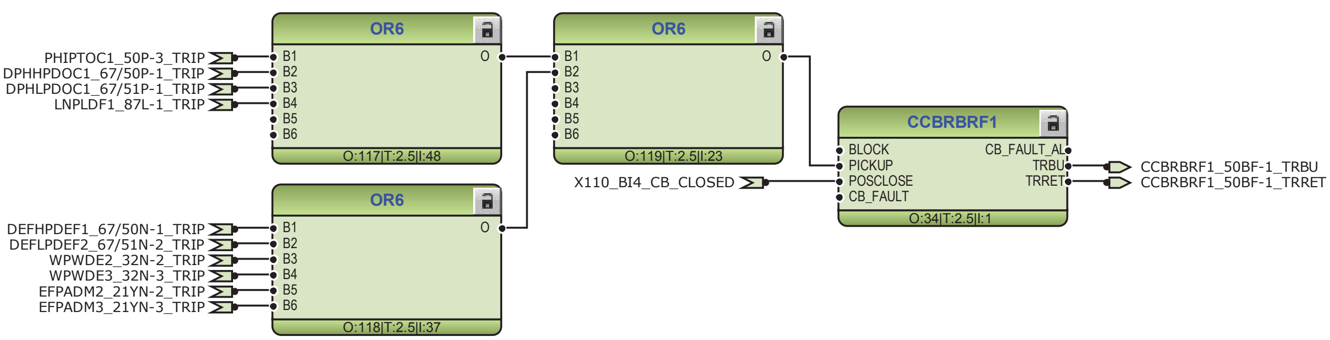


Figure 86: Circuit breaker failure protection function

General pickup and trip from all the functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

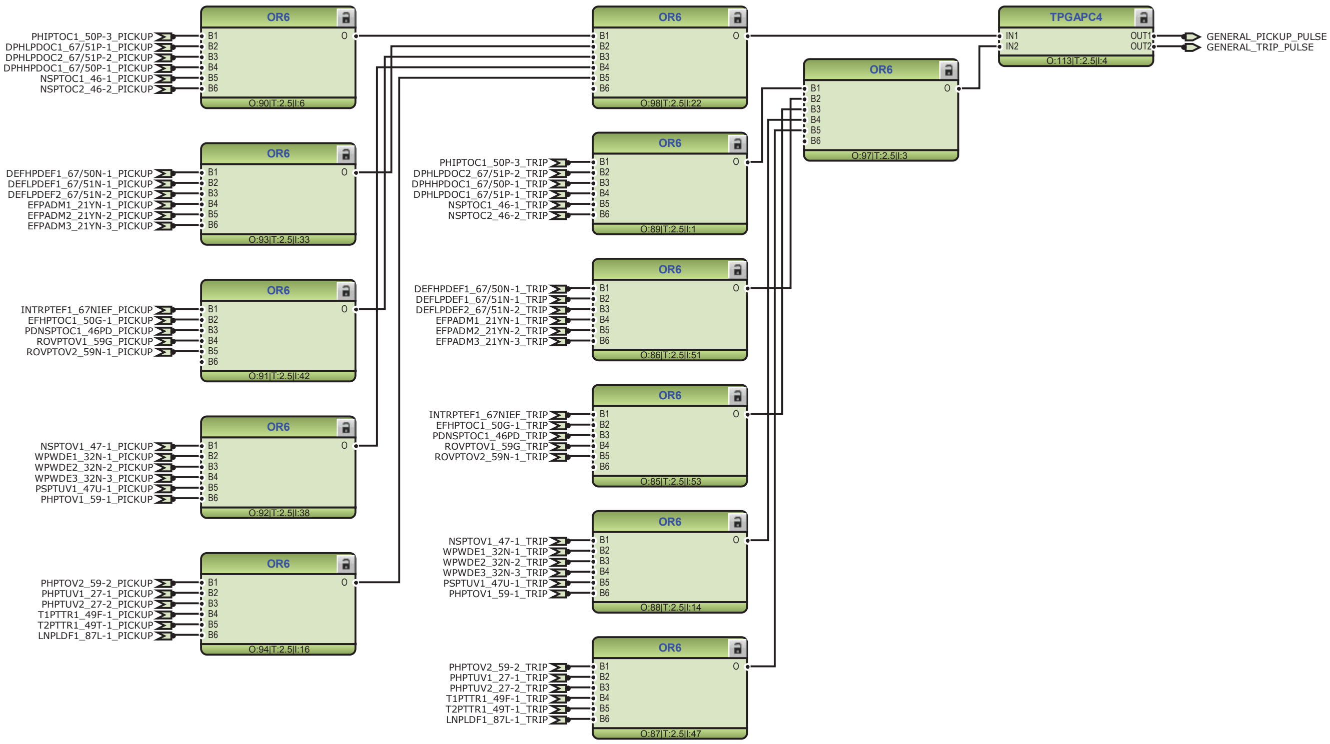


Figure 87: General pickup and trip

The trip signals from the protection functions are connected to the trip logic TRPPTRC1_86/94-1. The output of this trip logic function is available at binary outputs X100:PO3 and X100:PO4. The trip logic function is provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X110:BI1 can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

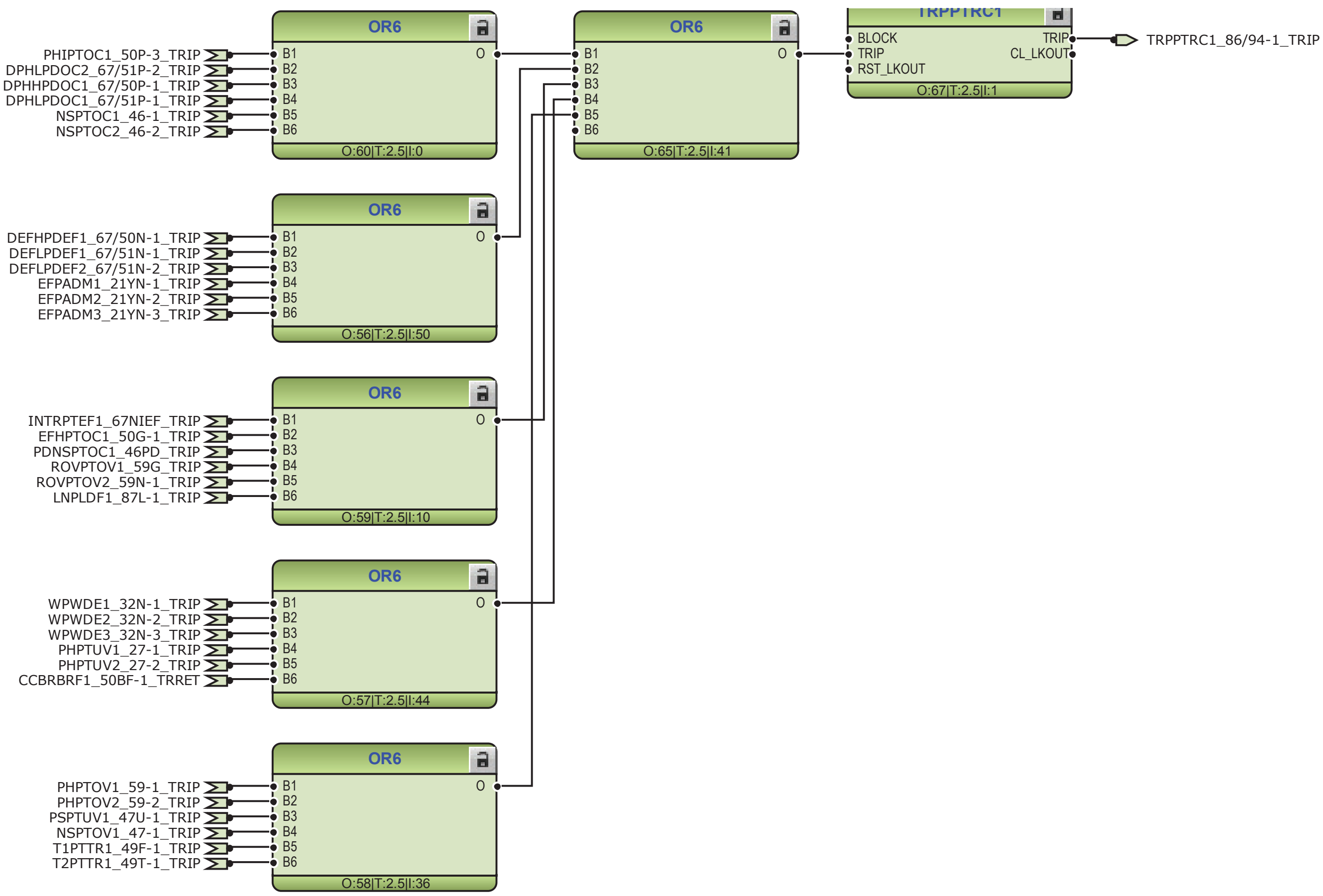


Figure 88: Trip logic TRPPTRC1

3.4.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs 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 selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

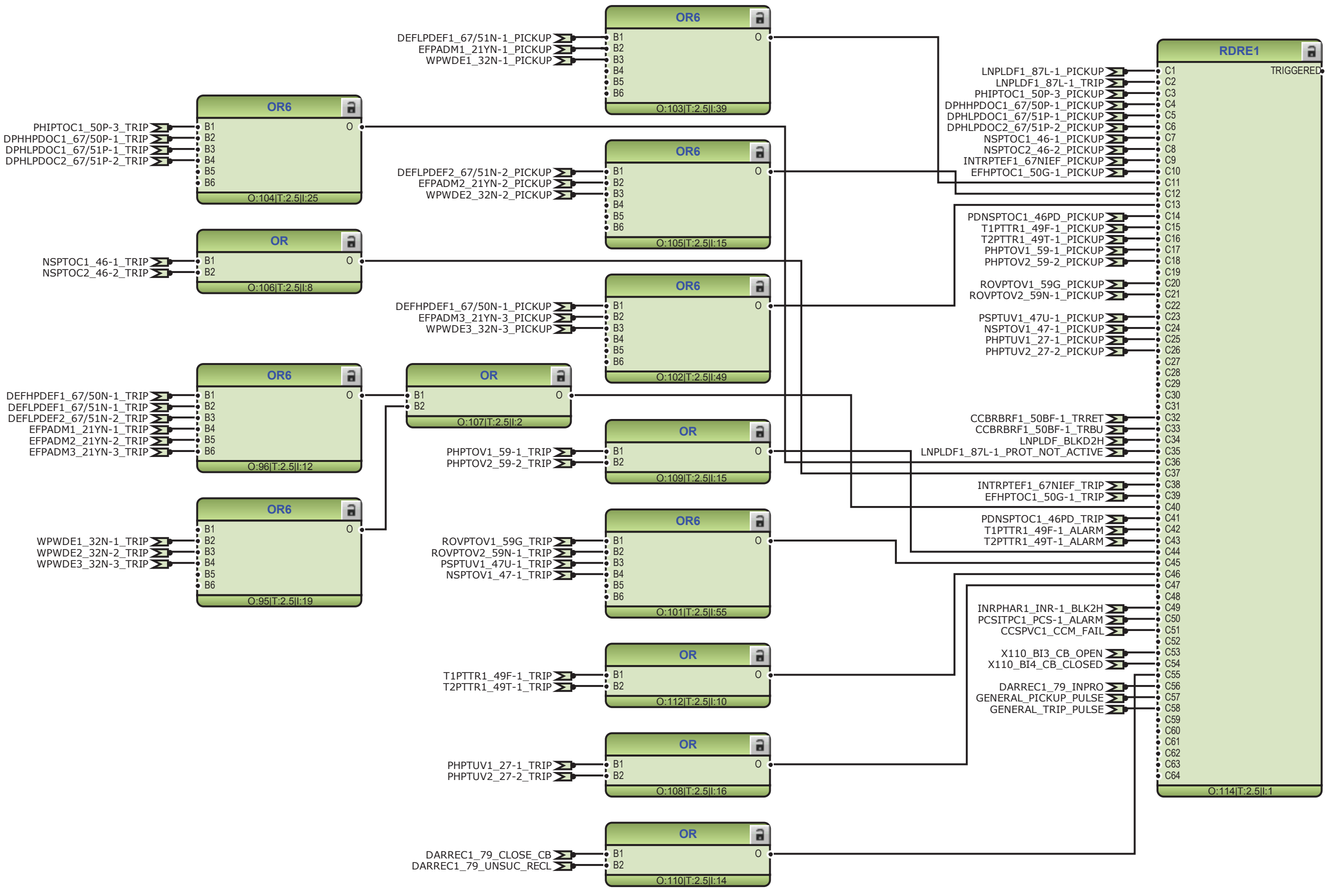


Figure 89: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

Failures in current measuring circuits are detected by CCSPVC1_CCM. When a failure is detected, it can be used to block the current protection functions that are measuring the calculated sequence component currents or residual current to avoid unnecessary operation.

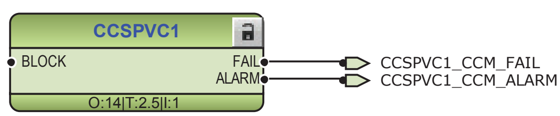


Figure 90: Current circuit supervision function

The fuse failure supervision SEQSPVC1_60-1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

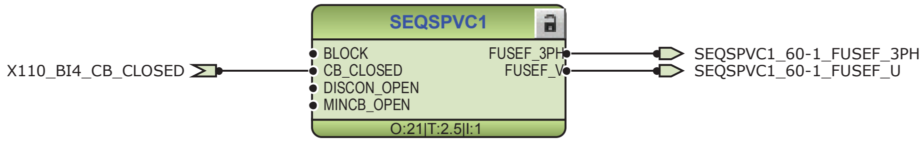


Figure 91: Fuse failure supervision function

Circuit-breaker condition monitoring SSCBR1_52CM-1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM-1 introduces various supervision methods.

Set the parameters for SSCBR1_52CM-1 properly.

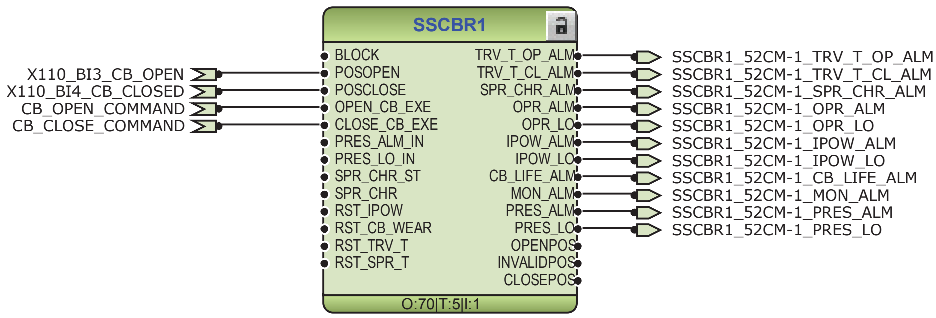


Figure 92: Circuit-breaker condition monitoring function

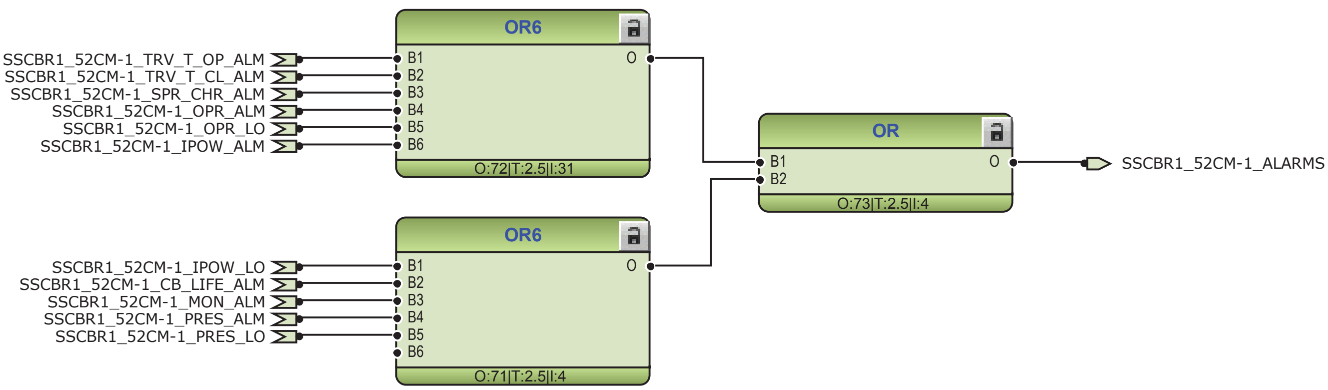


Figure 93: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. Both the functions are blocked by the master trip TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 and the circuit breaker open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR _TCM properly.

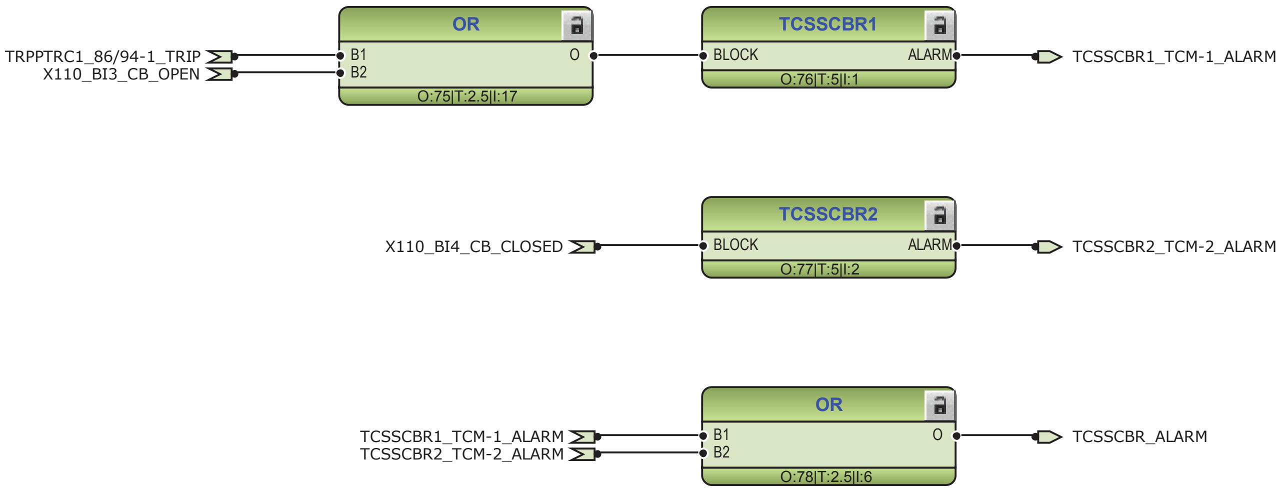


Figure 94: Trip circuit supervision function

Protection communication supervision PCSITPC_PCS-1 is used in the configuration to block the operation of the line differential function. This way, the malfunction of the line differential is prevented. The activation of binary signal transfer outputs during the protection communication failure is also blocked. These are done internally without connections in the configurations. The protection communication supervision alarm is connected to the alarm LED 4, disturbance recorder and binary output X100:SO2.

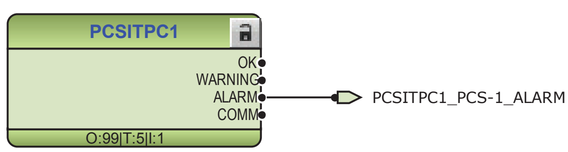


Figure 95: Protection communication supervision function

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 X110:BI2 is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to the BSTGGIO inputs 6 and 7. This is 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 the binary signal transfer function outputs. The remote binary transfer output signal is connected to the binary output X110:SO3.

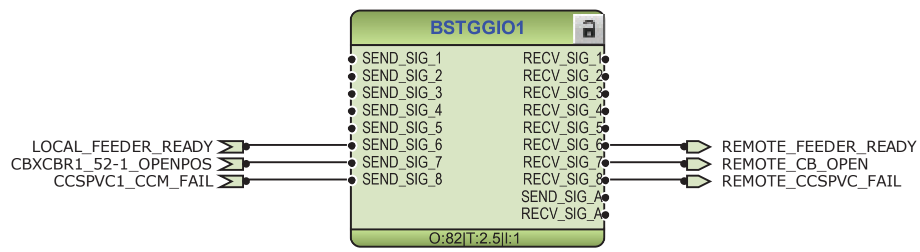


Figure 96: Binary signal transfer function

3.4.3.4 Functional diagrams for control and interlocking

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 disconnector or circuit breaker truck and ground switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and ground switch statuses are local feeder ready information to be sent for the remote end.

The OKPOS output from DCSXSWI defines if the disconnector or circuit breaker truck is either open (in test position) or close (in service position). This, together with the open ground switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for circuit breaker is always enabled.

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

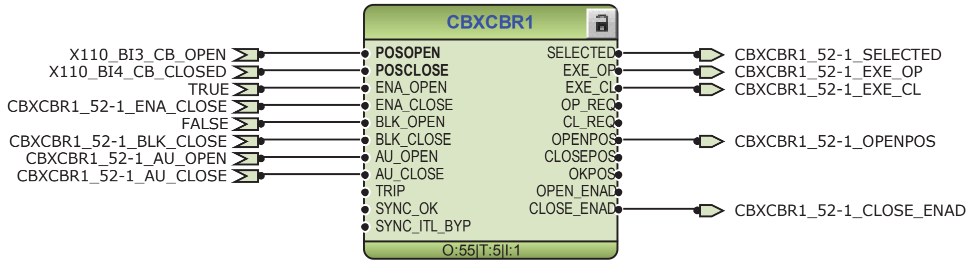


Figure 97: Circuit breaker 1 control logic

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

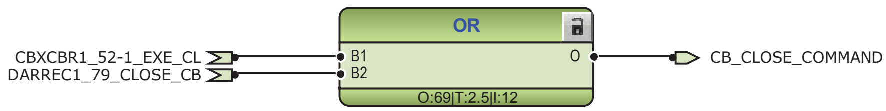


Figure 98: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

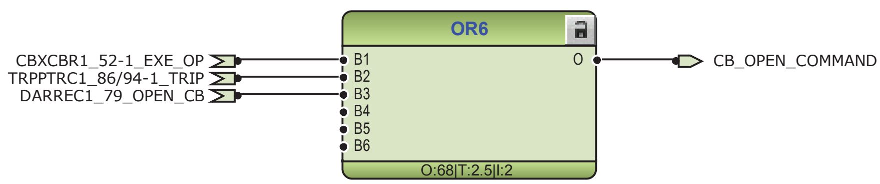


Figure 99: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

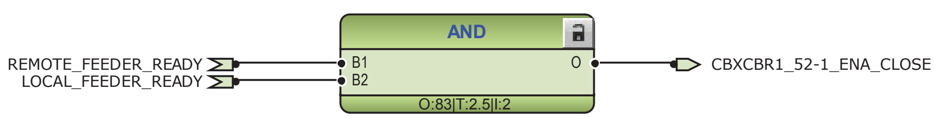


Figure 100: Circuit breaker close enable logic

The configuration includes the logic for generating circuit breaker external closing and opening command with the relay in local or remote mode.

Check the logic for the external circuit breaker closing command and modify it according to the application.

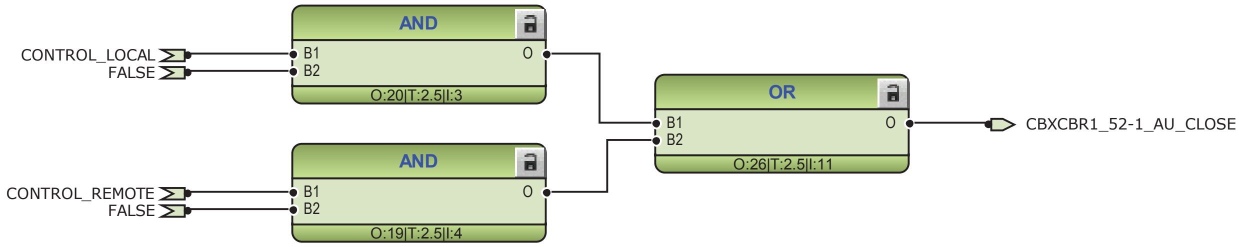


Figure 101: External closing command for circuit breaker

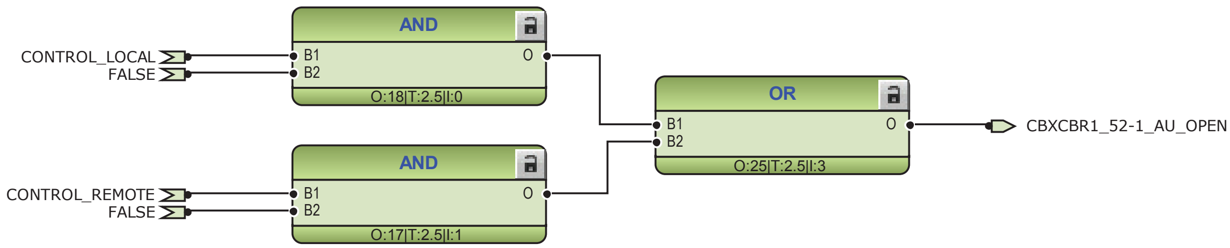


Figure 102: External opening command for circuit breaker

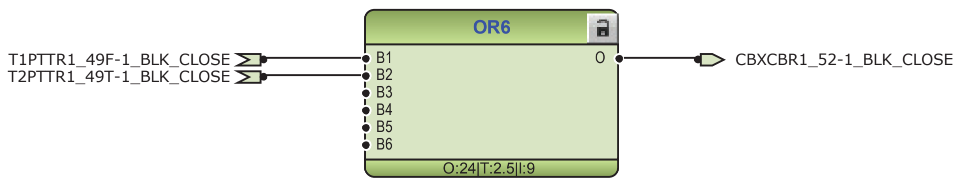


Figure 103: Circuit breaker 1 close blocking logic

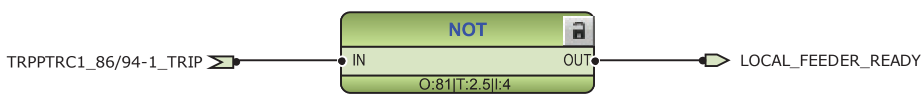


Figure 104: Logic for local feeder ready

3.4.3.5 Functional diagrams for measurement functions

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. Similarly, the sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase bus side phase voltage inputs to the relay are measured by three-phase voltage measurement VMMXU1. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESVMMXU1 measures the residual voltage.

The measurements can be seen from the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

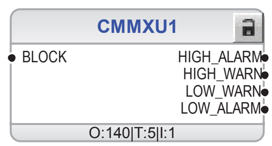


Figure 105: Three-phase current measurement

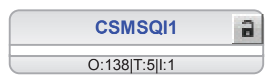


Figure 106: Sequence current measurements

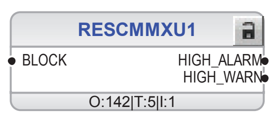


Figure 107: Ground current measurements

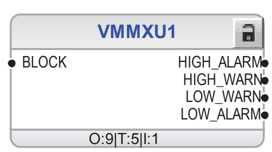


Figure 108: Three-phase voltage measurement

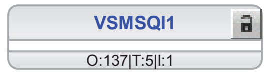


Figure 109: Sequence voltage measurements

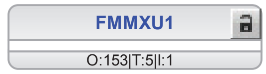


Figure 110: Frequency measurement

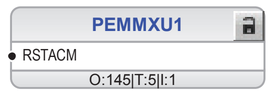


Figure 111: Three-phase power and energy measurement

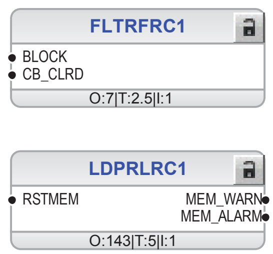


Figure 112: Data monitoring and load profile record

3.4.3.6 Functional diagrams for IO and alarm LEDs

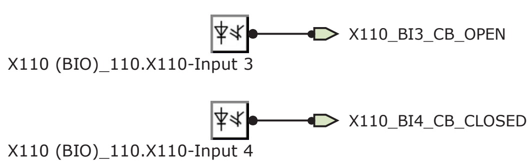


Figure 113: Default binary inputs - X110

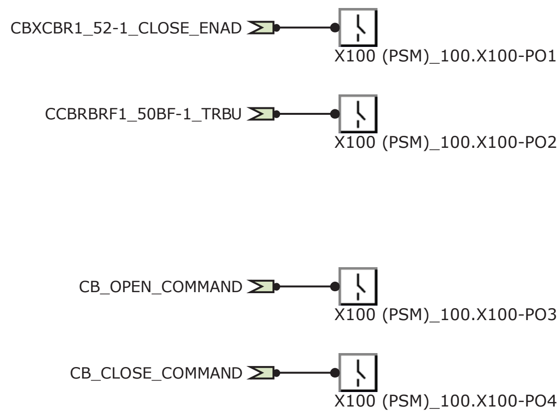


Figure 114: Default binary outputs - X100

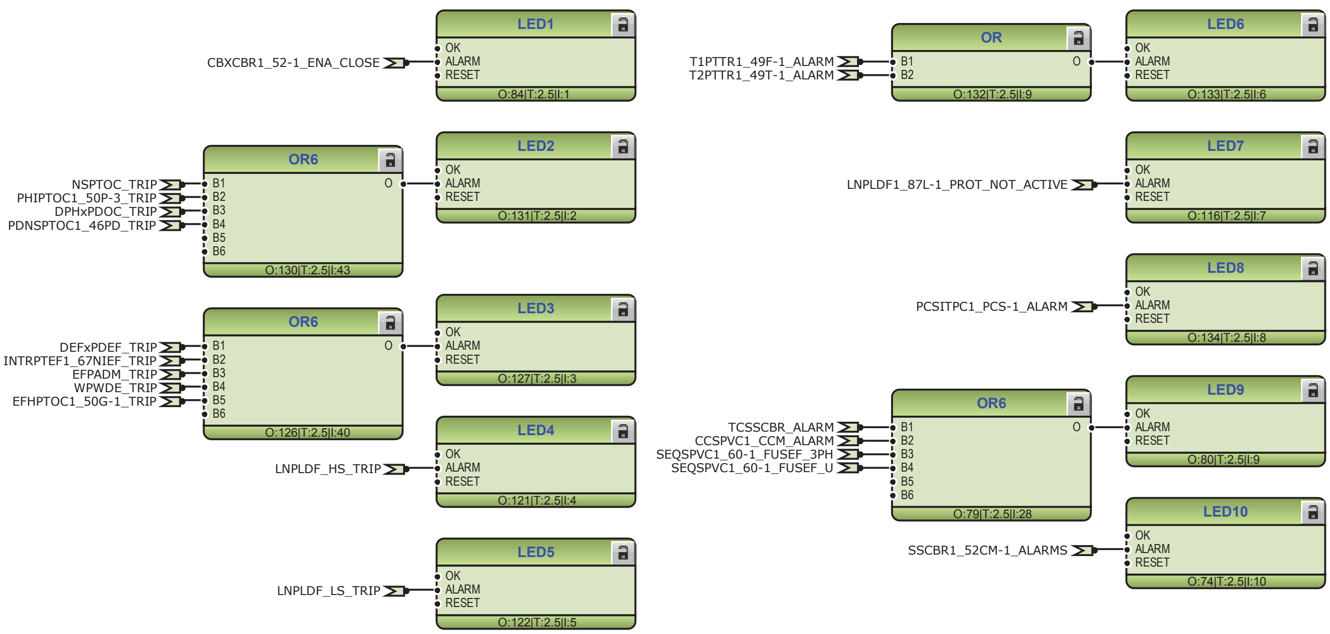


Figure 115: Default LED connection

3.4.3.7 Functional diagrams for other functions

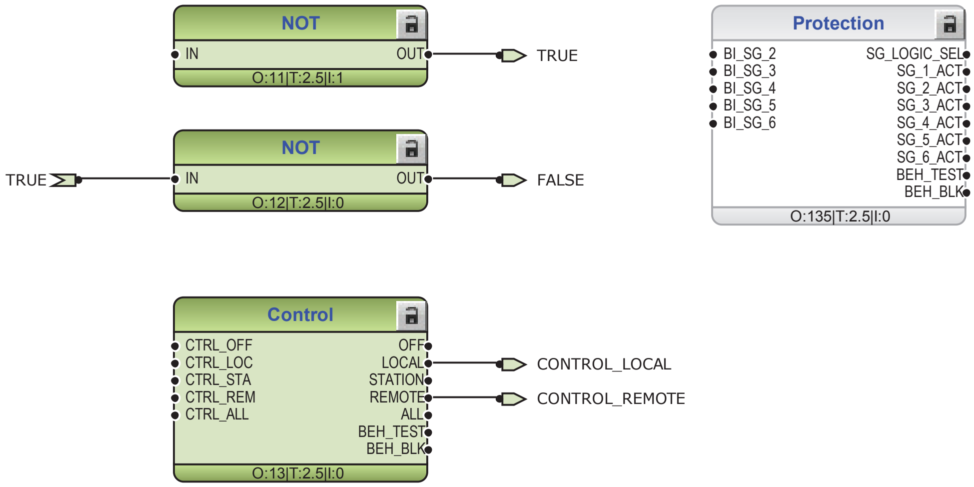


Figure 116: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.4.3.8 Functional diagrams for other timer logics

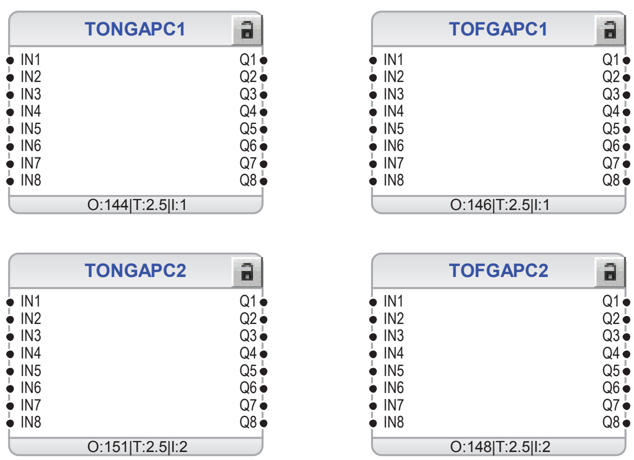


Figure 117: Programmable timers

3.4.3.9 Functional diagrams for communication

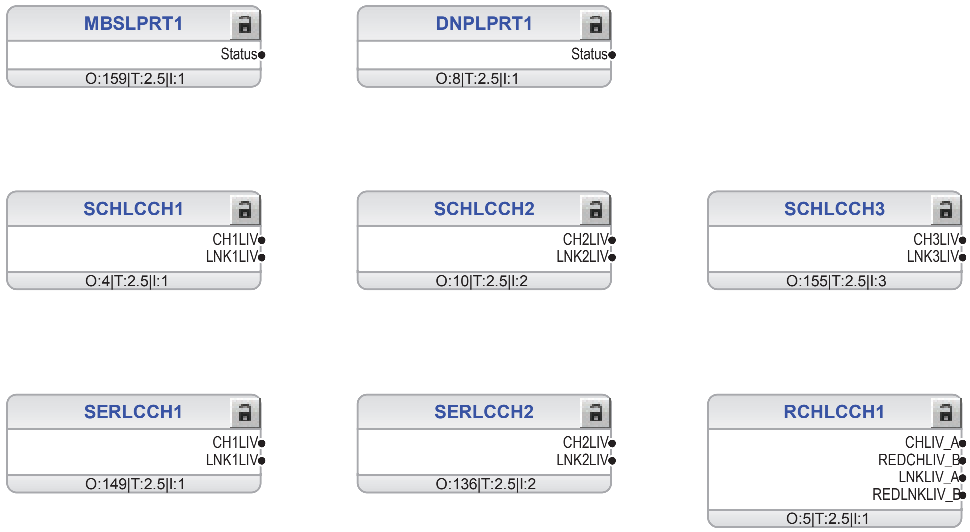


Figure 118: Default communication function connection

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden. The protection settings of the protection relay should be defined in accordance with the CT performance as well as other factors.

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 21: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The 5P class provides a better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering, and so on) of the protection relay.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it might have severe effects on the performance of the protection relay.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

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 protection relay is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$,

I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the protection relay. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended pickup current settings

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

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

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

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

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

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

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed protection relay operation. To ensure the time selectivity, the delay must be taken into account when setting the trip times of successive protection relays.

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

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

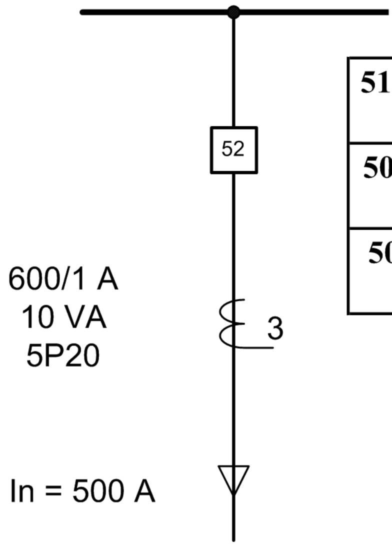
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the pickup current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

$F_a > 20 \times \textit{Current pickup value} / I_{1n}$

The *Current pickup value* is the primary pickup current setting of the protection relay.

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.



51P	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
50P-1/2	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
50P-3	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 119: Example of three-stage overcurrent protection

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

The pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next protection relay (not visible in Figure 119). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the pickup current settings have to be defined so that the protection relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in Figure 119.

For the application point of view, the suitable setting for instantaneous stage (50P-3) in this example is 3 500 A (5.83 × I_{2n}). I_{2n} is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

The protection relay 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 22: Phase current inputs included in configuration D

Terminal	Description
X120:7-8	IA
X120:9-10	IB
X120:11-12	IC

5.1.1.2 Ground current

Table 23: Ground current input included in configuration D

Terminal	Description
X120:13-14	IG

5.1.1.3 Phase voltages

Table 24: Phase voltage inputs included in configuration D

Terminal	Description
X130:11-12	VA
X130:13-14	VB
X130:15-16	VC

5.1.1.4 Ground voltage

Table 25: Additional residual voltage input included in configuration D

Terminal	Description
X130:17-18	VG

5.1.1.5 Sensor inputs

Table 26: Combi sensor inputs included in configuration E

Terminal	Description
X131	IA VA
X132	IB VB
X133	IC VC

5.1.2 Auxiliary supply voltage input

The auxiliary voltage of the protection relay is connected to terminals X100:1-2. At DC supply, the positive lead is connected to terminal X100:1. The permitted auxiliary voltage range is marked on the LHMI of the protection relay on the top of the HMI of the plug-in unit.

Table 27: 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 digital fault recorder or for remote control of protection relay's settings.

Binary inputs of slot X110 are available with configurations D and E.

Table 28: Binary input terminals X110:1-13 with BIO0005 module

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

Binary inputs of slot X120 are available with configuration D.

Table 29: Binary input terminals X120-1...6

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

Binary inputs of slot X130 are available for configuration D.

Table 30: Binary input terminals X130:1-8 with AIM0006 module

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

5.1.4 RTD/mA inputs

It is possible to connect mA and RTD based measurement sensors to the protection relay, if the protection relay is provided with optional with AIM0003 module in standard configuration D.

Table 31: Optional RTD/mA inputs with AIM0003 module

Terminal	Description
X130:1	mA 1 (AI1), +
X130:2	mA 1 (AI1), -
X130:3	RTD1 (AI2), +
X130:4	RTD1 (AI2), -
X130:5	RTD1 (AI2), ground
X130:6	RTD2 (AI3), +
X130:7	RTD2 (AI3), -
X130:8	RTD2 (AI3), ground

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. In the factory default configuration, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 32: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCM resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCM1 input), NO
X100:19	PO3 (TCM1 input), NO
X100:20	PO4, NO (TCM resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCM2 input), NO
X100:24	PO4 (TCM2 input), NO

5.2.2 Outputs for signalling

SO output contacts can be used for signalling on pickup and tripping of the protection relay. On delivery from the factory, the pickup and alarm signals from all the protection stages are routed to signalling outputs.

Table 33: 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

Output contacts of slot X110 are optional.

Table 34: Output contacts X110:14-24 with BIO0005

Terminal	Description
X110:14	SO1, common
X110:15	SO1, NO
X110:16	SO1, NC

Table continues on next page

Terminal	Description
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

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection relay. Under normal operating conditions, the protection relay 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 contact X100:3-5 drops off and the contact X100:3-4 closes.

Table 35: IRF contact

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

5.3 Protection communication options

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

Multi-mode or single-mode glass fiber can be used in a fiber optic link. Select the required glass fiber mode when ordering the protection relay. Link lengths up to 2 km with multi-mode fiber and link lengths up to 20 km with single-mode fiber can be achieved. The fiber optic cable used for protection communication is connected to the X16/LD connector in the protection relay. See the 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 protection relay. The protection communication link always requires two modems in a protection scheme, thus delivered in pairs of master (RPW600M) and follower (RPW600F) units. The protection relay is connected to the pilot wire modem using a single-mode fiber optic cable. Thus a single-mode version of protection relay is required if the pilot wire link is used. The fiber optic cable is connected to the X16/LD connector in the protection relay 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 protection relay. Pilot wire link lengths up to 8 km with 0.8 mm^2 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 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 protection relays. 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.

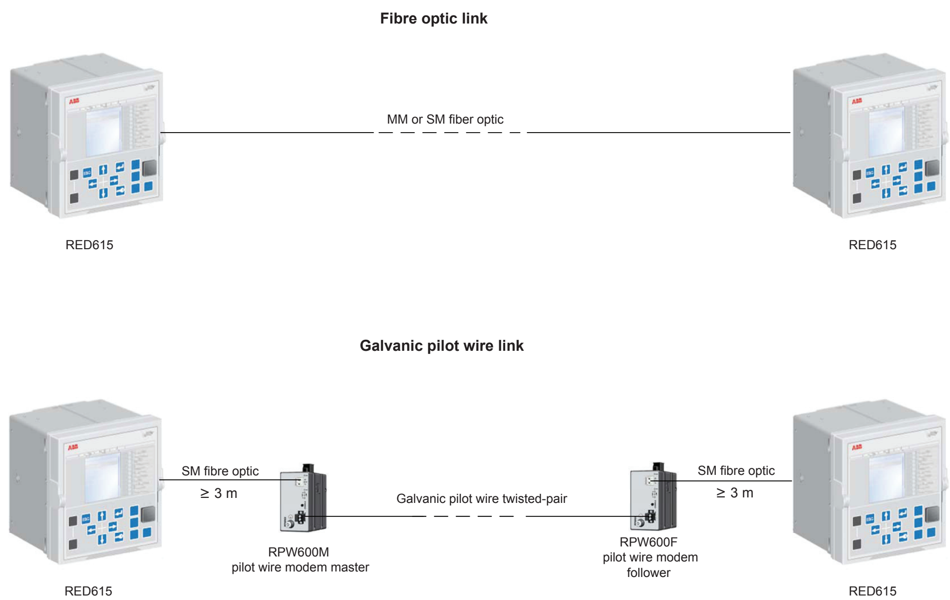


Figure 120: Protection communication options

See RPW600 user guide for more information.

Section 6 Glossary

AI	Analog input
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DFR	Digital fault recorder
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.
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
GPS	Global Positioning System
HMI	Human-machine interface
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
I/O	Input/output
IEC 61850	International standard for substation communication and modeling

IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IED	Intelligent electronic device
IEEE 1588 v2	Standard for a Precision Clock Synchronization Protocol for networked measurement and control systems
IP	Internet protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
QoS	Quality of service
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit
SAN	Single attached node

SLD	Single-line diagram
SNTP	Simple Network Time Protocol
SO	Signal output
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.
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
UDP	User datagram protocol
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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