RELION® 615 SERIES

Line Differential Protection and Control RED615

Application Manual

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Product version: 5.0 FP1

Warranty

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

www.abb.com/relion

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This product complies with following directive and regulations.

Directives of the European parliament and of the council:

- Electromagnetic compatibility (EMC) Directive 2014/30/EU
- Low-voltage Directive 2014/35/EU
- RoHS Directive 2011/65/EU

UK legislations:

- Electromagnetic Compatibility Regulations 2016
- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

These conformities are the result of tests conducted by the third-party testing in accordance with the product standard EN / BS EN 60255-26 for the EMC directive / regulation, and with the product standards EN / BS EN 60255-1 and EN / BS EN 60255-27 for the low voltage directive / safety regulation.

The product is designed in accordance with the international standards of the IEC 60255 series.

Contents

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

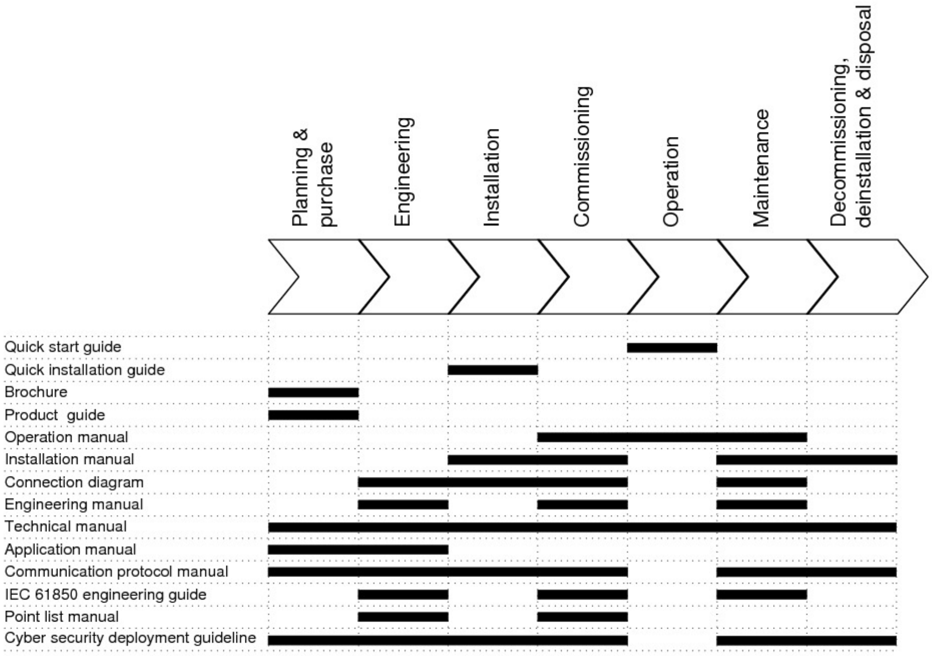


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2008-10-03	1.1	First release
B/2009-07-03	2.0	Content updated to correspond to the product version
C/2010-06-11	3.0	Content updated to correspond to the product version
D/2010-06-29	3.0	Terminology updated
E/2010-09-24	3.0	Content updated
F/2012-05-11	4.0	Content updated to correspond to the product version
G/2013-02-21	4.0 FP1	Content updated to correspond to the product version
H/2013-12-20	5.0	Content updated to correspond to the product version
K/2014-01-24	5.0	Content updated
L/2015-10-30	5.0 FP1	Content updated to correspond to the product version
M/2016-05-20	5.0 FP1	Content updated
N/2018-12-20	5.0 FP1	Content updated
P/2021-12-21	5.0 FP1	Content updated

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS756468
DNP3 Communication Protocol Manual	1MRS756709
IEC 60870-5-103 Communication Protocol Manual	1MRS756710
IEC 61850 Engineering Guide	1MRS756475
Engineering Manual	1MRS757121
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887
Cyber Security Deployment Guideline	1MRS758280

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push-button navigation in the LHMI menu structure is presented by using the push-button icons.

  To navigate between the options, use  and .
- Menu paths are presented in bold.

  Select **Main menu** > **Settings**.
- LHMI messages are shown in Courier font.

  To save the changes in nonvolatile memory, select `Yes` and press .
- Parameter names are shown in italics.

  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.

  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.

  When the function starts, the `START` output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67-1 (1)
	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67-2 (1)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Admittance-based earth-fault protection	EFPADM1	Yo> -> (1)	21YN (1)
	EFPADM2	Yo> -> (2)	21YN (2)
	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric-based earth-fault protection	WPWDE1	Po> -> (1)	32N (1)
	WPWDE2	Po> -> (2)	32N (2)
	WPWDE3	Po> -> (3)	32N (3)
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF (1)
Harmonics-based earth-fault protection	HAEFPTOC1	Io>HA (1)	51NHA (1)
Non-directional (cross-country) earth-fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1> (1)	46PD (1)
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
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)	47O- (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)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
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/G/C (1)
Binary signal transfer	BSTGGIO1	BST (1)	BST (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
Three-phase inrush detector	INRPHAR1	3I2f> (1)	68 (1)
Switch onto fault	CBPSOF1	SOTF (1)	SOTF (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (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)	PQM3I (1)
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQM3V (1)
Voltage variation	PHQVVR1	PQMU (1)	PQMV (1)
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC (1)	I <-> O ESC (1)
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Autoreclosing	DARREC1	O -> I (1)	79 (1)
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (1)
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
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			
Disturbance recorder	RDRE1	DR (1)	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
	VMMXU2	3U (2)	3V (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (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 (1)
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV	SMVRCV
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)
Time delay on (8 pcs)	TONGAPC1	TON (1)	TON (1)
	TONGAPC2	TON (2)	TON (2)
	TONGAPC3	TON (3)	TON (3)
	TONGAPC4	TON (4)	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)	SR (1)
	SRGAPC2	SR (2)	SR (2)
	SRGAPC3	SR (3)	SR (3)
	SRGAPC4	SR (4)	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)	MV (1)
	MVGAPC2	MV (2)	MV (2)
Generic control point (16 pcs)	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)

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. Further, standard configurations B and C also include earth-fault 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 earthed, compensated (impedance earthed) and solidly earthed 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, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302.

2.1.1 Product version history

Product version	Product history
1.1	Product released
2.0	• Support for DNP3 serial or TCP/IP • Support for IEC 60870-5-103 • New standard configurations B and C • Disturbance recorder upload via WHMI

Table continues on the next page

Product version	Product history
3.0	• Additions to configuration B • Application configurability support • Analog GOOSE support • Large display with single line diagram • Enhanced mechanical design • Increased maximum amount of events and fault records • Admittance-based earth-fault protection • Residual overvoltage protection • Low voltage power supply option • Pilot wire modem support
4.0	• Additions/changes for configurations A-C • Dual fiber-optic Ethernet communication option (COM0032) • Generic control point (SPCGGIO) function blocks • Additional logic blocks • Button object for SLD • Controllable disconnector and earth switch objects for SLD • Wattmetric based E/F • Harmonics based E/F • Increased maximum amount of events and fault records
4.0 FP1	• Parallel use of IEC 61850 and DNP3 protocols • Parallel use of IEC 61850 and IEC 60870-5-103 protocols • Two selectable indication colors for LEDs (red or green) • Online binary signal monitoring with PCM600
5.0	• New configurations D and E • New layout in Application Configuration tool for all configurations • In-zone transformer application support • Fault locator • Load profile recorder • Optional RTD/mA inputs • Profibus adapter support • Support for multiple SLD pages • Import/export of settings via WHMI • Setting usability improvements • HMI event filtering tool
5.0 FP1	• IEC 61850 Edition 2 • Currents sending support with IEC 61850-9-2 LE • Support for synchronism and energizing check with IEC 61850-9-2 LE • High-availability seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • Support for configuration migration (starting from Ver.3.0 to Ver.5.0 FP1) • Software closable Ethernet ports • Chinese language support • Report summary via WHMI • Voltage unbalance power quality option • Switch onto fault • Additional timer, set-reset and analog value scaling functions

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) 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 *www.abb.com/substationautomation* or directly with Update Manager in PCM600.

2.2 Operation functionality

2.2.1 Optional functions

- Autoreclosing (configurations B, C, D and E only)
- Modbus TCP/IP or RTU/ ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Admittance-based earth-fault protection (configurations B, D and E only)
- Wattmetric-based earth-fault protection (configurations B, D and E only)
- Harmonics-based earth-fault protection (configurations B, C, D and E only)
- Power quality functions (configurations D and E only)
- Fault locator (configurations D and E only)
- RTD/mA measurement (configuration D only)
- IEC 61850-9-2 LE (configurations D and E only, 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	Slot ID	Content options	
Plug-in unit	-	HMI	Small (5 lines, 20 characters) Large (10 lines, 20 characters) with SLD
			Small Chinese (3 lines, 8 or more characters) Large Chinese (7 lines, 8 or more 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 contacts 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BIO module	8 binary inputs 4 SO contacts
	X120	AI/BI module	Only with configuration B: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A) 1 residual voltage input (60...210 V) 3 binary inputs
			Only with configurations A, C and D: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A) [1] 4 binary inputs

Table continues on the next page

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

Main	Slot ID	Content options	
Case	X130	AI/ BI module	Only with configuration D: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
		AI/ RTD/mA module	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]
		Optional BIO module	Optional for configurations A, B and C: 6 binary inputs 3 SO contacts
	X000	Communication module	See the technical manual for details about different types of communication modules.

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

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

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

Table 3: Input/output overview

Std. conf.	Ordercode digit		Analog channels			Binary channels			
	5–6	7–8	CT	VT	Combi sensor	BI	BO	RTD	mA
A	AC	AD	4	–	–	12	4 PO + 6 SO	–	–
		AF	4	–	–	18	4 PO + 9 SO	–	–
B	AA / AB	AC	4	1	–	11	4 PO + 6 SO	–	–
		AE	4	1	–	17	4 PO + 9 SO	–	–
C	AC	AD	4	–	–	12	4 PO + 6 SO	–	–
		AF	4	–	–	18	4 PO + 9 SO	–	–
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 / DB	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.

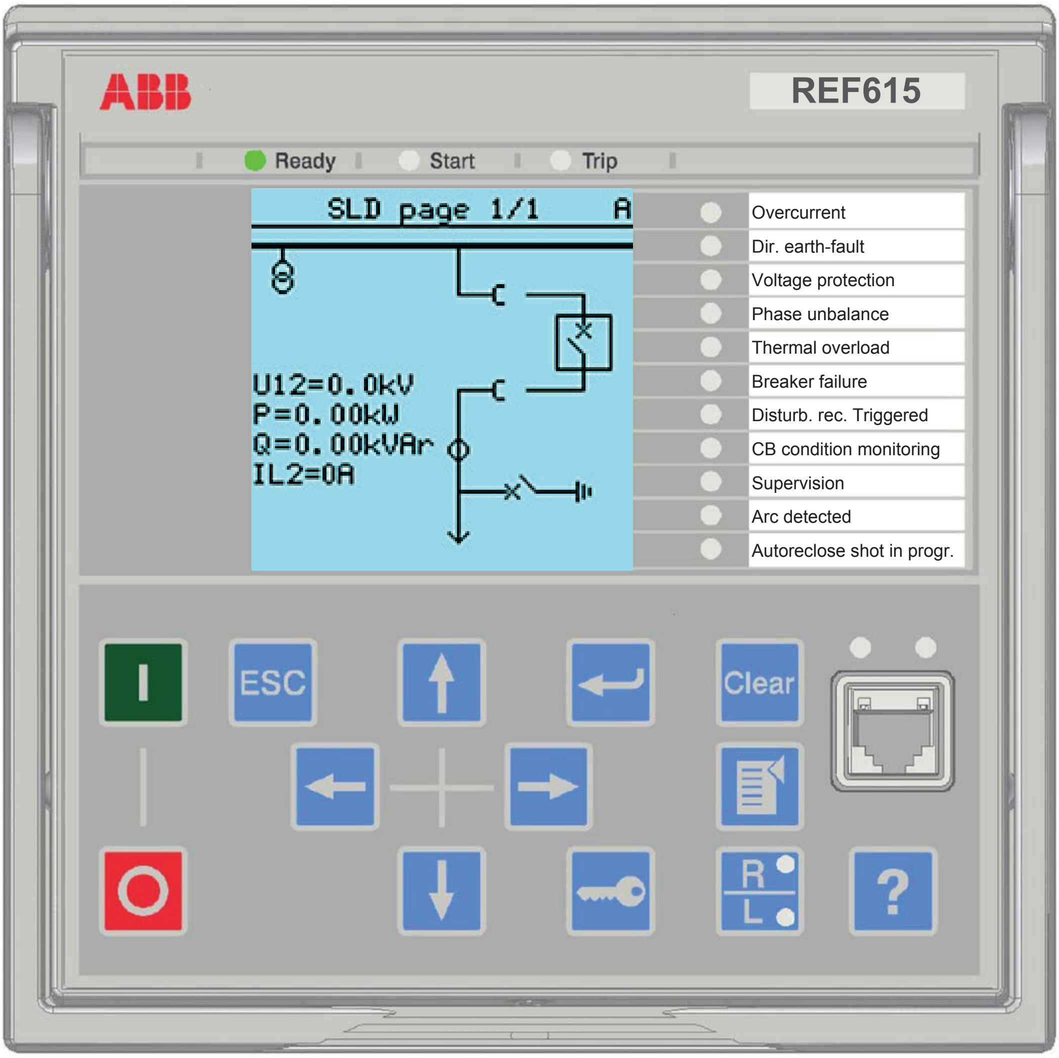


Figure 2: Example of the LHMI

2.4.1 Display

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

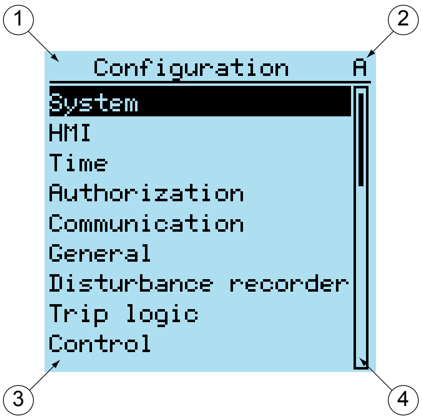
Table 4: Small display

Character size[1]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

Table 5: Large display

Character size[1]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20
Large, variable width (13 × 14 pixels)	7	8 or more

The display view is divided into four basic areas.



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

Figure 3: Display layout

2.4.2 LEDs

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

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.

1 Depending on the selected language

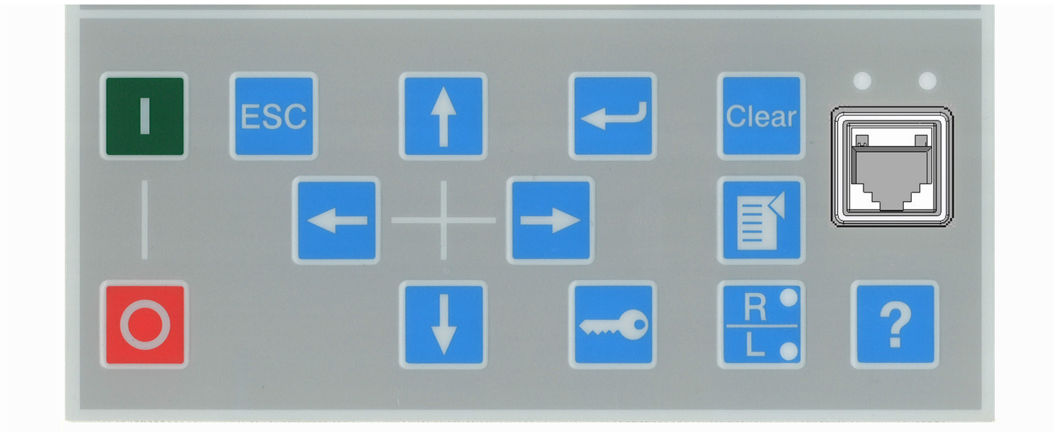


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

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

WHMI is disabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance 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.

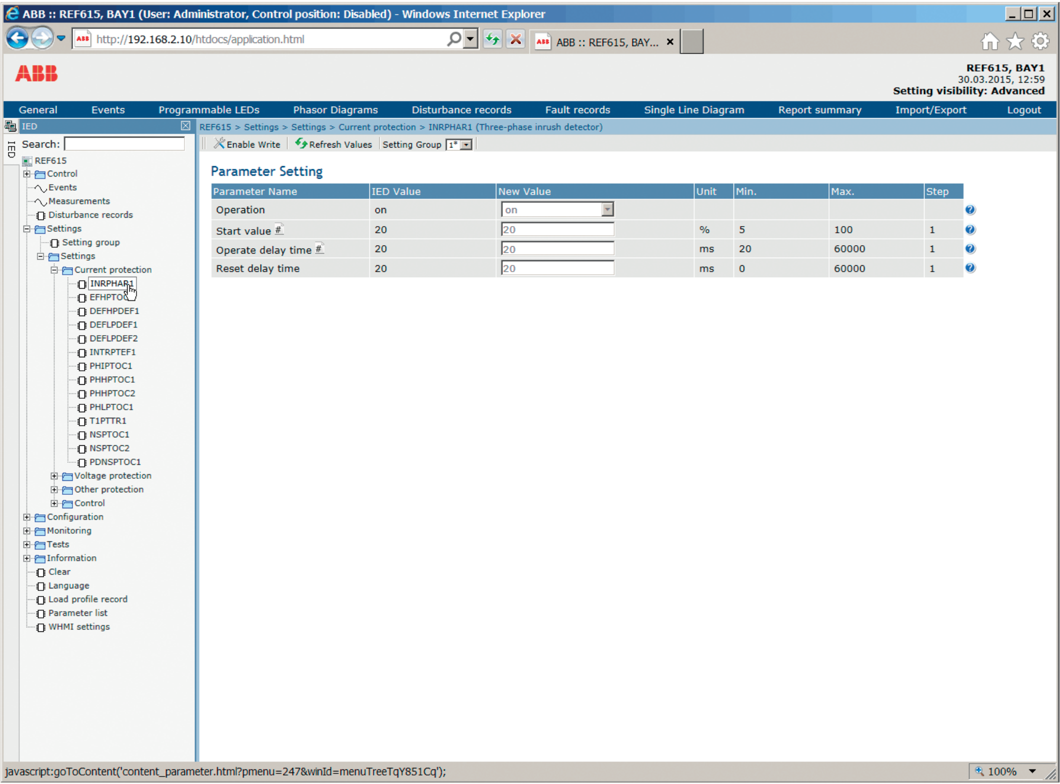


Figure 5: Example view of the WHMI

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 6: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.6.1 Audit trail

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

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

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

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

Table 7: Audit trail events

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

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

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

Table 8: Comparison of authority logging levels

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

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850, IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

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

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber-optic LC connector (100Base-FX). An optional serial interface is available for RS-232/RS-485 communication.

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.

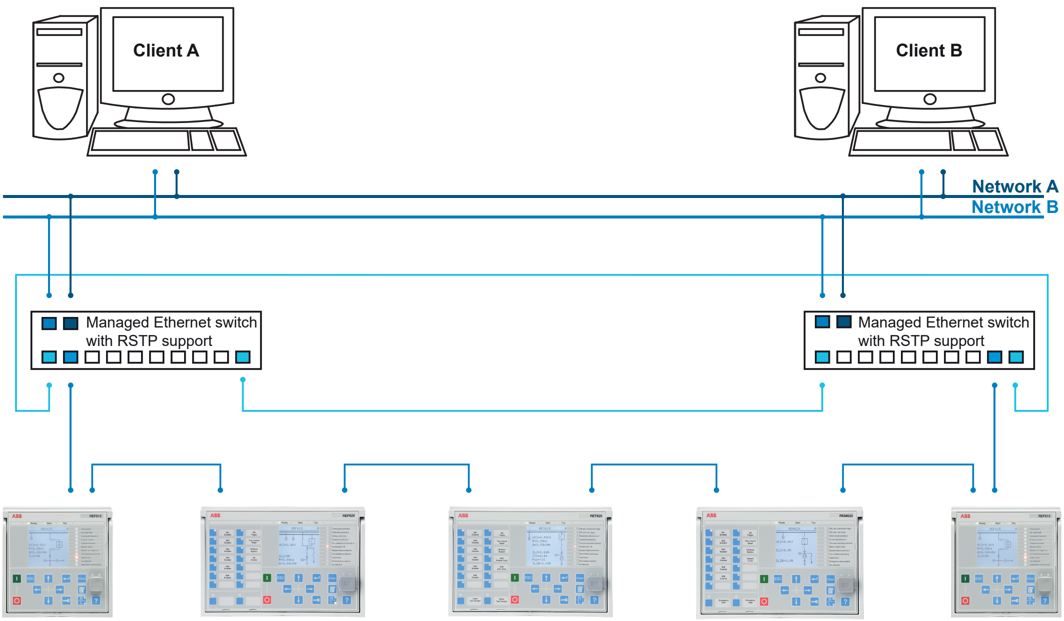


Figure 6: Self-healing Ethernet ring solution

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.

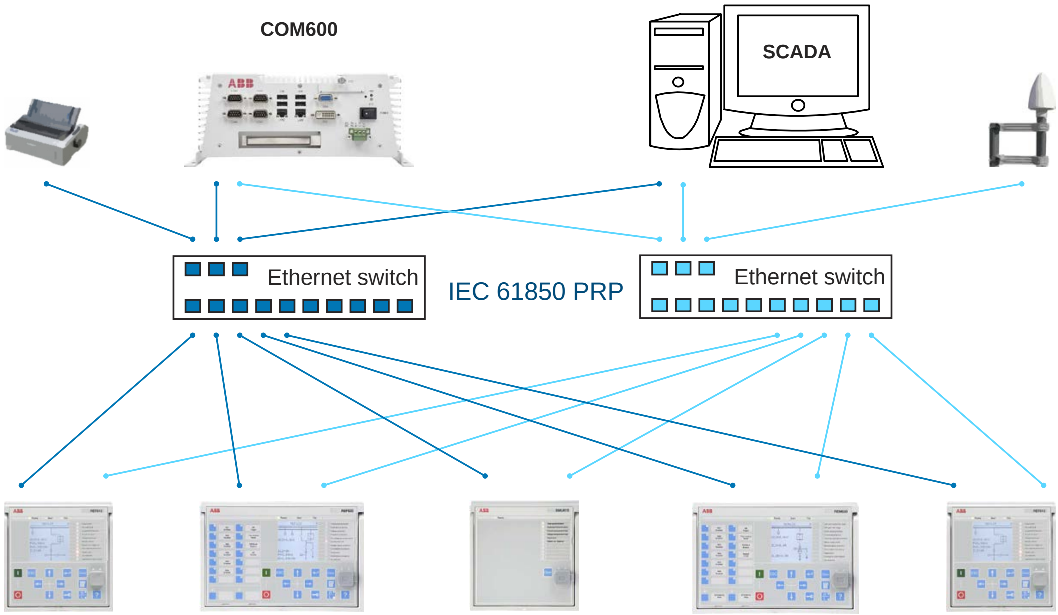


Figure 7: PRP solution

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.

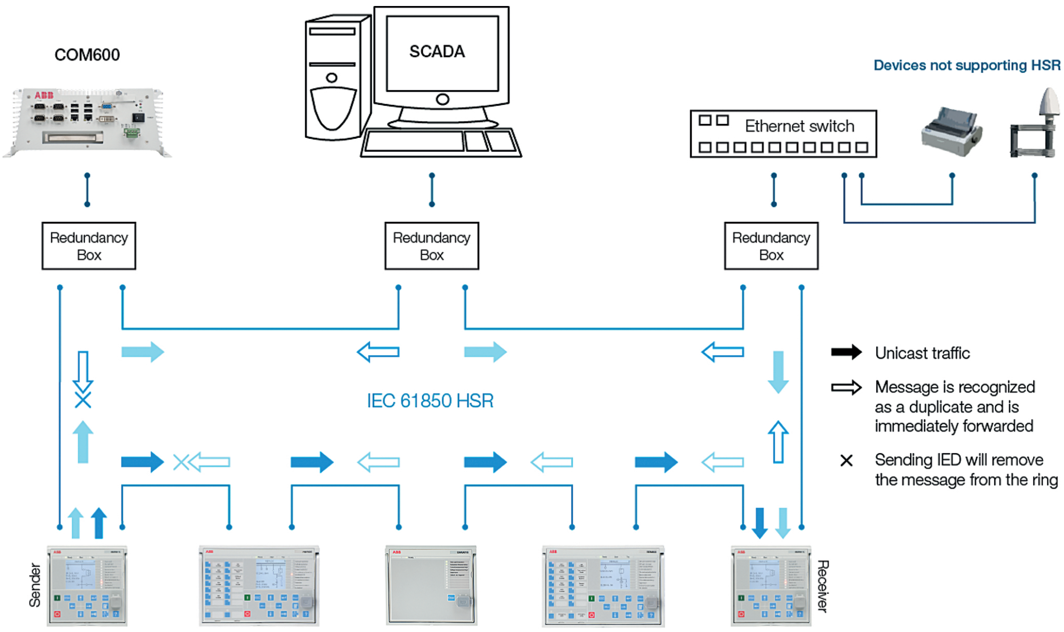


Figure 8: HSR solution

2.7.3 Process bus

Process bus IEC 61850-9-2 defines the transmission of Sampled Measured Values within the substation automation system. International Users Group created a guideline IEC 61850-9-2 LE that defines an application profile of IEC 61850-9-2 to facilitate implementation and enable interoperability. Process bus is used for distributing process data from the primary circuit to all process bus compatible devices in the local network in a real-time manner. The data can then be processed by any protection relay to perform different protection, automation and control functions.

UniGear Digital switchgear concept relies on the process bus together with current and voltage sensors. The process bus enables several advantages for the UniGear Digital like simplicity with reduced wiring, flexibility with data availability to all devices, improved diagnostics and longer maintenance cycles.

With process bus the galvanic interpanel wiring for sharing busbar voltage value can be replaced with Ethernet communication. Transmitting measurement samples over process bus brings also higher error detection because the signal transmission is automatically supervised. Additional contribution to the higher availability is the possibility to use redundant Ethernet network for transmitting SMV signals.

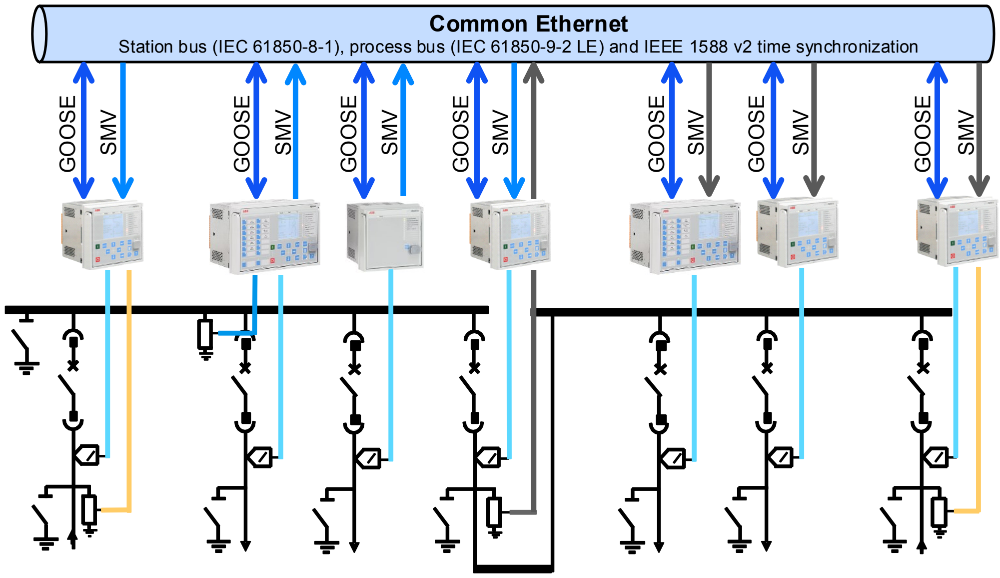


Figure 9: Process bus application of voltage sharing and synchrocheck

The 615 series supports IEC 61850 process bus with sampled values of analog currents and voltages. The measured values are transferred as sampled values using the IEC 61850-9-2 LE protocol which uses the same physical Ethernet network as the IEC 61850-8-1 station bus. The intended application for sampled values is sharing the measured voltages from one 615 series protection relay to other devices with phase voltage based functions and 9-2 support.

The 615 series protection relays with process bus based applications use IEEE 1588 v2 Precision Time Protocol (PTP) according to IEEE C37.238-2011 Power Profile for high accuracy time synchronization. With IEEE 1588 v2, the cabling infrastructure requirement is reduced by allowing time synchronization information to be transported over the same Ethernet network as the data communications.

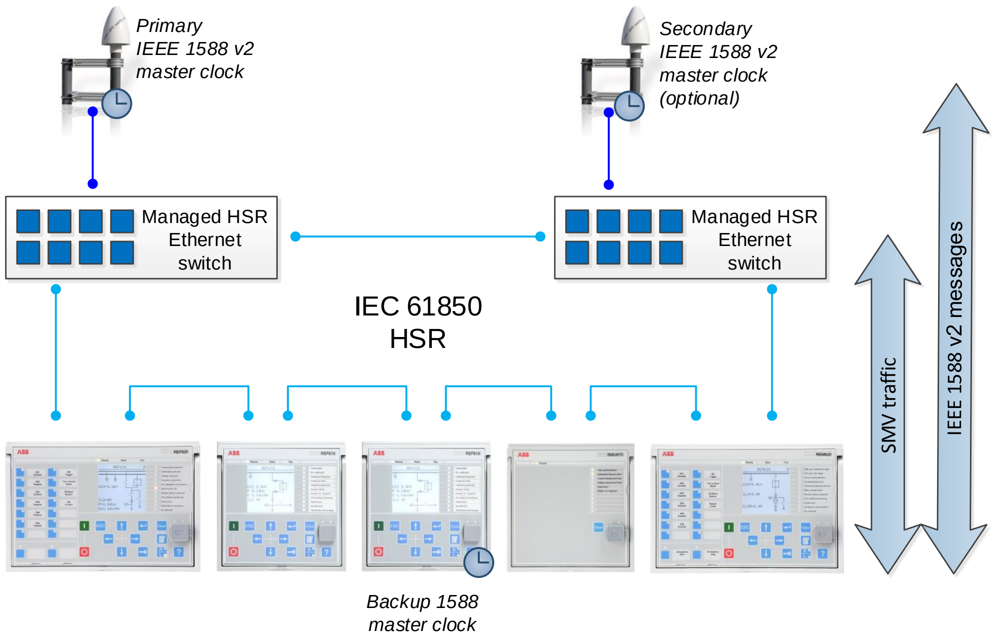


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

The process bus option is available for all 615 series protection relays equipped with phase voltage inputs. Another requirement is a communication card with IEEE 1588 v2 support (COM0031...COM0037). However, RED615 supports this option only with the communication card variant having fiber optic station bus ports. See the IEC 61850 engineering guide for detailed system requirements and configuration details.

2.7.4 Secure communication

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

2.7.5 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.

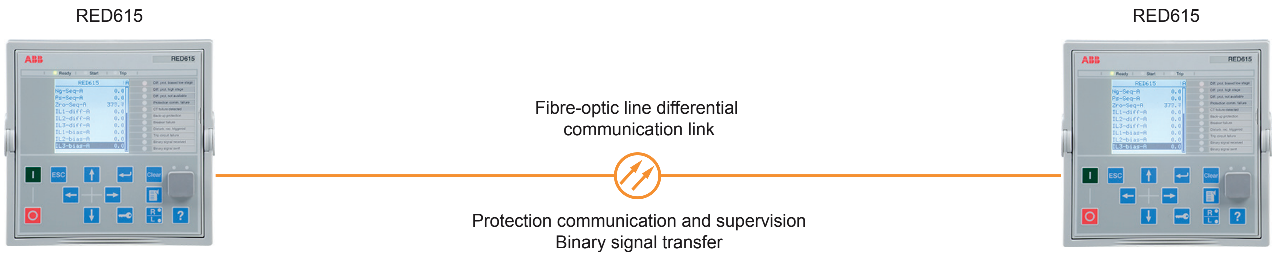


Figure 11: Fiber optic protection communication link

3 RED615 standard configurations

3.1 Standard configurations

RED615 is available with five 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 9: Standard configurations

Description	Std.conf
Line differential protection	A
Line differential protection with directional earth-fault protection and circuit-breaker condition monitoring	B
Line differential protection with non-directional earth-fault protection and circuit-breaker condition monitoring	C
Line differential protection with directional overcurrent and earth-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 earth-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

3.1.1 Supported functions in RED615

Table 10: Supported functions

Function	IEC 61850	A	B	C	D	E
		DE01	DE02	DE03	DE04	DE05
Protection						
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1	1		

Table continues on the next page

Function	IEC 61850	A	B	C	D	E
		DE01	DE02	DE03	DE04	DE05
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2	2		
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC				2	2
Three-phase directional overcurrent protection, high stage	DPHHPDOC				1	1
Non-directional earth-fault protection, low stage	EFLPTOC			2		
Non-directional earth-fault protection, high stage	EFHPTOC			1		
Non-directional earth-fault protection, instantaneous stage	EFIPTOC			1		
Directional earth-fault protection, low stage	DEFLPDEF		2		2	2
Directional earth-fault protection, high stage	DEFHPDEF		1 [1]		1	1 [2]
Admittance-based earth-fault protection	EFPADM		(3) [1 3]		(3) [3]	(3) [2 3]
Wattmetric-based earth-fault protection [3]	WPWDE		(3) [1 3]		(3) [3]	(3) [2 3]
Transient/intermittent earth-fault protection	INTRPTEF		1 [1]		1 [4]	1 [2 4]
Harmonics-based earth-fault protection [3]	HAEFPTOC		(1) [3 4]	(1) [3 4]	(1) [3 4]	(1) [3 4]
Non-directional (cross-country) earth-fault protection, using calculated Io	EFHPTOC		1		1	1
Negative-sequence overcurrent protection	NSPTOC	2	2	2	2	2
Phase discontinuity protection	PDNSPTOC		1	1	1	1
Residual overvoltage protection	ROVPTOV		3 [1]		3	3 [2]
Three-phase undervoltage protection	PHPTUV				3	3
Three-phase overvoltage protection	PHPTOV				3	3
Positive-sequence undervoltage protection	PSPTUV				1	1
Negative-sequence overvoltage protection	NSPTOV				1	1
Frequency protection	FRPFRQ				4	4
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR		1	1	1	1
Three-phase thermal overload protection, two time constants	T2PTTR		1	1	1	1
Binary signal transfer	BSTGGIO	1	1	1	1	1
Circuit breaker failure protection	CCBRBRF	1	1	1	1	1
Three-phase inrush detector	INRPHAR	1	1	1	1	1
Switch onto fault	CBPSOF	1	1	1	1	1
Master trip	TRPPTRC	2	2	2	2	2
Multipurpose protection	MAPGAPC	18	18	18	18	18
Fault locator	SCEFRFLO				(1)	(1)
Line differential protection with in-zone power transformer	LNPLDF	1	1	1	1	1
High-impedance fault detection	PHIZ	1	1	1	1	
Power quality						
Current total demand distortion	CMHAI				(1)	(1) [6]
Voltage total harmonic distortion	VMHAI				(1) [6]	(1) [6]

Table continues on the next page

1 "Uo measured" is always used.
2 "Uo calculated" is always used.
3 One of the following can be ordered as an option: admittance-based E/F, wattmetric-based E/F or harmonics-based E/F.
4 "Io measured" is always used.
5 "Io calculated" is always used.
6 Power quality option includes current total demand distortion, voltage total harmonic distortion, voltage variation and voltage unbalance.

Function	IEC 61850	A	B	C	D	E
		DE01	DE02	DE03	DE04	DE05
Voltage variation	PHQVVR				(1) [6]	(1) [6]
Voltage unbalance	VSQVUB				(1) [6]	(1) [6]
Control						
Circuit-breaker control	CBXCBR	1	1	1	1	1
Disconnector control	DCXSWI	2	2	2	2	2
Earthing switch control	ESXSWI	1	1	1	1	1
Disconnector position indication	DCSXSWI	3	3	3	3	3
Earthing switch indication	ESSXSWI	2	2	2	2	2
Autoreclosing	DARREC		(1)	(1)	(1)	(1)
Synchronism and energizing check	SECRSYN				1	(1)
Condition monitoring and supervision						
Circuit-breaker condition monitoring	SSCBR		1	1	1	1
Trip circuit supervision	TCSSCBR	2	2	2	2	2
Current circuit supervision	CCSPVC	1	1	1	1	1
Fuse failure supervision	SEQSPVC				1	1
Protection communication supervision	PCSITPC	1	1	1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1	1	1
Measurement						
Disturbance recorder	RDRE	1	1	1	1	1
Load profile record	LDPRLRC	1	1	1	1	1
Fault record	FLTRFRC	1	1	1	1	1
Three-phase current measurement	CMMXU	1	1	1	1	1
Sequence current measurement	CSMSQI	1	1	1	1	1
Residual current measurement	RESCMMXU		1	1	1	1
Three-phase voltage measurement	VMMXU				2	1 (1) [7]
Residual voltage measurement	RESVMMXU		1		1	
Sequence voltage measurement	VSMSQI				1	1
Three-phase power and energy measurement	PEMMXU				1	1
RTD/mA measurement	XRGGIO130				(1)	
Frequency measurement	FMMXU				1	1
IEC 61850-9-2 LE sampled value sending [7]	SMVSENDER				(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) [7] [8]	SMVRCV				(1)	(1)
Other						
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4	4	4
Move (8 pcs)	MVGAPC	2	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4	4	4

Table continues on the next page

[7] Available only with IEC 61850-9-2
[8] Available only with COM0031...0037

Function	IEC 61850	A	B	C	D	E
		DE01	DE02	DE03	DE04	DE05
Integer value move (4 pcs)	MVI4GAPC	1	1	1	1	1
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						

3.1.2 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

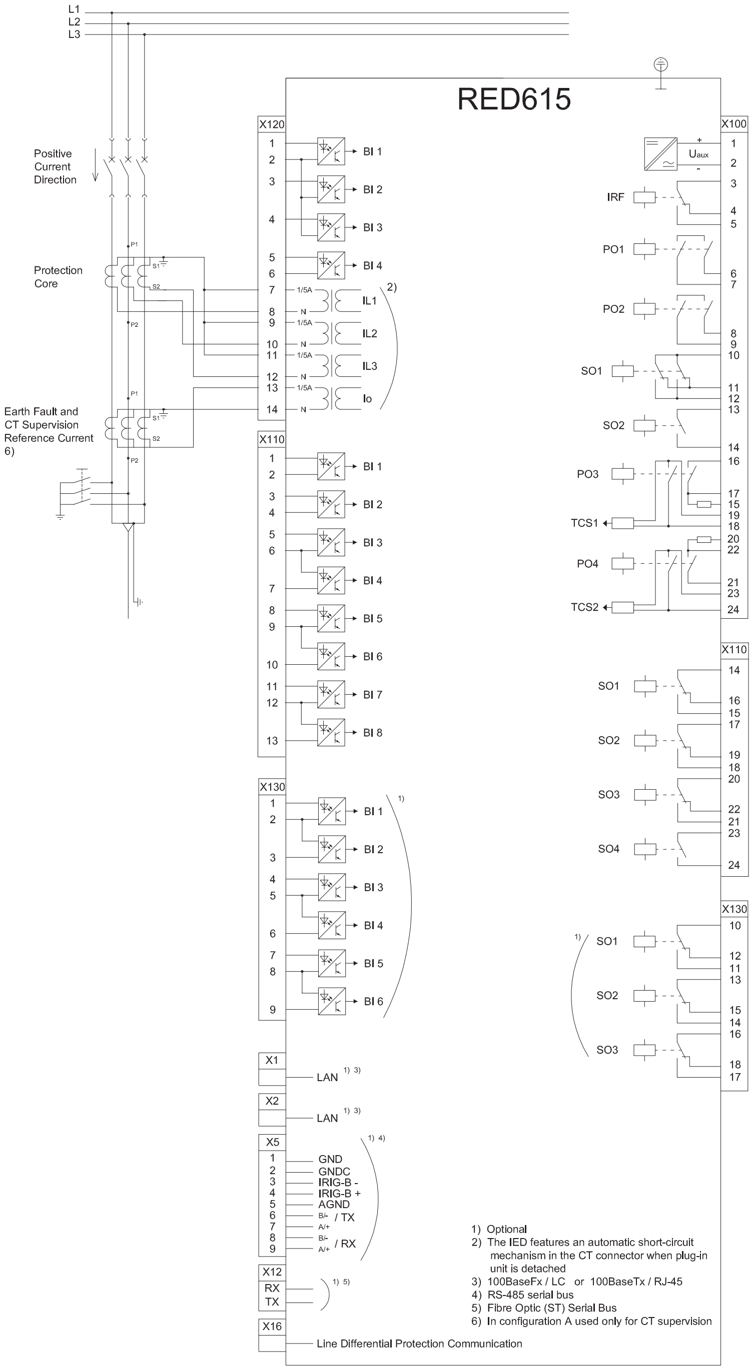


Figure 12: Connection diagram for the A and C configurations

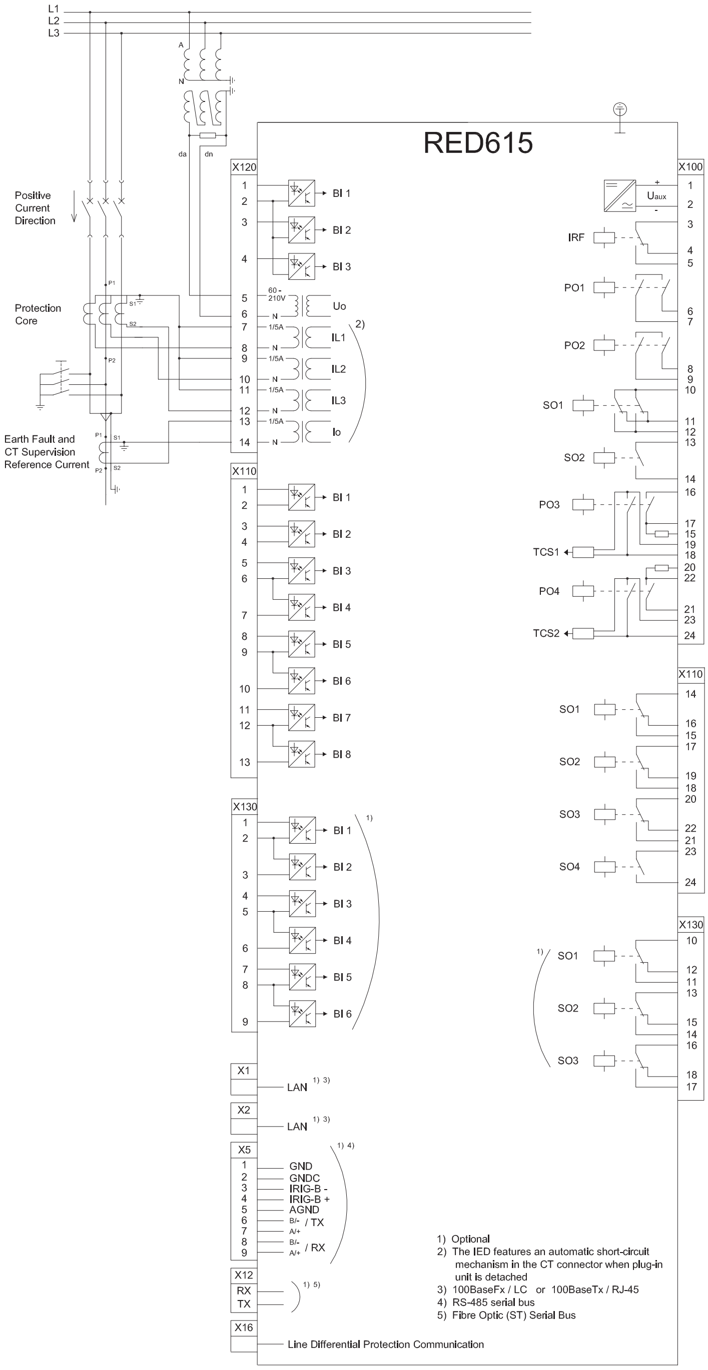


Figure 13: Connection diagram for the B configuration

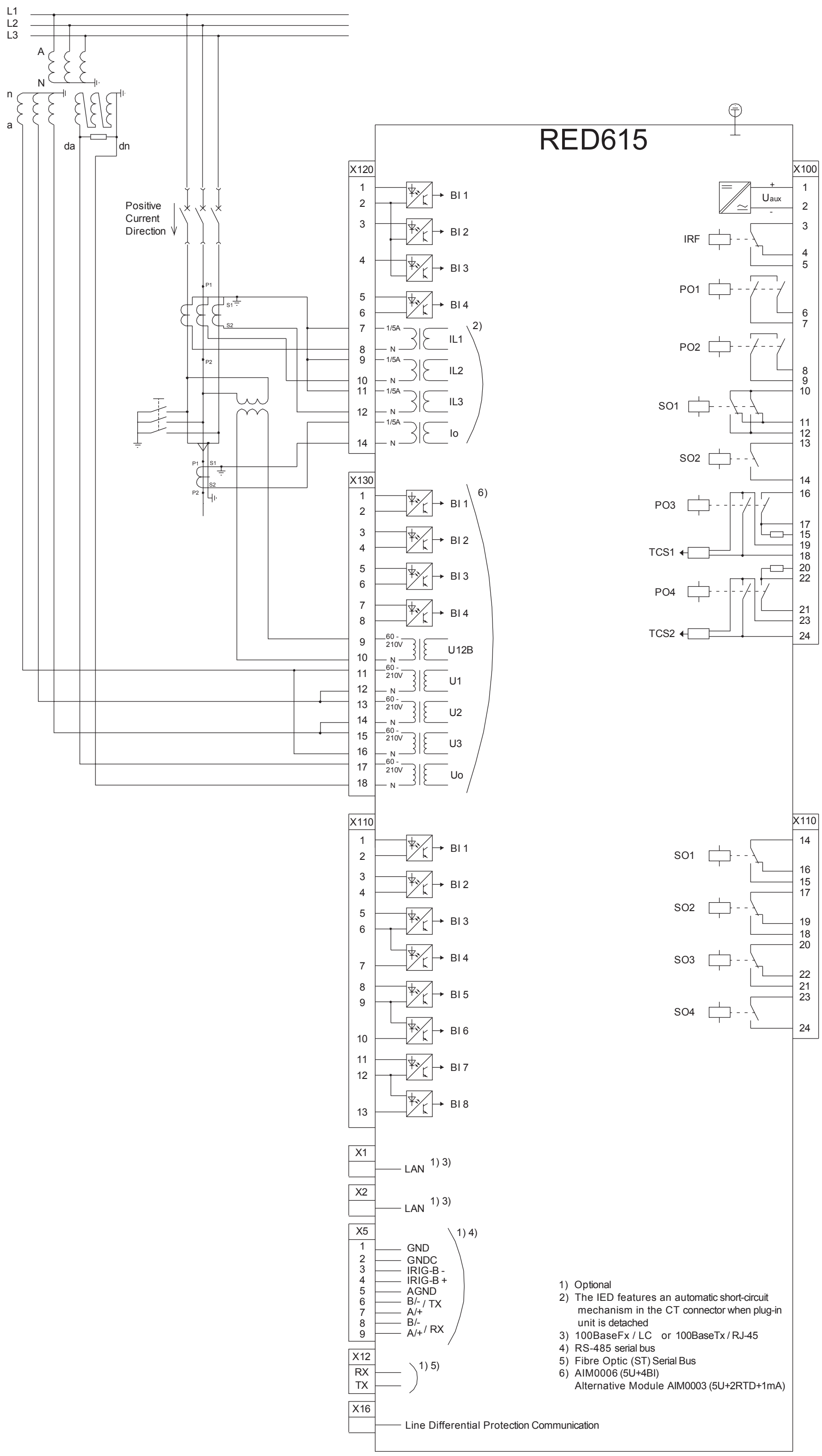


Figure 14: Connection diagram for the D configuration

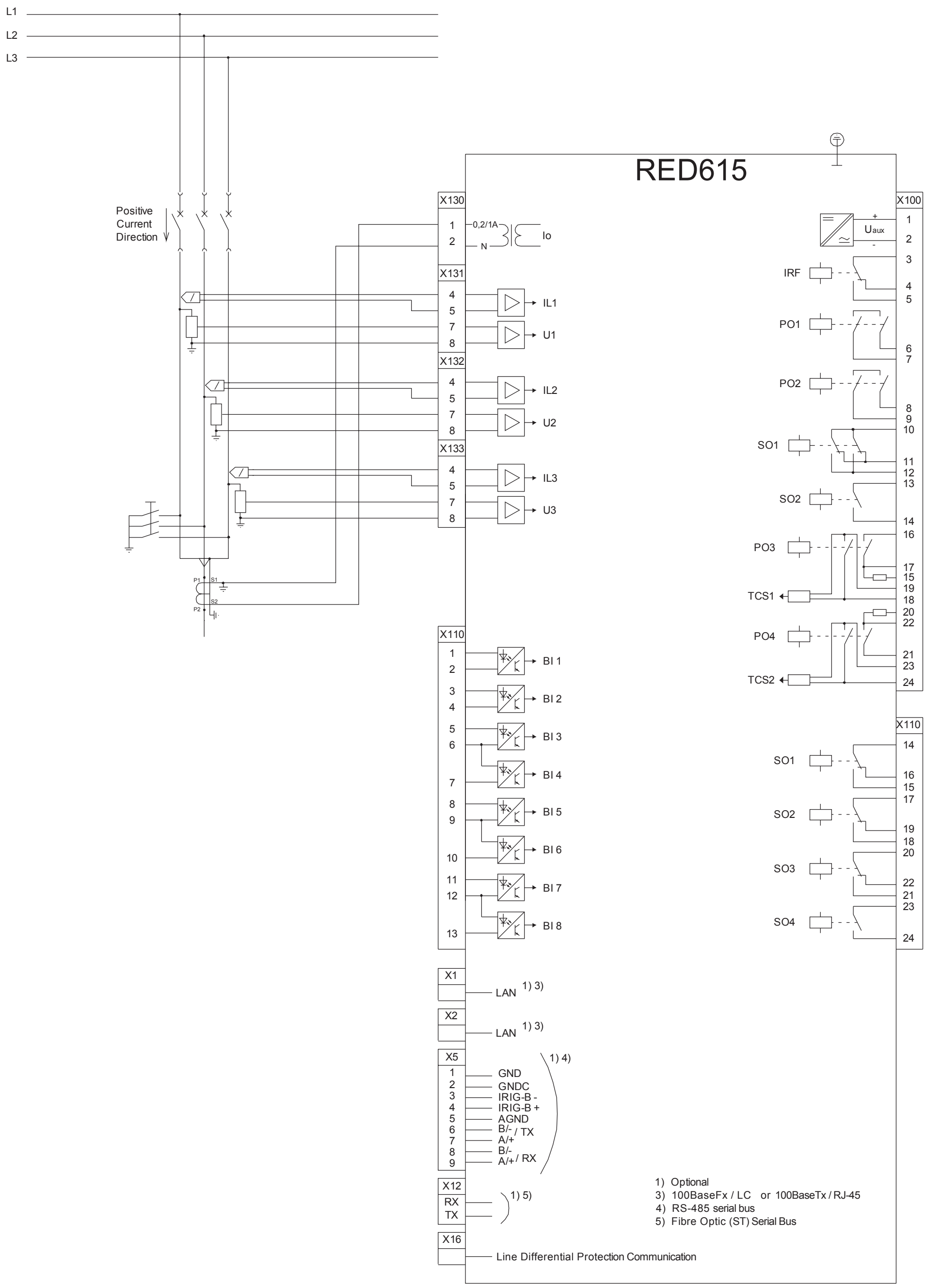


Figure 15: Connection diagram for the E configuration with SIM0002 module

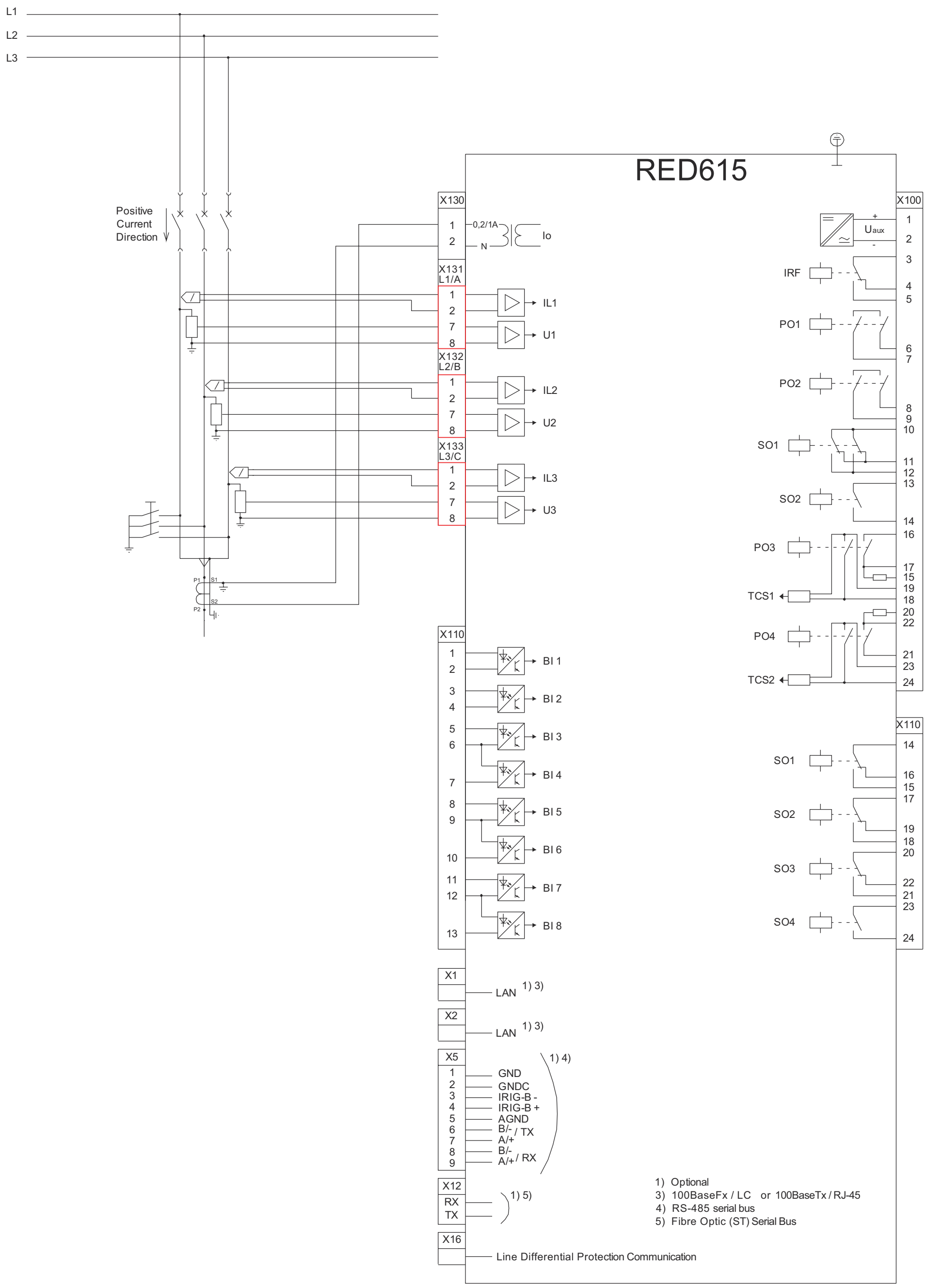


Figure 16: Connection diagram for the E configuration with SIM0005 module

3.3 Standard configuration A

3.3.1 Applications

The standard configuration for line current differential protection is intended for cable feeder applications in the distribution networks. The standard configuration for line current differential protection includes support for in-zone transformers.

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

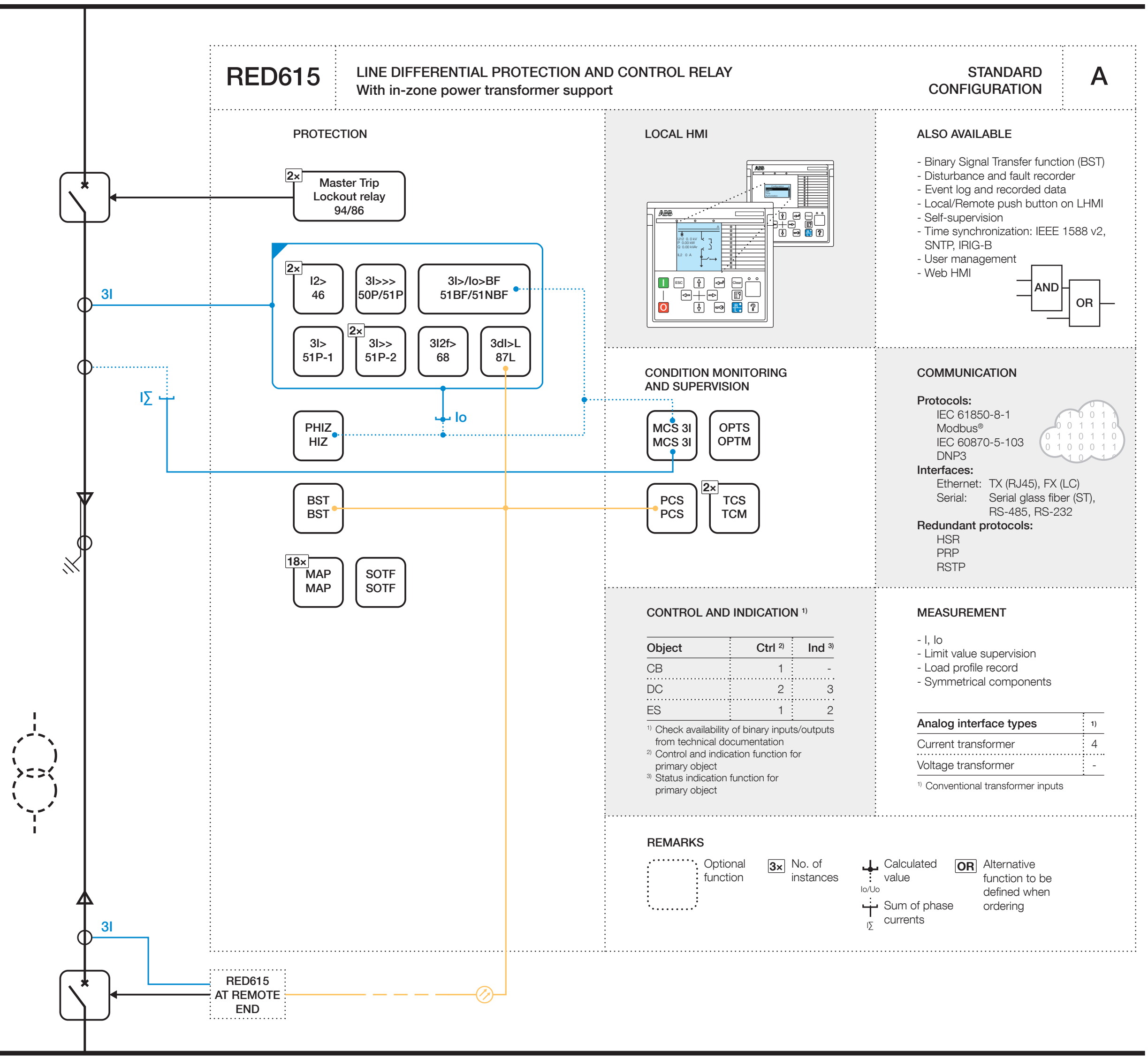


Figure 17: Functionality overview for standard configuration A

3.3.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 11: Default connections for binary inputs

Binary input	Description
X110-BI2	External start of breaker failure protection
X110-BI3	Setting group change
X110-BI4	Binary signal transfer input
X110-BI5	Disconnector open/truck in
X110-BI6	Disconnector open/truck out
X110-BI7	Earth-switch close
X110-BI8	Earth-switch open
X120-BI1	Blocking input for general use
X120-BI2	Circuit breaker close
X120-BI3	Circuit breaker open
X120-BI4	Lockout reset

Table 12: Default connections for binary outputs

Binary input	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Line differential protection trip alarm
X100-SO2	Protection communication failure or differential protection not available
X100-PO3	Open circuit breaker/trip 1
X100-PO4	Open circuit breaker/trip 2
X110- SO1	Upstream overcurrent blocking
X110- SO2	Backup protection operated
X110- SO3	Binary transfer signal

Table 13: Default connections for LEDs

LED	Description
1	Line differential protection biased stage operate
2	Line differential protection instantaneous stage operate
3	Line differential protection is not available
4	Protection communication failure
5	Current transformer failure detected
6	Phase or negative sequence component over current
7	Breaker failure operate

Table continues on the next page

LED	Description
8	Disturbance recorder triggered
9	Trip circuit supervision alarm
10	Binary signal transfer receive
11	Binary signal transfer send

3.3.2.2 Default disturbance recorder settings

Table 14: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	–
6	–
7	–
8	–
9	–
10	–
11	–
12	–

Table 15: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - start	Positive or Rising
2	LNPLDF1 - operate	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	PHHPTOC1 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC1 - start	Positive or Rising
7	NSPTOC1 - start	Positive or Rising
8	NSPTOC2 - start	Positive or Rising
9	CCBRBRF1 - trret	Level trigger off
10	CCBRBRF1 - trbu	Level trigger off
11	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
12	NSPTOC1 - operate	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
	NSPTOC2 - operate	
13	INRPHAR1 - blk2h	Level trigger off
14	PCSITPC1 - alarm	Level trigger off
15	LNPLDF1 - rstd2h	Level trigger off
16	LNPLDF1 - prot not active	Level trigger off
28	X110BI4 - binary transfer	Level trigger off
29	X110BI2 - ext ccbrbrf start	Level trigger off
30	X120BI3 - CB opened	Level trigger off
31	X120BI2 - CB closed	Level trigger off
32	X120BI1 - ext OC blocking	Level trigger off

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 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 or via binary input.

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 IED's protection functionality in detail and according to the factory set default connections.

The line differential protection with in-zone power transformer LNPLDF1 is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by predefined settings, if `ENA_MULT_HS` input is activated. In this configuration, it is activated by the open status information of the remote-end circuit breaker and earth-switch, and if the disconnector is not in the intermediate position. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with the 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.

Four non-directional overcurrent stages are offered for overcurrent and short-circuit protection. Three-phase non-directional overcurrent protection PHIPTOC1 can be blocked by energizing the binary input X120:BI1. The instantaneous and first high stage are blocked by activation of line differential protection.

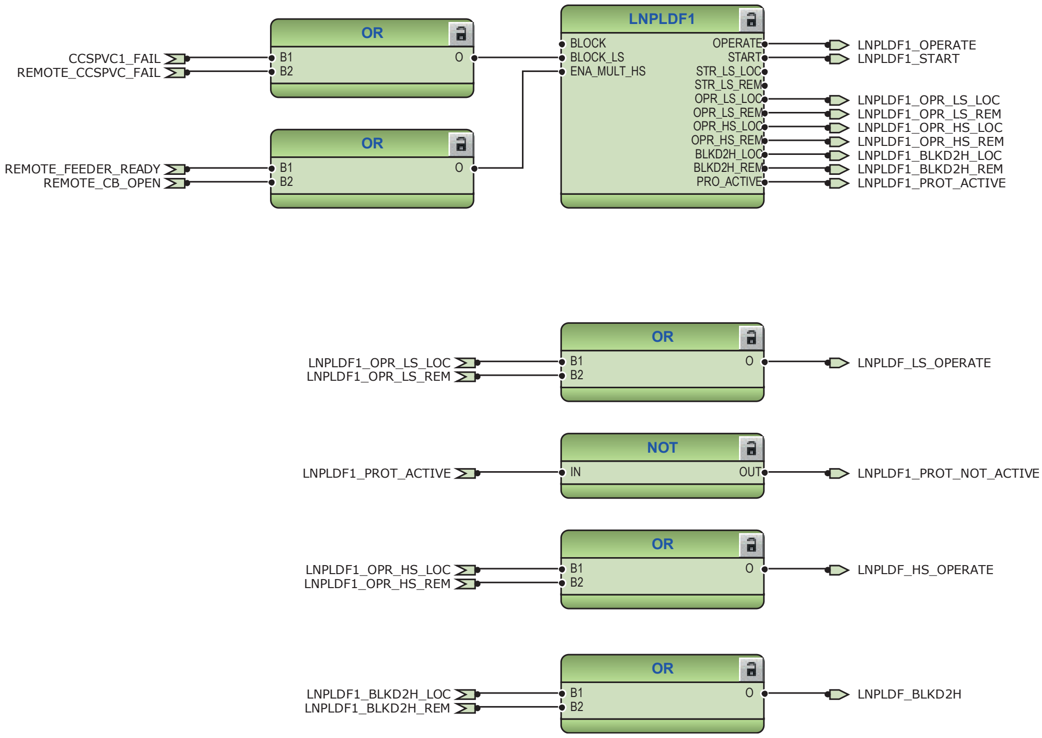


Figure 18: Line differential protection functions

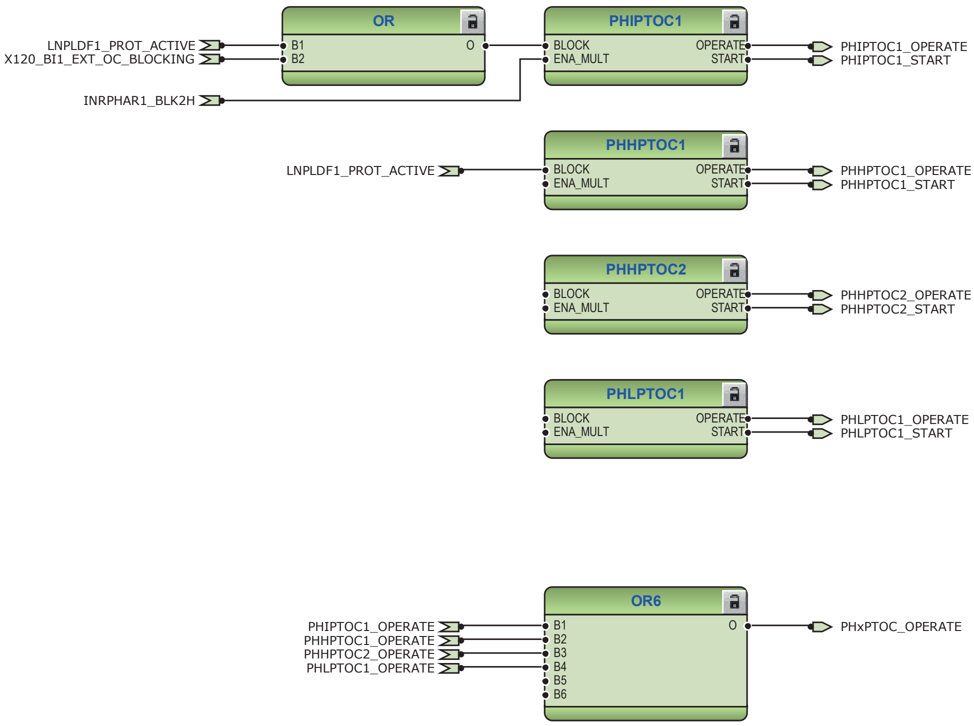


Figure 19: Overcurrent protection functions

The upstream blocking both from the start of the instantaneous and 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 IED at the upstream bay.

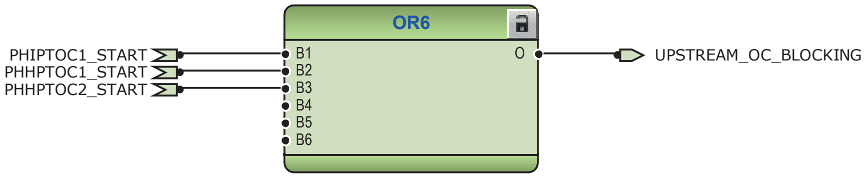


Figure 20: Upstream blocking logic

The output BLK2H of the three-phase inrush detector INRPHAR1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

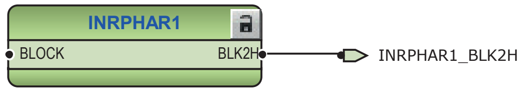
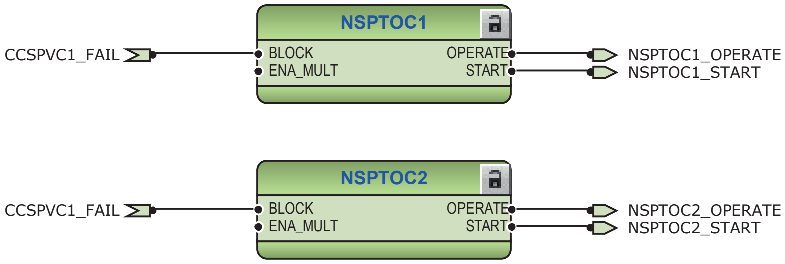


Figure 21: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. Both the negative-sequence overcurrent protection functions are blocked in case of detection in failure in secondary circuit of current transformer.



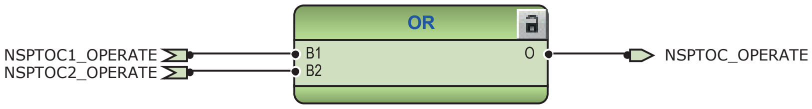


Figure 22: Negative-sequence overcurrent protection

The overcurrent protection and negative-sequence overcurrent protection are used as backup protection against line differential protection.

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

The circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. 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 operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

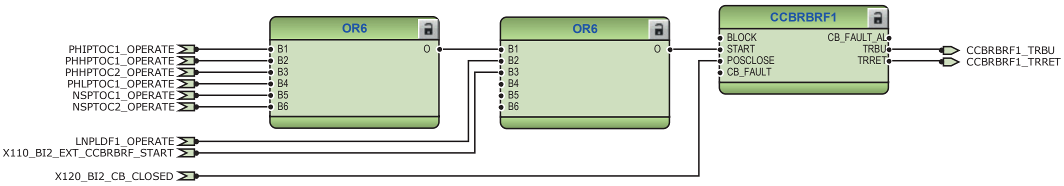


Figure 23: Circuit breaker failure protection function

The operate signals from the protection functions are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. 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 X120:BI4 can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

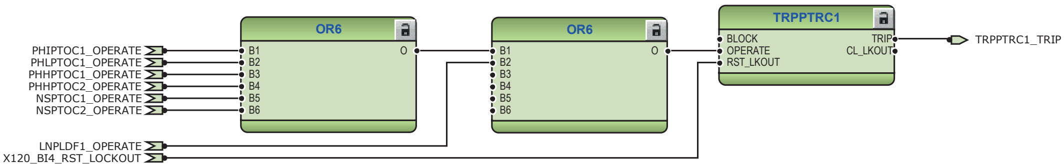


Figure 24: Trip logic TRPPTRC1

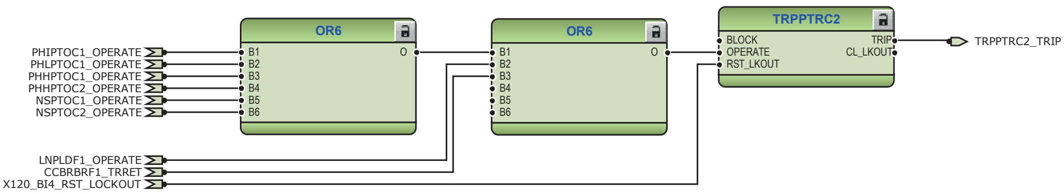


Figure 25: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE 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.

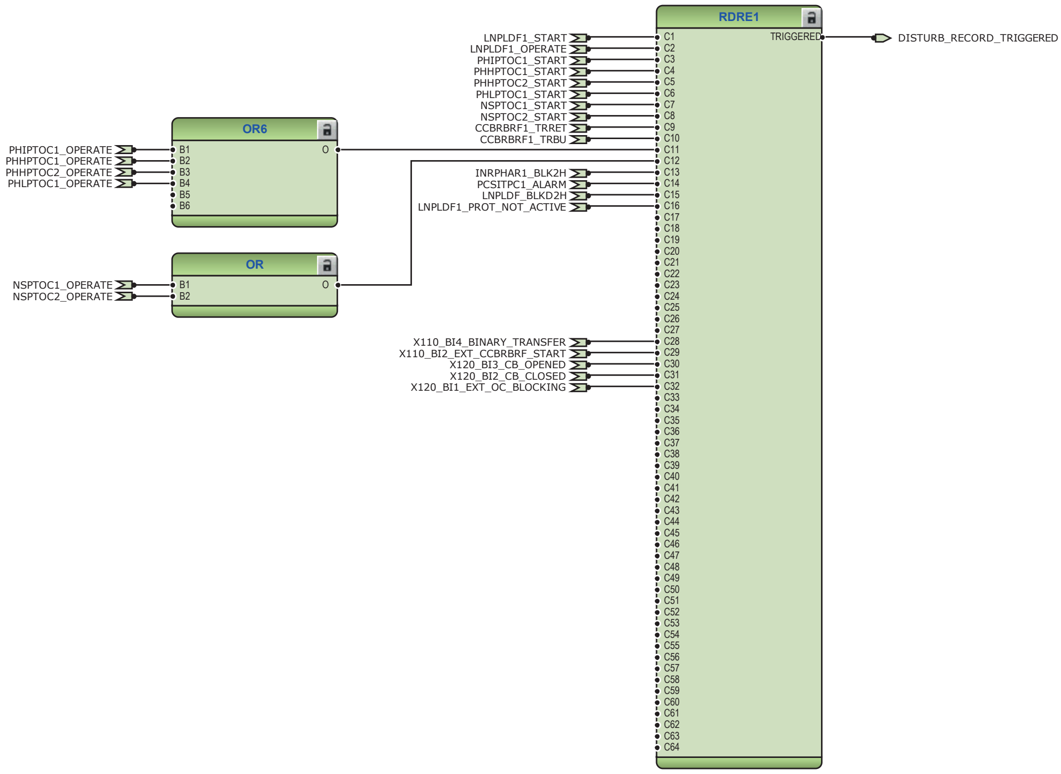


Figure 26: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measure the calculated sequence component currents or residual current to avoid unnecessary operation.

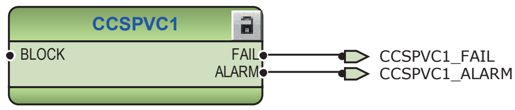


Figure 27: Current circuit supervision function

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. Both functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 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 TCSSCBR1 properly.

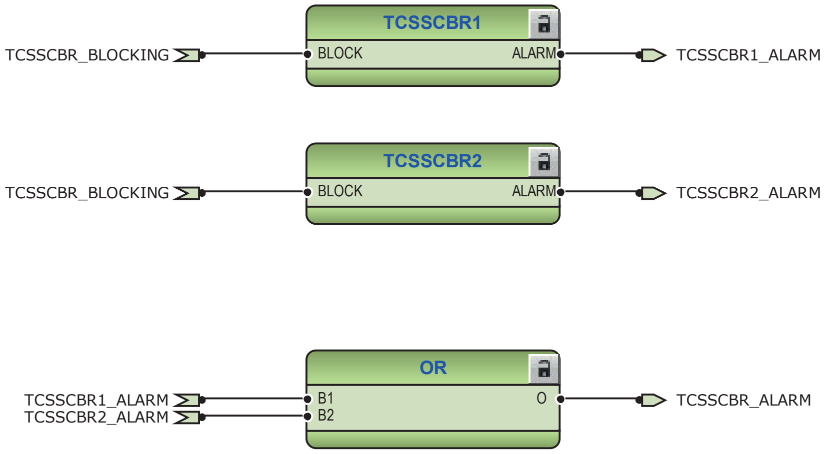


Figure 28: Trip circuit supervision function

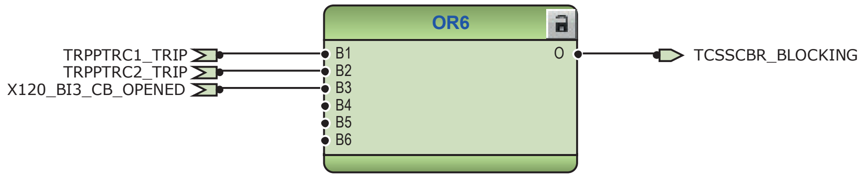


Figure 29: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC1 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 protection communication failure is also blocked. These are done internally without connections in the configurations. The protection communication supervision alarm is connected to alarm LED 4, disturbance recorder and binary output X100:SO2.

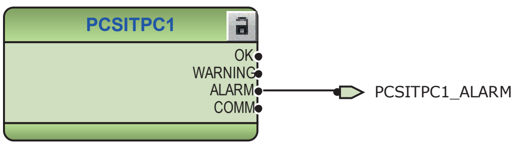


Figure 30: Protection communication supervision

Binary signal transfer BSTGGIO1 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:BI4 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. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

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

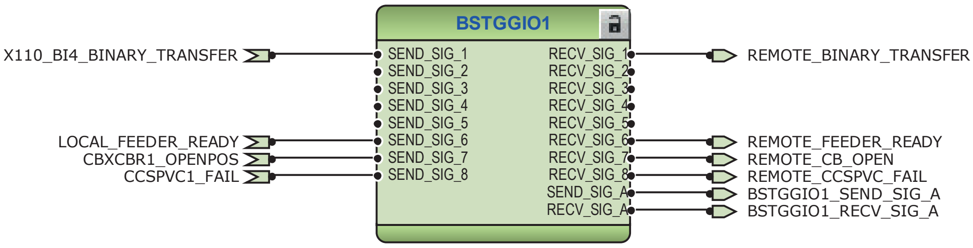


Figure 31: Binary signal transfer

3.3.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in the standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

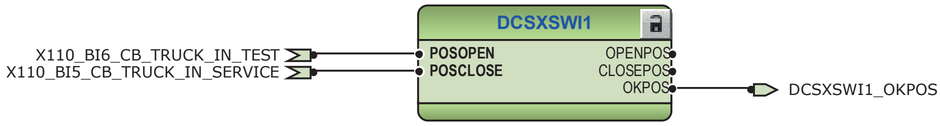


Figure 32: Disconnector 1 control logic

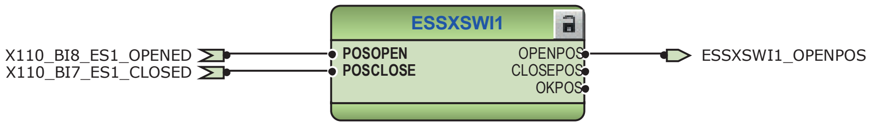


Figure 33: Earth-switch 1 control logic

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 earth-switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and earth-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 output, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for the circuit breaker is always enabled.

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

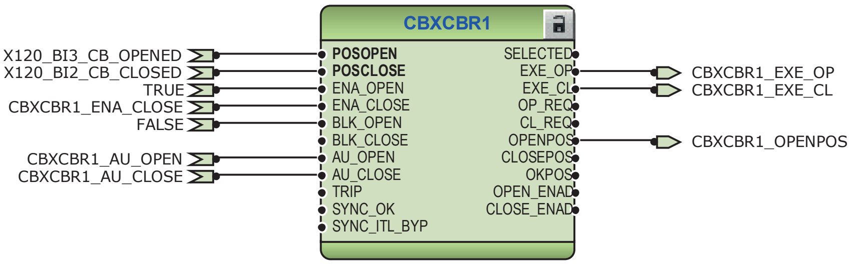


Figure 34: Circuit breaker 1 control logic

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

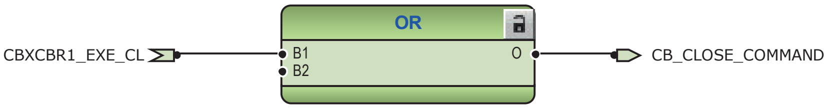


Figure 35: Signals for closing coil of circuit breaker 1

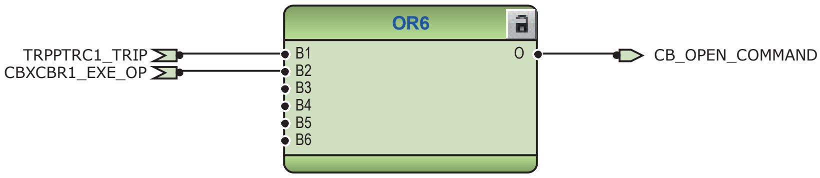


Figure 36: Signals for opening coil of circuit breaker 1

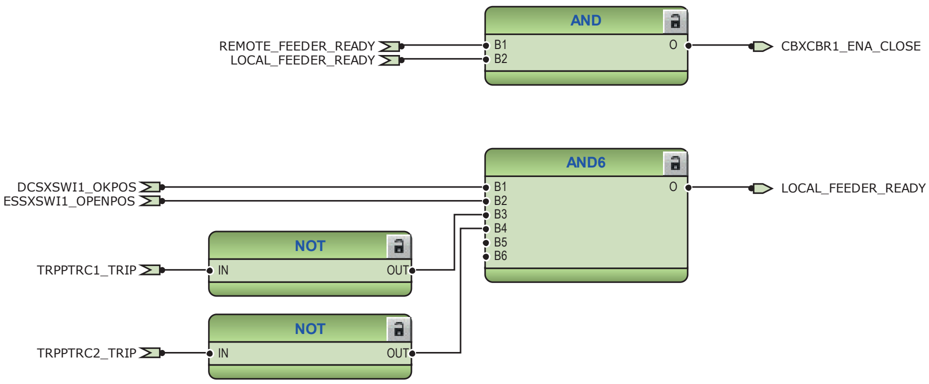


Figure 37: Circuit breaker 1 close enable logic

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

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

Connect the additional signals for closing and opening of the circuit breaker in local or remote mode, if applicable for the application.

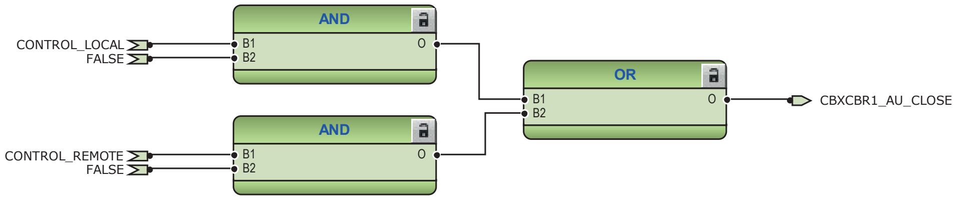


Figure 38: External closing command for circuit breaker 1

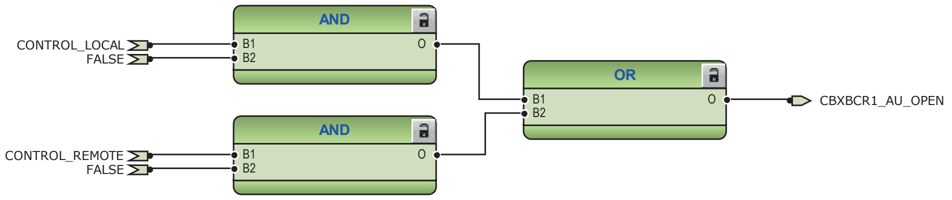


Figure 39: External opening command for circuit breaker 1

3.3.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current.

The measurements can be seen in the LHMI and they are available by using 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 load profile record function LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

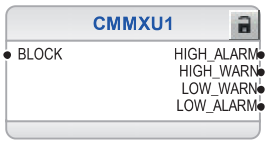


Figure 40: Current measurement: Three-phase current measurement

Figure 41: Current measurement: Sequence current measurement

Figure 42: Other measurement: Data monitoring

Figure 43: Other measurement: Load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

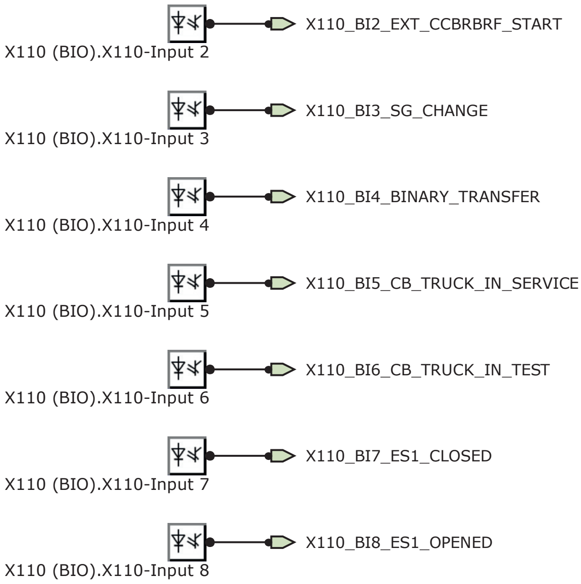


Figure 44: Binary inputs - X110 terminal block

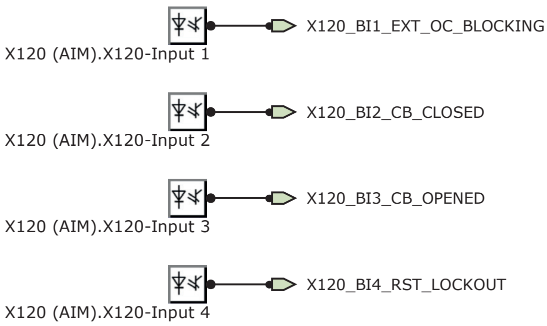


Figure 45: Binary inputs - X120 terminal block

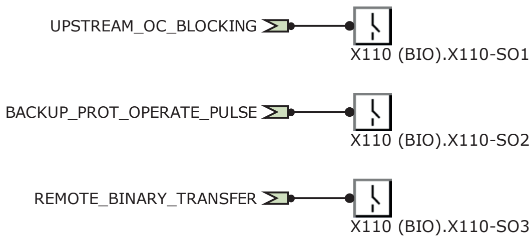


Figure 46: Binary outputs - X110 terminal block

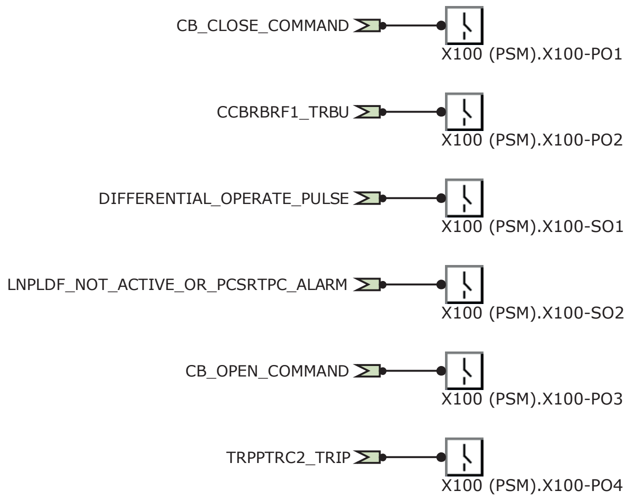
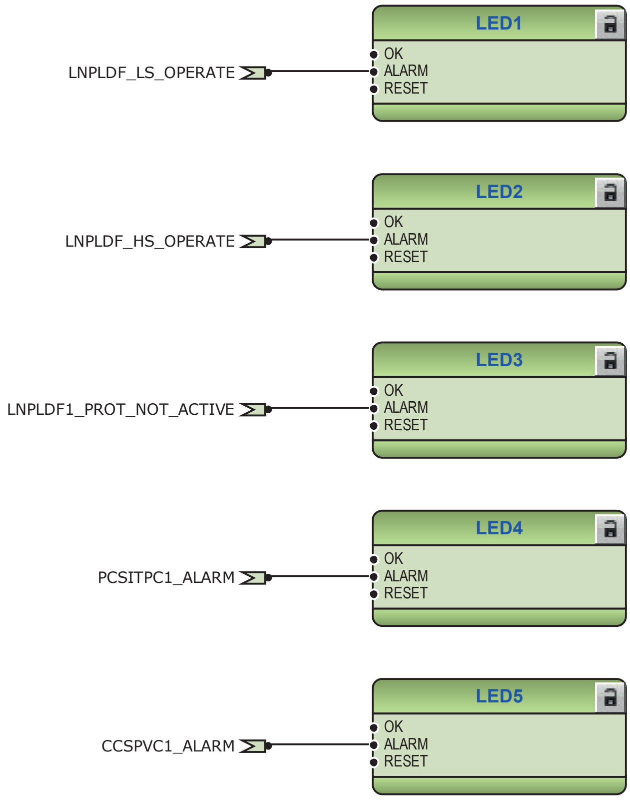


Figure 47: Binary outputs - X100 terminal block



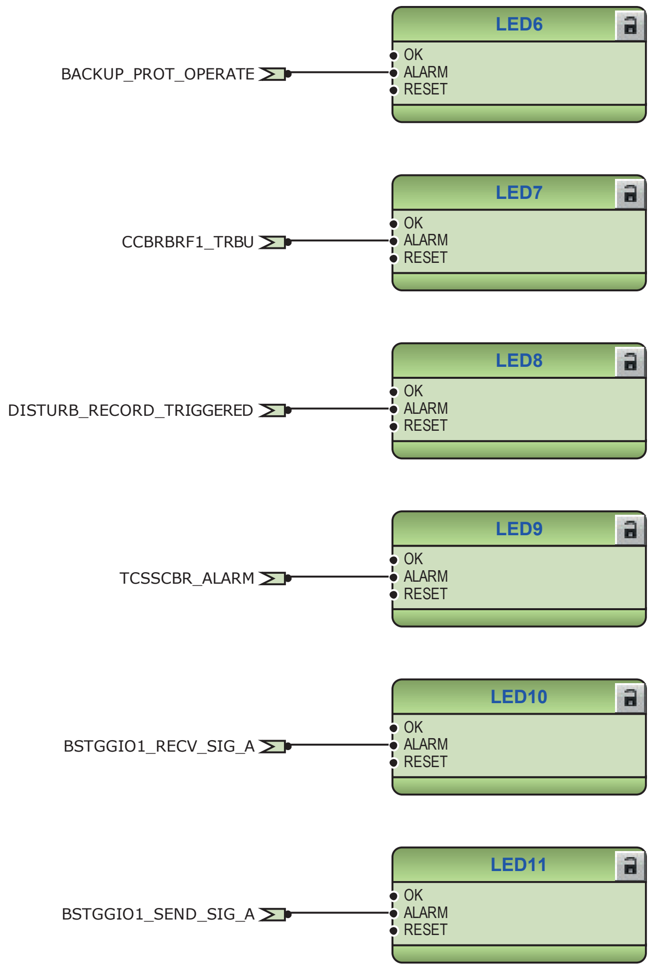


Figure 48: Default LED connection

3.3.3.7 Functional diagrams for other timer logics

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

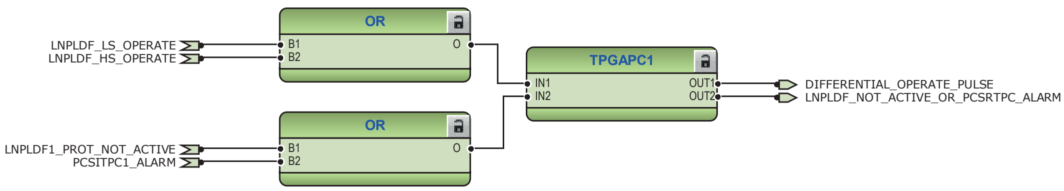


Figure 49: Timer logic for differential operate and communication not active

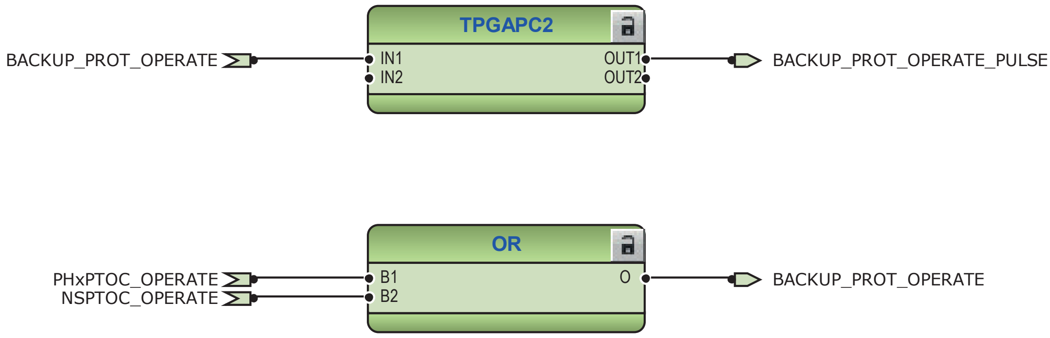


Figure 50: Timer logic for backup protection operate pulse

3.3.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, high impedance fault detection PHIZ, runtime counter for machines and devices MDSOPT and few instances of different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.4 Standard configuration B

3.4.1 Applications

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

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

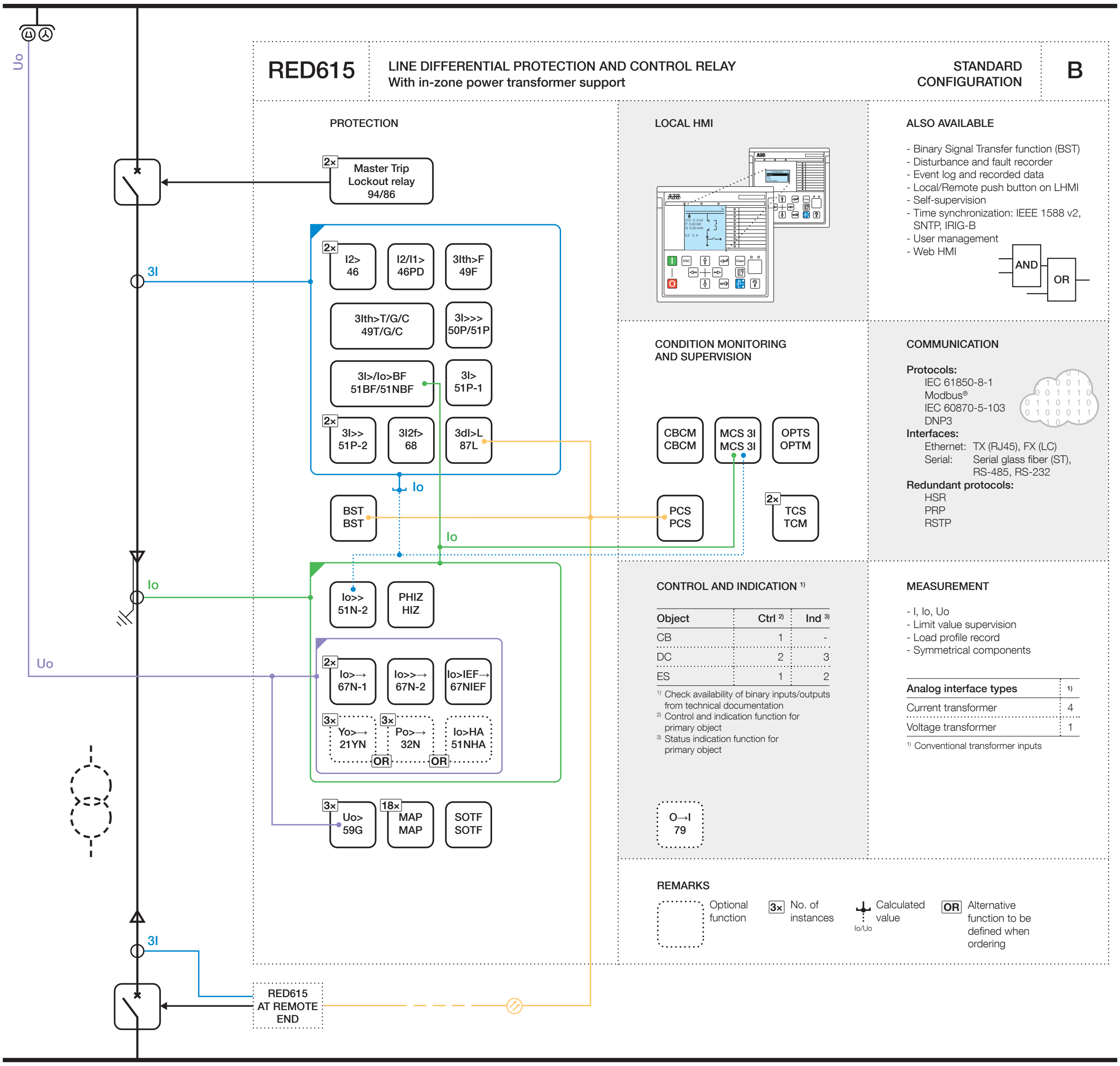


Figure 51: Functionality overview for standard configuration B

3.4.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 16: Default connections for binary inputs

Binary input	Description
X110-BI1	Lockout reset
X110-BI2	Binary signal transfer input
X110-BI3	Circuit breaker low gas pressure alarm
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (service position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking input for general use
X120-BI2	Circuit breaker close
X120-BI3	Circuit breaker open

Table 17: Default connections for binary outputs

Binary input	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Line differential protection trip alarm
X100-SO2	Protection communication failure or differential protection not available
X100-PO3	Open circuit breaker/trip 1
X100-PO4	Open circuit breaker/trip 2
X110- SO1	Upstream overcurrent blocking
X110- SO2	Backup protection operated
X110- SO3	Binary transfer signal

Table 18: Default connections for LEDs

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

Table continues on the next page

LED	Description
10	Binary signal transfer receive
11	Binary signal transfer send

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	Uo
6	–
7	–
8	–
9	–
10	–
11	–
12	–

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - start	Positive or Rising
2	LNPLDF1 - operate	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	PHHPTOC1 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC1 - start	Positive or Rising
7	T1PTTR1 - start	Positive or Rising
8	T2PTTR1 - start	Positive or Rising
9	PDNSPTOC1 - start	Positive or Rising
10	NSPTOC1 - start	Positive or Rising
11	NSPTOC2 - start	Positive or Rising
12	EFHPTOC1 - start	Positive or Rising
13	DEFLPDEF1 - start	Positive or Rising
	WPWDE1 - start	
	EFPADM1 - start	
14	DEFLPDEF2 - start	Positive or Rising
	WPWDE2 - start	

Table continues on the next page

Channel	ID text	Level trigger mode
	EFPADM2 - start	
15	DEFLPDEF3 - start	Positive or Rising
	WPWDE3 - start	
	EFPADM3 - start	
16	ROVPTOV1 - start	Positive or Rising
17	ROVPTOV2 - start	Positive or Rising
18	ROVPTOV3 - start	Positive or Rising
19	INTRPTEF1 - start	Positive or Rising
20	CCBRBRF1 - trret	Level trigger off
21	CCBRBRF1 - trbu	Level trigger off
22	LNPLDF1 - rstd2h	Level trigger off
23	LNPLDF1 - prot not active	Level trigger off
24	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
25	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
26	DEFLPDEF1 - operate	Level trigger off
	WPWDE1 - operate	
	EFPADM1 - operate	
	DEFLPDEF2 - operate	
	WPWDE2 - operate	
	EFPADM2 - operate	
	DEFLPDEF3 - operate	
	WPWDE3 - operate	
	EFPADM3 - operate	
27	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
28	PDNSPTOC1 - operate	Level trigger off
29	T1PTTR1 - operate	Level trigger off
	T2PTTR2 - operate	
30	T1PTTR1 - alarm	Level trigger off
31	T2PTTR2 - alarm	Level trigger off
32	INRPHAR1 - blk2h	Level trigger off
33	PCSITPC1 - alarm	Level trigger off
34	CCSPVC1 - alarm	Level trigger off
35	X110BI4 - CB spring charged	Level trigger off
36	X110BI3 - gas pressure alarm	Level trigger off
37	X120BI3 - CB opened	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
38	X120BI2 - CB closed	Level trigger off
39	X120BI1 - ext OC blocking	Level trigger off
40	DARREC1 - unsuc recl	Level trigger off
	DARREC1 - close CB	
41	DARREC1 - inpro	Level trigger off

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 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 residual voltage to the protection relay is fed from either residually connected VTs or an open delta connected VT.

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 or via binary input.

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 IED's protection functionality in detail and according to the factory set default connections.

Line differential protection with in-zone power transformer LNPLDF1 is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by predefined settings if the `ENA_MULT_HS` input is activated. In this configuration, the input is activated by the open status information of the remote-end circuit breaker and earth-switch, and if the disconnector is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult*, in case of internal fault.

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.

Four non-directional overcurrent stages are offered for overcurrent and short-circuit protection. The three-phase non-directional overcurrent protection, instantaneous stage PHIPTOC1 can be blocked by energizing the binary input

X120: BI1. The instantaneous and first high stage are blocked by activation of line differential protection.

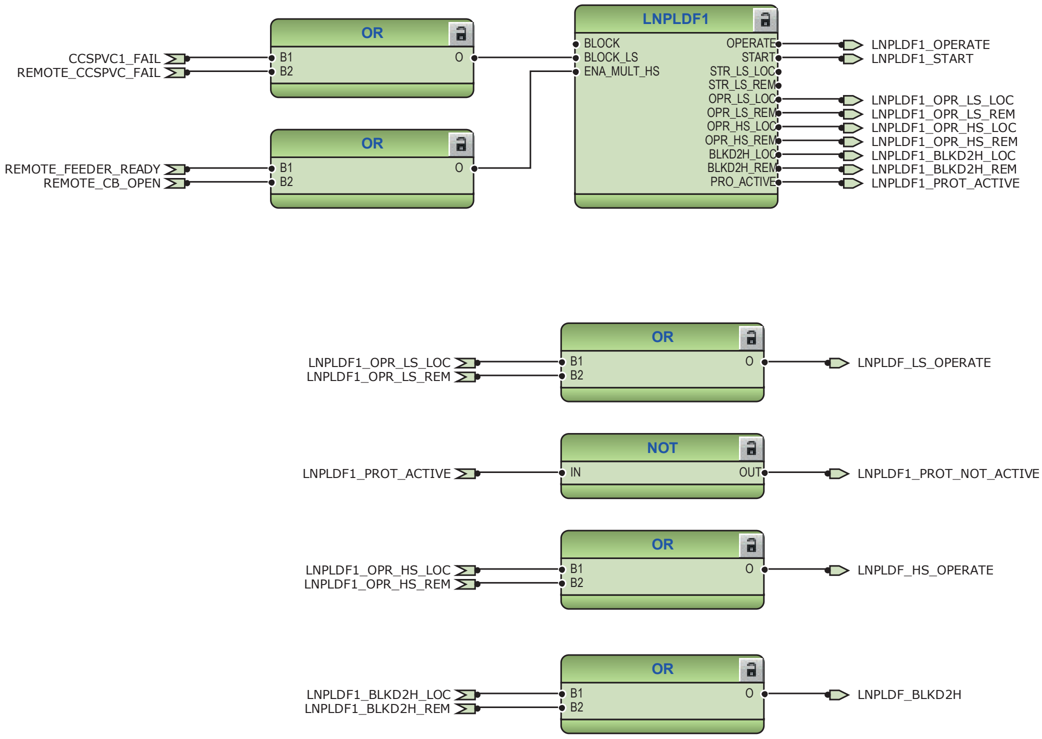


Figure 52: Line differential protection functions

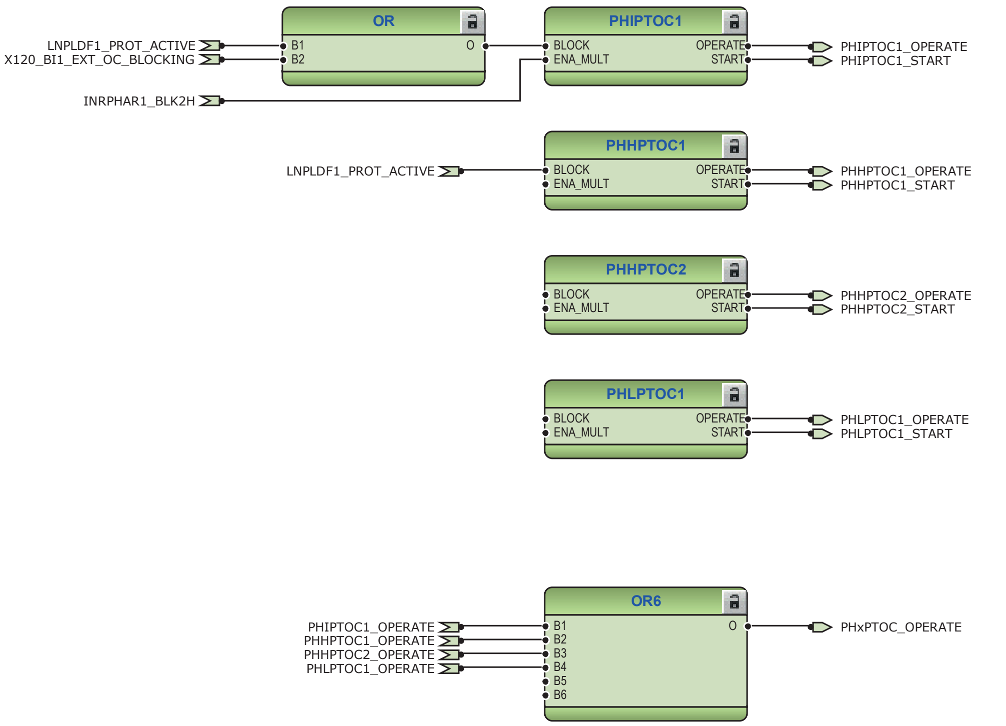


Figure 53: Overcurrent protection functions

The upstream blocking both from the start 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 IED at the upstream bay.

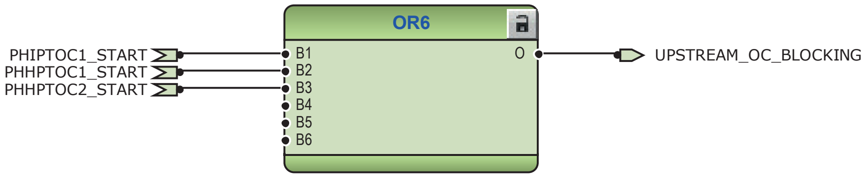


Figure 54: Upstream blocking logic

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

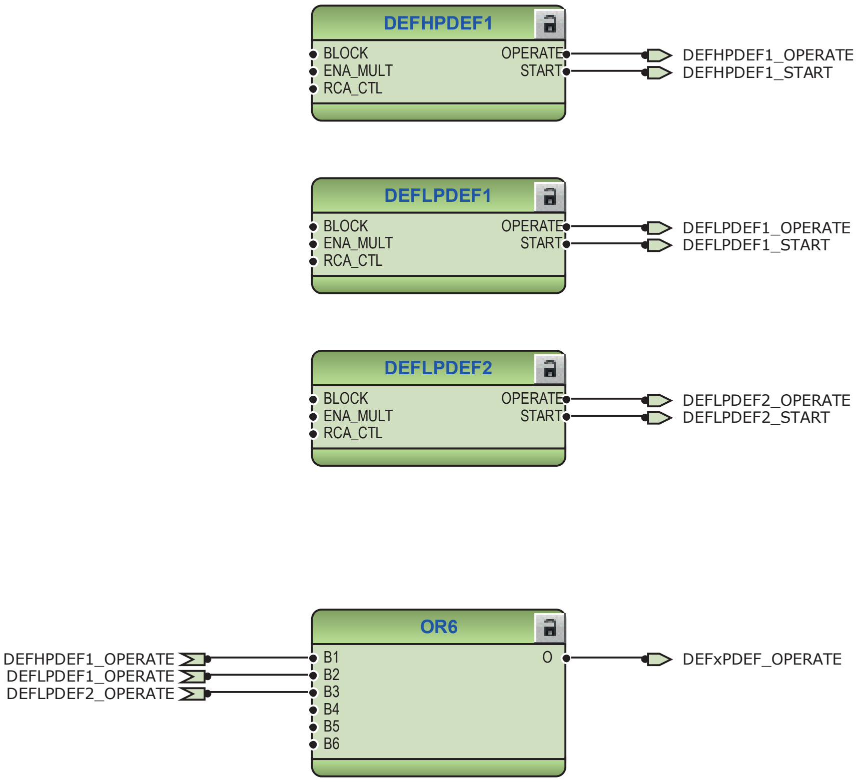


Figure 55: Directional earth-fault protection

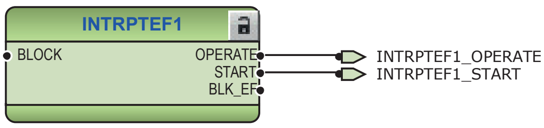


Figure 56: Transient or intermittent earth-fault protection function

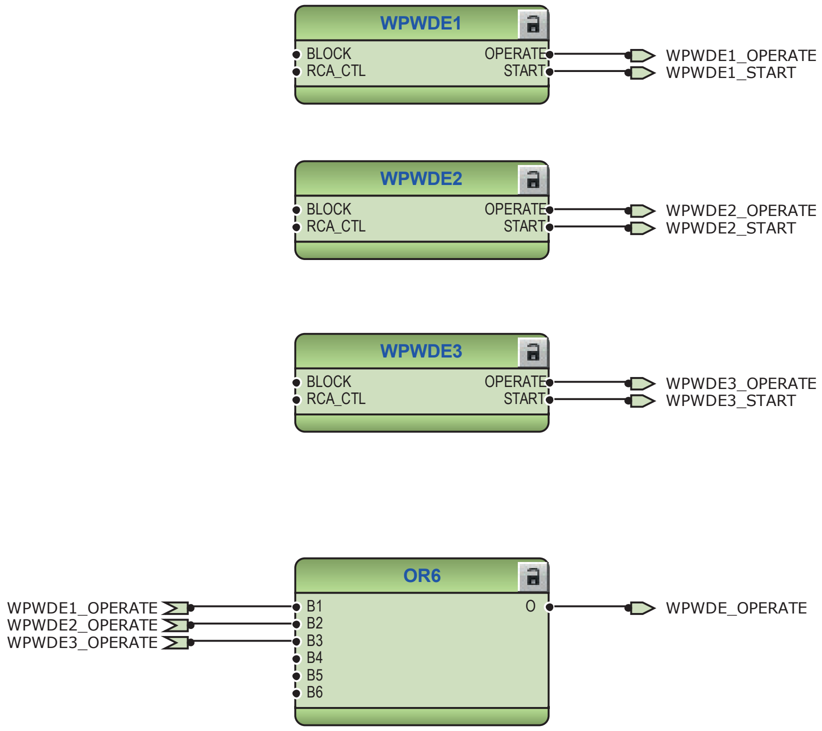


Figure 57: Wattmetric protection

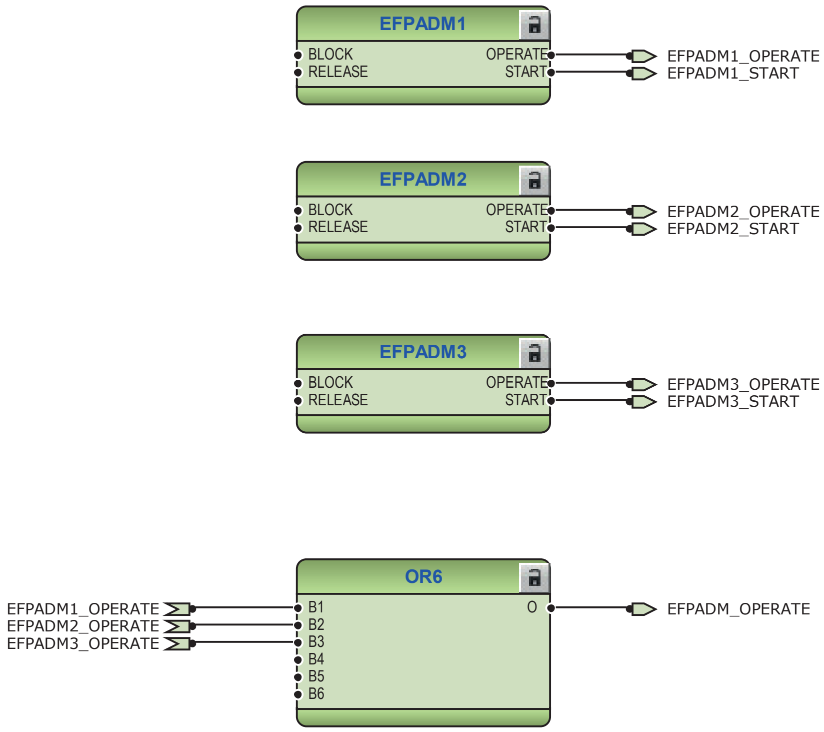


Figure 58: Admittance-based earth-fault protection function

Non-directional earth-fault protection EFHPTOC protects against double earth-fault situations in isolated or compensated networks.

Figure 59: Cross-country earth-fault protection

The output BLK2H of three-phase inrush detector INRPHAR1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

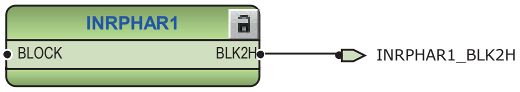


Figure 60: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. The negative-sequence overcurrent protection functions are blocked in case of detection in failure in secondary circuit of current transformer.

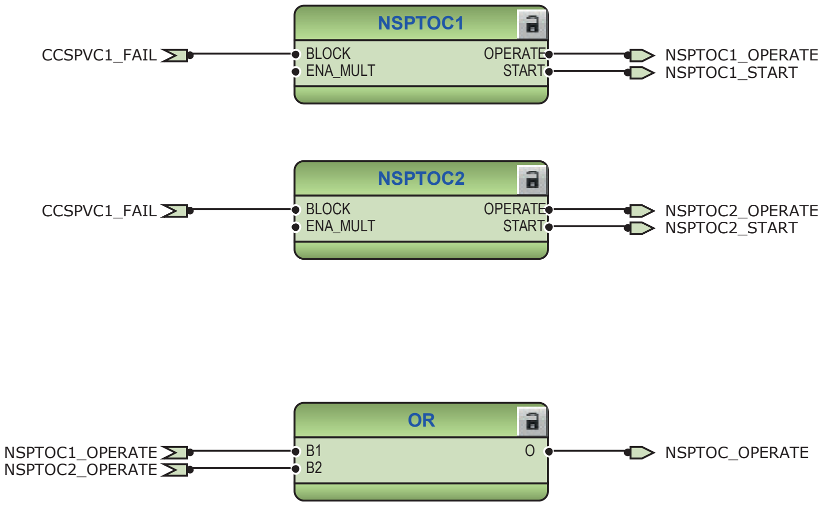


Figure 61: Negative sequence overcurrent protection function

The phase discontinuity protection PDNSPTOC1 protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The function is blocked in case of detection in failure in secondary circuit of current transformer.

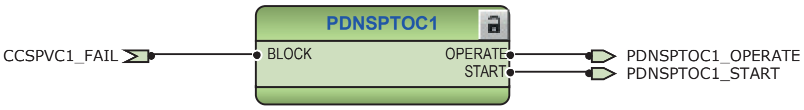


Figure 62: Phase discontinuity protection

Two three-phase thermal protection functions are incorporated, one with one time constant T1PTTR1 and other with two time constants T2PTTR1 for detecting overloads under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

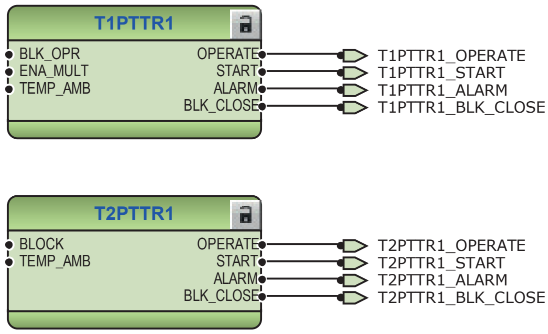


Figure 63: Thermal overcurrent protection function

The residual overvoltage protection ROVPTOV provides earth-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 earth-fault functionality.

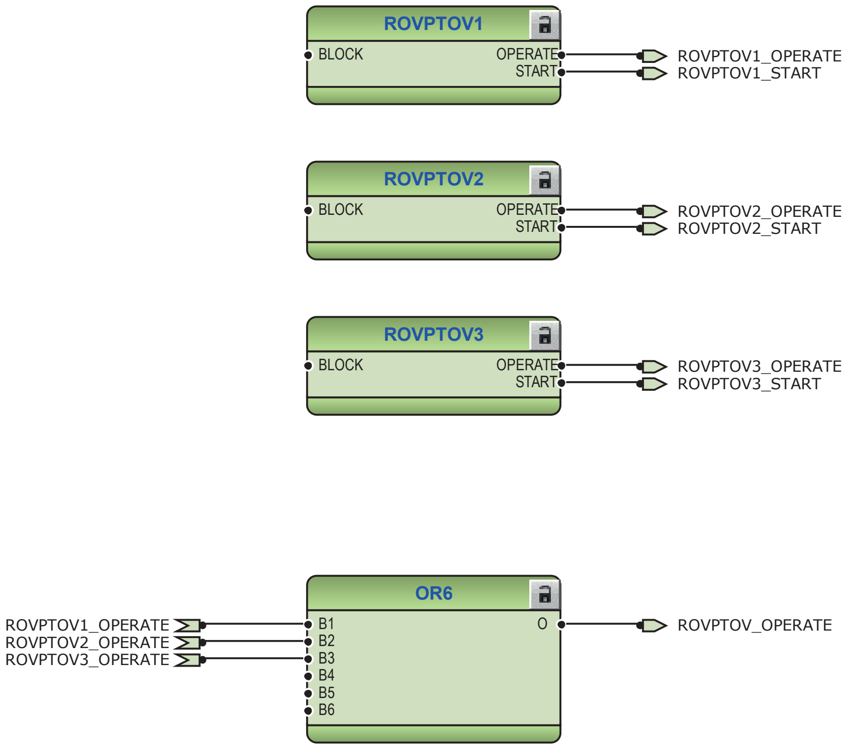


Figure 64: Residual voltage protection function

It should be noted that overcurrent protection, negative sequence overcurrent protection, phase discontinuity, earth-fault protection and residual overvoltage protections are all used as backup protection against line differential protection. The backup protection operated 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 operate signals from a number of protection stages through the `INIT_1...5` inputs. It is possible to create individual autoreclose 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-SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the CB_READY input in DARREC1. 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.

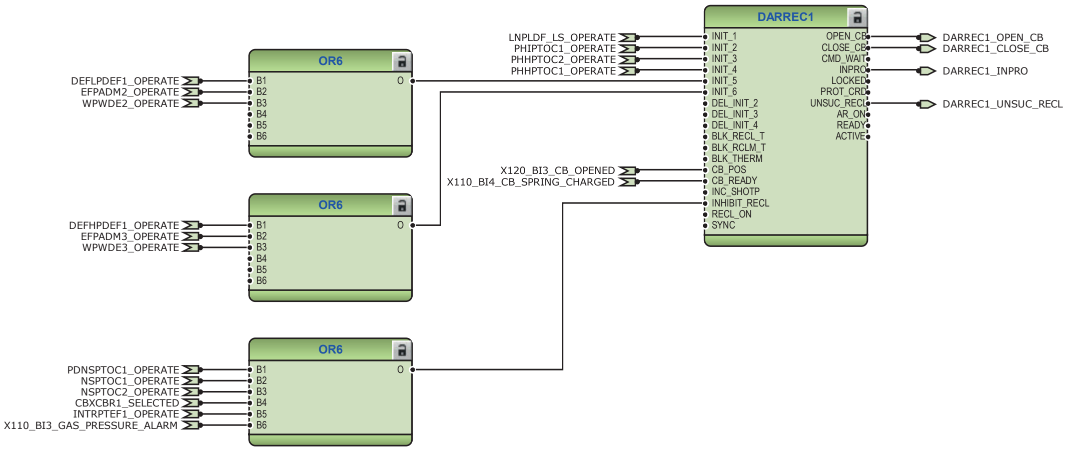


Figure 65: Autoreclosing function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by a number of different protection functions available in the IED. 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 operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

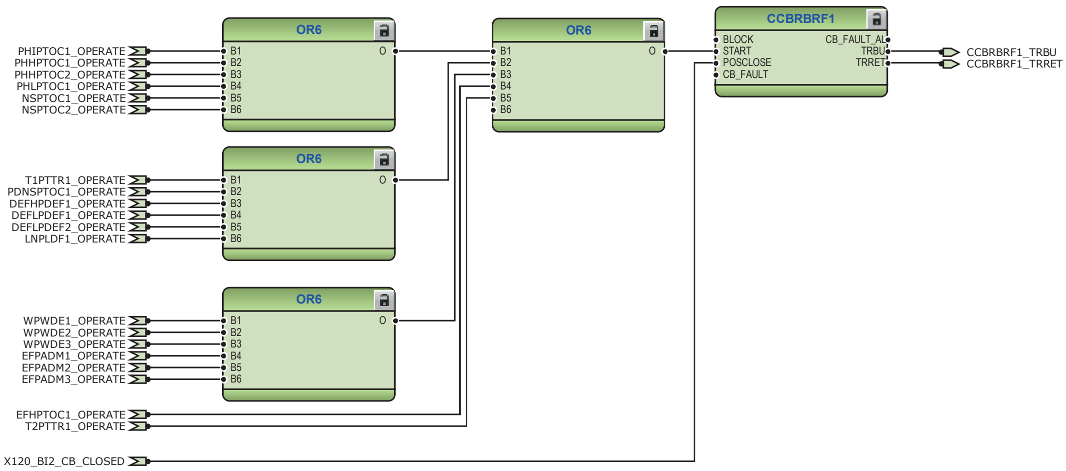


Figure 66: Circuit breaker failure protection function

The operate signals from the protection functions are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output 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.

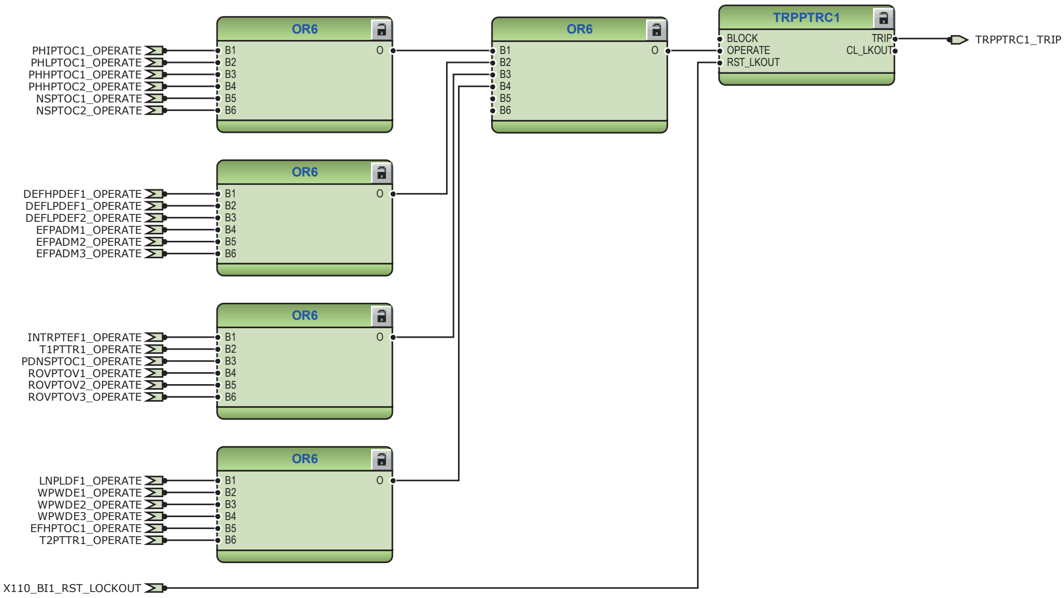


Figure 67: Trip logic TRPPTRC1

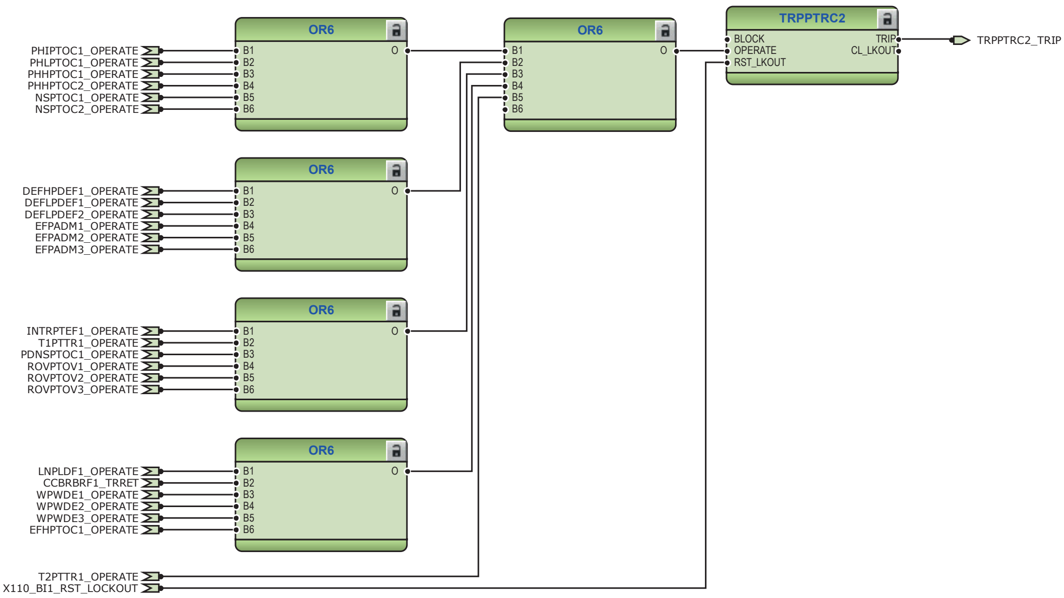


Figure 68: Trip logic TRPPTRC2

3.4.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE 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.

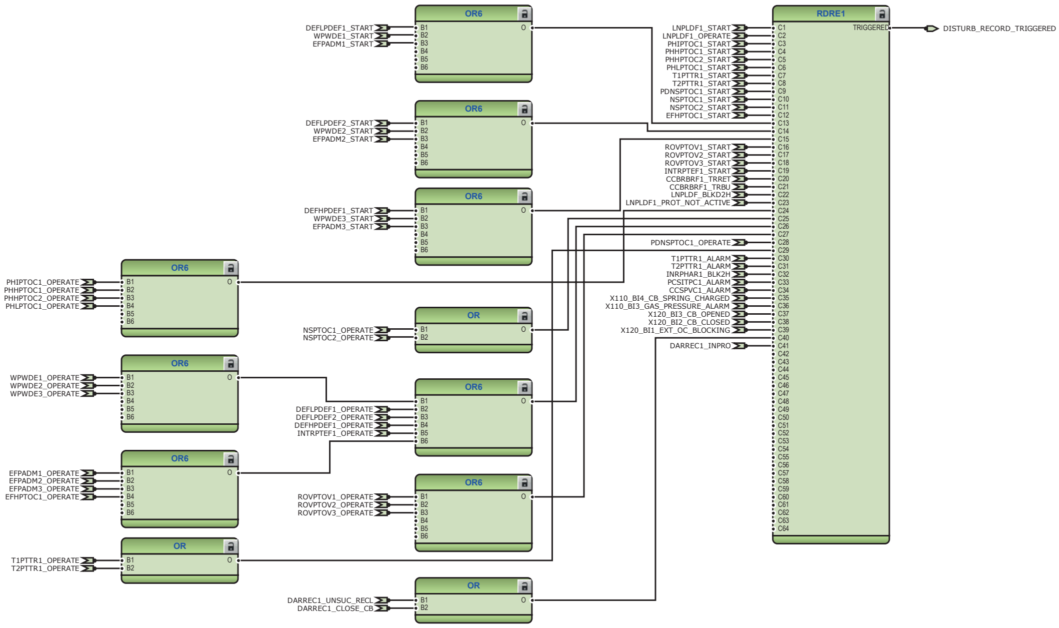


Figure 69: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failure in the current measuring circuits. When a failure is detected, it can be used to block current protection functions that measure calculated sequence component currents or residual current to avoid unnecessary operation.

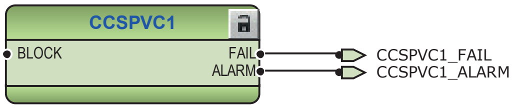


Figure 70: Current circuit supervision function

Circuit-breaker condition monitoring SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

Set parameters for SSCBR1 properly.

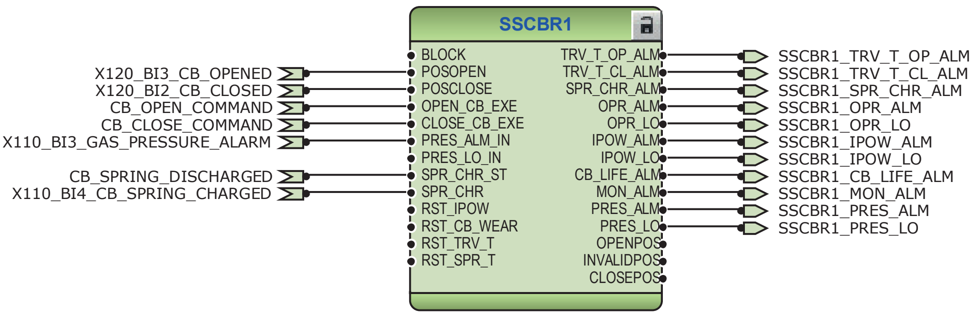


Figure 71: Circuit-breaker condition monitoring function

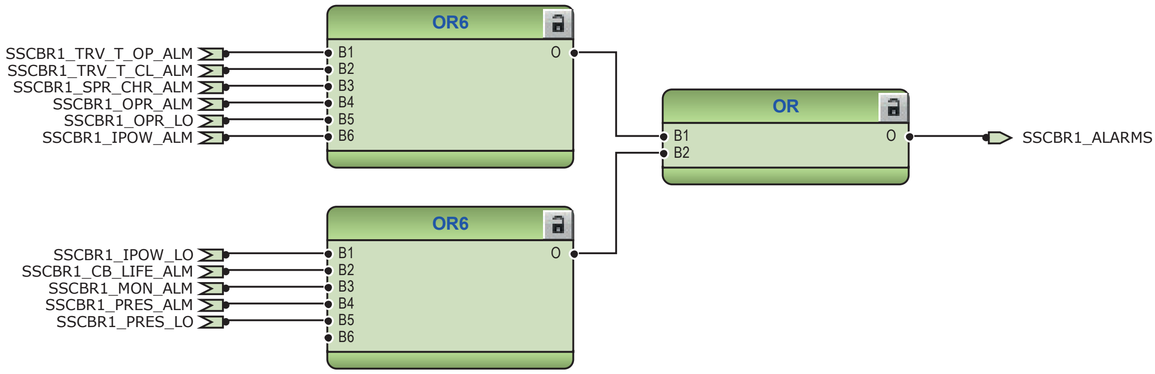


Figure 72: Logic for circuit breaker monitoring alarm

Figure 73: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. The functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 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 parameters for TCSSCBR1 properly.

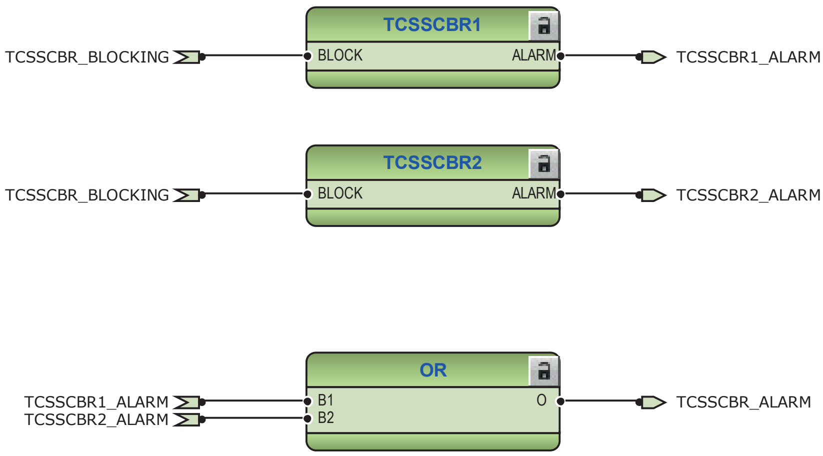


Figure 74: Trip circuit supervision function

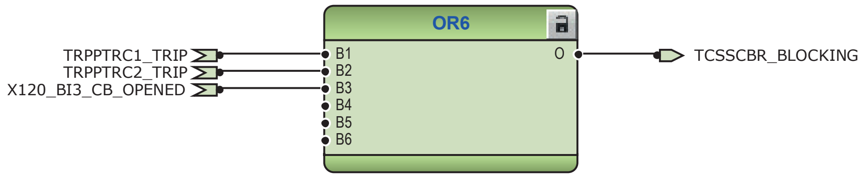


Figure 75: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC1 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 protection communication failure 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.

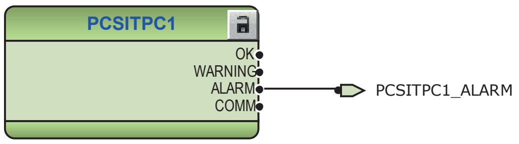


Figure 76: Protection communication supervision function

The binary signal transfer function BSTGGIO1 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 BSTGGIO1 inputs 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to the 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. Also the remote binary transfer output signal is connected to the binary output X110:SO3.

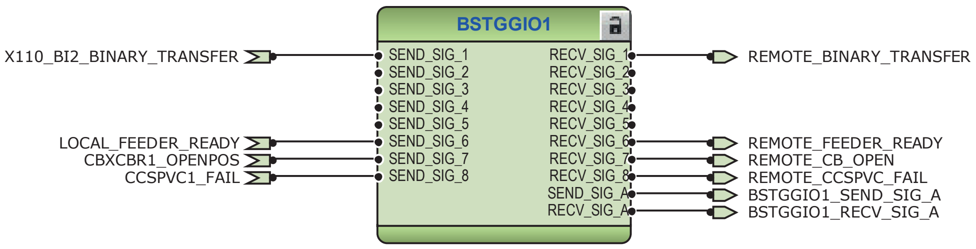


Figure 77: Binary signal transfer function

3.4.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in the standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

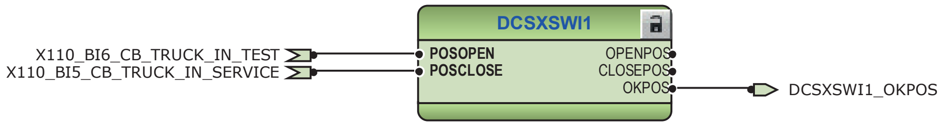


Figure 78: Disconnector 1 control logic

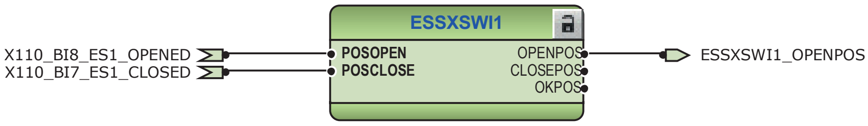


Figure 79: Earth-switch 1 control logic

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 earth-switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and earth-switch statuses are local feeder ready information to be sent for the remote end.

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

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

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

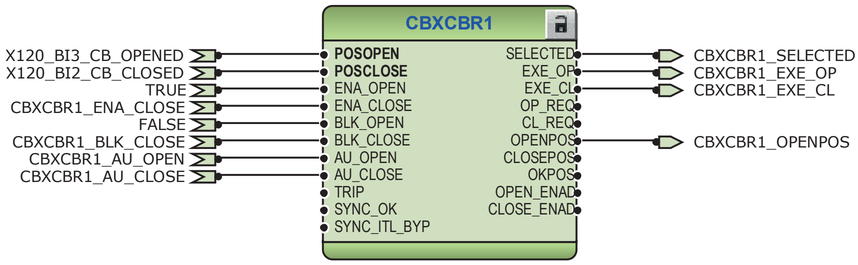


Figure 80: Circuit breaker 1 control logic

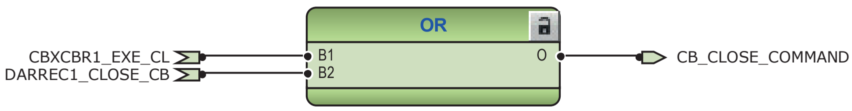


Figure 81: Signals for closing coil of circuit breaker 1

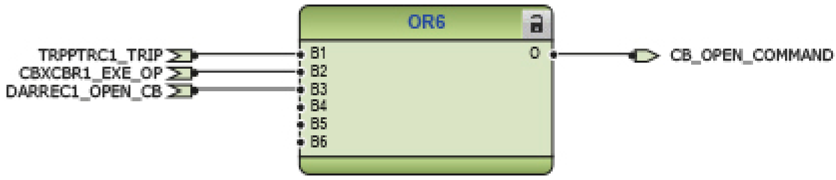


Figure 82: Signals for opening coil of circuit breaker 1

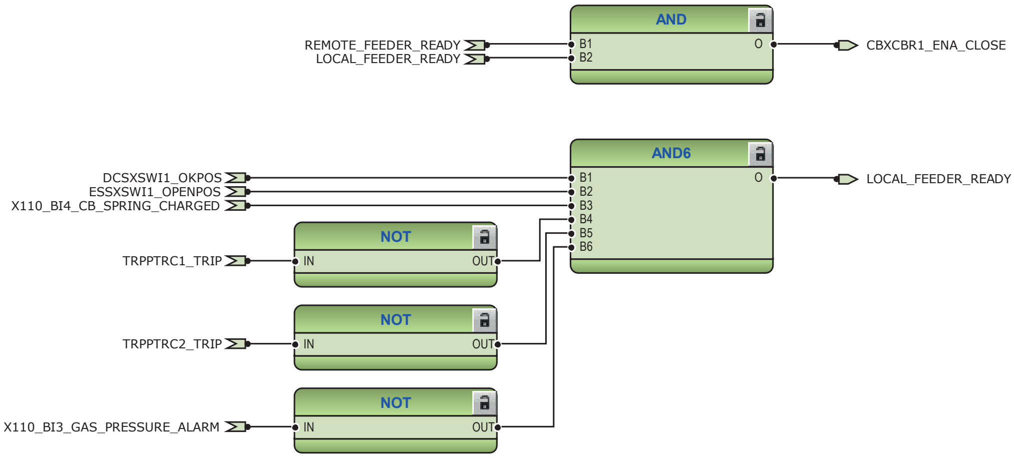


Figure 83: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

Figure 84: Circuit breaker 1 close blocking logic

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

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

Connect the additional signals for closing and opening of the circuit breaker in local or remote mode, if applicable for the application.

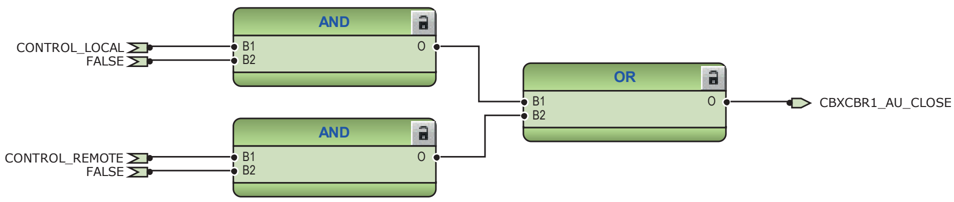


Figure 85: External closing command for circuit breaker 1

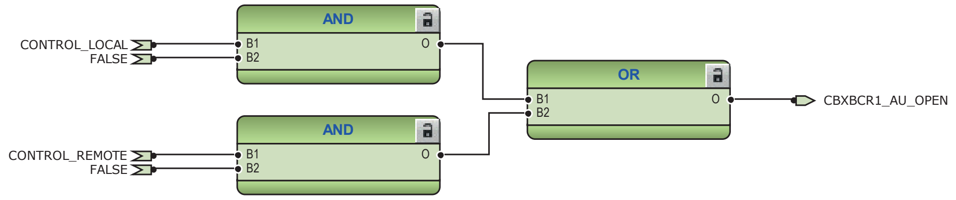


Figure 86: External opening command for circuit breaker 1

3.4.3.5 Functional diagrams for measurement functions

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

The residual voltage input is connected to the X120 card in the back panel and is measured by the residual voltage measurement RESVMMXU1.

The measurements can be seen in 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.

Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

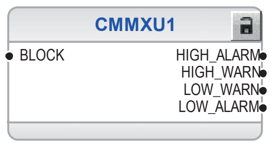


Figure 87: Current measurement: Three-phase current measurement

Figure 88: Current measurement: Sequence current measurement

Figure 89: Current measurement: Residual current measurement

Figure 90: Voltage measurement: Residual voltage measurement

Figure 91: Other measurement: Data monitoring

Figure 92: Other measurement: Load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

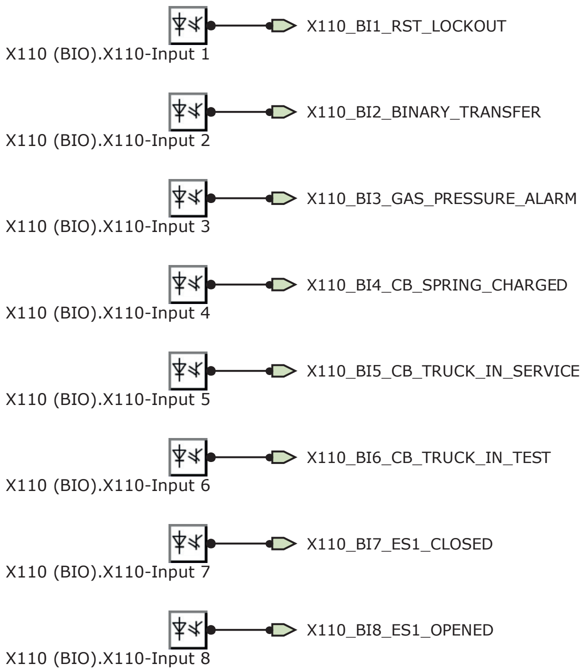


Figure 93: Binary inputs - X110 terminal block

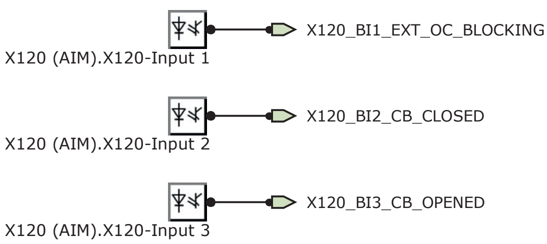


Figure 94: Binary inputs - X120 terminal block

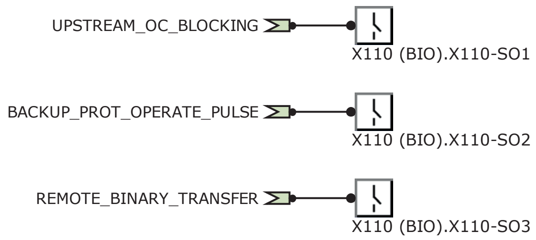


Figure 95: Binary outputs - X110 terminal block

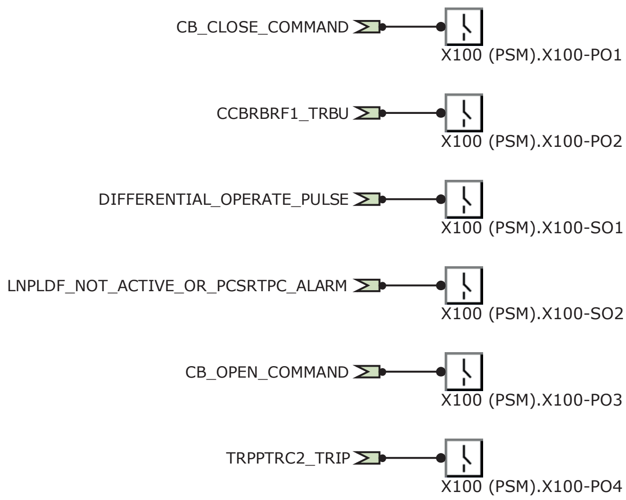
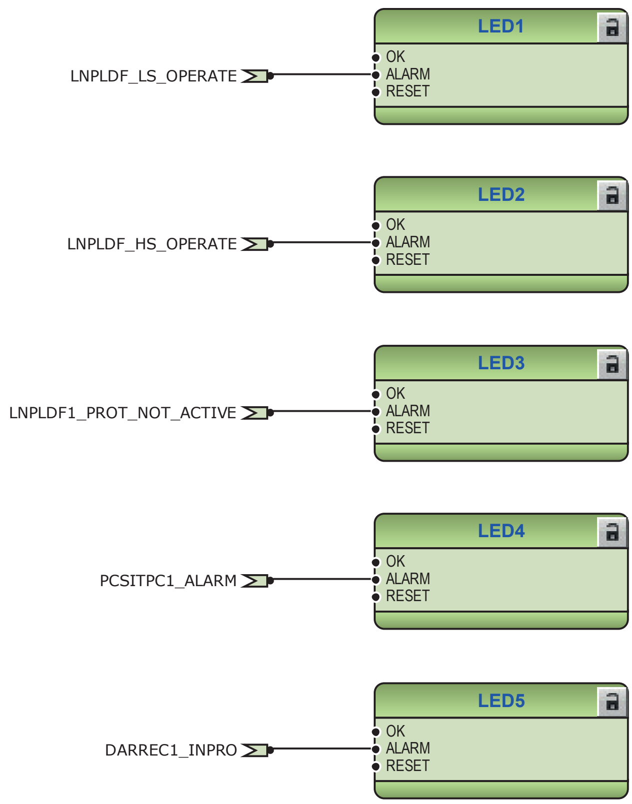


Figure 96: Binary outputs - X100 terminal block



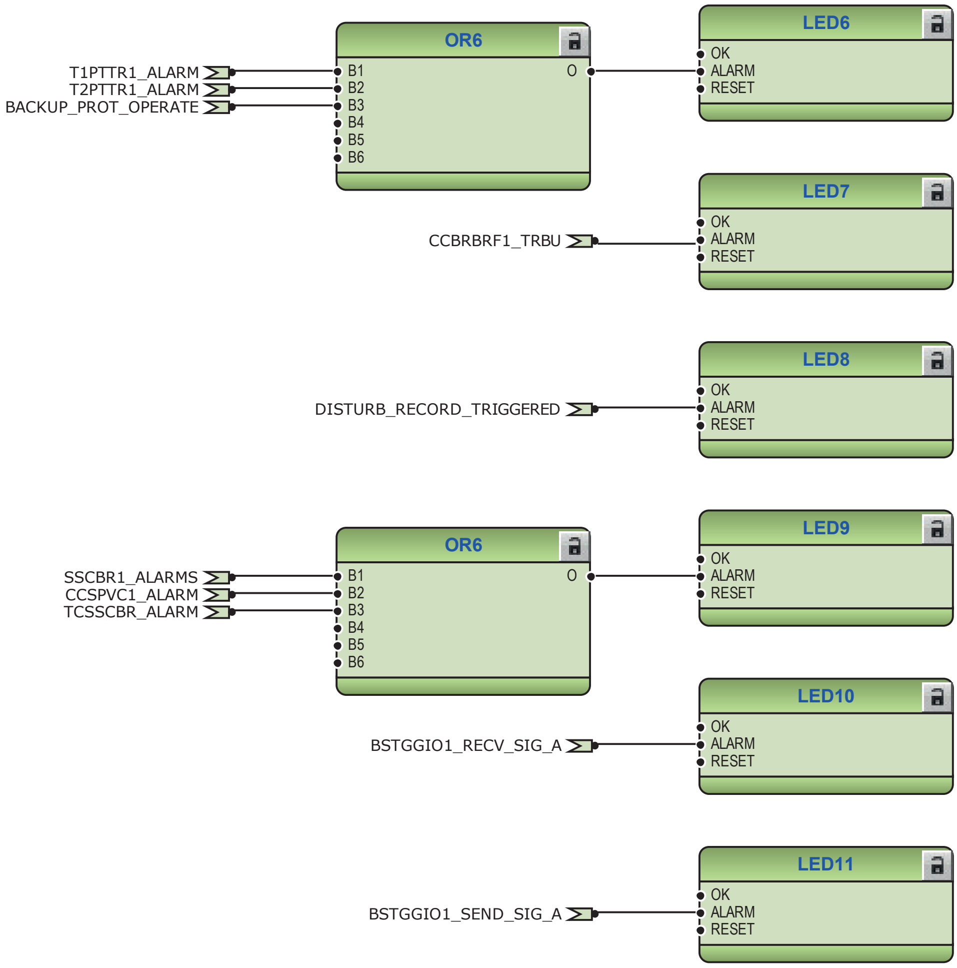


Figure 97: Default LED connection

3.4.3.7 Functional diagrams for other timer logics

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

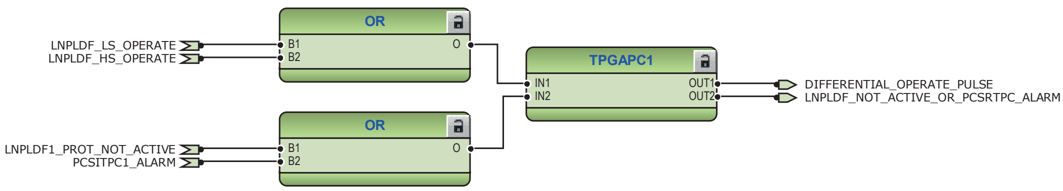


Figure 98: Timer logic for differential operate and communication not active

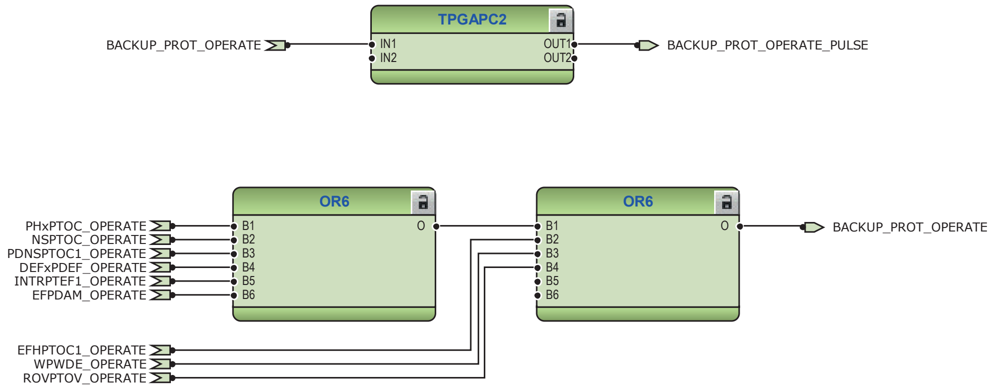


Figure 99: Timer logic for backup protection operate pulse

3.4.3.8 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, harmonics-based earth-fault protection, high-impedance fault detection function PHIZ, runtime counter for machines and devices MDSOPT and few instances of different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.5 Standard configuration C

3.5.1 Applications

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

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.

3.5.2 Functions

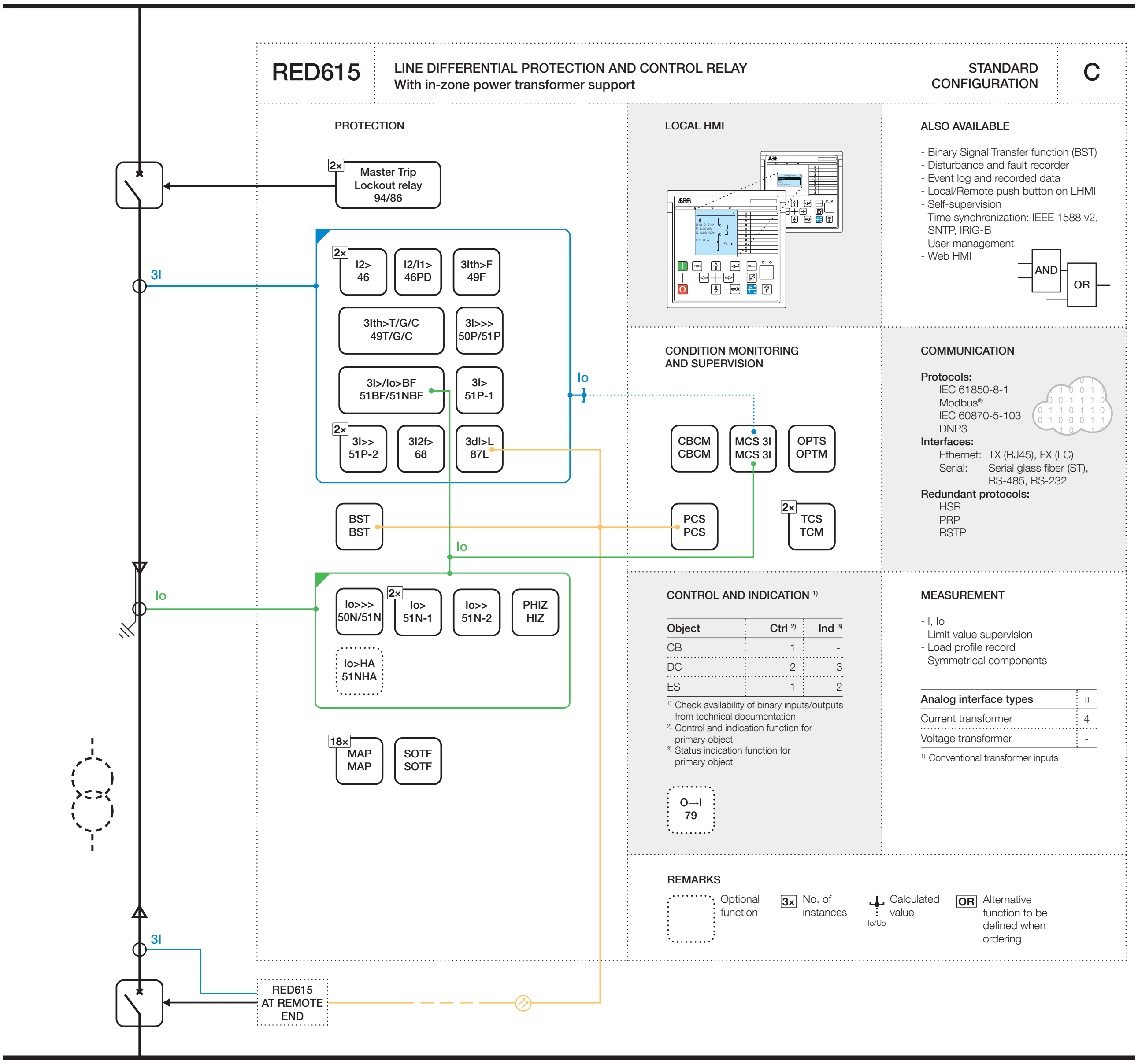


Figure 100: Functionality overview for standard configuration C

3.5.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 21: Default connections for binary inputs

Binary input	Description
X110-BI1	External start of breaker failure protection
X110-BI2	Binary signal transfer input
X110-BI3	Circuit breaker low gas pressure alarm
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (service position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking input for general use
X120-BI2	Circuit breaker close
X120-BI3	Circuit breaker open
X120-BI4	Lockout reset

Table 22: Default connections for binary outputs

Binary input	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Line differential protection trip alarm
X100-SO2	Protection communication failure or differential protection not available
X100-PO3	Open circuit breaker/trip 1
X100-PO4	Open circuit breaker/trip 2
X110- SO1	Upstream overcurrent blocking
X110- SO2	Backup protection operated
X110- SO3	Binary transfer signal

Table 23: Default connections for LEDs

LED	Description
1	Line differential protection biased stage operate
2	Line differential protection instantaneous stage operate
3	Line differential protection is not available
4	Protection communication failure
5	Autoreclose in progress
6	Backup protection operated
7	Circuit breaker failure protection - backup trip operate
8	Disturbance recorder triggered

Table continues on the next page

LED	Description
9	Current transformer failure or trip circuit or circuit breaker supervision
10	Binary signal transfer receive
11	Binary signal transfer send

3.5.2.2 Default disturbance recorder settings

Table 24: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	–
6	–
7	–
8	–
9	–
10	–
11	–
12	–

Table 25: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - start	Positive or Rising
2	LNPLDF1 - operate	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	PHHPTOC1 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC1 - start	Positive or Rising
7	T1PTTR1 - start	Positive or Rising
8	T2PTTR1 - start	Positive or Rising
9	PDNSPTOC1 - start	Positive or Rising
10	NSPTOC1 - start	Positive or Rising
11	NSPTOC2 - start	Positive or Rising
12	EFHPTOC1 - start	Positive or Rising
13	EFIPTOC1- start	Positive or Rising
14	EFLPTOC1 - start	Positive or Rising
15	EFLPTOC2 - start	Positive or Rising
16	CCBRBRF1 - trret	Level trigger off
17	CCBRBRF1 - trbu	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
18	LNPLDF1 - rstd2h	Level trigger off
19	LNPLDF1 - prot not active	Level trigger off
20	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
21	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
22	T1PTTR1- operate	Level trigger off
	T2PTTR2 - operate	
23	PDNSPTOC1 - operate	Level trigger off
24	EFIPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
	EFLPTOC1 - operate	
	EFLPTOC2 - operate	
25	T1PTTR1 - alarm	Level trigger off
26	T2PTTR2 - alarm	Level trigger off
27	INRPHAR1 - blk2h	Level trigger off
28	PCSITPC1 - alarm	Level trigger off
29	CCSPVC1 - alarm	Level trigger off
30	X110BI4 - CB spring charged	Level trigger off
31	X110BI3 - gas pressure alarm	Level trigger off
32	X120BI3 - CB opened	Level trigger off
33	X120BI2 - CB closed	Level trigger off
34	X120BI1 - ext OC blocking	Level trigger off
35	DARREC1 - unsuc recl	Level trigger off
	DARREC1 - close CB	
36	DARREC1 - inpro	Level trigger off

3.5.3 Functional diagrams

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

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 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 or via binary input.

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

3.5.3.1 Functional diagrams for protection

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

Line differential protection with in-zone power transformer LNPLDF1 is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by predefined settings if the `ENA_MULT_HS` input is activated. In this configuration it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnector is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult*, in case of internal fault.

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.

Four non-directional overcurrent stages are offered for overcurrent and short-circuit protection. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1 can be blocked by energizing the binary input X120:BI1. The instantaneous and first high stages are blocked by activation of line differential protection.

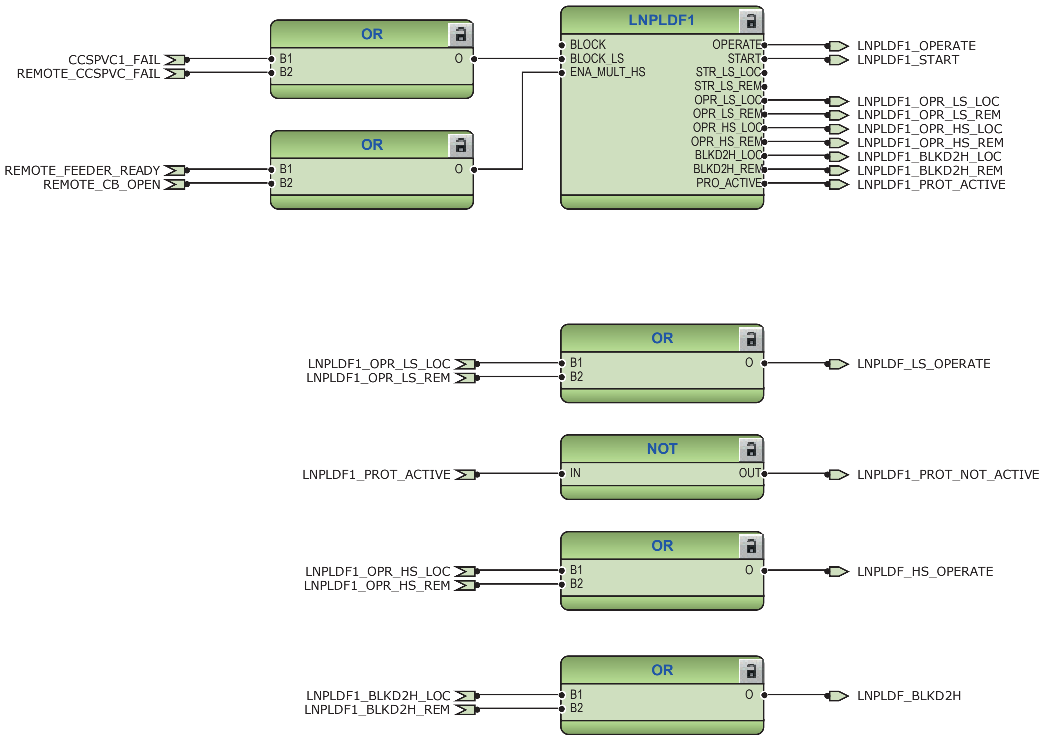


Figure 101: Line differential protection functions

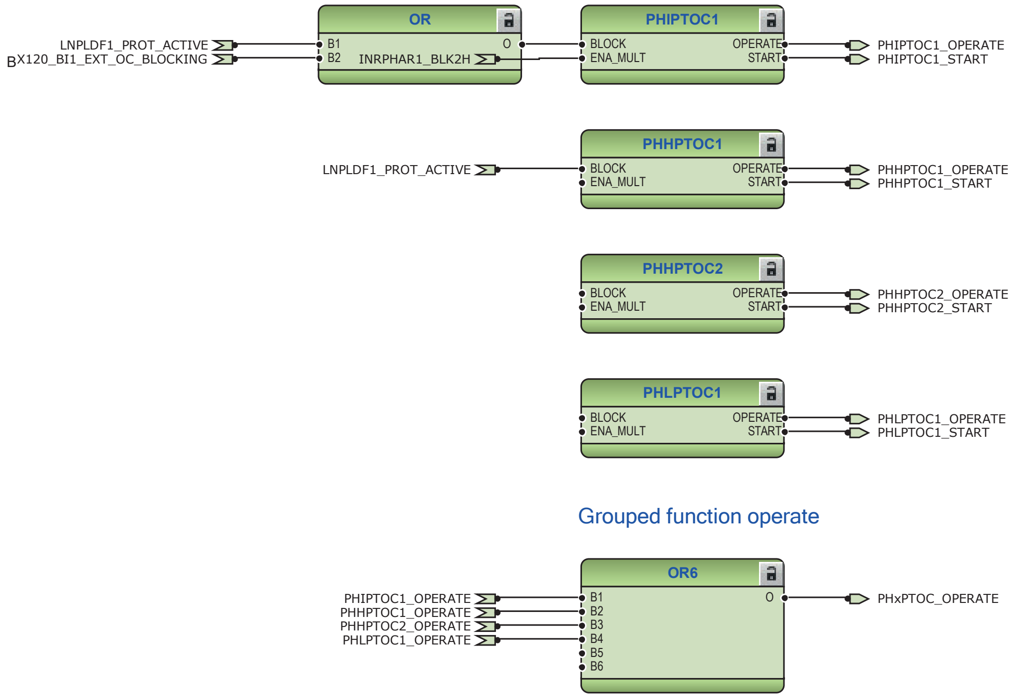


Figure 102: Overcurrent protection functions

The upstream blocking from the start 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 IED at the upstream bay.

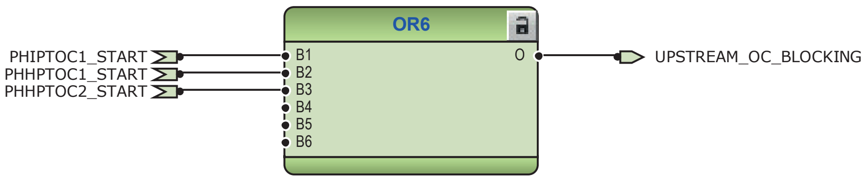


Figure 103: Upstream blocking logic

Four stages are provided for non-directional earth-fault protection. According to the order code, the configuration can also include optional harmonics-based earth-fault protection HAEFPTOC1. On detection of current circuit failure, all earth-fault functions are blocked to inhibit unwanted operation, which can occur due to apparent residual current.

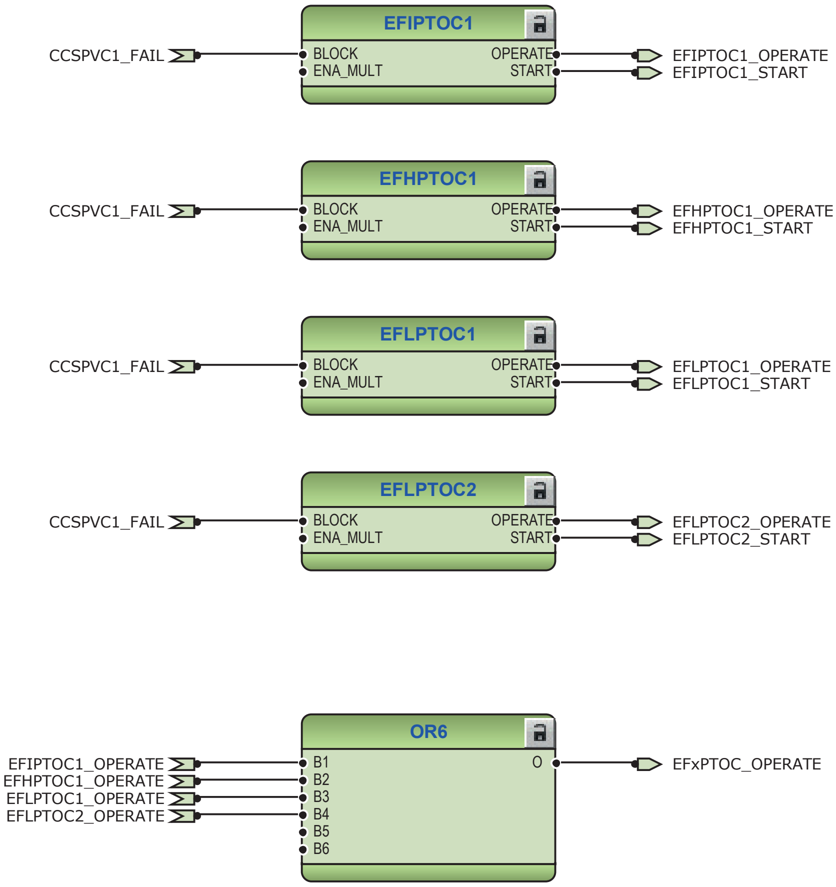


Figure 104: Earth-fault protection functions

The output `BLK2H` of three-phase inrush detector INRPHAR1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

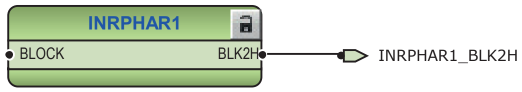


Figure 105: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. The negative sequence overcurrent protections are blocked in case of detection in failure in secondary circuit of current transformer.

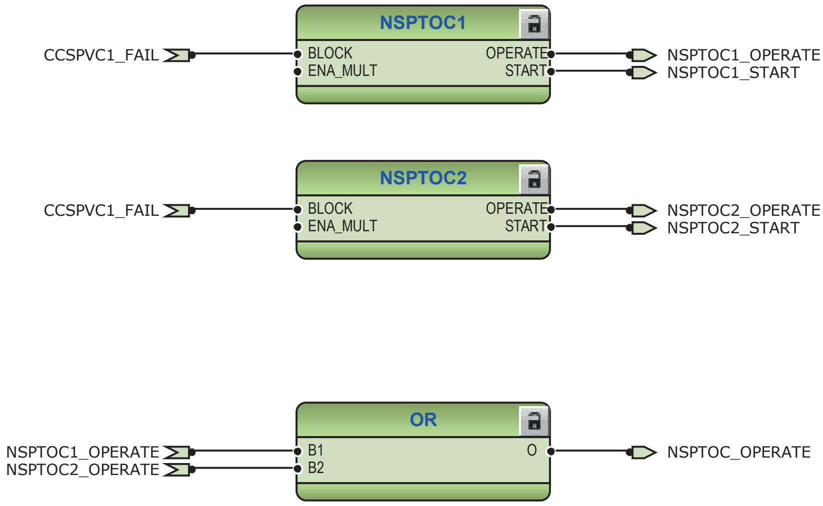


Figure 106: Negative-sequence overcurrent protection function

The phase discontinuity protection PDNSPTOC1 protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The function is blocked in case of detection in failure in secondary circuit of current transformer.

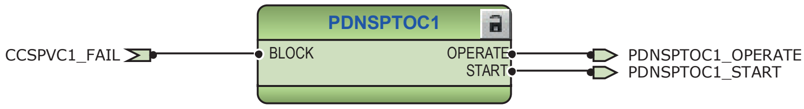


Figure 107: Phase discontinuity protection

Two thermal overload protection functions are incorporated one with one time constant T1PTTR1 and other with two time constants T2PTTR1 for detecting overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

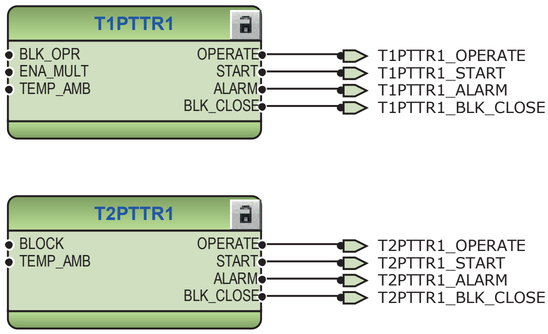


Figure 108: Thermal overcurrent protection function

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

The backup protection operated 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 operate signals from a number of protection stages through the INIT_1...5 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-SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the CB_READY input in DARREC1. 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 the close command is connected directly to binary output X100:PO1.

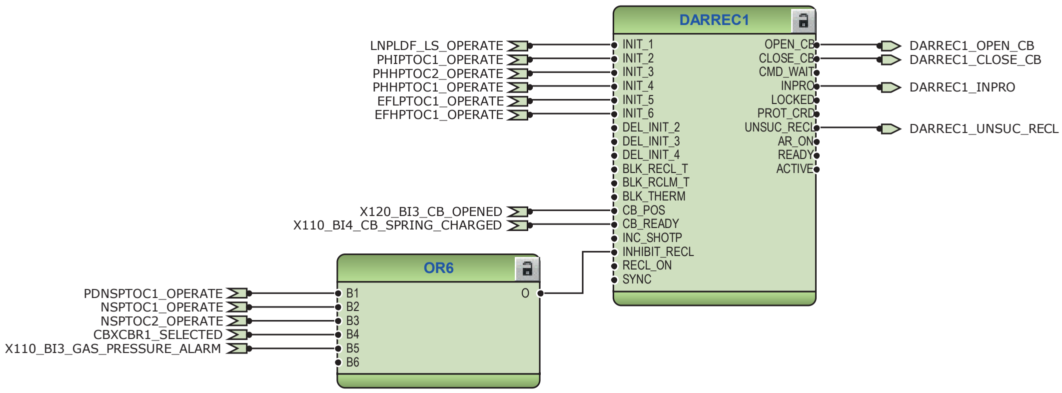


Figure 109: Autorecloser function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by a number of different protection functions available in the IED as well as externally by binary input X110:BI1. 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 operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

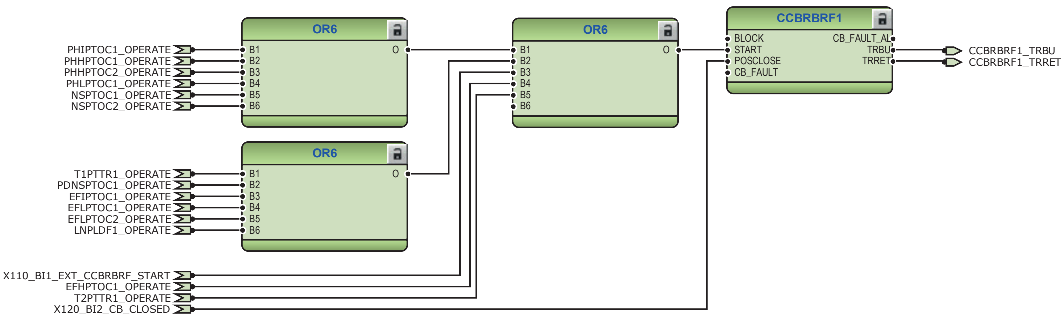


Figure 110: Circuit breaker failure protection function

The operate signals from the protection functions are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output 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 X120:BI4 can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

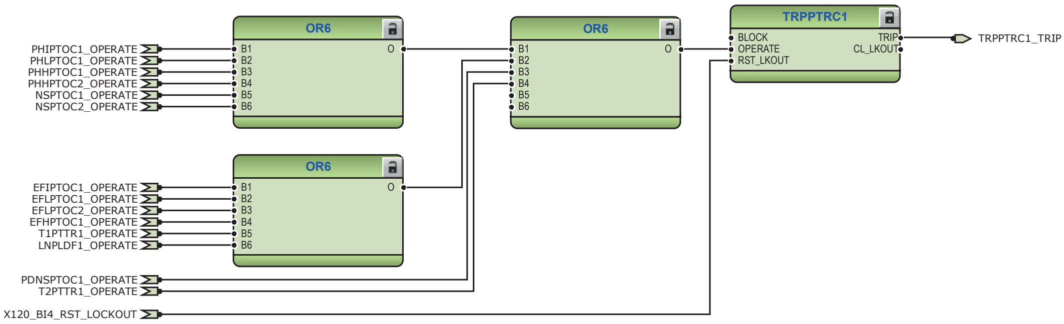


Figure 111: Trip logic TRPPTRC1

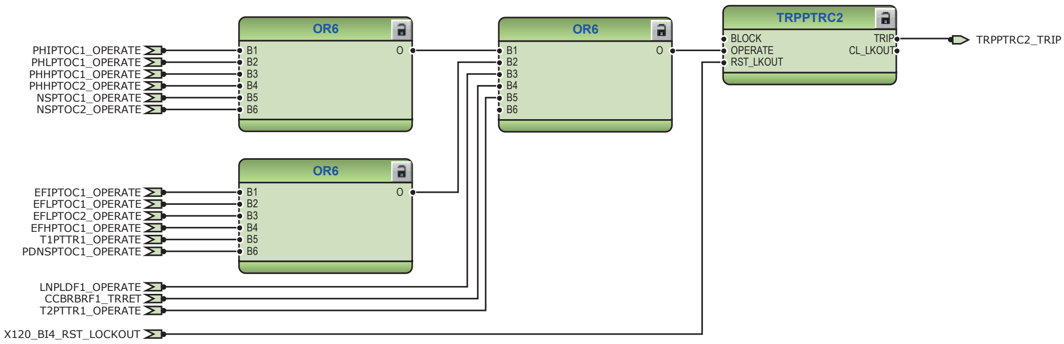


Figure 112: Trip logic TRPPTRC2

3.5.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE 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.

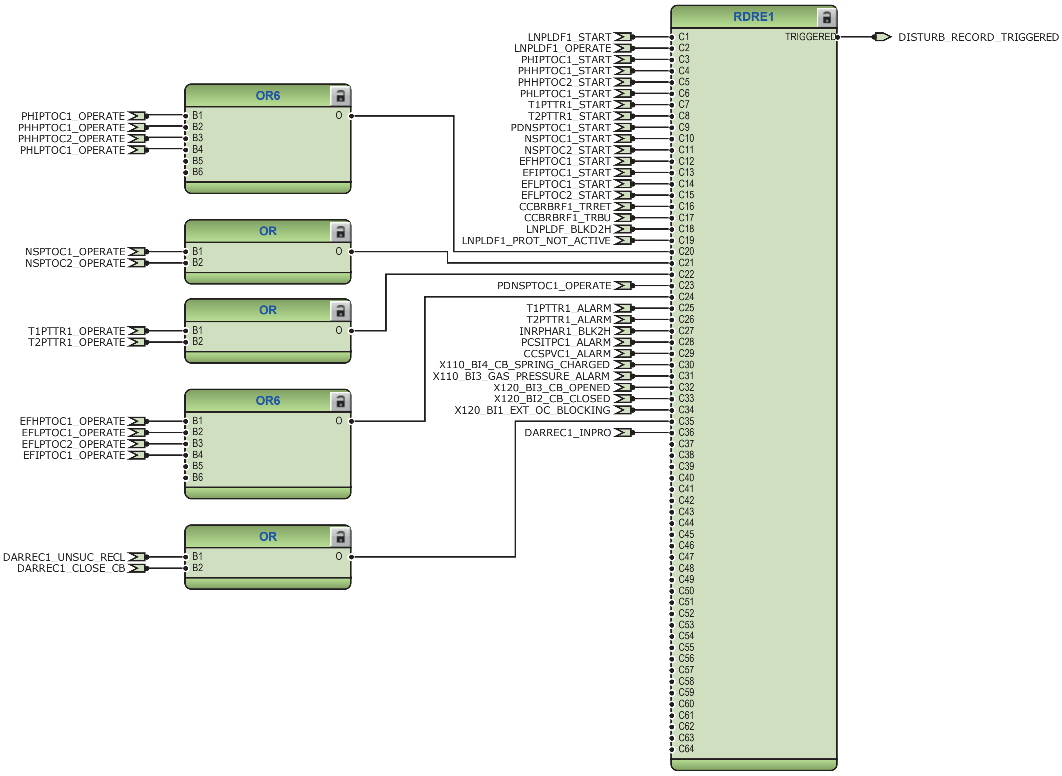


Figure 113: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measure calculated sequence component currents or residual current to avoid unnecessary operation.

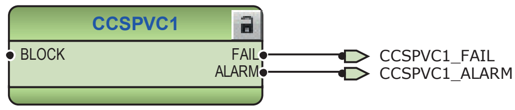


Figure 114: Current circuit supervision function

Circuit-breaker condition monitoring SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

Set the parameters for SSCBR1 properly.

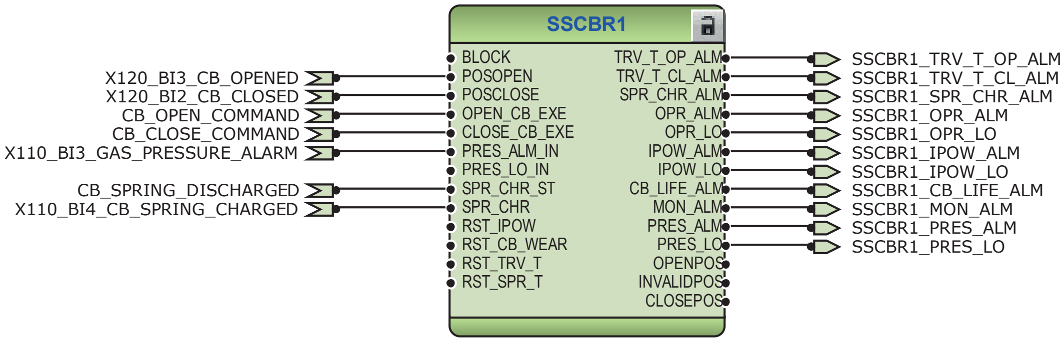


Figure 115: Circuit breaker condition monitoring alarm

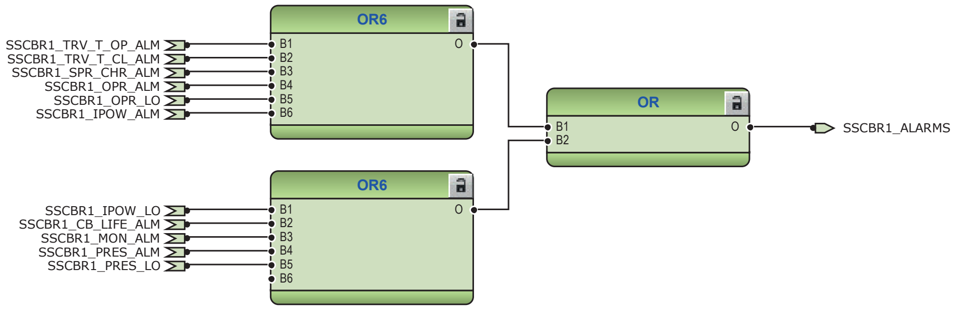


Figure 116: Logic for circuit breaker monitoring alarm

Figure 117: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included; TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. The functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 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 TCSSCBR1 properly.

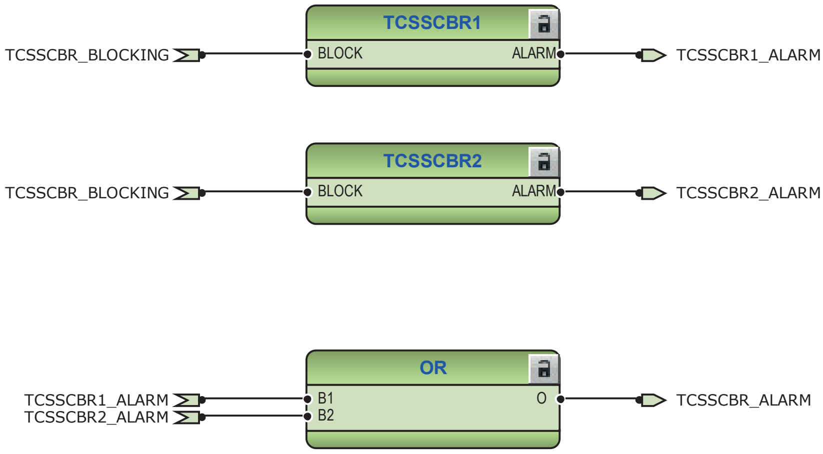


Figure 118: Trip circuit supervision function

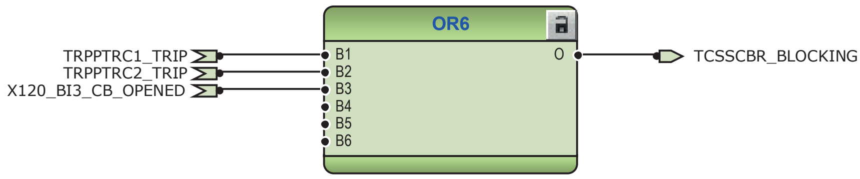


Figure 119: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC1 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 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.

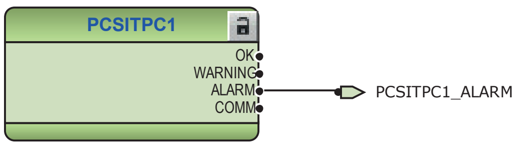


Figure 120: Protection communication supervision function

The binary signal transfer function BSTGGIO1 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 input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to the 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.

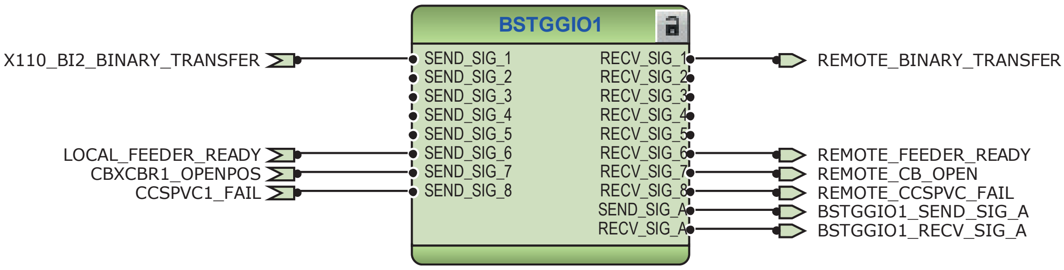


Figure 121: Binary signal transfer function

3.5.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

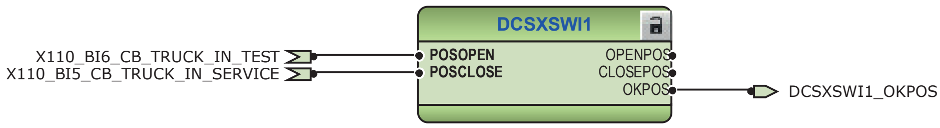


Figure 122: Disconnector 1 control logic

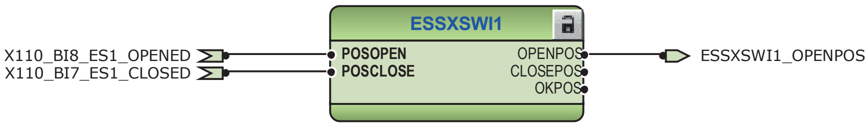


Figure 123: Earthswitch 1 control logic

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 earth-switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and earth-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 earth-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 connected, it disables the breaker closing in the local IED.

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

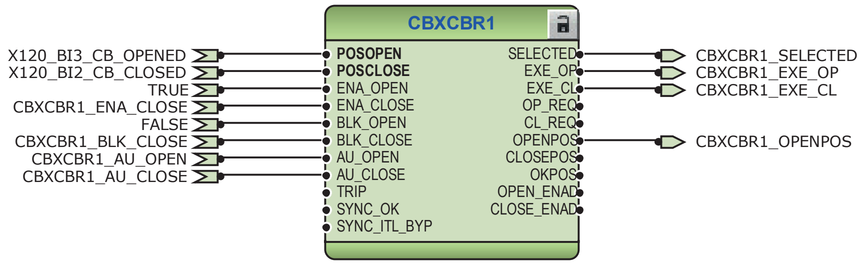


Figure 124: Circuit breaker 1 control logic

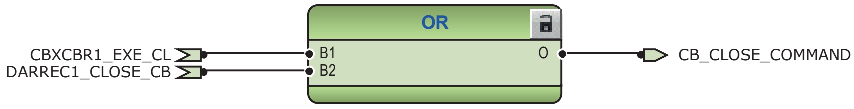


Figure 125: Signals for closing coil of circuit breaker 1

Figure 126: Signals for opening coil of circuit breaker 1

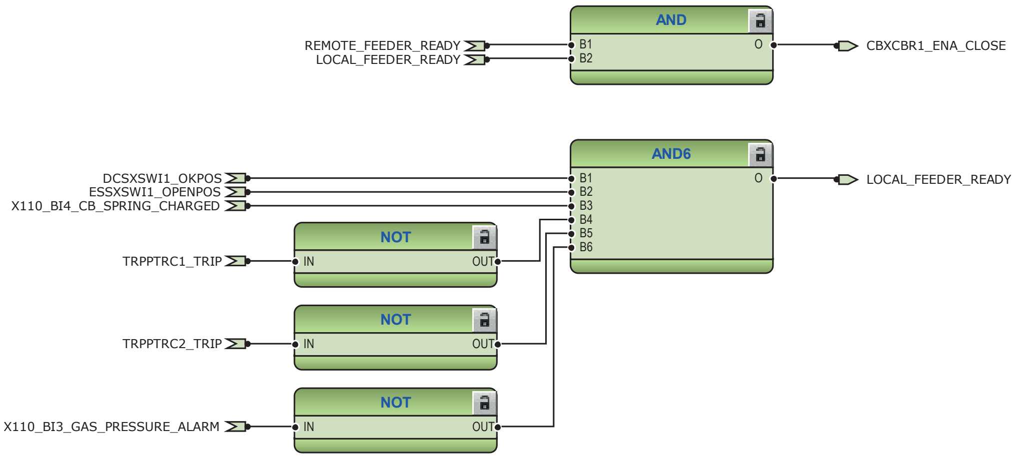


Figure 127: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

Figure 128: Circuit breaker 1 close blocking logic

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

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

Connect the additional signals for closing and opening of the circuit breaker in local or remote mode, if it is applicable for the application.

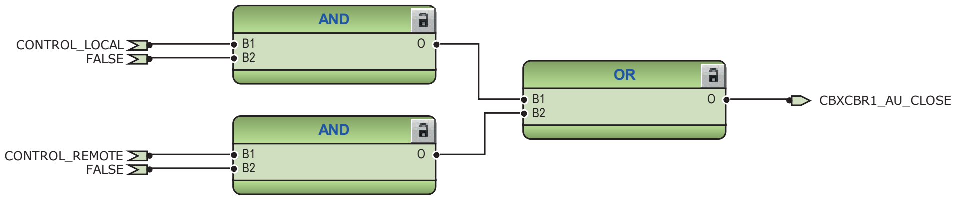


Figure 129: External closing command for circuit breaker 1

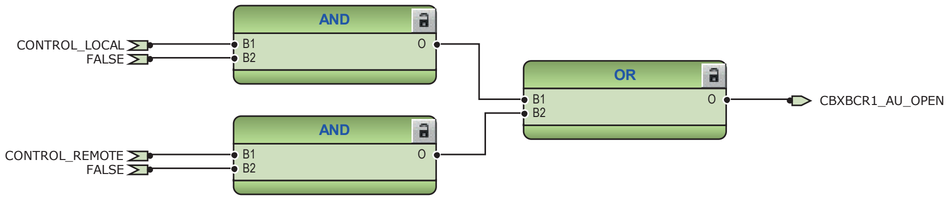


Figure 130: External opening command for circuit breaker 1

3.5.3.5 Functional diagrams for measurement functions

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

The measurements can be seen in 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.

Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

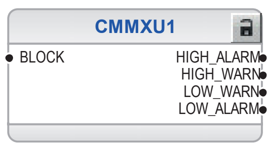


Figure 131: Current measurement: Three-phase current measurement

Figure 132: Current measurement: Sequence current measurement

Figure 133: Current measurement: Residual current measurement

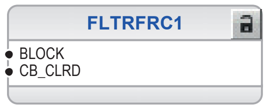


Figure 134: Other measurement: Data monitoring

Figure 135: Other measurement: Load profile record

3.5.3.6 Functional diagrams for I/O and alarm LEDs

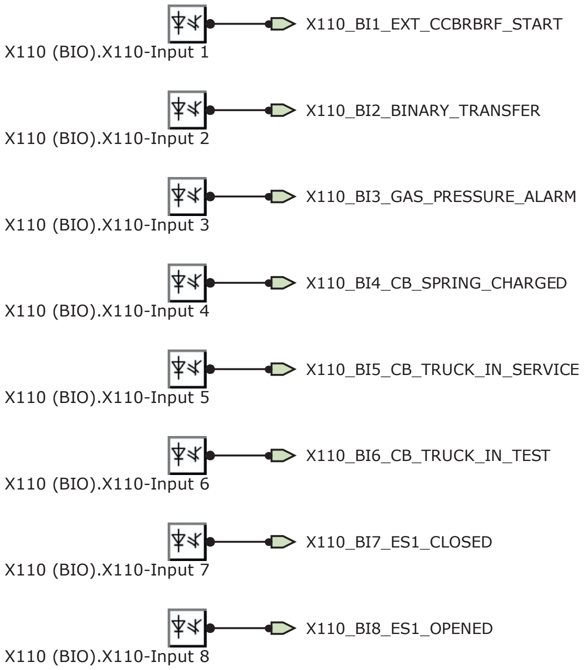


Figure 136: Binary inputs - X110 terminal block

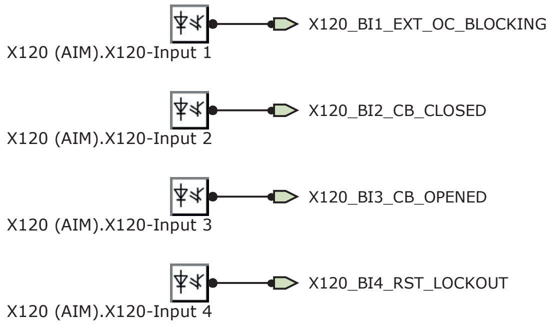


Figure 137: Binary inputs - X120 terminal block

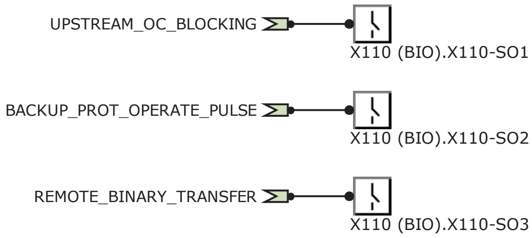


Figure 138: Binary outputs - X110 terminal block

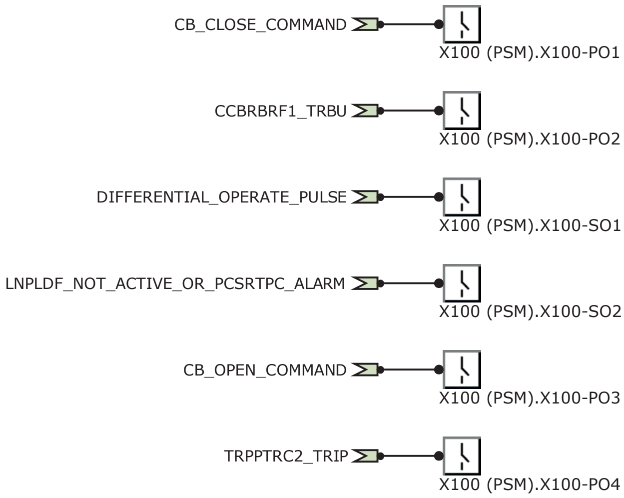
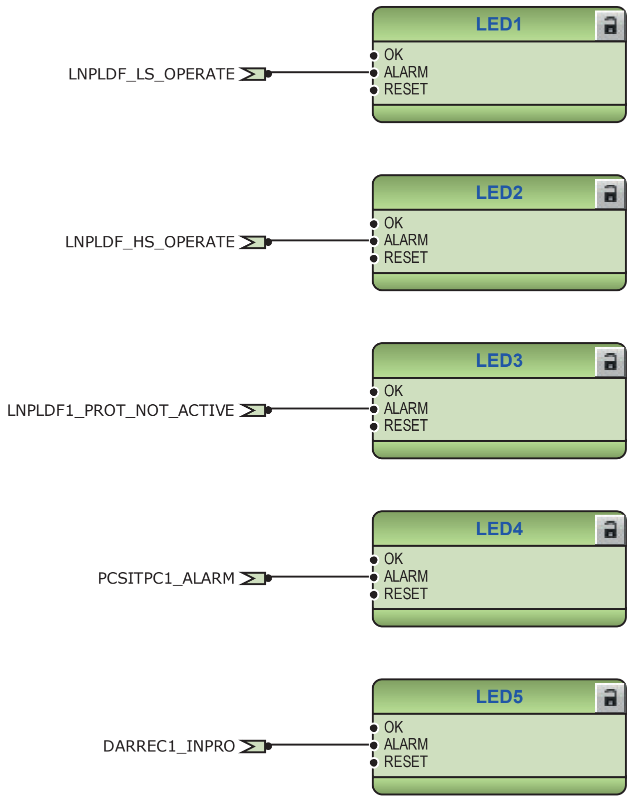


Figure 139: Binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
LNPLDF_LS_OPERATE
LED2
OK
ALARM
RESET
LNPLDF_HS_OPERATE
LED3
OK
ALARM
RESET
LNPLDF1_PROT_NOT_ACTIVE
LED4
OK
ALARM
RESET
PCSITPC1_ALARM
LED5
OK
ALARM
RESET
DARREC1_INPRO

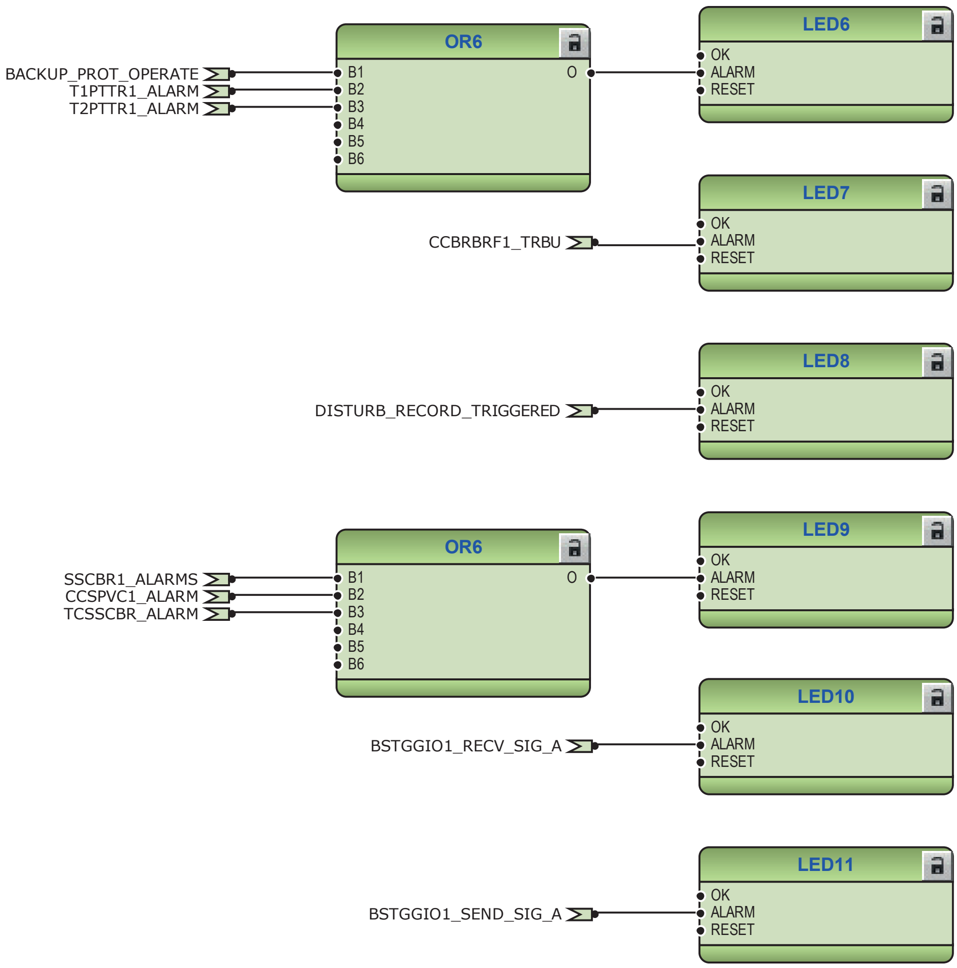


Figure 140: Default LED connection

3.5.3.7 Functional diagrams for other timer logics

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

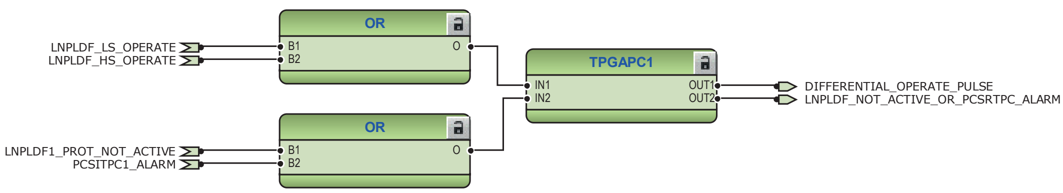


Figure 141: Timer logic for differential operate and communication not active

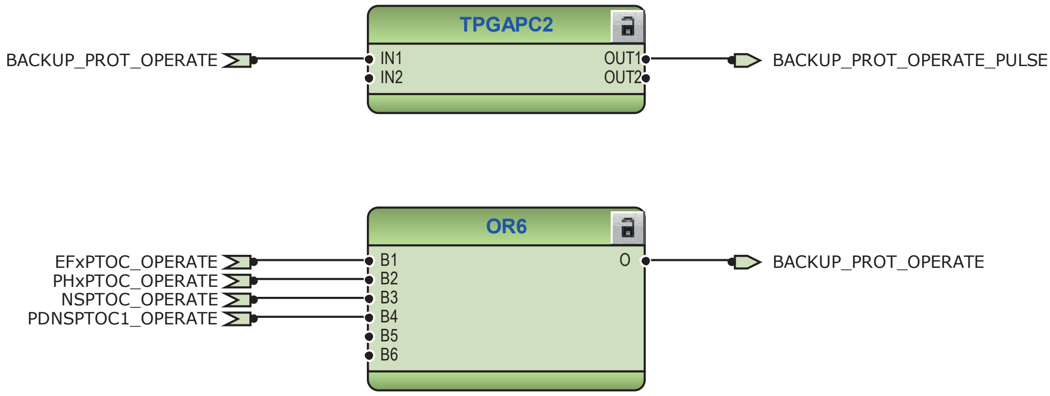


Figure 142: Timer logic for backup protection operate pulse

3.5.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, harmonics-based earth-fault protection, high-impedance fault detection function PHIZ, runtime counter for machines and devices MDSOPT and few instances of different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.6 Standard configuration D

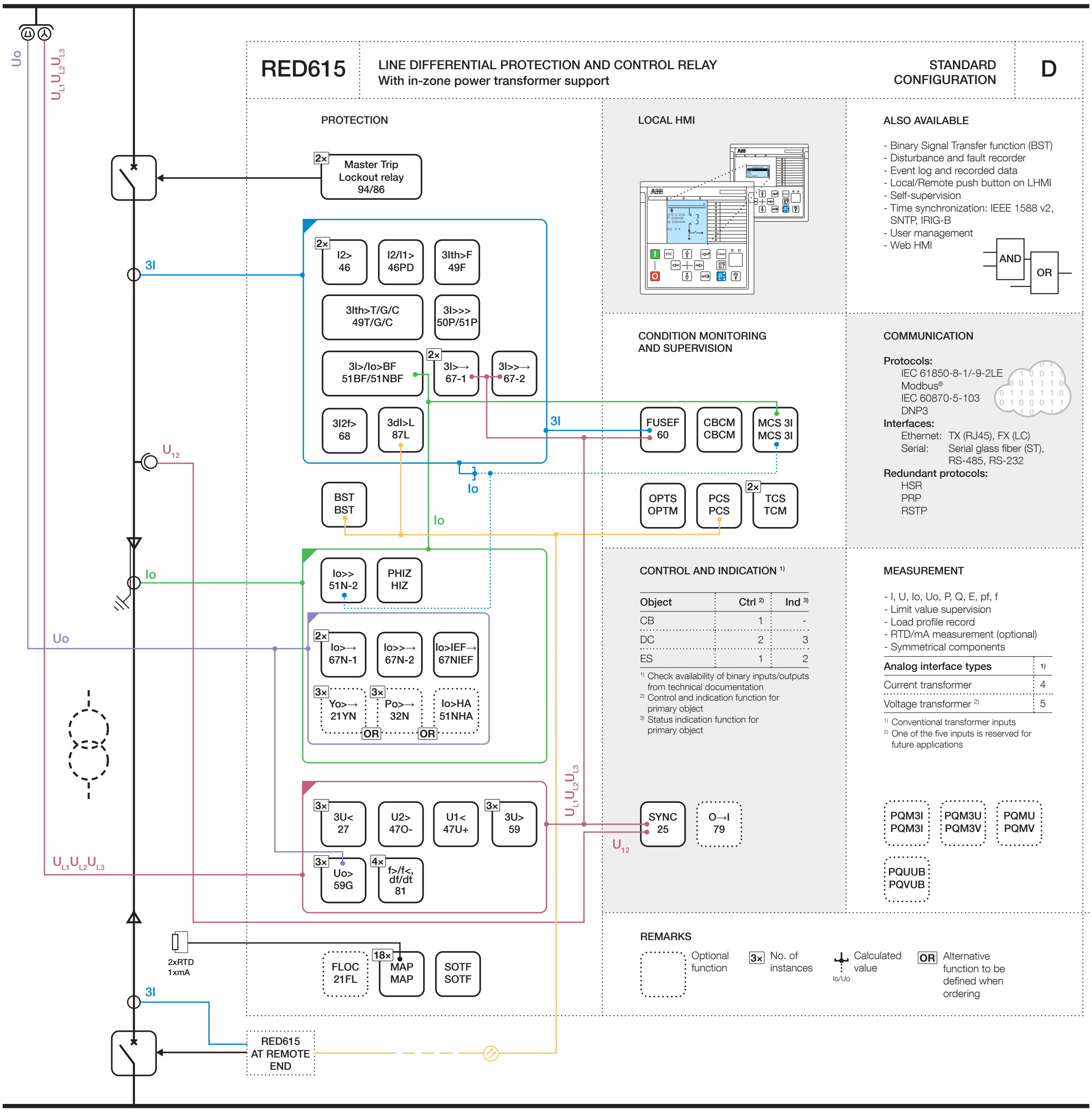
3.6.1 Applications

The standard configuration with directional overcurrent and directional earth-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 earth-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.

3.6.2 Functions



Object	Ctrl 2)	Ind 3)
CB	1	-
DC	2	3
ES	1	2

1) Check availability of binary inputs/outputs from technical documentation
2) Control and indication function for primary object
3) Status indication function for primary object

Analog interface types	1)
Current transformer	4
Voltage transformer 2)	5

1) Conventional transformer inputs
2) One of the five inputs is reserved for future applications

Figure 143: Functionality overview for standard configuration D

3.6.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 26: Default connections for binary inputs

BIO card	Description
X110-BI1	Lockout reset
X110-BI2	Binary transfer signal input
X110-BI3	Circuit breaker gas pressure alarm signal
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in service
X110-BI6	Circuit breaker truck in test
X110-BI7	Earthing switch in closed position
X110-BI8	Earthing switch in opened position
X120-BI1	External blocking signal for overcurrent instantaneous stage
X120-BI2	Circuit breaker in closed position
X120-BI3	Circuit breaker opened position
X120-BI4	–

Table 27: Default connections for binary outputs

Binary input	Description
X100-PO1	Close circuit close command
X100-PO2	Circuit breaker failed signal - Backup trip to upstream breaker
X100-SO1	Line differential protection operated
X100-SO2	Protection communication failure or differential protection not available
X100-PO3	Circuit breaker open command
X100-PO4	Master trip 2 activated
X110- SO1	Blocking signal for upstream overcurrent protection
X110- SO2	Backup protection operated
X110- SO3	Binary transfer signal
X110- SO4	–

Table 28: Default connections for LEDs

LED	Description
1	Line differential protection biased stage operated
2	Line differential protection instantaneous stage operated
3	Line differential protection not active
4	Protection communication supervision alarm
5	Autoreclose operation in progress
6	Backup protection operated
7	Circuit breaker failure protection - backup trip operate

Table continues on the next page

LED	Description
8	Disturbance recorder triggered
9	Supervision alarm
10	Binary transfer signal received
11	Binary transfer signal send

3.6.2.2 Default disturbance recorder settings

Table 29: Default disturbance recorder analog channels

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

Table 30: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - start	Positive or Rising
2	LNPLDF1 - operate	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	DPHHPDOC1 - start	Positive or Rising
5	DPHLPDOC1 - start	Positive or Rising
6	DPHLPDOC2 - start	Positive or Rising
7	NSPTOC1 - start	Positive or Rising
8	NSPTOC2 - start	Positive or Rising
9	INTRPTEF1 - start	Positive or Rising
10	EFHPTOC1 - start	Positive or Rising
11	DEFLPDEF1 - start	Positive or Rising
	WPWDE1 - start	
	EFPADM1 - start	
12	DEFLPDEF2 - start	Positive or Rising
	WPWDE2 - start	
	EFPADM2 - start	

Table continues on the next page

Channel	ID text	Level trigger mode
13	DEFHPDEF1 - start	Positive or Rising
	WPWDE3 - start	
	EFPADM3 - start	
14	PDNSPTOC1 - start	Positive or Rising
15	T1PTTR1 - start	Positive or Rising
16	T2PTTR1 - start	Positive or Rising
17	PHPTOV1 - start	Positive or Rising
18	PHPTOV2 - start	Positive or Rising
20	ROVPTOV1 - start	Positive or Rising
21	ROVPTOV2 - start	Positive or Rising
23	PSPTUV1 - start	Positive or Rising
24	NSPTOV1 - start	Positive or Rising
25	PHPTUV1 - start	Positive or Rising
26	PHPTUV2 - start	Positive or Rising
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	PHIPTOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
37	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
38	INTRPTEF1 - operate	Level trigger off
39	EFHPTOC1 - operate	Level trigger off
40	DEFLPDEF1 - operate	Level trigger off
	WPWDE1 - operate	
	EFPADM1 - operate	
	DEFLPDEF2 - operate	
	WPWDE2 - operate	
	EFPADM2 - operate	
	DEFLPDEF3 - operate	
	WPWDE3 - operate	
	EFPADM3 - operate	
41	PDNSPTOC1 - operate	Level trigger off
42	T1PTTR1 - alarm	Level trigger off
43	T2PTTR2 - alarm	Level trigger off
44	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
45	ROVPTOV1 - operate	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
	ROVPTOV2 - operate	
	PSPTUV1 - operate	
	NSPTOV1 - operate	
46	T1PTTR1 - operate	Level trigger off
	T2PTTR2 - operate	
47	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
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	X110BI4 - CB spring charged	Level trigger off
55	X110BI3 - gas pressure alarm	Level trigger off
56	X120BI3 - CB opened	Level trigger off
57	X120BI2 - CB closed	Level trigger off
58	X120BI1 - ext OC blocking	Level trigger off
59	DARREC1 - unsuc recl	Level trigger off
	DARREC1 - close CB	
60	DARREC1 - inpro	Level trigger off

3.6.3 Functional diagrams

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

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 phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay is fed from either residually connected VTs, an open delta connected VT or calculated internally.

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 or via binary input.

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

3.6.3.1 Functional diagrams for protection

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

Line differential protection with in-zone power transformer LNPLDF1 is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by predefined settings if the `ENA_MULT_HS` input is activated. In this configuration, it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnector is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult*, in case of internal fault.

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.

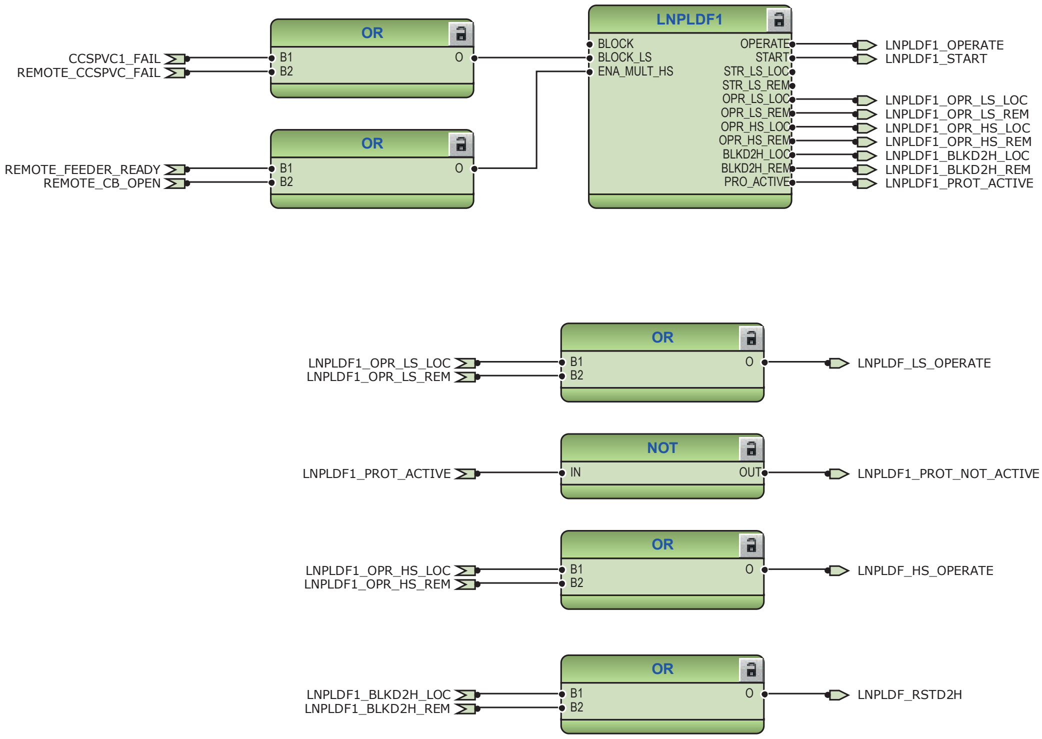


Figure 144: Line differential protection functions

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1 can be blocked by energizing the binary input X120:BI1.

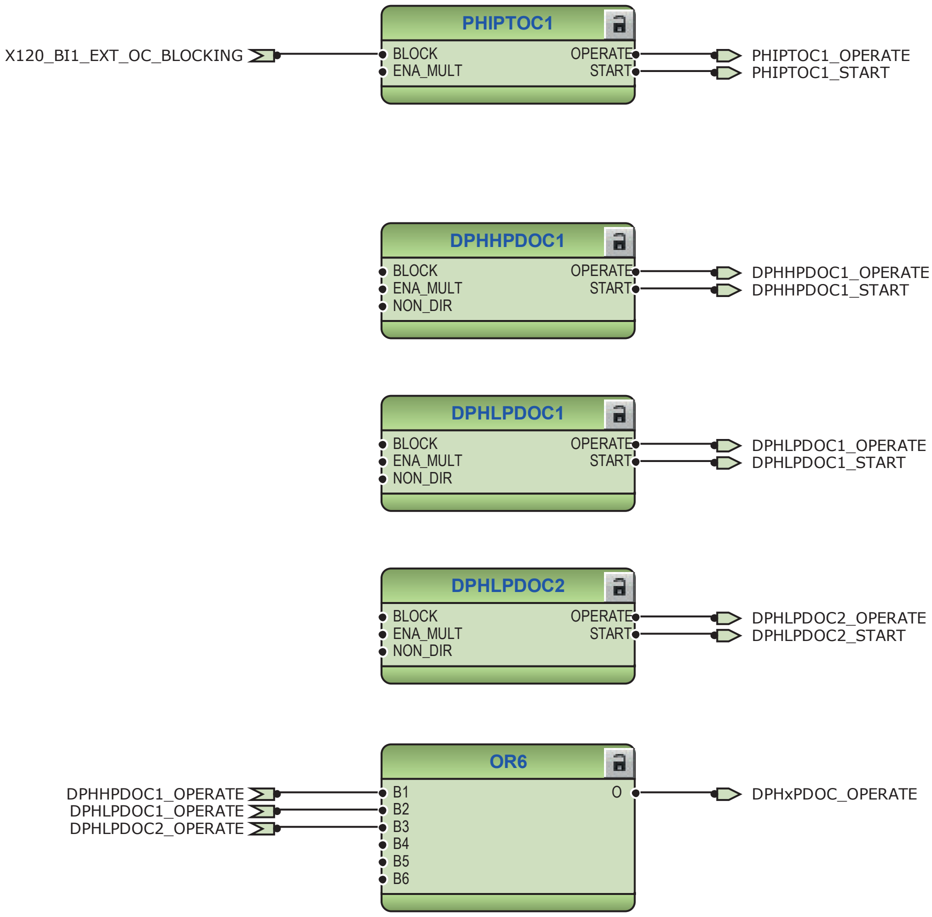


Figure 145: Overcurrent protection functions

The upstream blocking from the start 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 IED at the upstream bay.

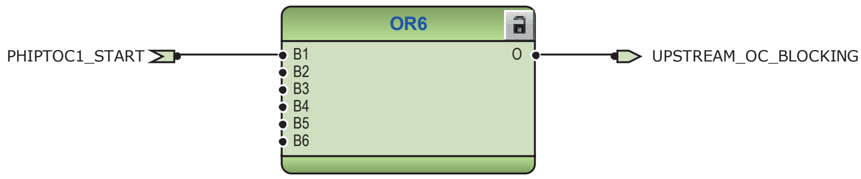


Figure 146: Upstream blocking logic

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

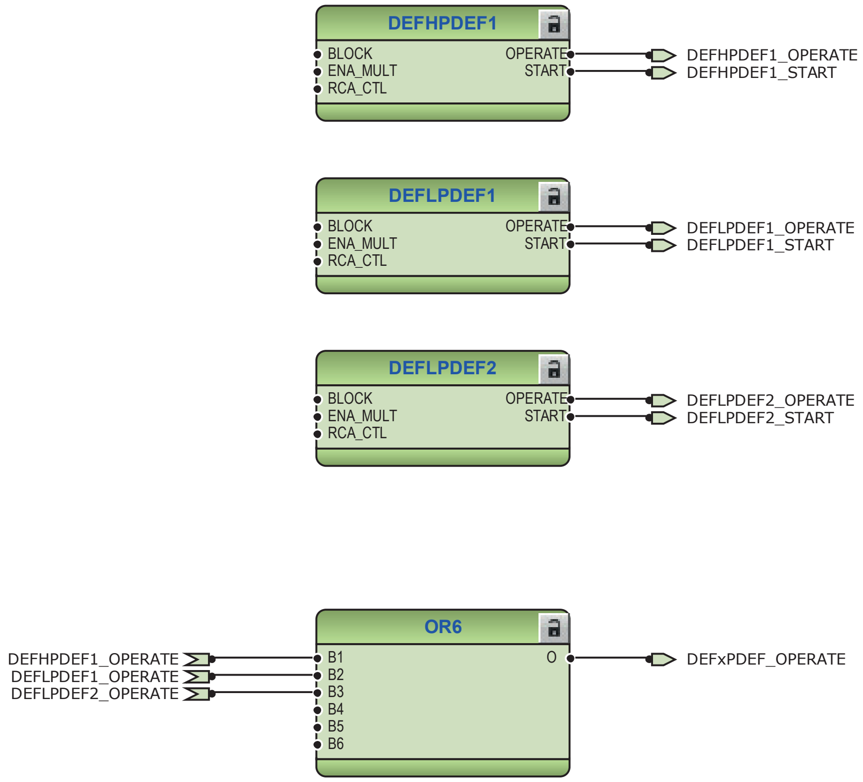


Figure 147: Directional earth-fault protection function

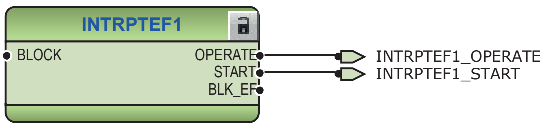


Figure 148: Transient or intermittent earth-fault protection function

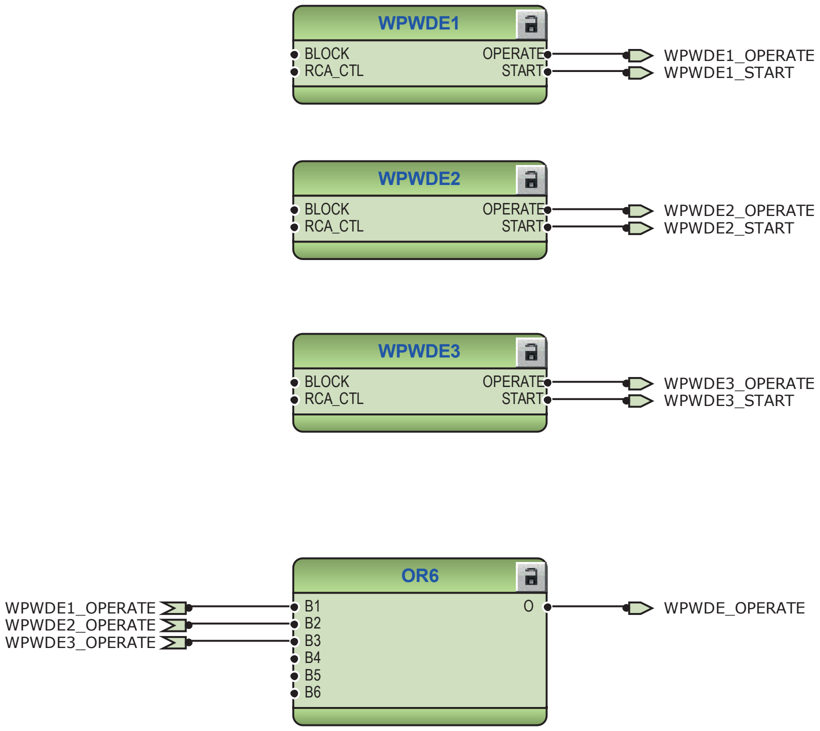


Figure 149: Wattmetric protection function

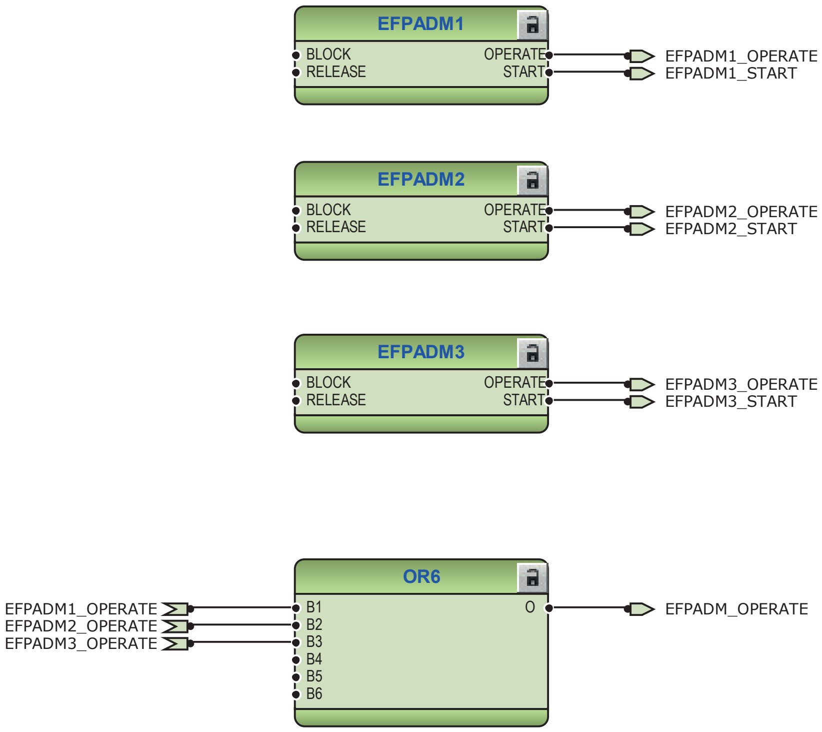


Figure 150: Admittance-based earth-fault protection function

Non-directional (cross-country) earth-fault protection, using calculated Io, EFHPTOC protects against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

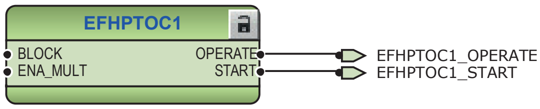


Figure 151: Cross-country earth-fault protection

The output BLK2H of three-phase inrush detector INRPHAR1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

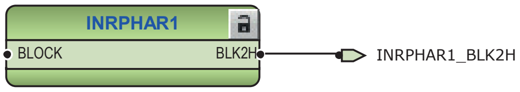


Figure 152: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance.

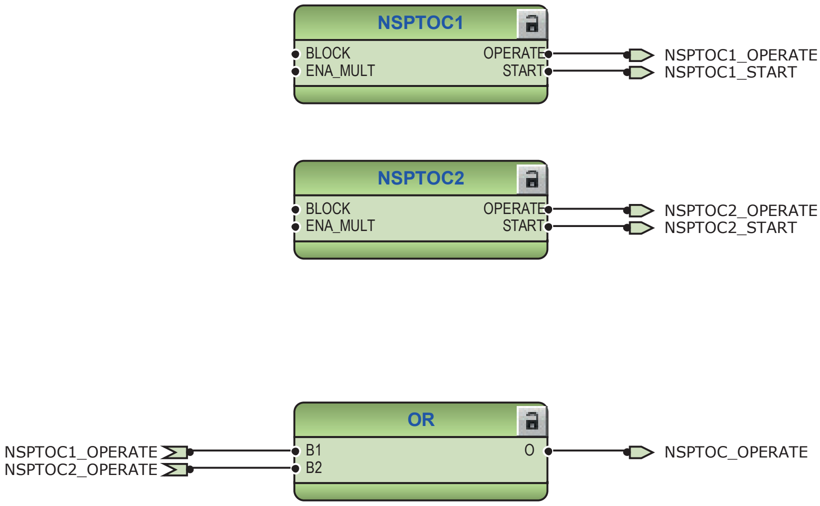


Figure 153: Negative-sequence overcurrent protection function

Phase discontinuity protection PDNSPTOC1 protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

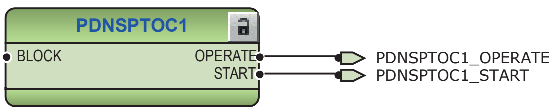


Figure 154: Phase discontinuity protection

Two thermal overload protection functions are incorporated, one with one time constant T1PTTR1 and other with two time constants T2PTTR1 for detecting overloads under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

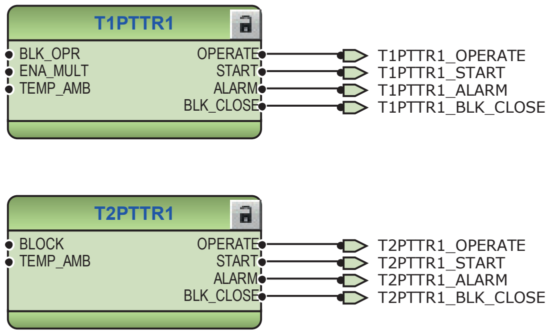


Figure 155: Thermal overcurrent protection function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. However, only two instances of PHPTOV and PHPTUV are used in the configuration. Positive-sequence undervoltage PSPTUV and negative-sequence overvoltage NSPTOV 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.

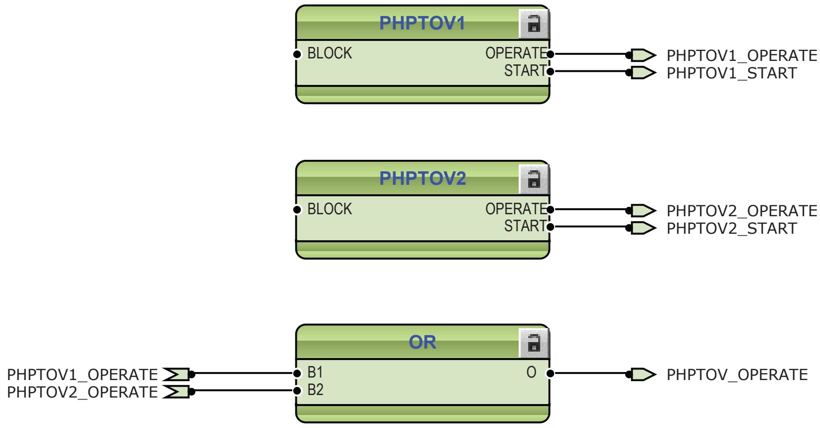


Figure 156: Overvoltage protection function

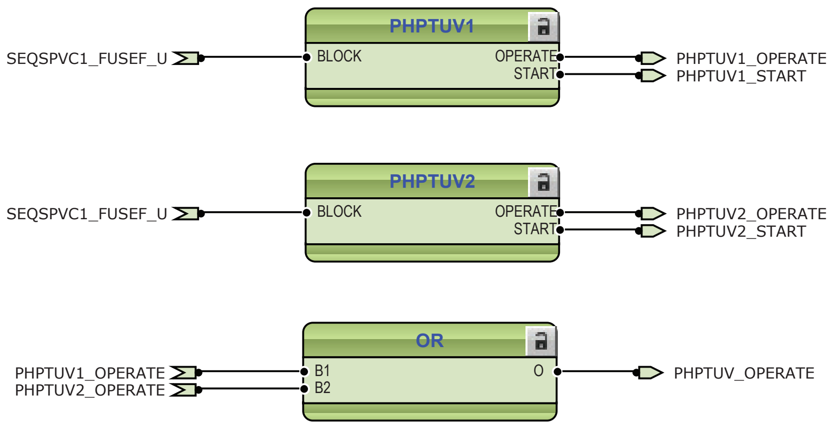


Figure 157: Undervoltage protection function

The residual overvoltage protection ROVPTOV provides earth-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 earth-fault functionality.

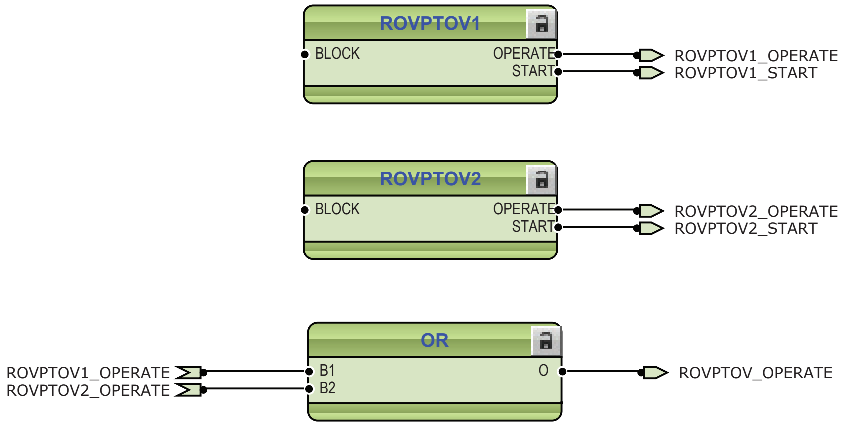


Figure 158: Residual voltage protection function

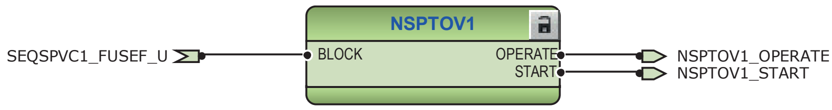


Figure 159: Negative sequence overvoltage protection function

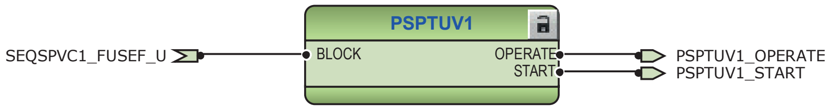


Figure 160: Positive sequence undervoltage protection function

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

The backup protection operated 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 operate signals from a number of protection stages through the `INIT_1...6` inputs. It is possible to create individual autoreclose 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-SELECTED` signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1. 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.

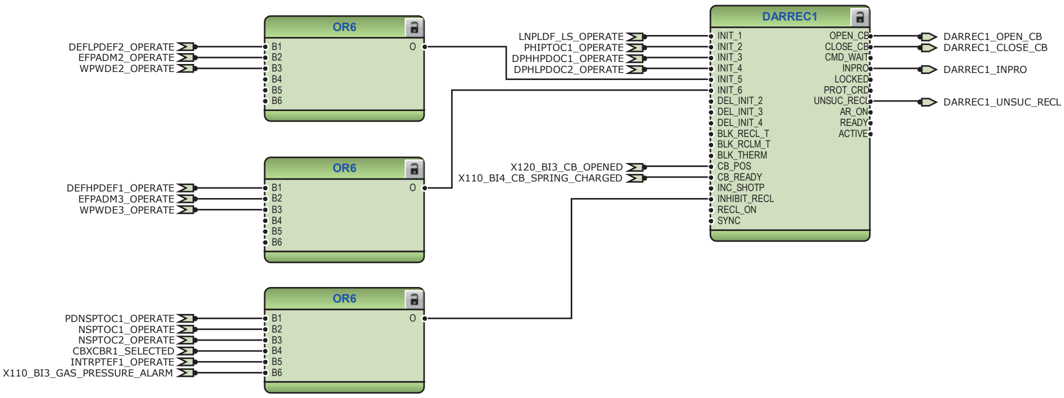


Figure 161: Autoreclosing function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by a number of different protection functions available in the IED. 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` operate output is used for retripping its own breaker through `TRPPTRC2_TRIP`. The `TRBU` output is used to give a backup trip to the breaker feeding upstream. For this purpose, the `TRBU` operate output signal is connected to the binary output X100:PO2.

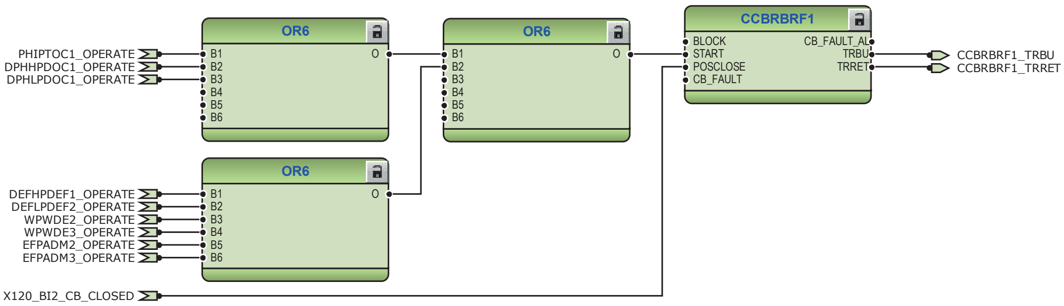


Figure 162: Circuit breaker failure protection function

The operate signals from the protection functions are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output 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.

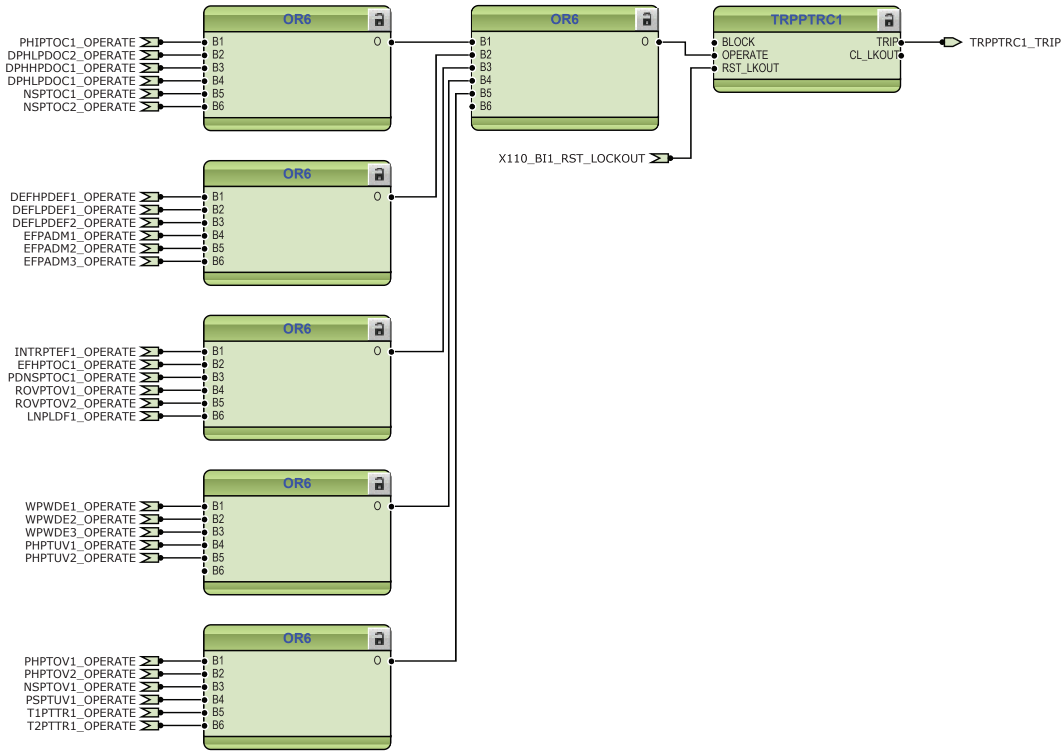


Figure 163: Trip logic TRPPTRC1

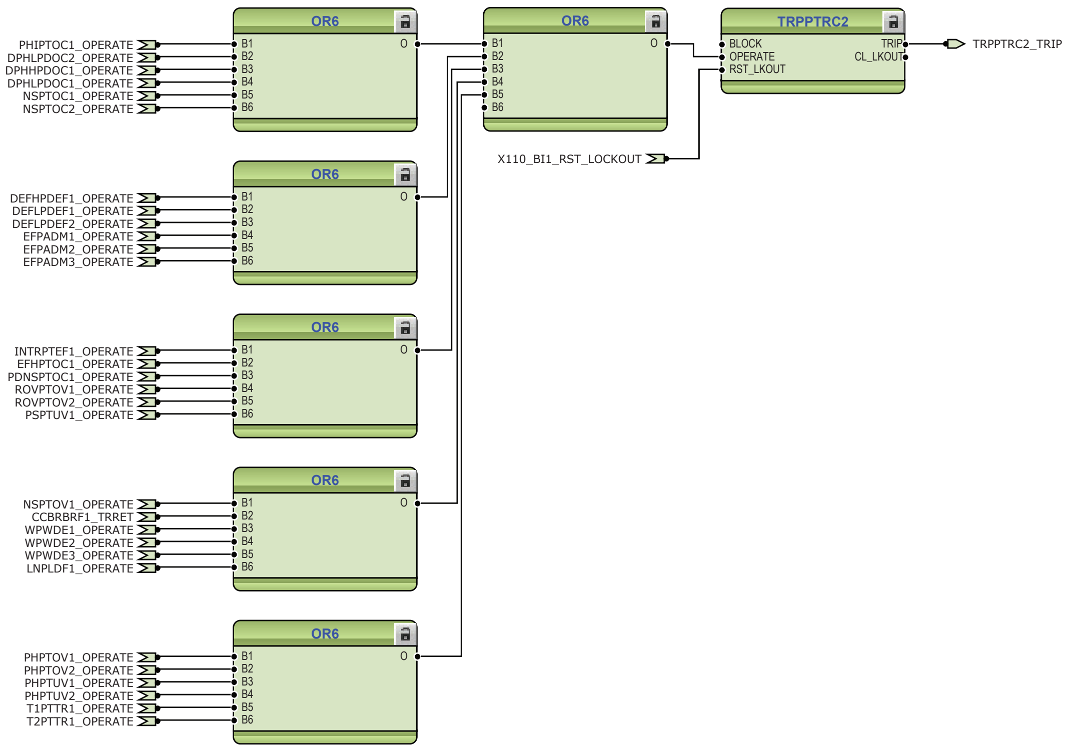


Figure 164: Trip logic TRPPTRC2

3.6.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE 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.

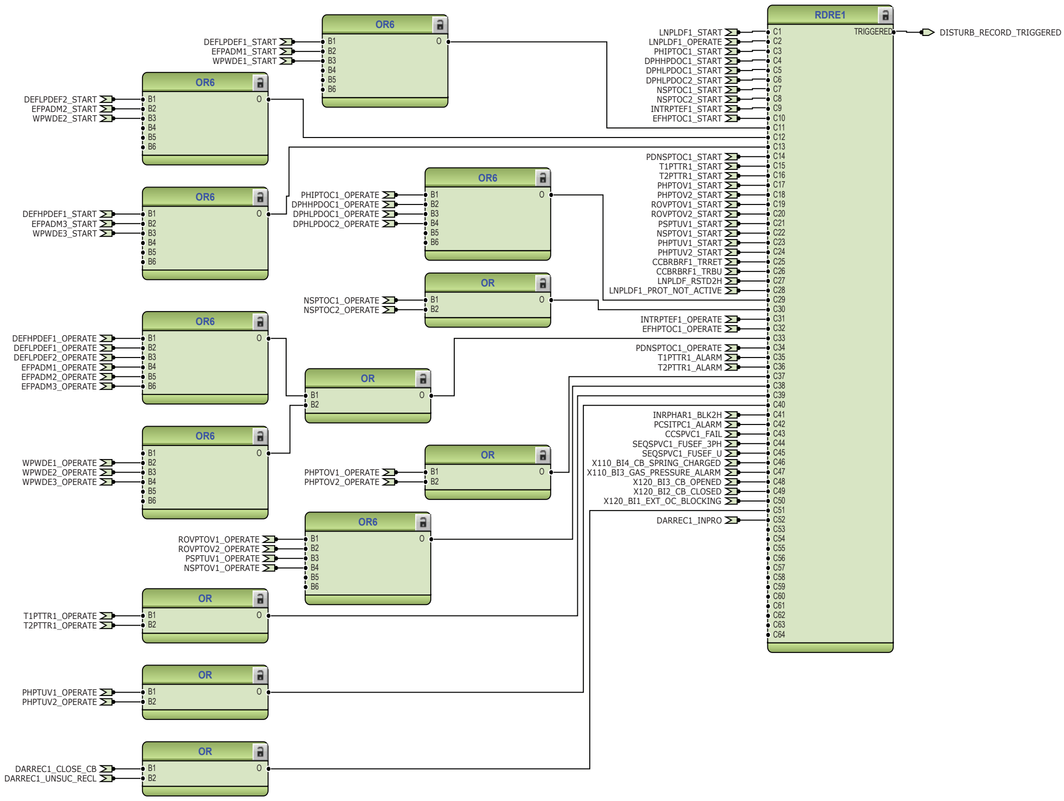


Figure 165: Disturbance recorder

3.6.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measures the calculated sequence component currents or residual current to avoid unnecessary operation.

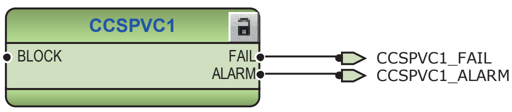


Figure 166: Current circuit supervision function

Fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits at bus side. Failures, such as an open MCB, raise an alarm.

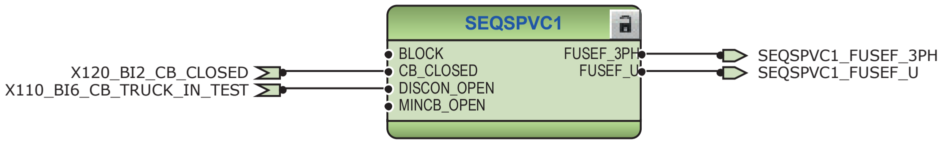


Figure 167: Fuse failure supervision function

The circuit breaker condition monitoring function SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

Set parameters for SSCBR1 properly.

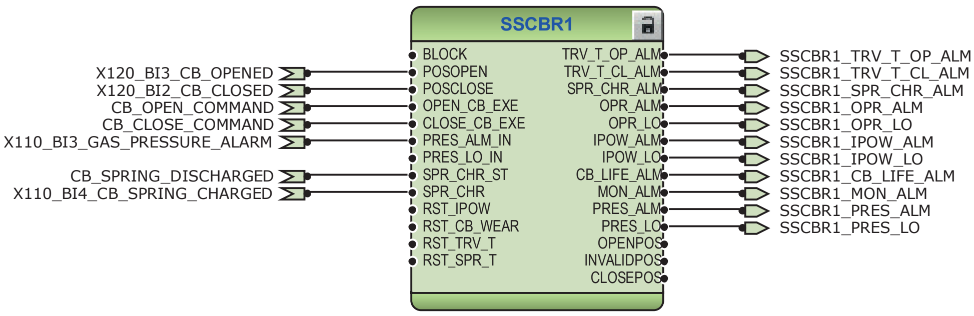


Figure 168: Circuit breaker condition monitoring function

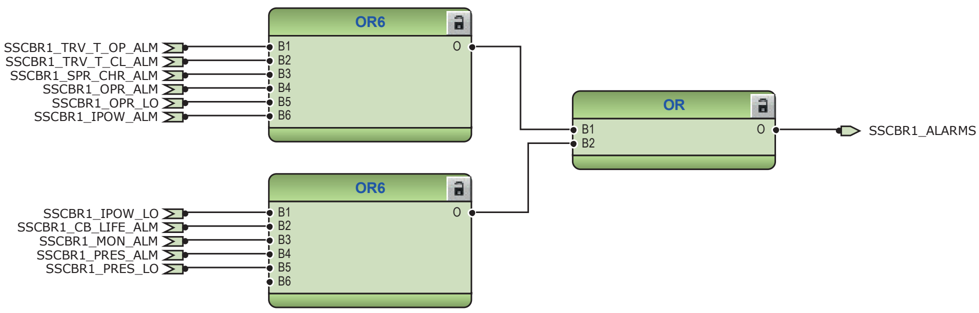


Figure 169: Logic for circuit breaker monitoring alarm

Figure 170: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. The functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 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 TCSSCBR1 properly.

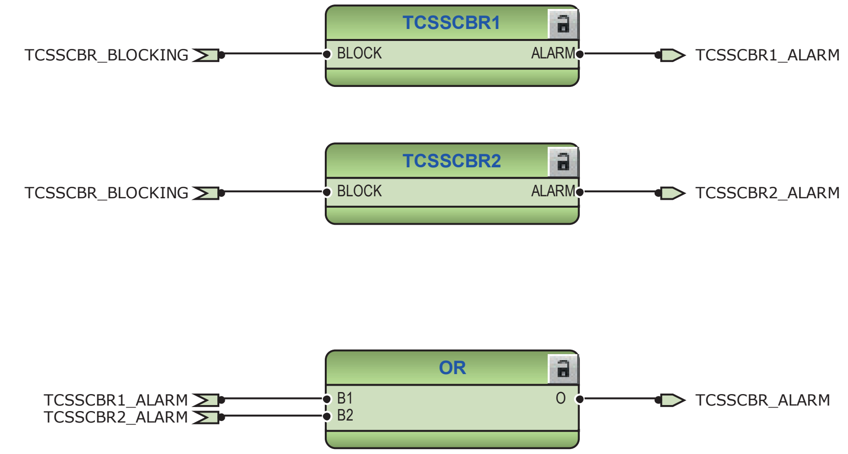


Figure 171: Trip circuit supervision function

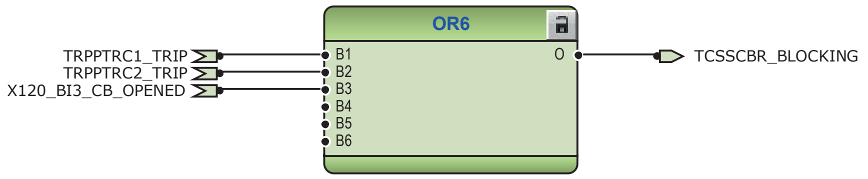


Figure 172: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC 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.

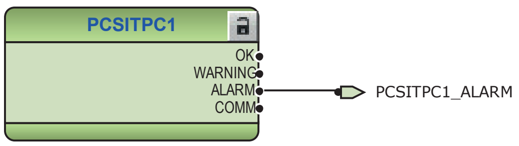


Figure 173: Protection communication supervision function

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.

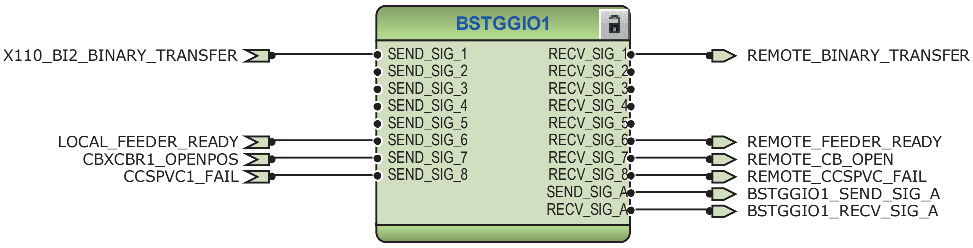


Figure 174: Binary signal transfer function

3.6.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in the standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

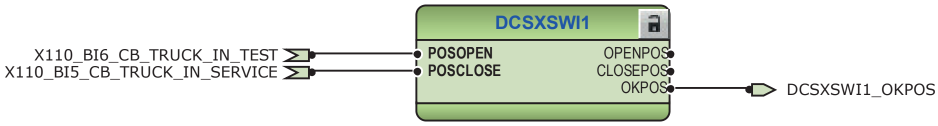


Figure 175: Disconnector 1 control logic

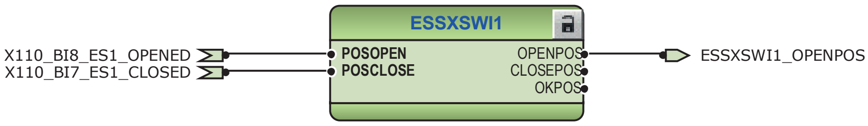


Figure 176: Earth-switch 1 control logic

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 earth-switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and earth-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 earth-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 connected, it disables the circuit breaker closing in the local IED.

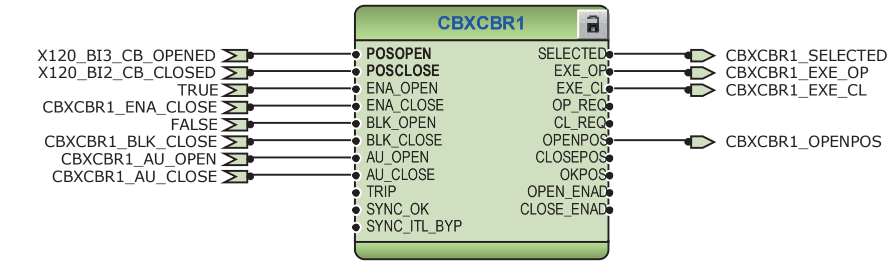


Figure 177: Circuit breaker 1 control logic

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

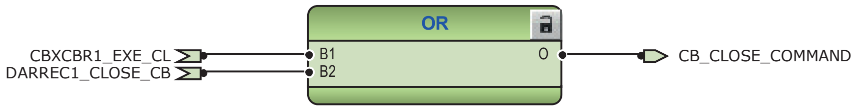


Figure 178: Signals for closing coil of circuit breaker 1

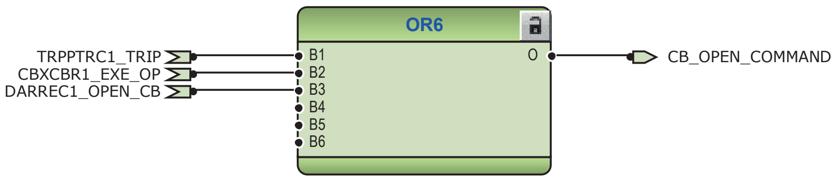


Figure 179: Signals for opening coil of circuit breaker 1

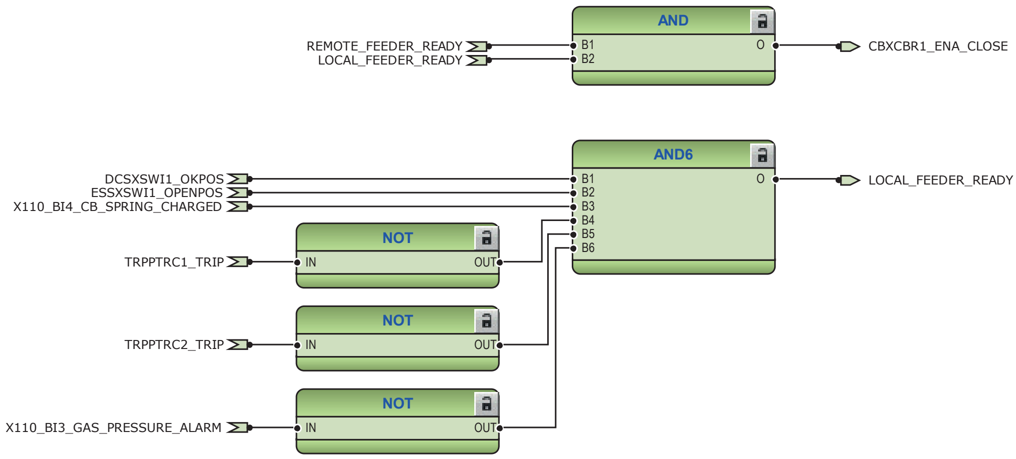


Figure 180: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

Figure 181: Circuit breaker 1 close blocking logic

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

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

Connect the additional signals for closing and opening of the circuit breaker in local or remote mode, if applicable for the application.

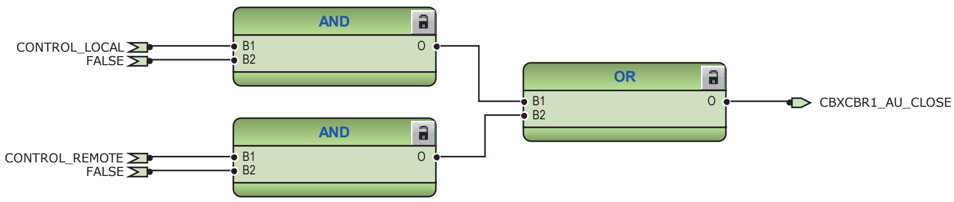


Figure 182: External closing command for circuit breaker 1

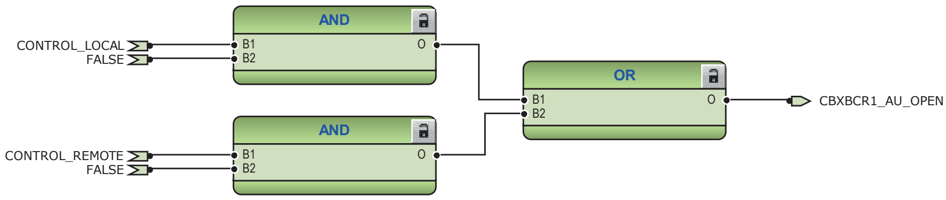


Figure 183: External opening command for circuit breaker 1

3.6.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. 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 IED 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 in 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.

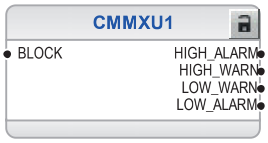


Figure 184: Current measurement: Three-phase current measurement

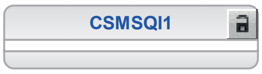


Figure 185: Current measurement: Sequence current measurement

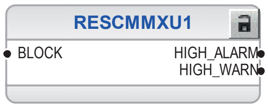


Figure 186: Current measurement: Residual current measurement

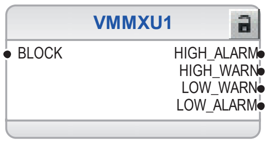


Figure 187: Voltage measurement: Three-phase voltage measurement

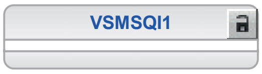


Figure 188: Voltage measurement: Sequence voltage measurement

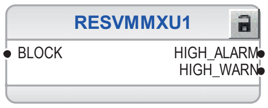


Figure 189: Voltage measurement: Residual voltage measurement

Figure 190: Other measurement: Frequency measurement

Figure 191: Other measurement: Three-phase power and energy measurement

Figure 192: Other measurement: Data monitoring

Figure 193: Other measurement: Load profile record

3.6.3.6 Functional diagrams for I/O and alarm LEDs

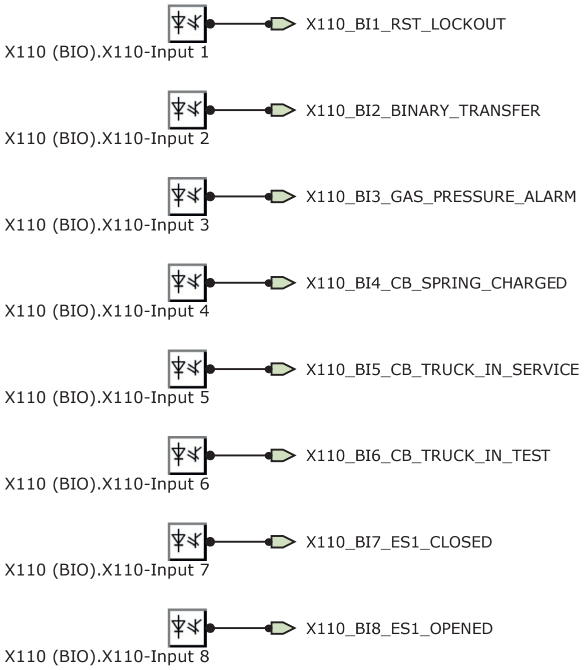


Figure 194: Binary inputs - X110 terminal block

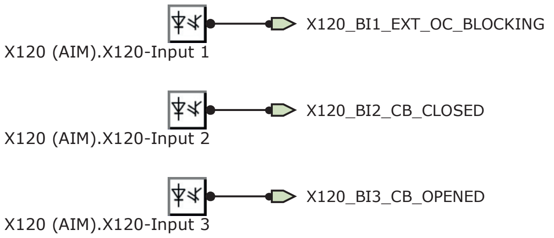


Figure 195: Binary inputs - X120 terminal block

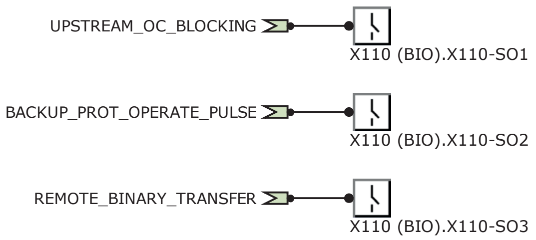


Figure 196: Binary outputs - X110 terminal block

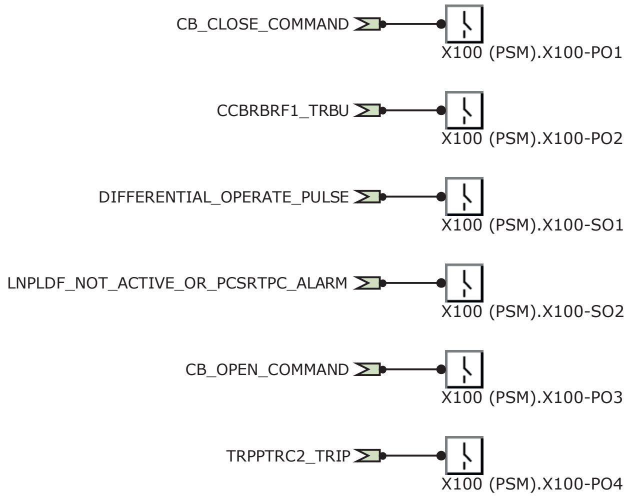
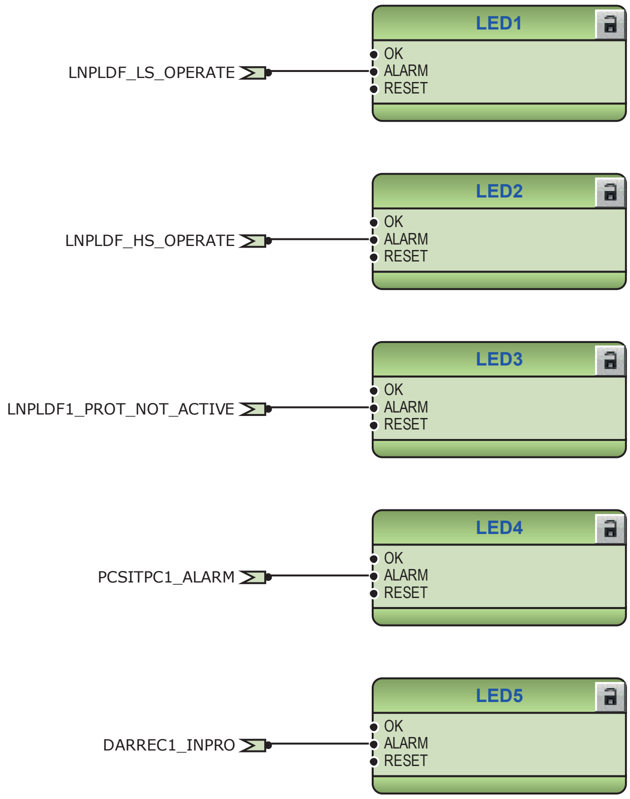


Figure 197: Binary outputs - X100 terminal block



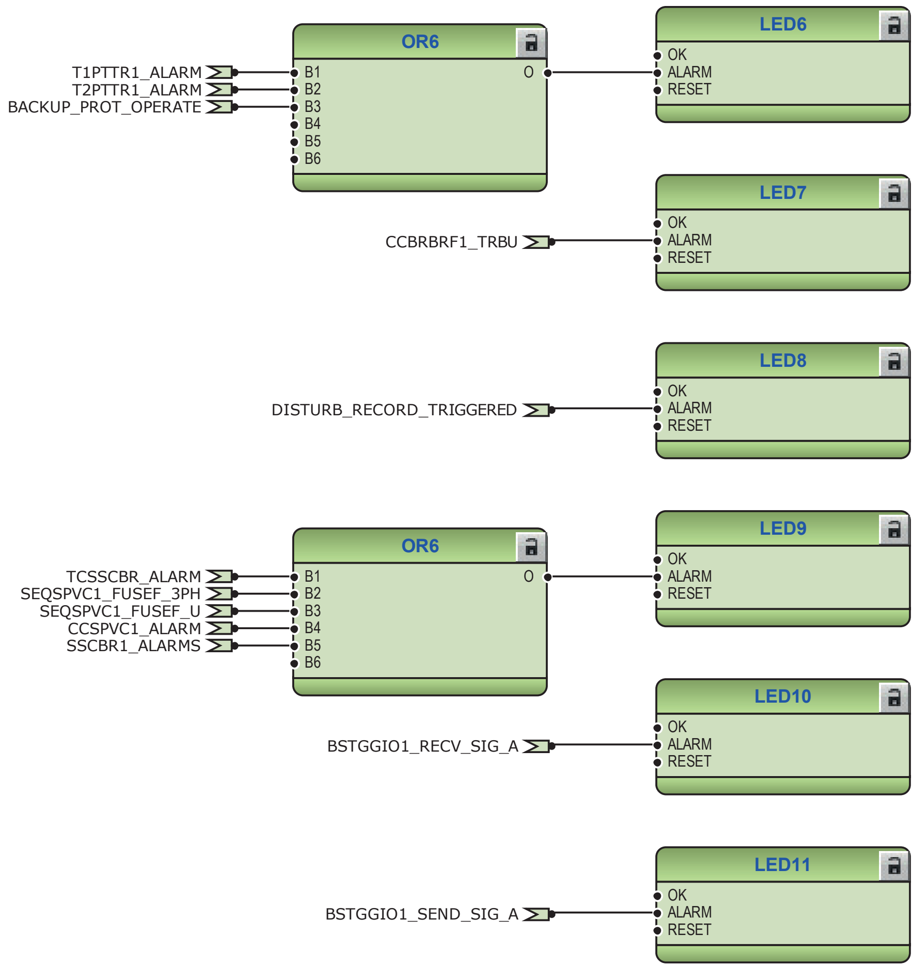


Figure 198: Default LED connection

3.6.3.7 Functional diagrams for other timer logics

The configuration also includes line differential operate, inactive communication and backup protection operate logic. The operate 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.

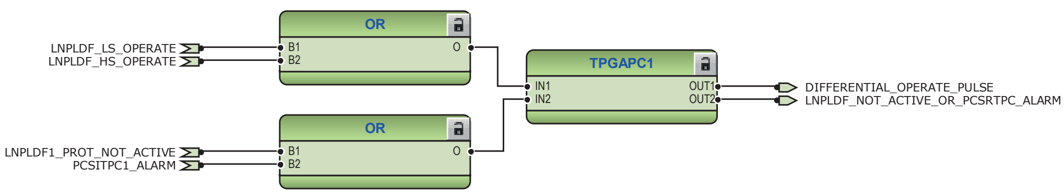


Figure 199: Timer logic for differential operate and communication not active

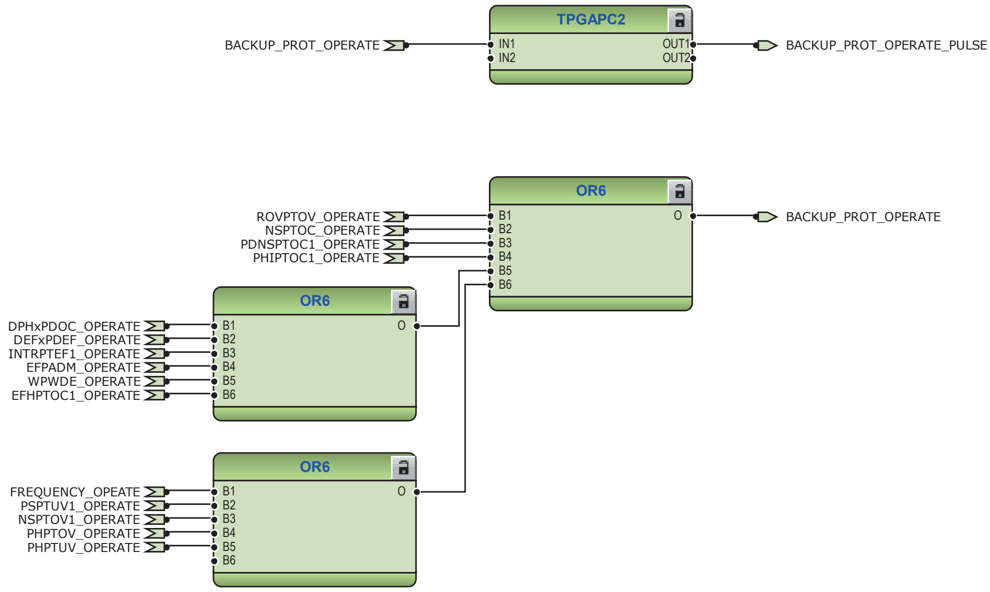


Figure 200: Timer logic for backup protection operate pulse

3.6.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, fault locator, harmonics-based earth-fault protection, high-impedance fault detection function PHIZ, runtime counter for machines and devices MDSOPT and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.7 Standard configuration E

3.7.1 Applications

The standard configuration with directional overcurrent and directional earth-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 earth-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.

3.7.2 Functions

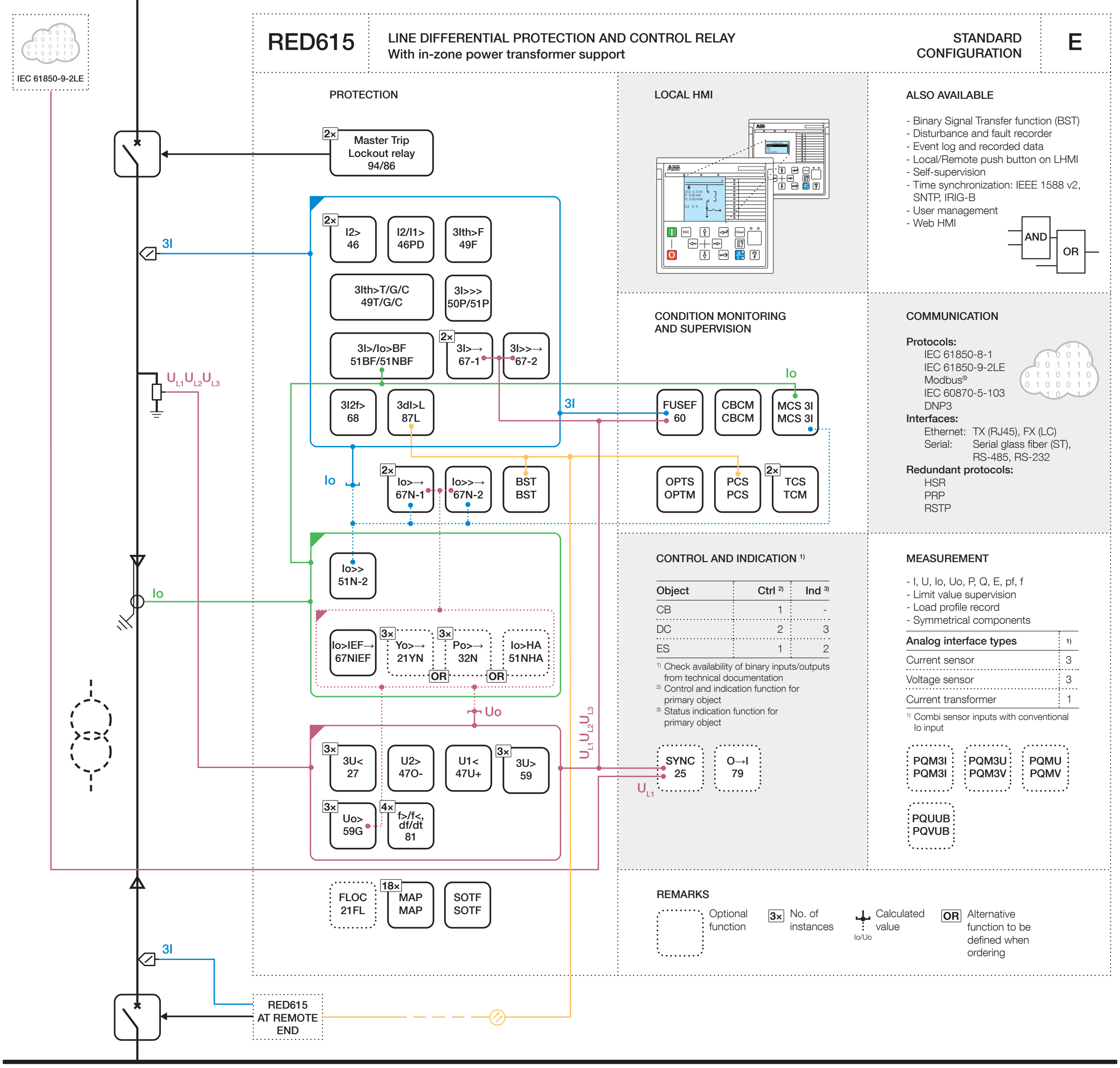


Figure 201: Functionality overview for standard configuration E

3.7.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 31: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker plug not inserted
X110-BI2	Circuit breaker spring charged
X110-BI3	Circuit breaker in opened position
X110-BI4	Circuit breaker closed position
X110-BI5	Circuit breaker truck in test
X110-BI6	Circuit breaker truck in service
X110-BI7	Earthing switch in opened position
X110-BI8	Earthing switch in closed position

Table 32: Default connections for binary outputs

Binary input	Description
X100-PO1	Release for circuit breaker closing
X100-PO2	Circuit breaker closed command
X100-SO1	Release for circuit breaker truck
X100-SO2	Release for earthing switch
X100-PO3	Circuit breaker open command
X100-PO4	Circuit breaker failed signal - Retrip
X110- SO1	–
X110- SO2	–
X110- SO3	–
X110- SO4	–

Table 33: Default connections for LEDs

LED	Description
1	Circuit breaker close enabled
2	Overcurrent protection operated
3	Earth-fault protection operated
4	Line differential protection instantaneous stage operated
5	Line differential protection biased stage operated
6	Thermal protection
7	Line differential protection not active
8	Protection communication supervision alarm
9	Supervision alarm
10	Circuit breaker monitoring alarm
11	–

3.7.2.2 Default disturbance recorder settings

Table 34: Default disturbance recorder analog channels

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

Table 35: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	LNPLDF1 - start	Positive or Rising
2	LNPLDF1 - operate	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	DPHHPDOC1 - start	Positive or Rising
5	DPHLPDOC1 - start	Positive or Rising
6	DPHLPDOC2 - start	Positive or Rising
7	NSPTOC1 - start	Positive or Rising
8	NSPTOC2 - start	Positive or Rising
9	INTRPTEF1 - start	Positive or Rising
10	EFHPTOC1 - start	Positive or Rising
11	DEFLPDEF1 - start	Positive or Rising
	WPWDE1 - start	
	EFPADM1 - start	
12	DEFLPDEF2 - start	Positive or Rising
	WPWDE2 - start	
	EFPADM2 - start	
13	DEFHPDEF1 - start	Positive or Rising
	WPWDE3 - start	
	EFPADM3 - start	
14	PDNSPTOC1 - start	Positive or Rising
15	T1PTTR1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
16	T2PTTR1 - start	Positive or Rising
17	PHPTOV1 - start	Positive or Rising
18	PHPTOV2 - start	Positive or Rising
20	ROVPTOV1 - start	Positive or Rising
21	ROVPTOV2 - start	Positive or Rising
23	PSPTUV1 - start	Positive or Rising
24	NSPTOV1 - start	Positive or Rising
25	PHPTUV1 - start	Positive or Rising
26	PHPTUV2 - start	Positive or Rising
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	PHIPTOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
37	NSPTOC1 - operater	Level trigger off
	NSPTOC2 - operate	
38	INTRPTEF1 - operate	Level trigger off
39	EFHPTOC1 - operate	Level trigger off
40	DEFLPDEF1 - operate	Level trigger off
	WPWDE1 - operate	
	EFPADM1 - operate	
	DEFLPDEF2 - operate	
	WPWDE2 - operate	
	EFPADM2 - operate	
	DEFLPDEF3 - operate	
	WPWDE3 - operate	
	EFPADM3 - operate	
41	PDNSPTOC1 - operate	Level trigger off
42	T1PTTR1 - alarm	Level trigger off
43	T2PTTR2 - alarm	Level trigger off
44	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
45	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	PSPTUV1 - operate	
	NSPTOV1 - operate	
46	T1PTTR1 - operate	Level trigger off
	T2PTTR2 - operate	

Table continues on the next page

Channel	ID text	Level trigger mode
47	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
49	INRPHAR1 - blk2h	Level trigger off
50	PCSITPC1 - alarm	Level trigger off
51	CCSPVC1 - alarm	Level trigger off
52	X110BI2 - CB spring discharged	Level trigger off
53	X110BI3 - CB opened	Level trigger off
54	X110BI4 - CB closed	Level trigger off
55	DARREC1 - unsuc recl	Level trigger off
	DARREC1 - close CB	
56	DARREC1 - inpro	Level trigger off
57	General start pulse	Level trigger off
58	General operate pulse	Level trigger off

3.7.3 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 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 or via binary input.

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

3.7.3.1 Functional diagrams for protection

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

Line differential protection with in-zone power transformer LNPLDF1 is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by predefined settings if the ENA_MULT_HS input is activated. In this configuration, it is activated by the open status information of the remote-end circuit breaker and earth switch, and if the disconnector is not in the intermediate state. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult*, in case of internal fault.

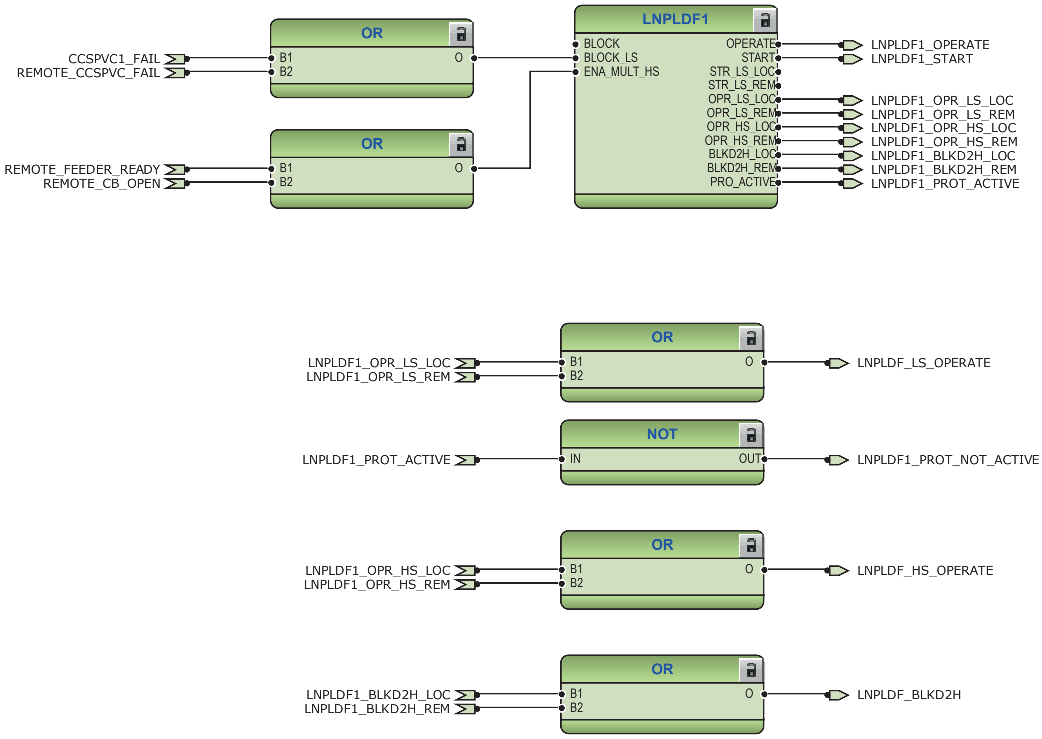


Figure 202: Line differential protection functions

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1 is blocked when line differential is active.

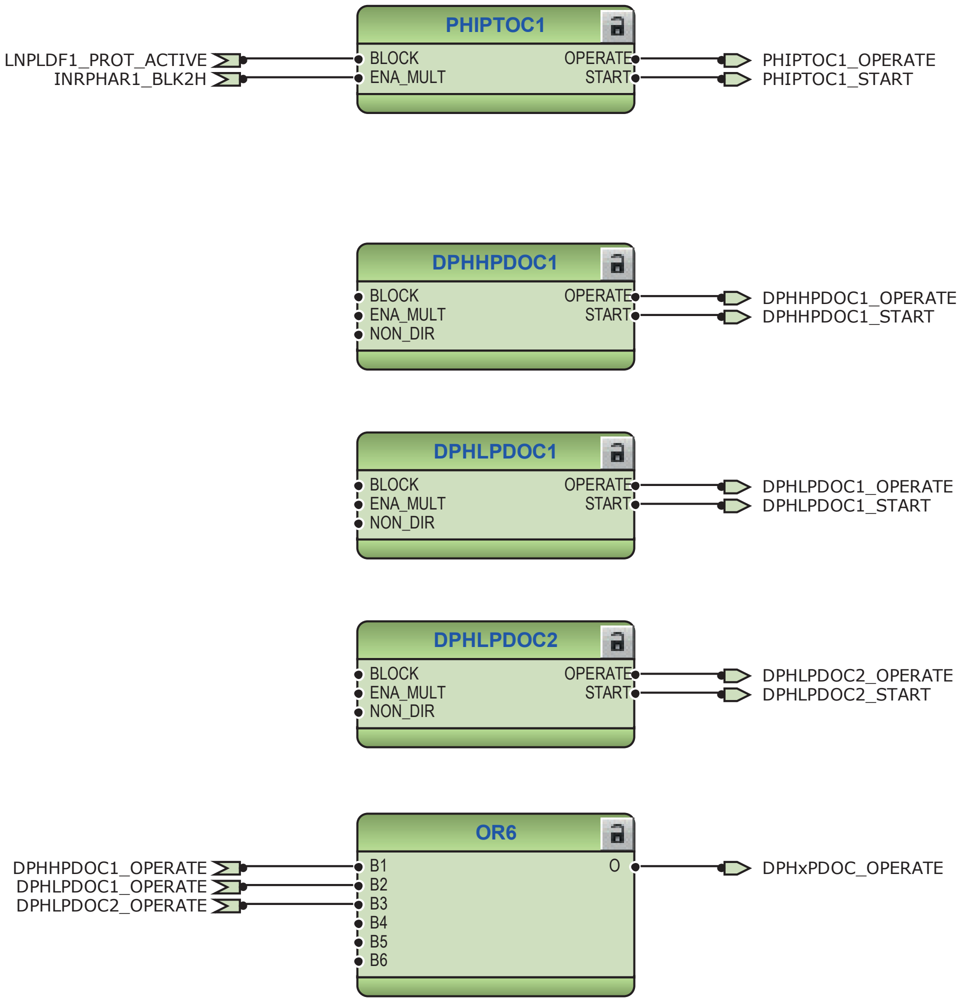


Figure 203: Overcurrent protection functions

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

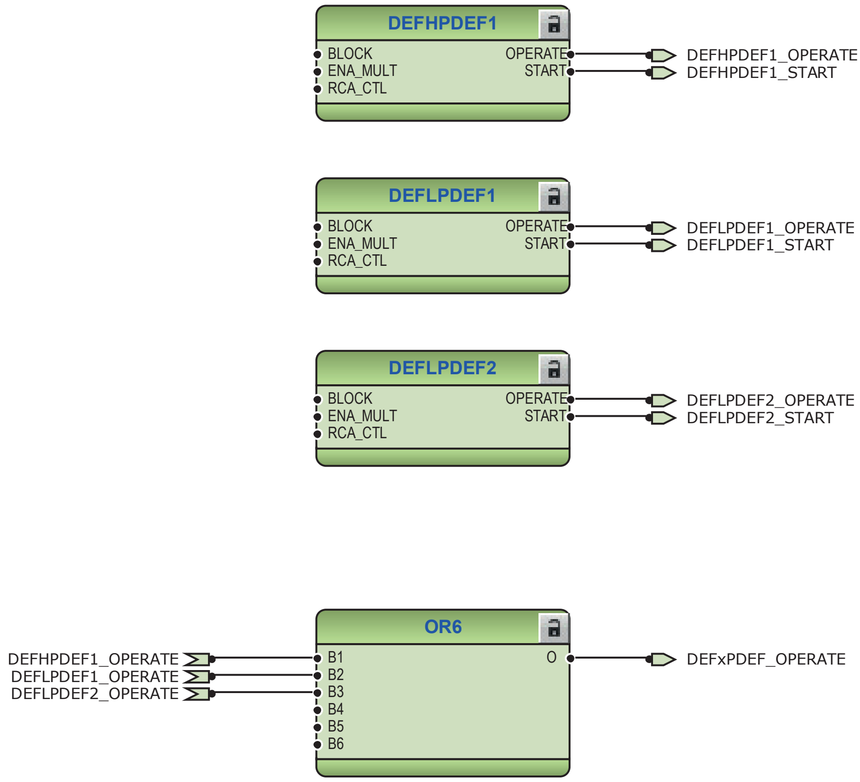


Figure 204: Directional earth-fault protection function

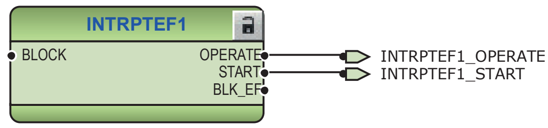


Figure 205: Transient/intermittent earth-fault protection function

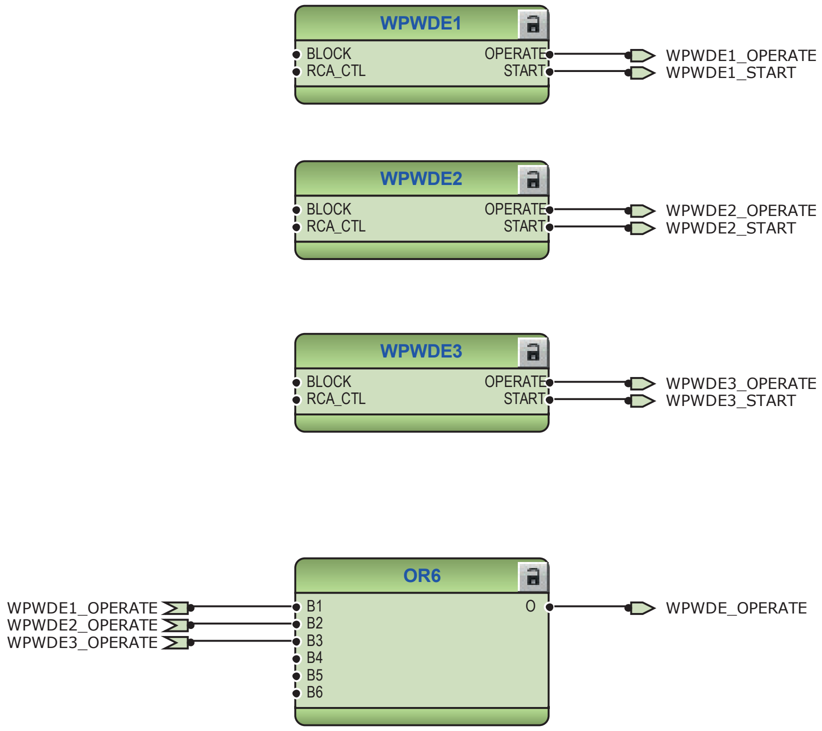


Figure 206: Wattmetric earth-fault protection function

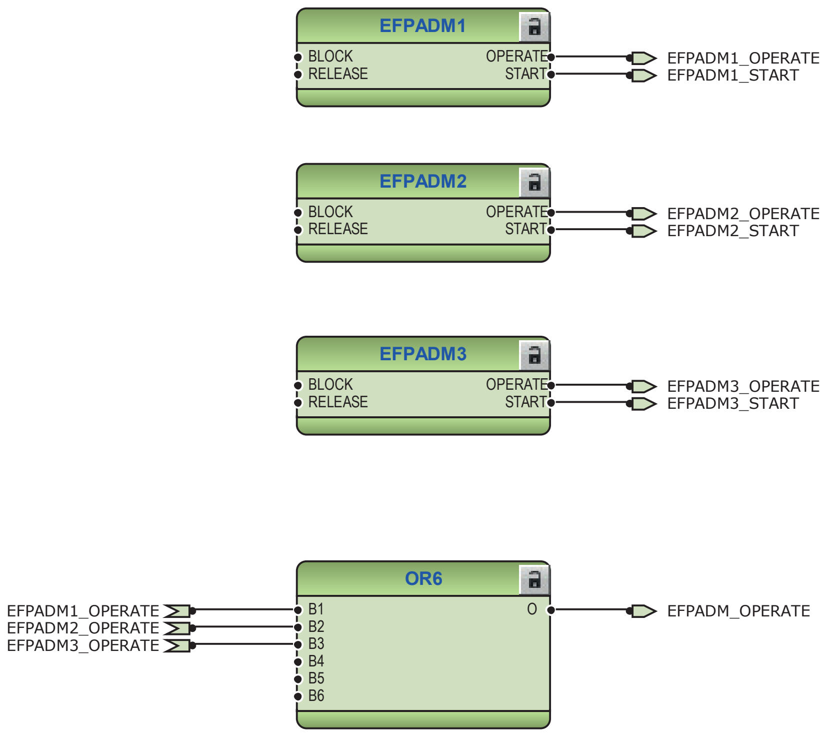


Figure 207: Admittance-based earth-fault protection function

Non-directional (cross-country) earth-fault protection, using calculated Io, EFHPTOC1 protects against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

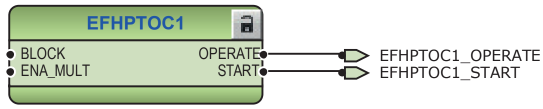


Figure 208: Earth-fault protection function

The output `BLK2H` of three-phase inrush detector INRPHAR1 offers the possibility to either block the function or multiply the active settings for any of the available overcurrent function blocks.

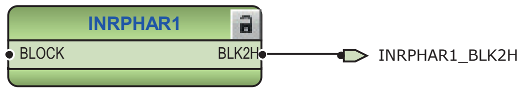


Figure 209: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. The function is blocked on detection of failure in current secondary circuit.

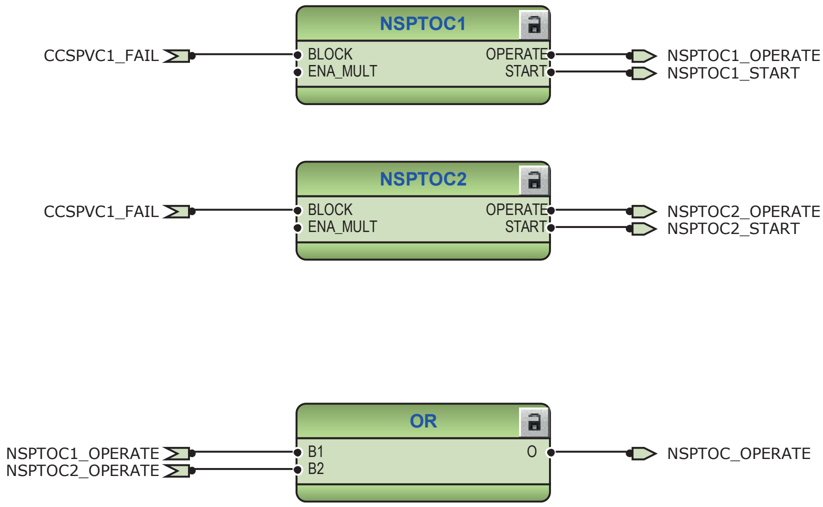


Figure 210: Negative sequence overcurrent protection function

Phase discontinuity protection PDNSPTOC1 protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

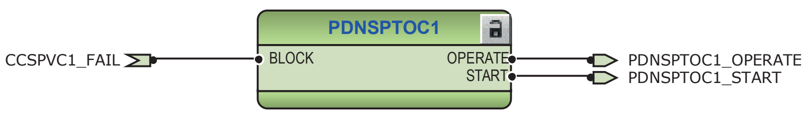


Figure 211: Phase discontinuity protection function

Two thermal overload protection functions are incorporated one with one time constant T1PTTR1 and other with two time constants T2PTTR1 for detecting overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

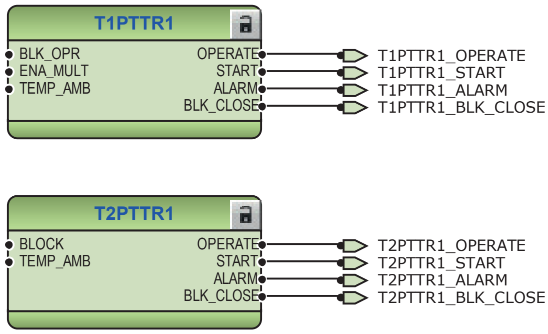


Figure 212: Thermal overcurrent protection function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. However, only two instances of PHPTOV and PHPTUV are used in the configuration. Positive-sequence undervoltage PSPTUV and negative-sequence overvoltage NSPTOV protection functions enable voltage-based unbalance protection.

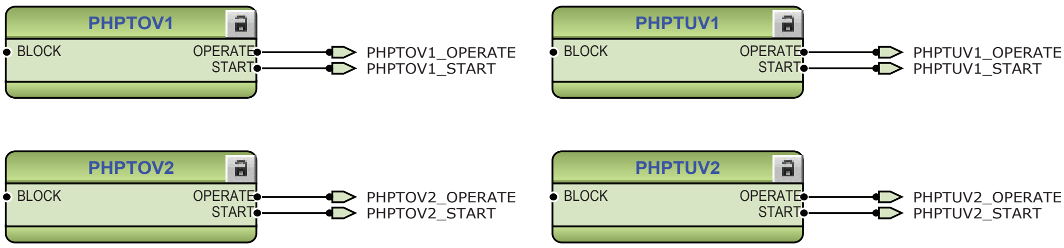


Figure 213: Overvoltage and undervoltage protection function

Residual overvoltage protection ROVPTOV provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality.

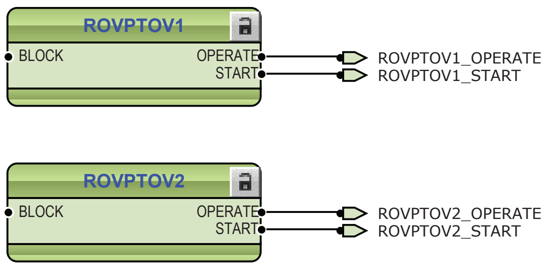


Figure 214: Residual overvoltage protection function

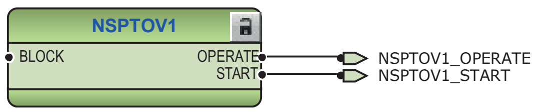


Figure 215: Negative sequence overvoltage protection function

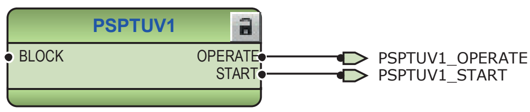


Figure 216: Positive sequence undervoltage protection function

The optional autoreclosing function is configured to be initiated by operate signals from a number of protection stages through the INIT_1...6 inputs. It is possible to create individual autoreclose 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-SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the CB_READY input in DARREC1. 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.

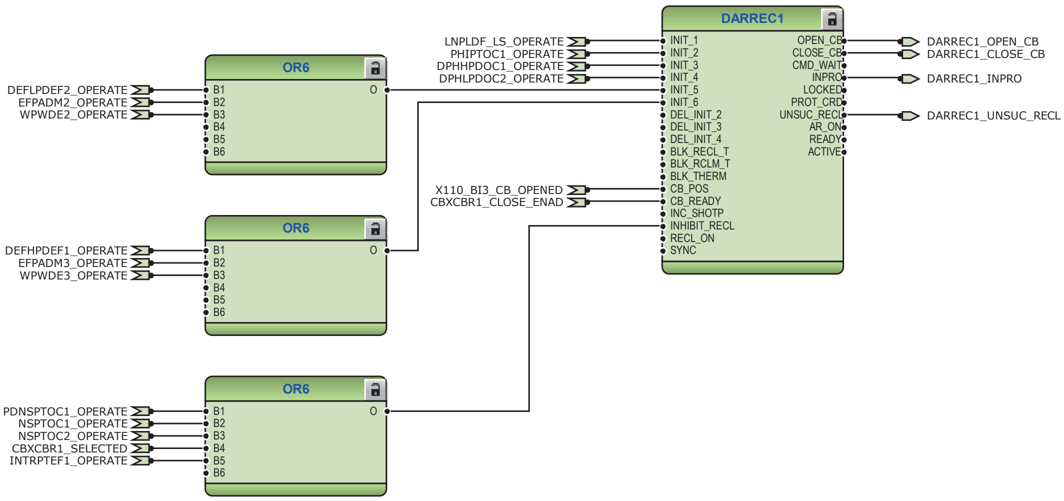


Figure 217: Autoreclosing function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by a number of different protection functions available in the IED. 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 operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The same TRRET output is also connected to the binary output X100:PO4.

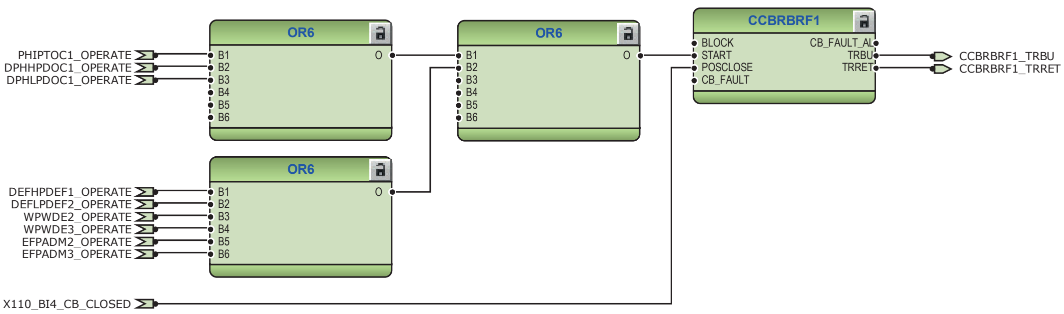


Figure 218: Circuit breaker failure protection function

General start and operate from all the functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 can be connected to binary outputs.

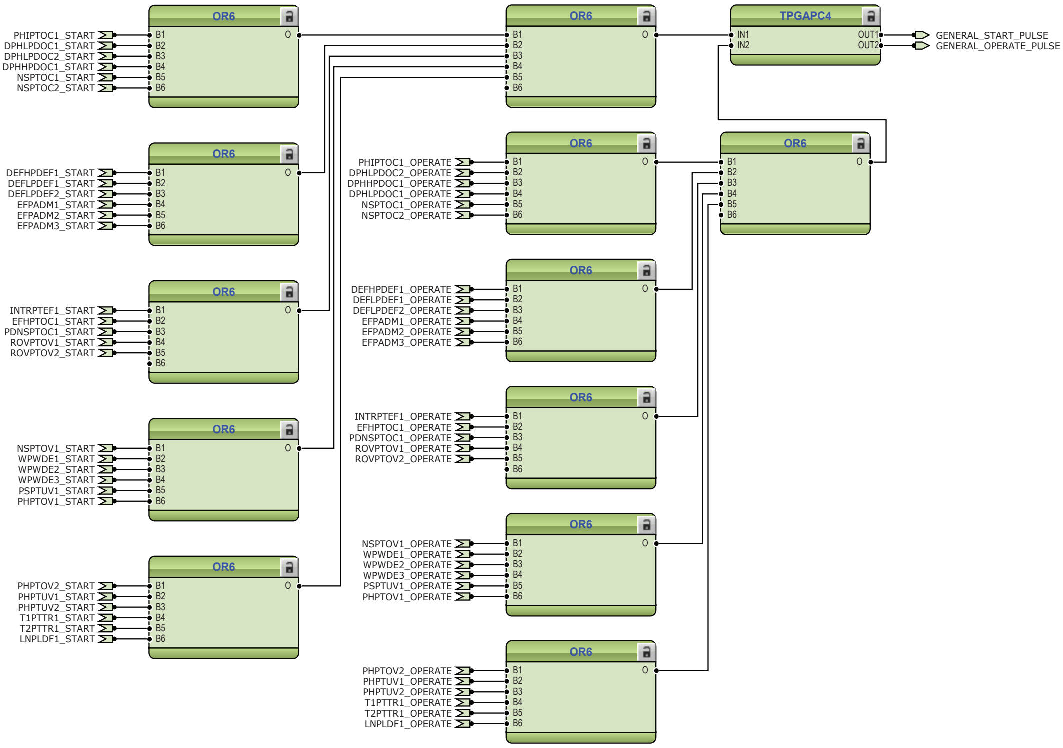


Figure 219: General start and operate signals

The operate signals from the protection functions are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output from TRPPTRC1 trip logic functions is available at binary output X100:PO3. 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 required, binary input can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

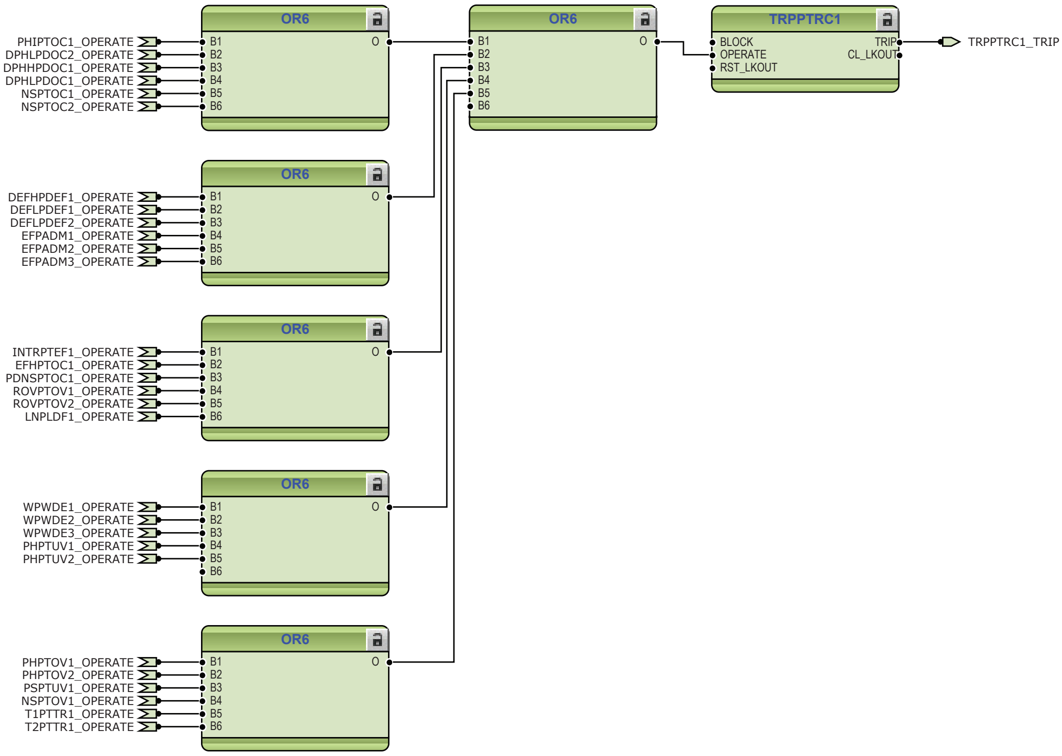


Figure 220: Trip logic TRPPTRC1

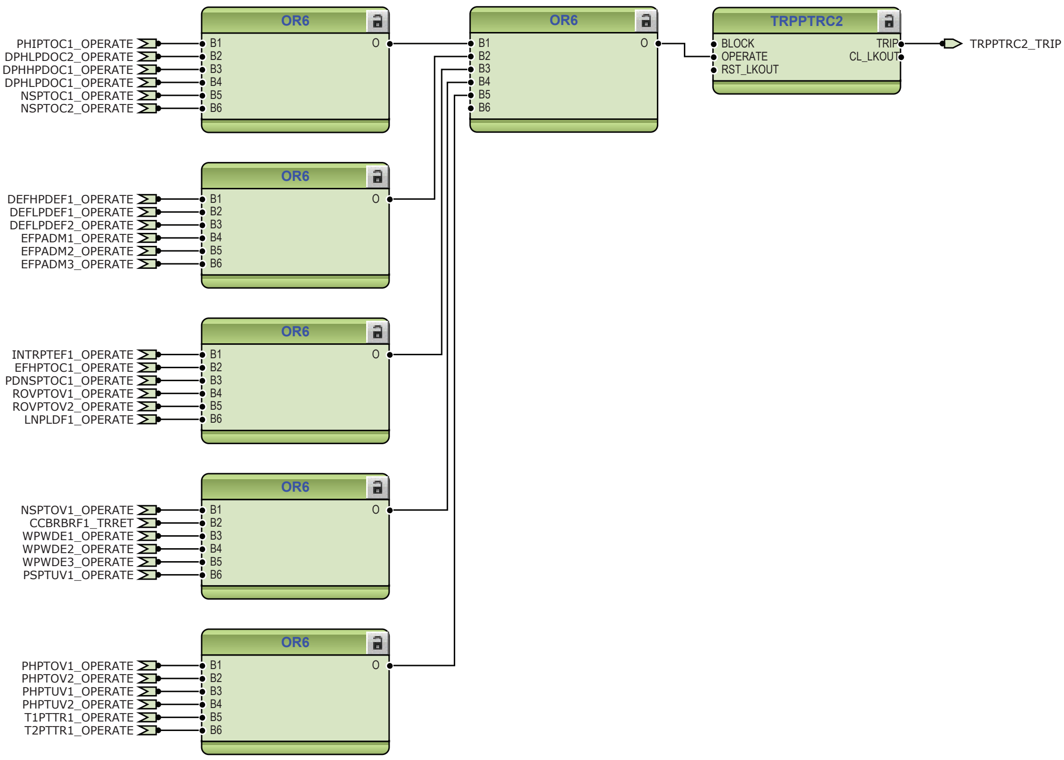


Figure 221: Trip logic TRPPTRC2

3.7.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE 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.

Once the order of signals connected to binary inputs of RDRE is changed, make the changes to parameter setting tool.

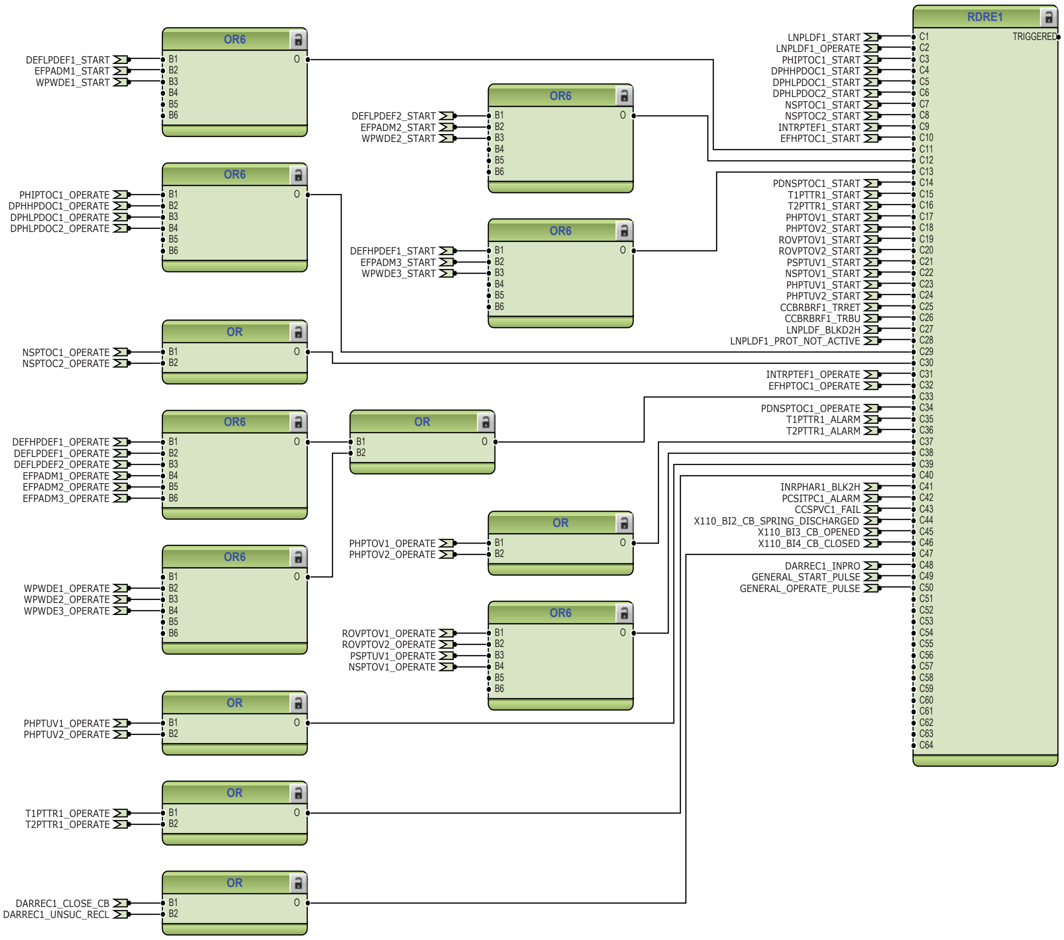


Figure 222: Disturbance recorder

3.7.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measures the calculated sequence component currents or residual current to avoid unnecessary operation.

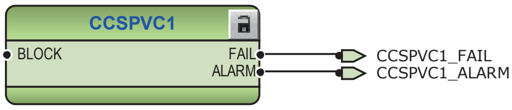


Figure 223: Current circuit supervision function

Circuit-breaker condition monitoring SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

Set the parameters for SSCBR1 properly.

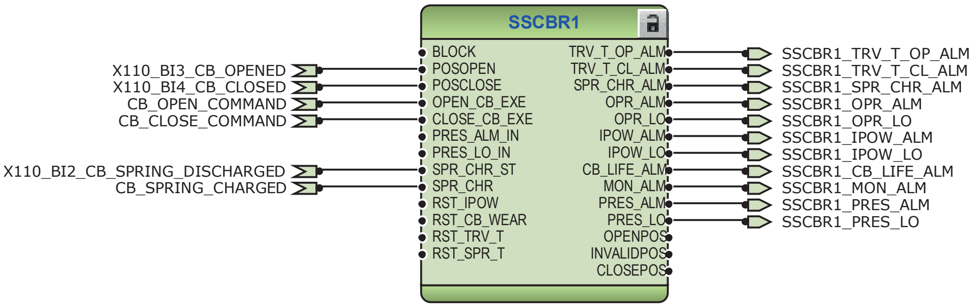


Figure 224: Circuit breaker condition monitoring function

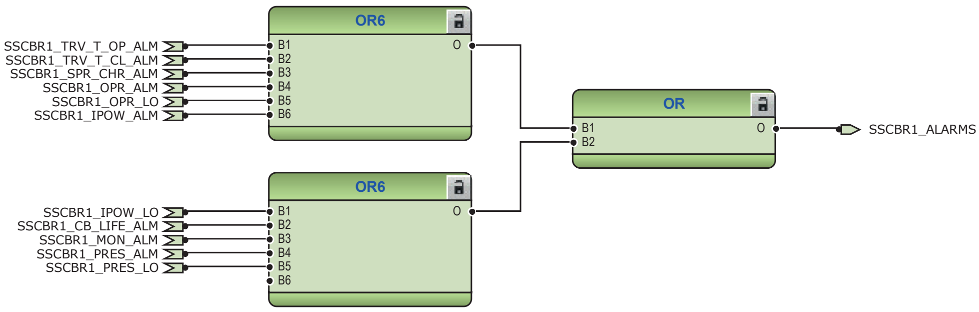


Figure 225: Logic for circuit breaker monitoring alarm

Figure 226: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. The functions are blocked by both the master trip TRPPTRC1 and TRPPTRC2 and the binary input X110:BI1 indicating the IED plug out.

It is assumed that there is external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR1 properly.

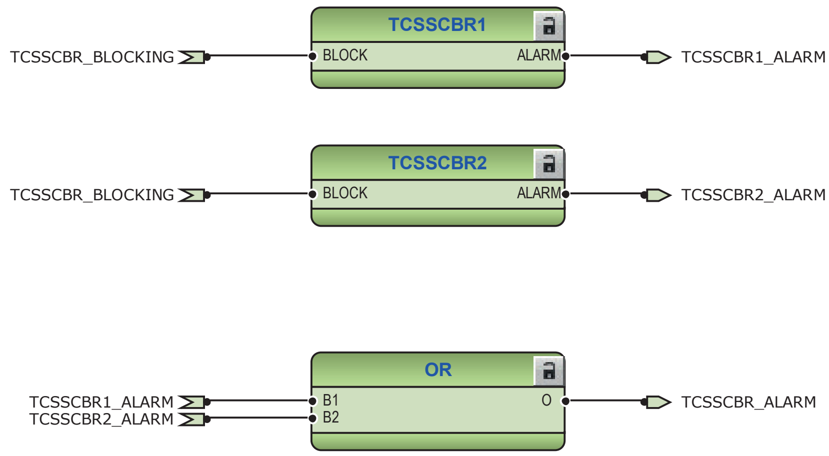


Figure 227: Trip circuit supervision function

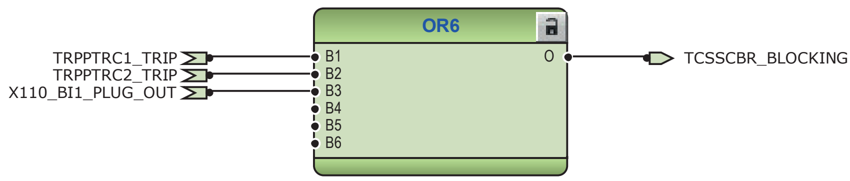


Figure 228: Logic for blocking of trip circuit supervision

Protection communication supervision PCSITPC1 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.

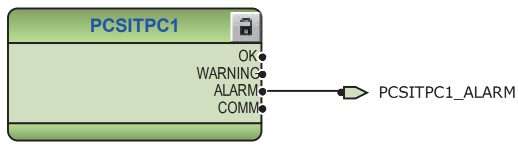


Figure 229: Protection communication supervision function

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, 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.

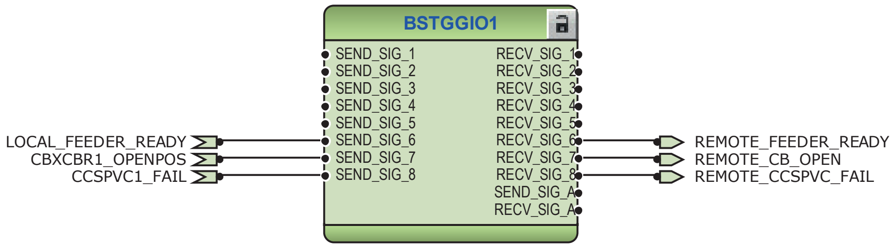


Figure 230: Binary signal transfer

3.7.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in the standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1 respectively.

The configuration also includes closed enable interlocking logic for disconnector and earthing switch. These signals are available for binary outputs X100:SO1 and X100:SO2 respectively.

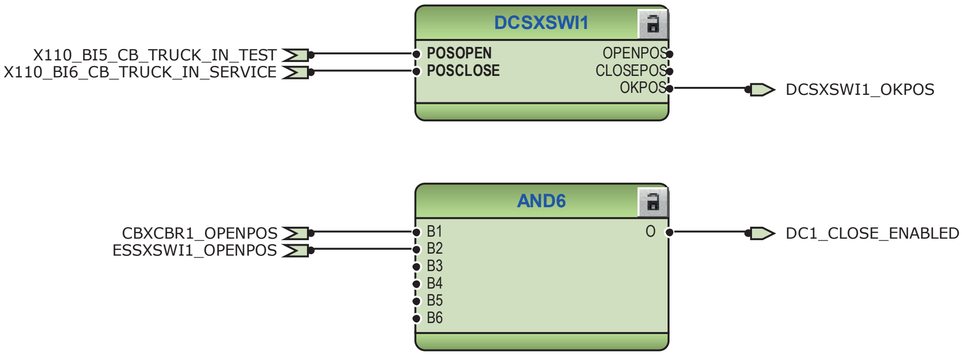


Figure 231: Disconnector 1 interlocking logic

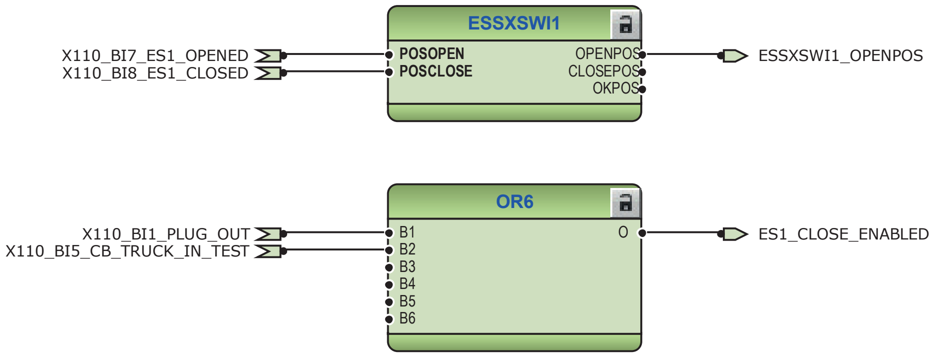


Figure 232: Earth-switch 1 control logic

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 earth-switch position status, status of the trip logics and remote feeder position indication. Master trip logic, disconnector and earth-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 earth-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 connected, it disables the circuit breaker closing in the local IED.

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

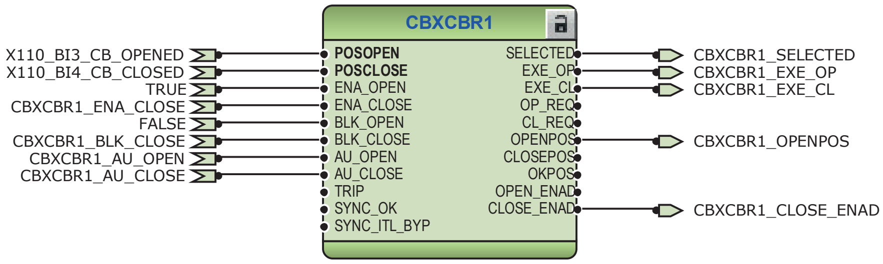


Figure 233: Circuit breaker 1 control logic

Figure 234: Signals for closing coil of circuit breaker 1

Figure 235: Signals for opening coil of circuit breaker 1

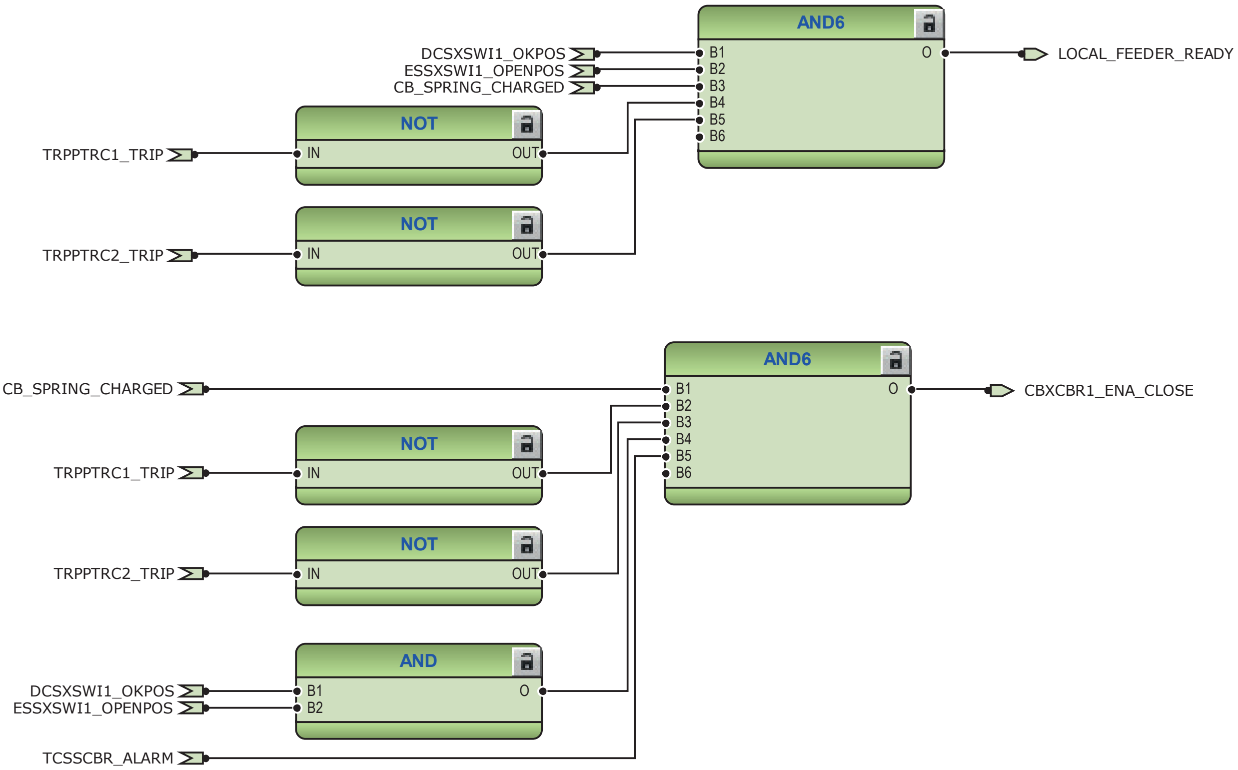


Figure 236: Circuit breaker close enable logic

Connect higher-priority conditions before enabling the circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

Figure 237: Circuit breaker 1 close blocking logic

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

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

Connect the additional signals for closing and opening of the circuit breaker in local or remote mode, if it is applicable for the application.

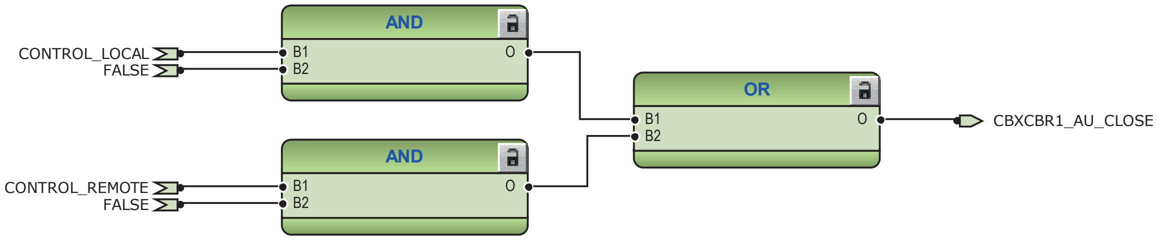


Figure 238: External closing command for circuit breaker 1

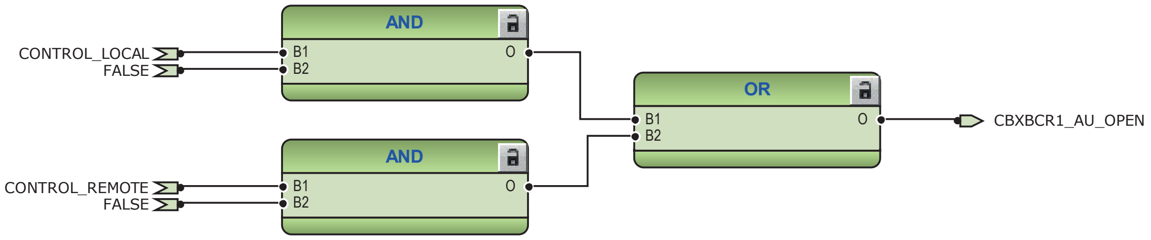


Figure 239: External opening command for circuit breaker 1

3.7.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. 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 IED are measured by the three-phase voltage measurement function VMMXU1. The voltage input is connected to the X130 card in the back panel. Sequence voltage measurement VSMSQI1 measures the sequence voltage.

The measurements can be seen in 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.

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.

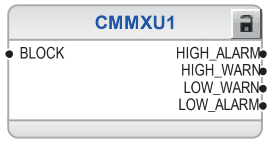


Figure 240: Current measurement: Three-phase current measurement

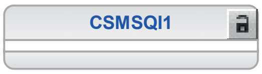


Figure 241: Current measurement: Sequence current measurement

Figure 242: Current measurement: Residual current measurement

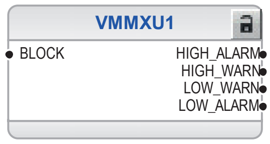


Figure 243: Voltage measurement: Three-phase voltage measurement

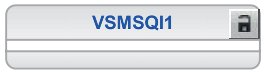


Figure 244: Voltage measurement: Sequence voltage measurement

Figure 245: Other measurement: Frequency measurement

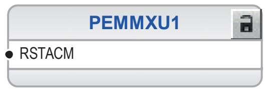


Figure 246: Other measurement: Three-phase power and energy measurement

Figure 247: Other measurement: Data monitoring

Figure 248: Other measurement: Load profile record

The power quality functions CMHAI1 and VMHAI1 can be used to measure the harmonic contents of the phase current and phase voltages. The voltage variation, that is, sage and swells can be measured by the voltage variation function PHQVVR1. By default, these power quality functions are not included in the configuration. Depending on the application, the required logic connections can be made by PCM600.

3.7.3.6 Functional diagrams for I/O and alarm LEDs

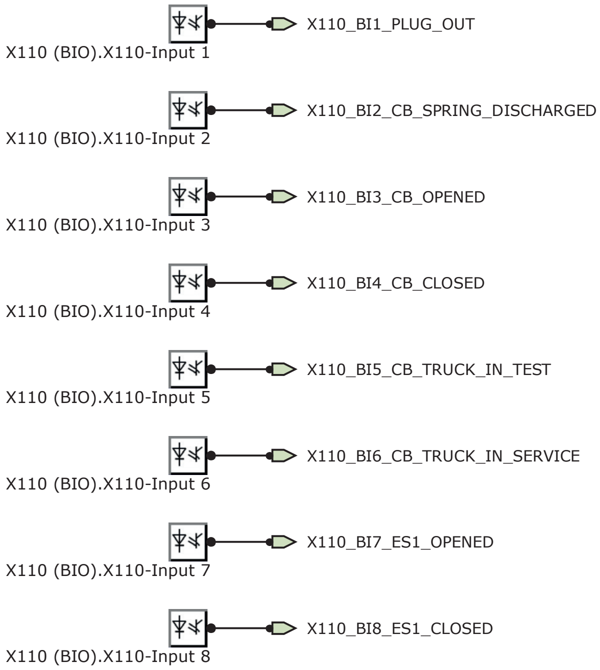


Figure 249: Default binary inputs - X110

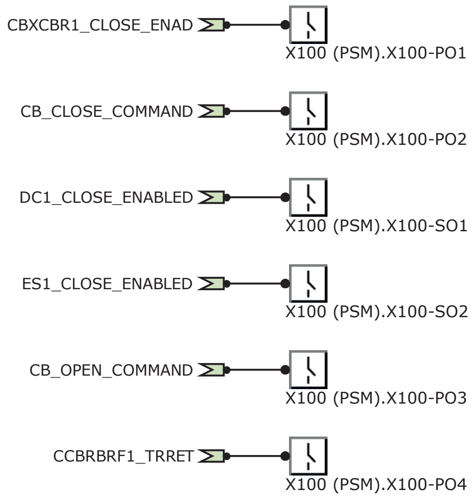
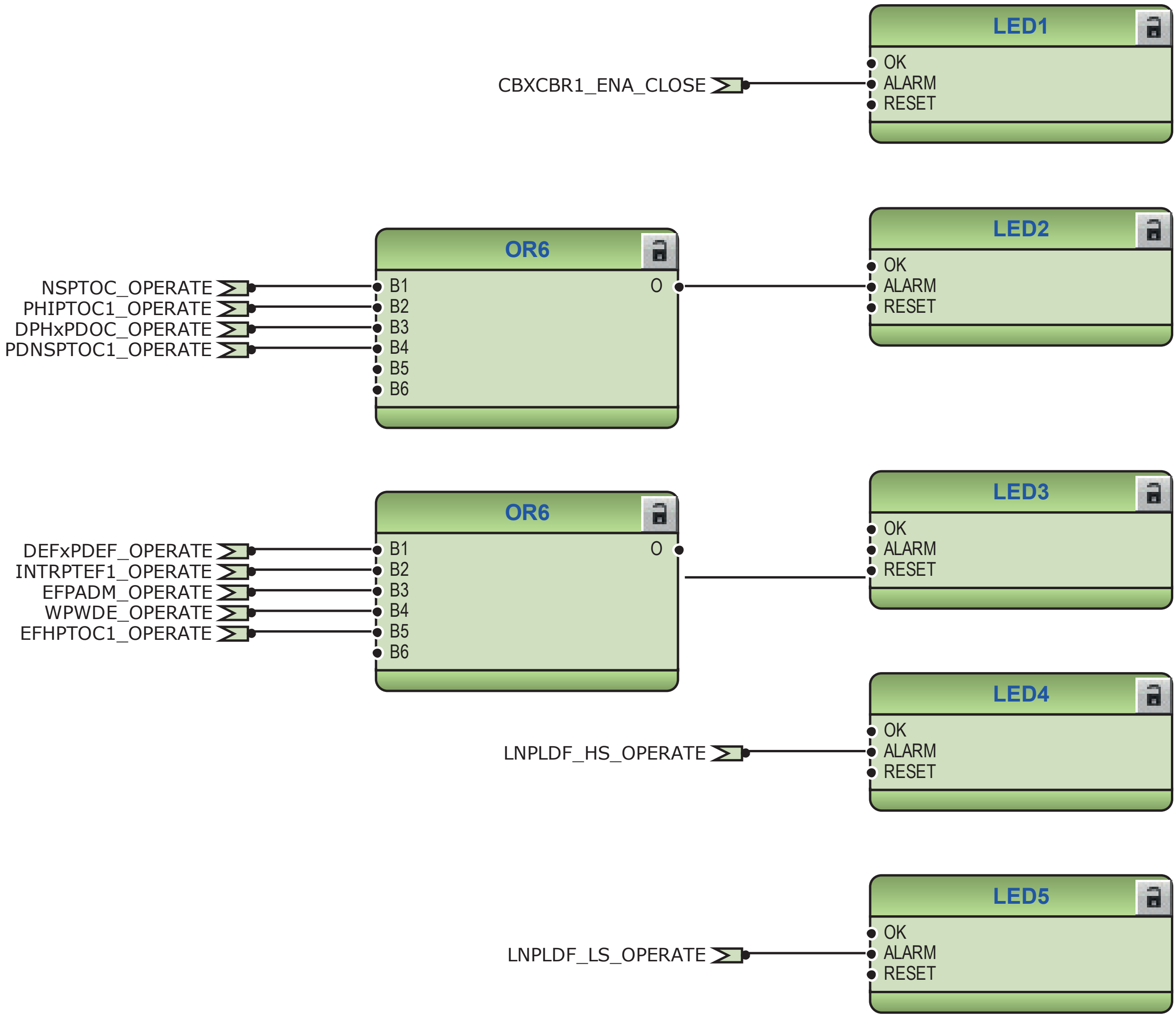


Figure 250: Default binary outputs - X100


LED1
OK
ALARM
RESET
CBXCBR1_ENA_CLOSE
OR6
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
NSPTOC_OPERATE
PHIPTOC1_OPERATE
DPHxPDOC_OPERATE
PDNSPTOC1_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
DEFxPDEF_OPERATE
INTRPTEF1_OPERATE
EFPADM_OPERATE
WPWDE_OPERATE
EFHPTOC1_OPERATE
LED4
OK
ALARM
RESET
LNPLDF_HS_OPERATE
LED5
OK
ALARM
RESET
LNPLDF_LS_OPERATE

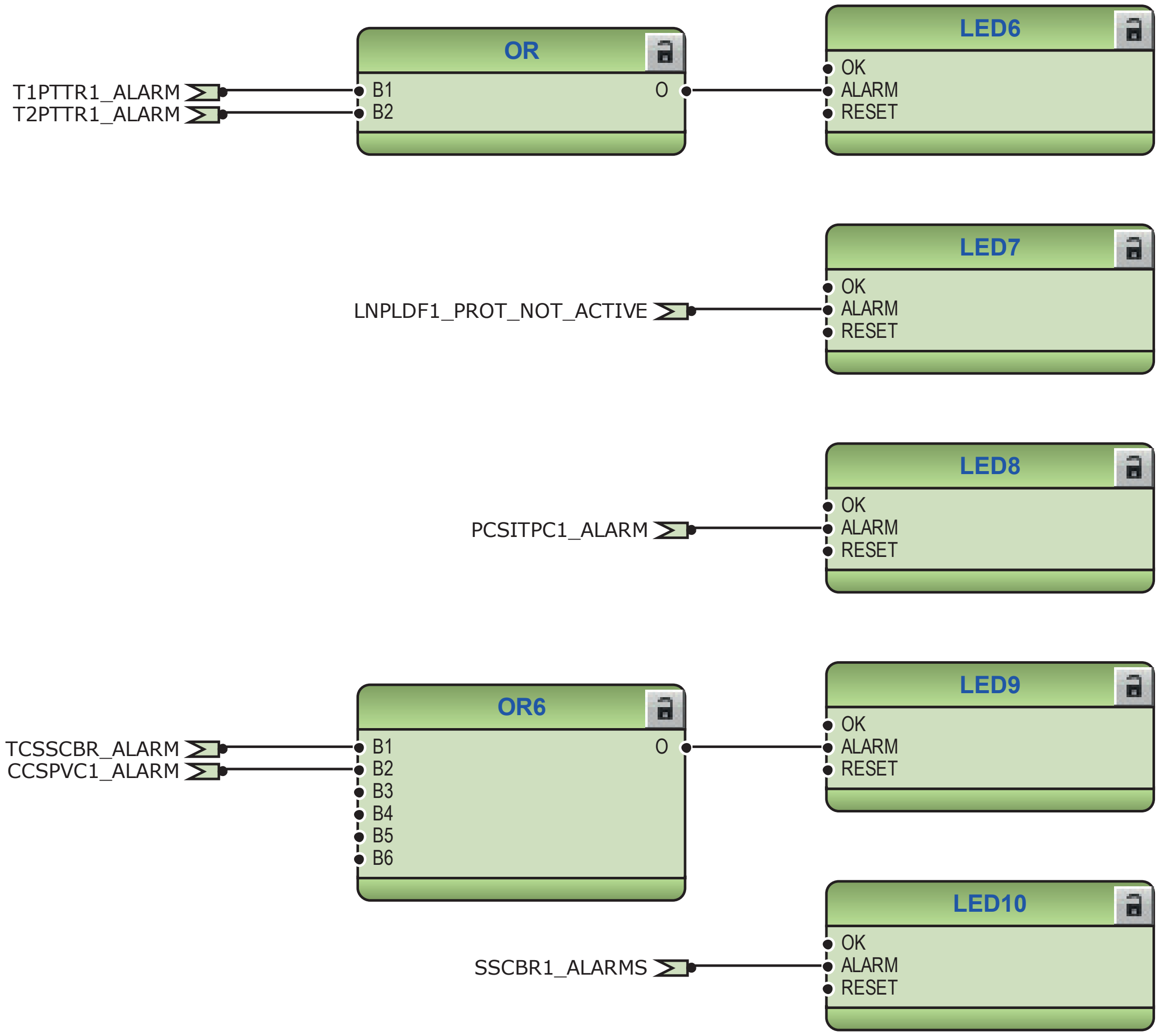


Figure 251: Default LED connection

3.7.3.7 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, fault locator, harmonics-based earth-fault protection, runtime counter for machines and devices MDSOPT and few instances of different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

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 36: 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

Current transformer selection

Non-directional overcurrent protection does not set high requirements on the accuracy class or on the actual accuracy limit factor (F_a) of the CTs. It is, however, recommended to select a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the protection relay is not exceeded. This is always fulfilled when

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

I_{kmax} is the highest fault current.

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

Recommended start current settings

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

Current start value < 0.7 × (I_{kmin} / I_{1n})

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

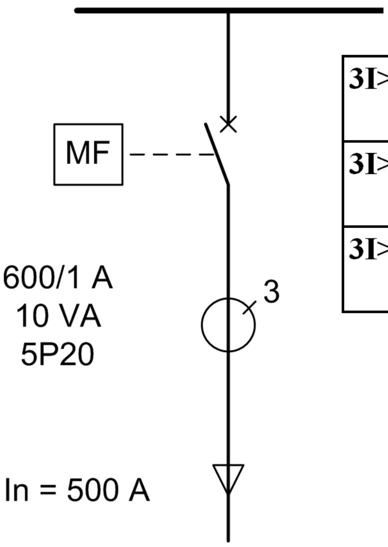
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

F_a > 20 × *Current start value* / I_{1n}

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

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.



3I>	1200 A 0.75 s	2.00 x I_{2n} 0.75 s
3I>>	1800A 0.50 s	3.00 x I_{2n} 0.50 s
3I>>>	3500 A 0.20 s	5.83 x I_{2n} 0.20 s

Figure 252: Example of three-stage overcurrent protection

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in *Figure 252*). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in *Figure 252*.

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

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 37: Phase current inputs included in configurations A, B, C and D

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

5.1.1.2 Residual current

Table 38: Residual current input included in configurations A, B, C and D

Terminal	Description
X120:13-14	Io

Table 39: Residual current input included in configuration E

Terminal	Description
X130:1-2	Io

5.1.1.3 Phase voltages

Table 40: Phase voltage inputs included in configuration D

Terminal	Description
X130:11-12	U1
X130:13-14	U2
X130:15-16	U3

5.1.1.4 Residual voltage

Table 41: Additional residual voltage input included in configuration B

Terminal	Description
X120:5-6	Uo

Table 42: Additional residual voltage input included in configuration D

Terminal	Description
X130:17-18	Uo

5.1.1.5 Sensor inputs

Table 43: Combi sensor inputs included in configuration E

Terminal	Description
X131	IL1 U1
X132	IL2 U2
X133	IL3 U3

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 (AC/DC or DC) is marked on the top of the LHMI of the protection relay.

Table 44: Auxiliary voltage supply

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

5.1.3 Binary inputs

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

Table 45: 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 configurations A, C and D.

Table 46: 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 X120 are available with configuration B.

Table 47: Binary input terminals X120:1-4

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

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

Table 48: Binary input terminals X130:1-9

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

Optional binary inputs of slot X130 are available with configuration D.

Table 49: Optional binary input terminals X130:1-8 with AIM0006

Terminal	Description
X130:1 X130:2	BI1, + BI1, -
X130:3 X130:4	BI2, + BI2, -
X130:5 X130:6	BI3, + BI3, -
X130:7 X130:8	BI4, + 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 50: Optional RTD/mA inputs with AIM0003 module

Terminal	Description
X130:1 X130:2	mA 1 (AI1), + mA 1 (AI1), -
X130:3 X130:4 X130:5	RTD1 (AI2), + RTD1 (AI2), - RTD1 (AI2), ground
X130:6 X130:7 X130:8	RTD2 (AI3), + RTD2 (AI3), - 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 51: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCS resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCS1 input), NO
X100:19	PO3 (TCS1 input), NO
X100:20	PO4, NO (TCS resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCS2 input), NO
X100:24	PO4 (TCS2 input), NO

5.2.2 Outputs for signalling

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

Table 52: Output contacts X100:10-14

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

Table 53: Output contacts X110:14-24 with BIO0005

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

Output contacts of slot X130 are available in the optional BIO0006 module with configurations A, B and C.

Table 54: Output contacts X130:10-18

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

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection 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 55: IRF contact

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

5.3 Protection communication options

Two different protection communication options are available for the 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.

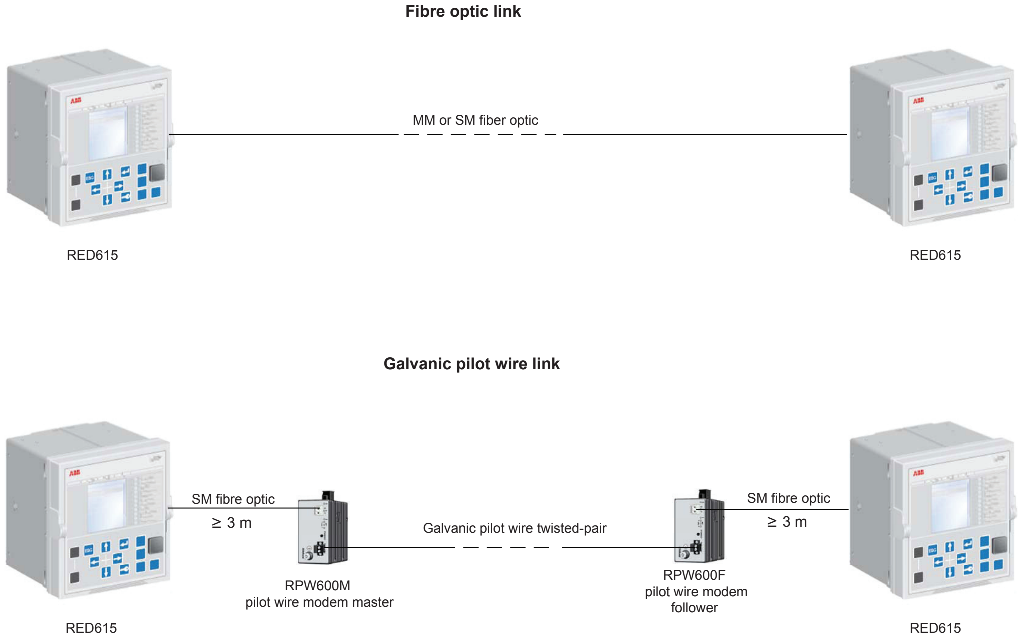


Figure 253: Protection communication options

See RPW600 user guide for more information.

6 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
615 series	Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
AI	Analog input
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
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
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	International Electrotechnical Commission

Table continues on the next page

IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
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 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
QoS	Quality of service
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RS-232	Serial interface standard
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit

Table continues on the next page

SAN	Single attached node
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SMV	Sampled measured values
SNTP	Simple Network Time Protocol
SO	Signal output
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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