RELION® 615 SERIES

Feeder Protection and Control REF615

Application Manual

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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.

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- 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.

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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

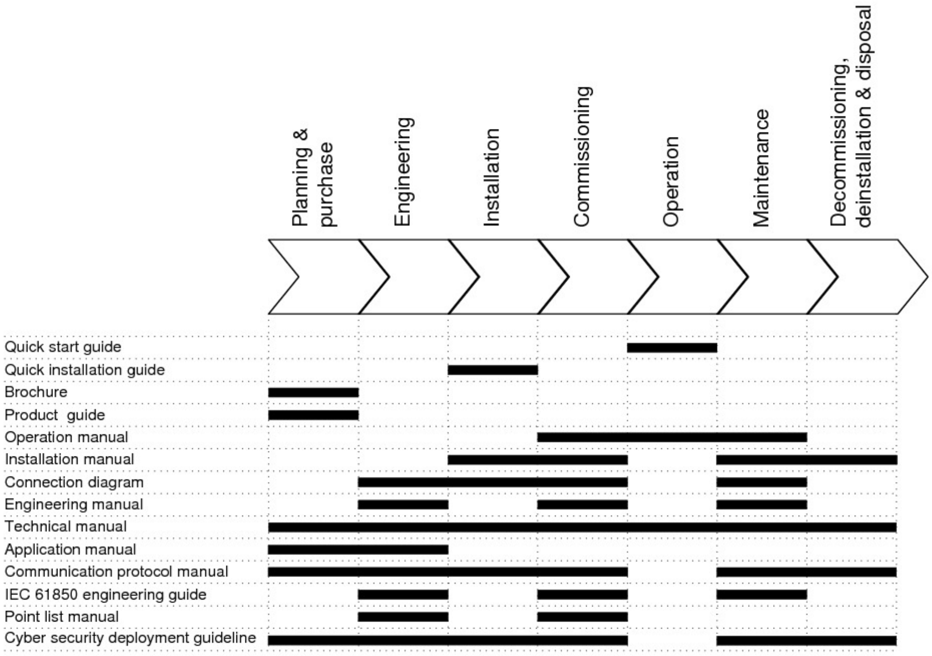


Figure 1: The intended use of documents during the product life cycle

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/2007-12-20	1.0	First release
B/2008-02-08	1.0	Content updated
C/2008-07-02	1.1	Content updated to correspond to the product version
D/2009-03-04	2.0	Content updated to correspond to the product version
E/2009-07-03	2.0	Content updated
F/2010-06-11	3.0	Content updated to correspond to the product version
G/2010-06-29	3.0	Terminology updated
H/2010-09-24	3.0	Content updated
K/2012-05-11	4.0	Content updated to correspond to the product version
L/2013-02-21	4.0 FP1	Content updated to correspond to the product version
M/2013-12-20	5.0	Content updated to correspond to the product version
N/2014-01-24	5.0	Content updated
P/2014-04-10	5.0	Content updated
R/2015-10-30	5.0 FP1	Content updated to correspond to the product version
S/2016-05-20	5.0 FP1	Content updated
T/2018-12-20	5.0 FP1	Content updated
U/2021-11-10	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

Table continues on the next page

Name of the document	Document ID
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 in this manual are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push-button navigation in the LHMI menu structure is presented by using the push-button icons.

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

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

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

The function can be enabled and disabled with the *Operation* setting.

- Parameter values are indicated with quotation marks.

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

  When the function starts, the `START` output is set to TRUE.
- 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)
	PHLPTOC2	3I> (2)	51P-1 (2)
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)
	PSPTUV2	U1< (2)	47U+ (2)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
	NSPTOV2	U2> (2)	47O- (2)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81 (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
	FRPFRQ3	f>/f<,df/dt (3)	81 (3)
	FRPFRQ4	f>/f<,df/dt (4)	81 (4)
	FRPFRQ5	f>/f<,df/dt (5)	81 (5)
	FRPFRQ6	f>/f<,df/dt (6)	81 (6)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F (1)	49F (1)
High-impedance based restricted earth-fault protection	HREFPDIF1	dIoHi> (1)	87NH (1)
High-impedance differential protection for phase A	HIAPDIF1	dHi_A>(1)	87A(1)
High-impedance differential protection for phase B	HIBPDIF1	dHi_B>(1)	87B(1)
High-impedance differential protection for phase C	HICPDIF1	dHi_C>(1)	87C(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)
	TRPPTRC3	Master Trip (3)	94/86 (3)
	TRPPTRC4	Master Trip (4)	94/86 (4)
	TRPPTRC5	Master Trip (5)	94/86 (5)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
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)
High-impedance fault detection	PHIZ1	HIF (1)	HIZ (1)
Reverse power/directional overpower protection	DOPPDPR1	P>/Q> (1)	32R/32O (1)
	DOPPDPR2	P>/Q> (2)	32R/32O (2)
Multifrequency admittance-based earth-fault protection	MFADPSDE1	Io> ->Y (1)	67YN (1)
Interconnection functions			
Directional reactive power undervoltage protection	DQPTUV1	Q> ->,3U< (1)	32Q,27 (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Low-voltage ride-through protection	LVRTPTUV1	U<RT (1)	27RT (1)
	LVRTPTUV2	U<RT (2)	27RT (2)
	LVRTPTUV3	U<RT (3)	27RT (3)
Voltage vector shift protection	VVSPPAM1	VS (1)	78V (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)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC1	MCS I_A(1)	MCS I_A(1)
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC1	MCS I_B(1)	MCS I_B(1)
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC1	MCS I_C(1)	MCS I_C(1)
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60 (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)
	RESCMMXU2	Io (2)	In (2)
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)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
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 REF615 overview

2.1 Overview

REF615 is a dedicated feeder protection and control relay designed for the protection, control, measurement and supervision of utility substations and industrial power systems including radial, looped and meshed distribution networks with or without distributed power generation. REF615 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 designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices.

The relay provides main protection for overhead lines and cable feeders in distribution networks. The relay is also used as back-up protection in applications, where an independent and redundant protection system is required.

Depending on the chosen standard configuration, the relay is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance earthed, compensated and solidly earthed networks. Once the standard configuration 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
1.0	Product released
1.1	• IRIG-B • Support for parallel protocols added: IEC 61850 and Modbus • X130 BIO added: optional for variants B and D • CB interlocking functionality enhanced • TCS functionality in HW enhanced • Non-volatile memory added

Table continues on the next page

Product version	Product history
2.0	• Support for DNP3 serial or TCP/IP • Support for IEC 60870-5-103 • Voltage measurement and protection • Power and energy measurement • New standard configurations E and F • Disturbance recorder upload via WHMI • Fuse failure supervision
3.0	• New configurations G and H • Additions to configurations A, B, E and F • 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 • Frequency measurement and protection • Synchronism and energizing check • Combi sensor inputs • Multi-port Ethernet option
4.0	• New configuration J • Additions/changes for configurations A-H • 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 • Power Quality functions • Increased maximum amount of events and fault records
4.0 FP1	• High-availability seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • 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

Table continues on the next page

Product version	Product history
5.0	• New configurations K, L and N • New layout in Application Configuration tool for all configurations • Support for IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • Fault locator • Load profile recorder • High-speed binary outputs • Optional RTD 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 • 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 • Multifrequency admittance-based E/F • Support for high-impedance differential protection • Voltage unbalance power quality option • Interconnection protection option • Reverse power/directional overpower • 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
- REF615 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

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

- Arc protection
- Autoreclosing
- Modbus TCP/IP or RTU/ ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Admittance-based earth-fault protectiont (configurations A, B, E, F, G, J, L and N only)
- Wattmetric-based earth-fault protection (configurations A, B, E, F, G, J, L and N only)
- Harmonics-based earth-fault protection (configurations B, D, F, J, L and N only)
- Interconnection protection (configurations L and N only)
- Power quality functions (configurations J, K, L and N only)
- Fault locator (configurations K, L and N only)
- RTD/mA measurement (configurations B, D, E, F, H, J and N only)
- IEC 61850-9-2 LE (configurations E, F, G, H, J, K, L and N only)
- IEEE 1588 v2 time synchronization

2.3 Physical hardware

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

Table 2: Plug-in unit and case

Main unit	Slot ID	Content 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

Table continues on the next page

Main unit	Slot ID	Content options	
	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	Only with configurations B, D, E, F, G, H, J, K, L and N: 8 binary inputs 4 SO contacts
			Only with configurations B, D, E, F, G, H, J, K, L and N: 8 binary inputs 3 HSO contacts
	X120	AI/BI module	Only with configurations A and 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 C, D, E, F, H, J and N: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A) [1] 4 binary inputs
			Only with configuration K: 6 phase current inputs (1/5 A) 1 residual current input (1/5 A)
Case	X130	AI/ BI module	Only with configurations E, F, H, J, K and N: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs Additionally with configurations H, J, K and N: 1 reference voltage input for SECRSYN1 (60...210 V)
		AI/ RTD/mA module	Only with configurations E, F, H, J and N: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA input 2 RTD sensor inputs Additionally with configurations H, J and N: 1 reference voltage input for SECRSYN1 (60...210 V)
		Sensor input module	Only with configurations G and L: 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)

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 unit	Slot ID	Content options	
		Optional BIO module	Optional for configurations B and D: 6 binary inputs 3 SO contacts
		Optional RTD/mA module	Optional for configurations B and D: 2 generic mA inputs 6 RTD sensor inputs
	X000	Optional 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 protection relay. The binary input thresholds are selectable within the range 16…176 V DC by adjusting the binary input setting parameters.

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

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

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	AA / AB	AA	4	1	–	3	4 PO + 2 SO	–	–
B	AA / AB	AE	4	1	–	17	4 PO + 9 SO	–	–
		FA	4	1	–	17	4 PO + 5 SO + 3 HSO	–	–
	FA / FB	AC	4	1	–	11	4 PO + 6 SO	6	2
		FG	4	1	–	11	4 PO + 2 SO + 3 HSO		
C	AC / AD	AB	4	–	–	4	4 PO + 2 SO	–	–
D	AC / AD	AF	4	–	–	18	4 PO + 9 SO	–	–
		FB	4	–	–	18	4 PO + 5 SO + 3 HSO	–	–
	FC / FD	AD	4	–	–	12	4 PO + 6 SO	6	2
		FE	4	–	–	12	4 PO + 2 SO + 3 HSO		
EFHJN	AE / AF	AG	4	5	–	16	4 PO + 6 SO	–	–
		FC	4	5	–	16	4 PO + 2 SO + 3 HSO	–	–
	FE / FF	AG	4	5	–	12	4 PO + 6 SO	2	1
		FC	4	5	–	12	4 PO + 2 SO + 3 HSO	2	1
GL	DA / DB	AH	1	–	3	8	4 PO + 6 SO	–	–
		FD	1	–	3	8	4 PO + 2 SO + 3 HSO	–	–
K	BC	AD	5	5	–	12	4 PO + 6 SO	–	–
		FE	5	5	–	12	4 PO + 2 SO + 3 HSO	–	–

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.

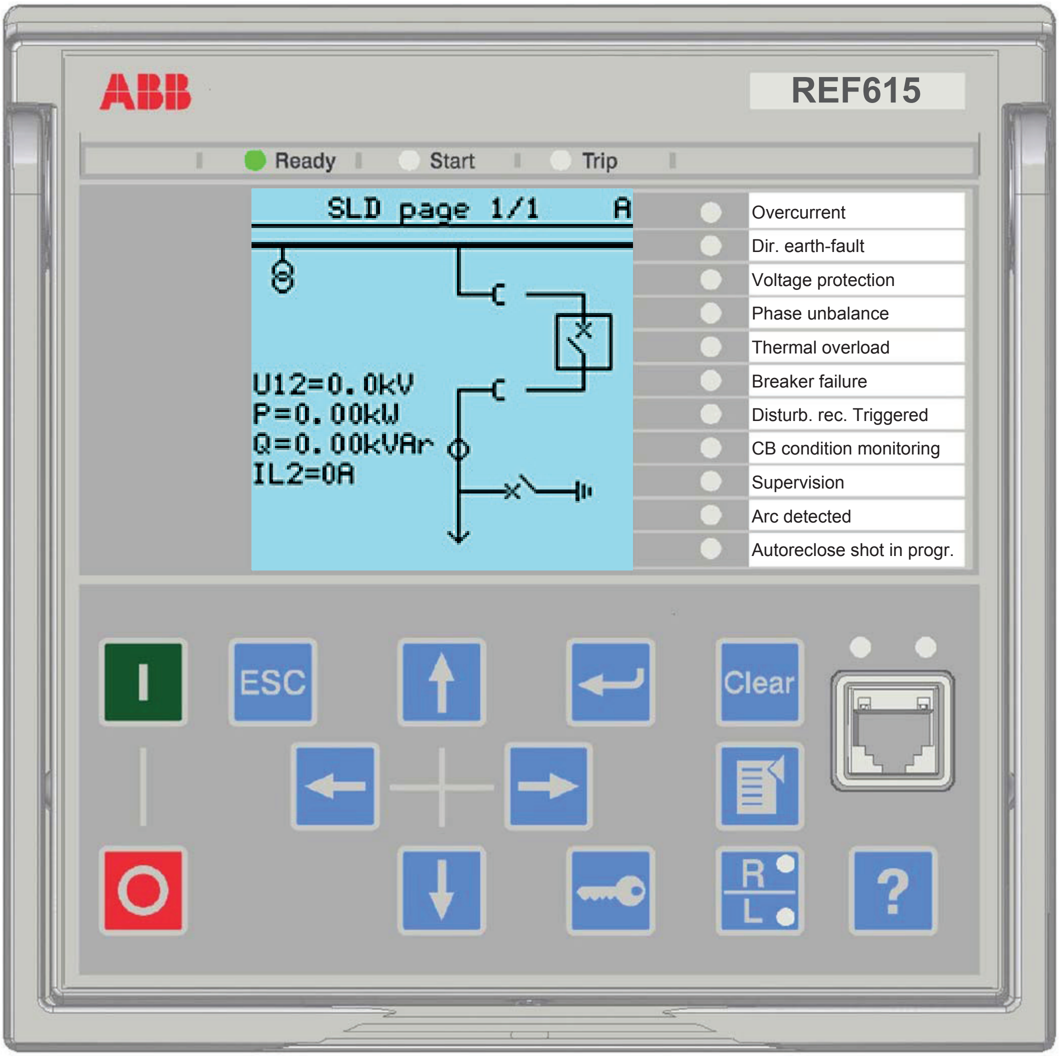


Figure 2: Example of the LHMI

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

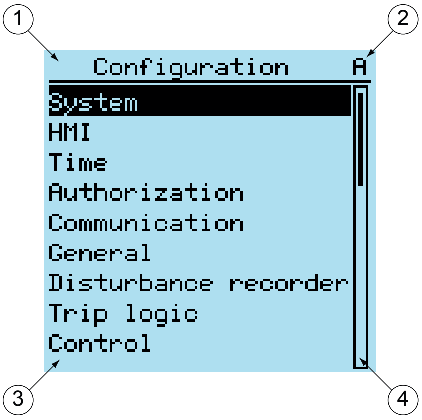
Character size[1]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

[1] Depending on the selected language

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.

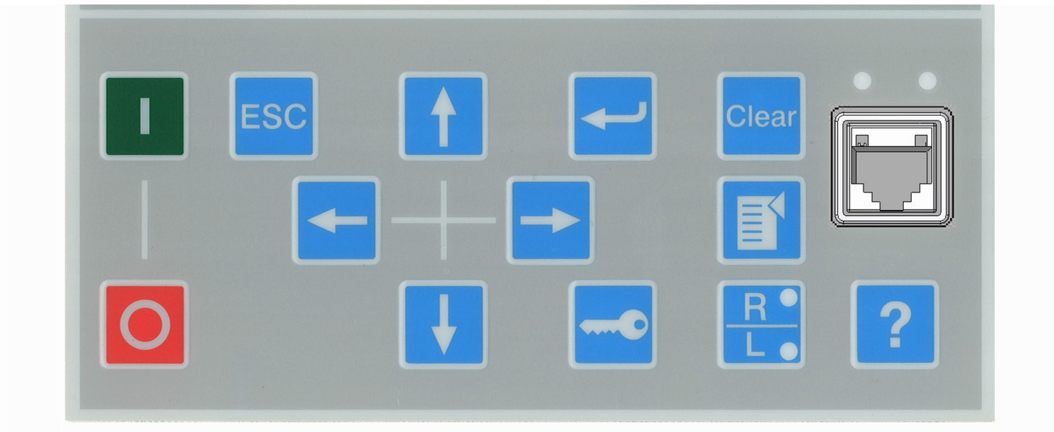


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

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.

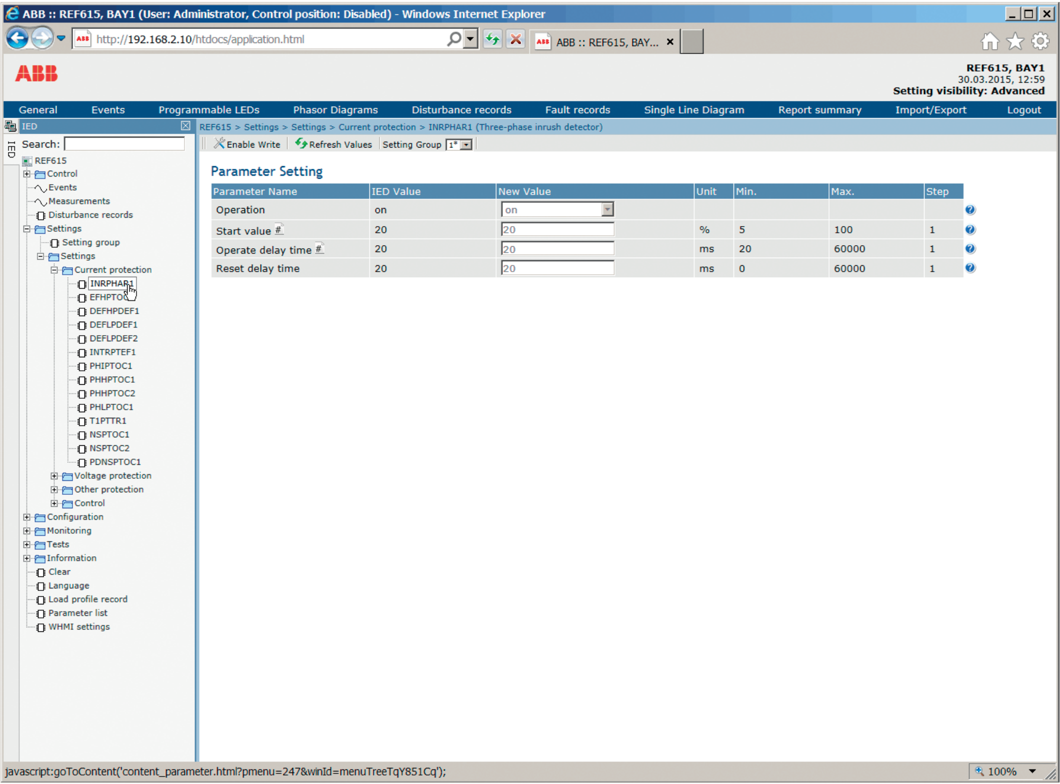


Figure 5: Example view of the WHMI

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	Configura-tion change	Setting group	Setting group, control	Settings edit	All
Configuration change		•	•	•	•	•
Firmware change		•	•	•	•	•
Firmware change fail		•	•	•	•	•
Attached to retrofit test case		•	•	•	•	•
Removed from retro-fit 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.

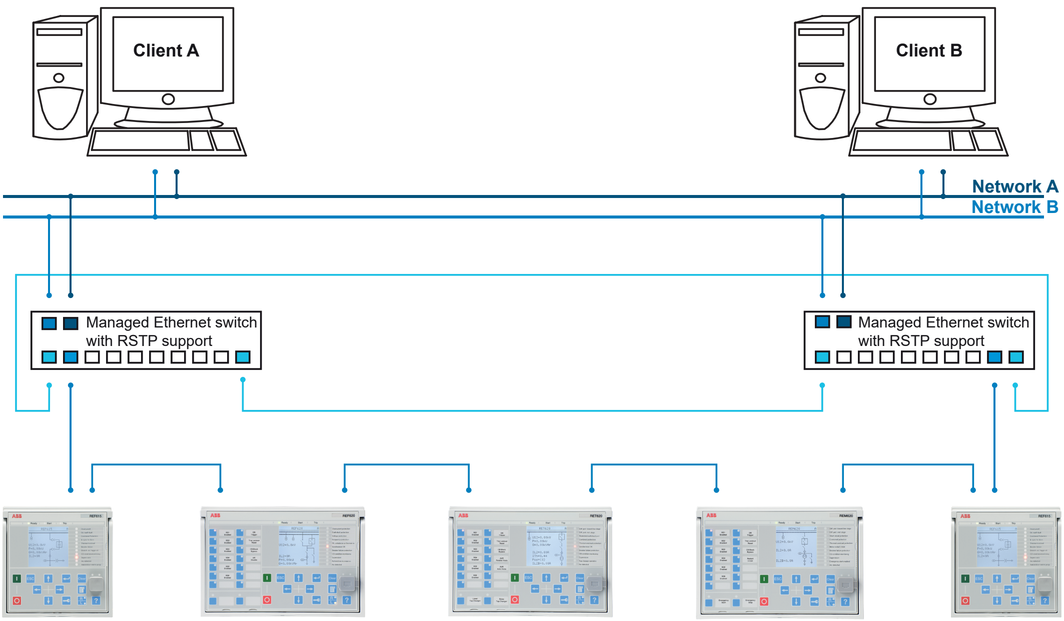


Figure 6: Self-healing Ethernet ring solution

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.

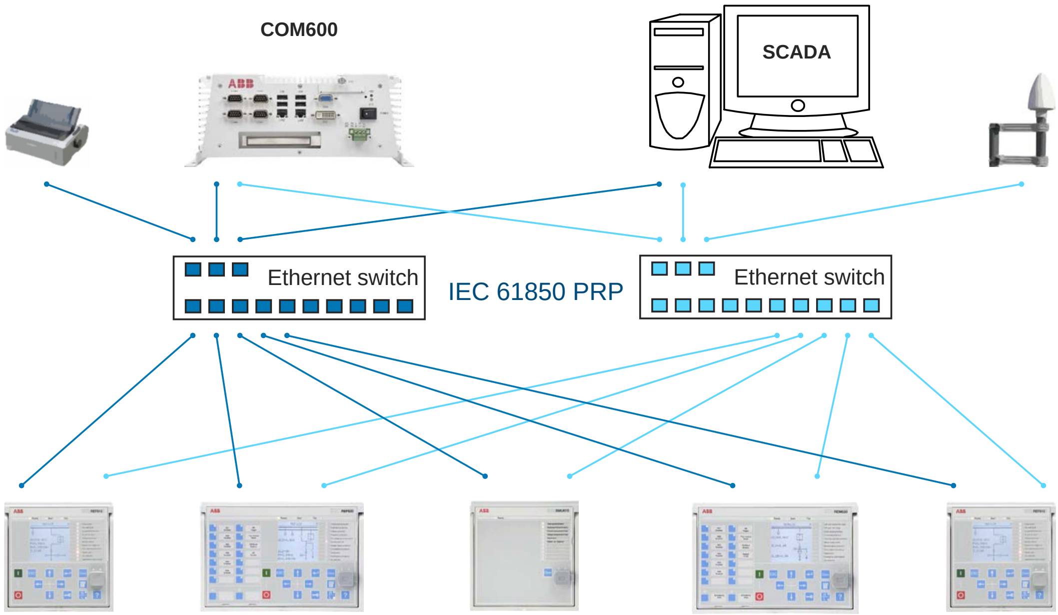


Figure 7: PRP solution

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.

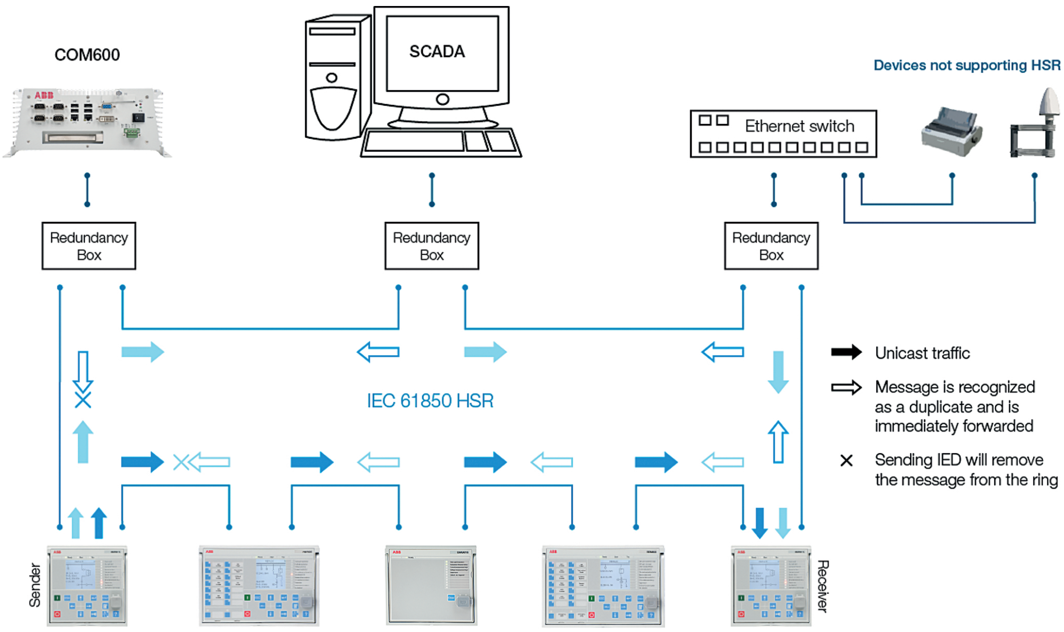


Figure 8: HSR solution

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.

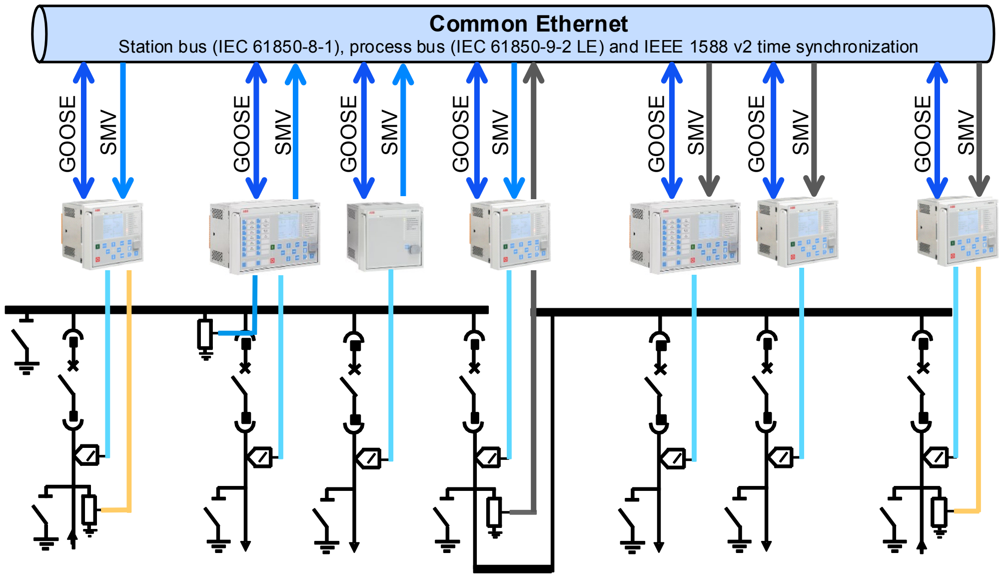


Figure 9: Process bus application of voltage sharing and synchrocheck

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.

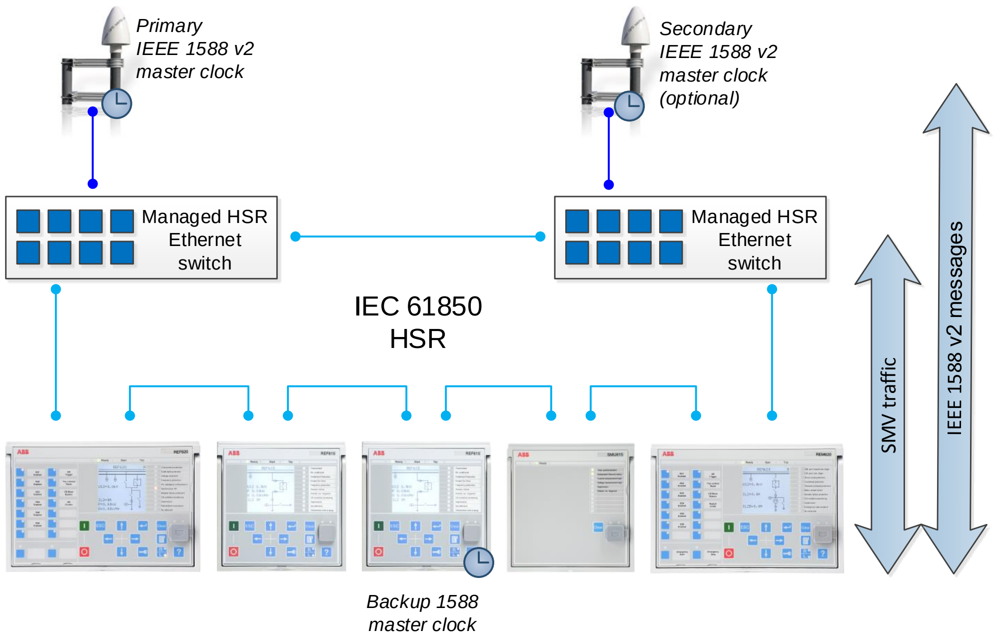


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

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.

3 REF615 standard configurations

3.1 Standard configurations

REF615 is available with twelve 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 using 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 REF615 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.
Non-directional overcurrent and directional earth-fault protection	A
Non-directional overcurrent and directional earth-fault protection and circuit-breaker condition monitoring (RTD option)	B
Non-directional overcurrent and earth-fault protection	C
Non-directional overcurrent and earth-fault protection and circuit-breaker condition monitoring (RTD option)	D
Non-directional overcurrent and directional earth-fault protection, voltage-based measurements and circuit-breaker condition monitoring (RTD option)	E
Directional overcurrent and earth-fault protection, voltage-based protection and measurements, and circuit-breaker condition monitoring (RTD option)	F
Directional overcurrent and earth-fault protection, voltage-based protection and measurements, and circuit-breaker condition monitoring (sensor inputs and optional synchro-check with IEC 61850-9-2 LE)	G
Non-directional overcurrent and earth-fault protection, voltage and frequency based protection and measurements, synchro-check and circuit-breaker condition monitoring (RTD option)	H
Directional overcurrent and earth-fault protection, voltage and frequency based protection and measurements, synchro-check and circuit-breaker condition monitoring (optional power quality and RTD option)	J

Table continues on the next page

Description	Std. conf.
Directional and non-directional overcurrent and earth-fault protection, high-impedance restricted earth-fault protection, voltage and frequency based protection and measurements, synchro-check and circuit-breaker condition monitoring (optional power quality and fault locator)	K
Directional and non-directional overcurrent and earth-fault protection with multifrequency neutral admittance, voltage, frequency and power based protection and measurements, and circuit-breaker condition monitoring (sensor inputs, optional power quality, fault locator, interconnetion protection and synchro-check with IEC 61850-9-2 LE)	L
Directional and non-directional overcurrent and earth-fault protection with multifrequency neutral admittance, voltage, frequency and power based protection and measurements, high-impedance differential protection, synchro-check and circuit-breaker condition monitoring (optional power quality, fault locator and interconnection protection)	N

3.1.1 Supported functions in REF615

Table 10: Supported functions

Function	IEC 61850	A	B	C	D	E	F	G	H	J	K	L	N
		FE01	FE02	FE03	FE04	FE05	FE06	FE07	FE08	FE09	FE10	FE11	FE12
Protection													
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1	1	1	1			1		1	2	2
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2	2	2	2			2		1	1	1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1	1	1	1	1	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC						2	2		2	1	2	2
Three-phase directional overcurrent protection, high stage	DPHHPDOC						1	1		1	1	1	1
Non-directional earth-fault protection, low stage	EFLPTOC			2	2				2		2	2	2
Non-directional earth-fault protection, high stage	EFHPTOC			1	1				1		1		1
Non-directional earth-fault protection, instantaneous stage	EFIPTOC			1	1				1		1	1	1
Directional earth-fault protection, low stage	DEFLPDEF	2	2 [1]			2	2	2		2	1	2 [2]	2

Table continues on the next page

1 "Uo measured" is always used.
2 "Uo calculated" is always used.

Function	IEC 61850	A	B	C	D	E	F	G	H	J	K	L	N
		FE01	FE02	FE03	FE04	FE05	FE06	FE07	FE08	FE09	FE10	FE11	FE12
Directional earth-fault protection, high stage	DEFHPDEF	1[1]	1[1]			1	1	1[2]		1	1	1[2]	1
Admittance-based earth-fault protection	EFPADM	(3)[1,3]	(3)[1,3]			(3)[3]	(3)[3]	(3)[2,3]		(3)[3]		(3)[2,3]	(3)[3]
Wattmetric-based earth-fault protection[3]	WPWDE	(3)[1,3]	(3)[1,3]			(3)[3]	(3)[3]	(3)[2,3]		(3)[3]		(3)[2,3]	(3)[3]
Transient/intermittent earth-fault protection	INTRPTEF	1	1[4]			1[4]	1[4]			1[4]		1[2,4]	1[4]
Harmonics-based earth-fault protection[3]	HAEFPTOC		(1)[3,4]		(1)[3,4]		(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	1	1		1		1	
Negative-sequence overcurrent protection	NSPTOC	2	2	2	2	2	2	2	2	2	2	2	2
Phase discontinuity protection	PDNSPTOC	1	1	1	1	1	1	1	1	1		1	1
Residual overvoltage protection	ROVPTOV	3[1]	3[1]			3	3	3[2]	3	3	2	3[2]	3
Three-phase undervoltage protection	PHPTUV						3	3	3	3	2	3	3
Three-phase overvoltage protection	PHPTOV						3	3	3	3	2	3	3
Positive-sequence undervoltage protection	PSPTUV						1	1		1		2	2
Negative-sequence overvoltage protection	NSPTOV						1	1		1		2	2
Frequency protection	FRPFRQ								3	3	3	6	6
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	1	1	1	1	1	1	1		1	1	1	1
High-impedance based restricted earth-fault protection	HREFPDIF										1		
High-impedance differential protection for phase A	HIAPDIF												1
High-impedance differential protection for phase B	HIBPDIF												1
High-impedance differential protection for phase C	HICPDIF												1
Circuit breaker failure protection	CCBRBRF	1	1	1	1	1	1	1	1	1	1	1	1

Table continues on the next page

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 "IoB measured" is always used.

Function	IEC 61850	A	B	C	D	E	F	G	H	J	K	L	N
		FE01	FE02	FE03	FE04	FE05	FE06	FE07	FE08	FE09	FE10	FE11	FE12
Three-phase inrush detector	INRPHAR	1	1	1	1	1	1	1	1	1	1	1	1
Switch onto fault	CBPSOF	1	1	1	1	1	1	1	1	1	1	1	1
Master trip	TRPPTRC	2	2 (3)	2	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]	2 (3) [6]
Arc protection	ARCSARC	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Multipurpose protection	MAPGAPC	18	18	18	18	18	18	18	18	18	18	18	18
Fault locator	SCEFRFLO										(1)	(1)	(1)
High-impedance fault detection	PHIZ		1		1	1	1	1	1	1			1
Reverse power/directional overpower protection	DOPPDPR											2	2
Multifrequency admittance-based earth-fault protection	MFADPSDE											1	1
Interconnection functions													
Directional reactive power undervoltage protection	DQPTUV											(1)	(1)
Low-voltage ride-through protection	LVRTPTUV											(3)	(3)
Voltage vector shift protection	VVSPPAM											(1)	(1)
Power quality													
Current total demand distortion	CMHAI									(1)	(1) [7]	(1) [7]	(1) [7]
Voltage total harmonic distortion	VMHAI									(1) [7]	(1) [7]	(1) [7]	(1) [7]
Voltage variation	PHQVVR									(1) [7]	(1) [7]	(1) [7]	(1) [7]
Voltage unbalance	VSQVUB									(1) [7]	(1) [7]	(1) [7]	(1) [7]
Control													
Circuit-breaker control	CBXCBR	1	1	1	1	1	1	1	1	1	1	1	1
Disconnector control	DCXSWI		2		2	2	2	2	2	2	2	2	2
Earthing switch control	ESXSWI		1		1	1	1	1	1	1	1	1	1
Disconnector position indication	DCSXSWI		3		3	3	3	3	3	3	3	3	3
Earthing switch indication	ESSXSWI		2		2	2	2	2	2	2	2	2	2
Autoreclosing	DARREC	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Synchronism and energizing check	SECRSYN							(1)	1	1	1	(1) [8]	1
Condition monitoring and supervision													
Circuit-breaker condition monitoring	SSCBR		1		1	1	1	1	1	1	1	1	1

Table continues on the next page

6 Master trip is included and connected to the corresponding HSO in the configuration only when the BIO0007 module is used. If additionally the ARC option is selected, ARCSARC is connected in the configuration to the corresponding master trip input.

7 Power quality option includes current total demand distortion, voltage total harmonic distortion, voltage variation and voltage unbalance.

8 Available only with IEC 61850-9-2

Function	IEC 61850	A	B	C	D	E	F	G	H	J	K	L	N
		FE01	FE02	FE03	FE04	FE05	FE06	FE07	FE08	FE09	FE10	FE11	FE12
Trip circuit supervision	TCSSCBR	2	2	2	2	2	2	2	2	2	2	2	2
Current circuit supervision	CCSPVC					1	1	1	1	1	1	1	1
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC												1
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC												1
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC												1
Fuse failure supervision	SEQSPVC					1	1	1	1	1	1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1	1	1	1	1	1	1	1	1	1
Measurement													
Disturbance recorder	RDRE	1	1	1	1	1	1	1	1	1	1	1	1
Load profile record	LDPRLRC		1		1	1	1	1	1	1	1	1	1
Fault record	FLTRFRC	1	1	1	1	1	1	1	1	1	1	1	1
Three-phase current measurement	CMMXU	1	1	1	1	1	1	1	1	1	1	1	1
Sequence current measurement	CSMSQI	1	1	1	1	1	1	1	1	1	1	1	1
Residual current measurement	RESCMMXU	1	1	1	1	1	1	1	1	1	2	1	1
Three-phase voltage measurement	VMMXU					1	1	1 (1) [8]	2	2	2	1 (1) [8]	2
Residual voltage measurement	RESVMMXU	1	1			1	1		1	1	1		1
Sequence voltage measurement	VSMSQI					1	1	1	1	1	1	1	1
Three-phase power and energy measurement	PEMMXU					1	1	1	1	1	1	1	1
RTD/mA measurement	XRGGIO130		(1)		(1)	(1)	(1)		(1)	(1)			(1)
Frequency measurement	FMMXU					1	1	1	1	1	1	1	1
IEC 61850-9-2 LE sampled value sending [8]	SMVSENDER					(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) [8 9]	SMVRCV					(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Other													
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4	4	4	4	4	4	4	4	4	4

Table continues on the next page

9 Available only with COM0031...0037

Function	IEC 61850	A	B	C	D	E	F	G	H	J	K	L	N
		FE01	FE02	FE03	FE04	FE05	FE06	FE07	FE08	FE09	FE10	FE11	FE12
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1	1	1	1	1	1	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1	1	1	1	1	1	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2	2	2	2	2	2	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4	4	4	4	4	4	4	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4	4	4	4	4	4	4	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4	4	4	4	4	4	4	4	4	4
Move (8 pcs)	MVGAPC	2	2	2	2	2	2	2	2	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2	2	2	2	2	2	2	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4	4	4	4	4	4	4	4	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1	1	1	1	1	1	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

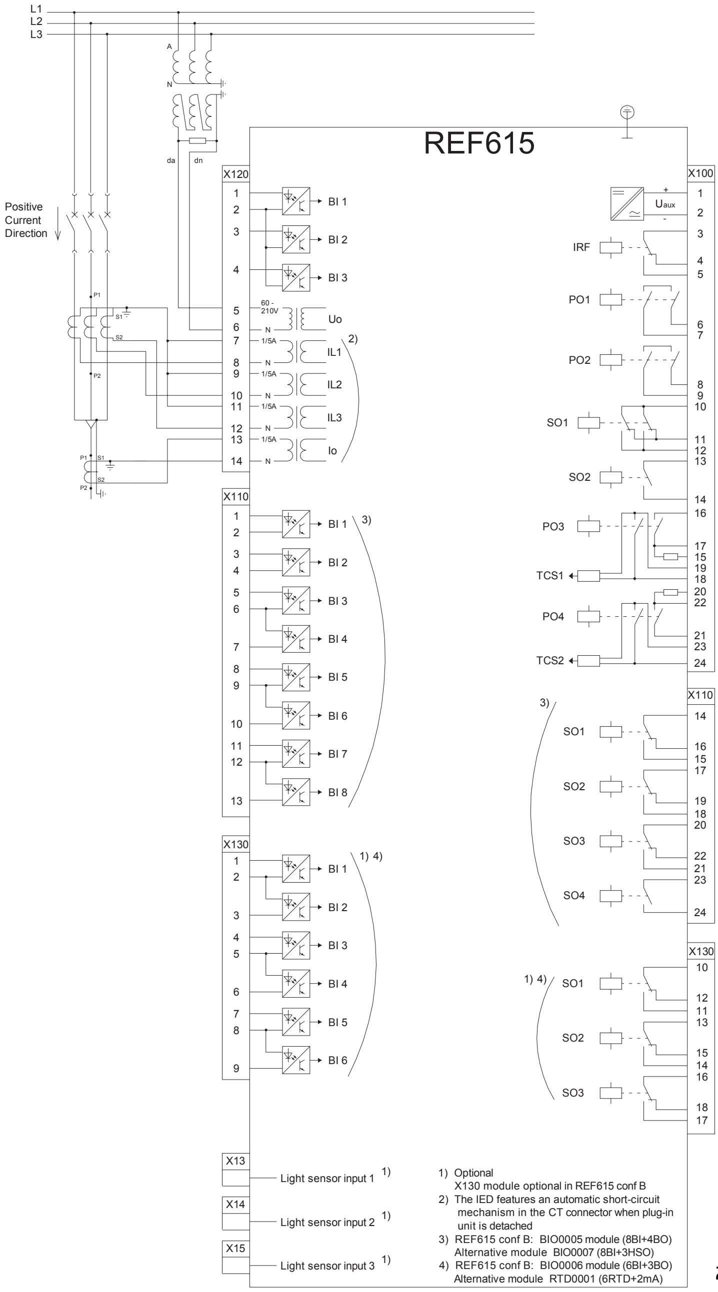
If extra control functions intended for controllable primary devices are added to the configuration, additional binary inputs and/or outputs are needed to complement the standard configuration.

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



[2]

Figure 11: Connection diagram for the A and B configurations

[2] Additional BIO-module (X110 in the diagram) is included in the IED variant B

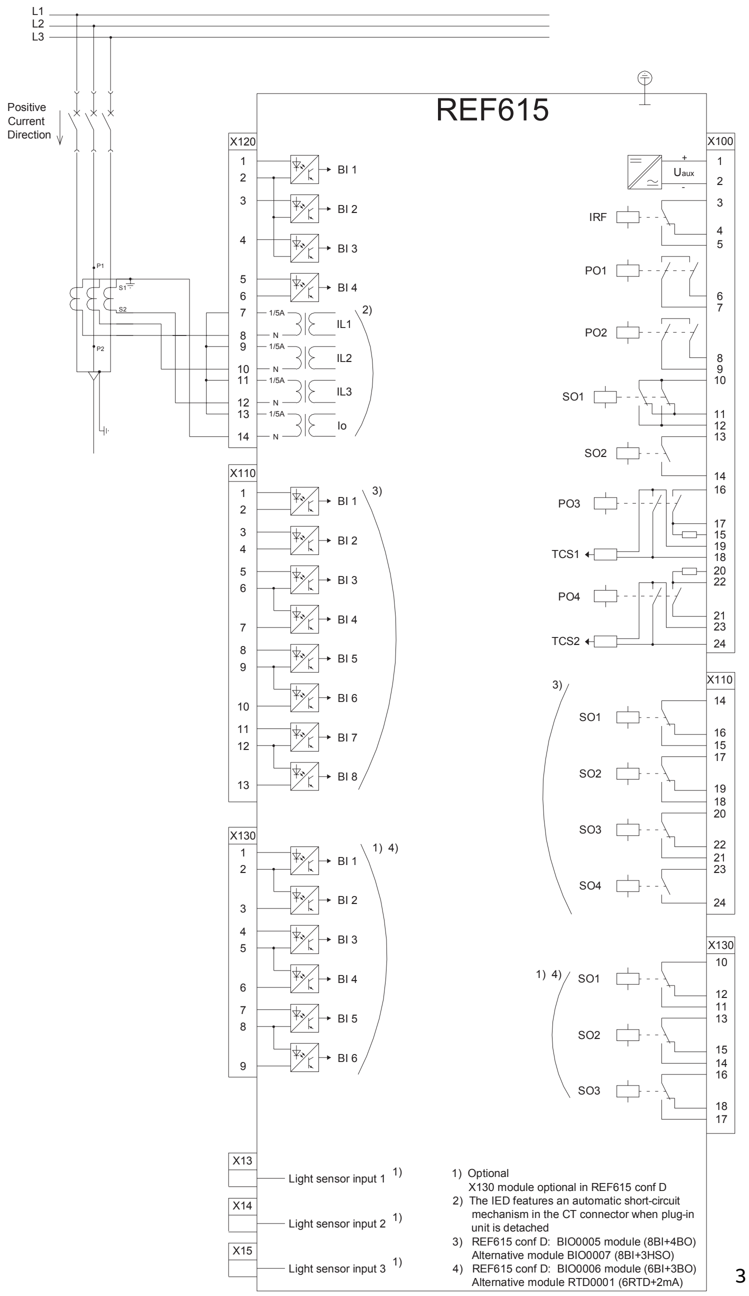


Figure 12: Connection diagram for the C and D configurations

3 Additional BIO-module (X110 in the diagram) is included in the IED variant D

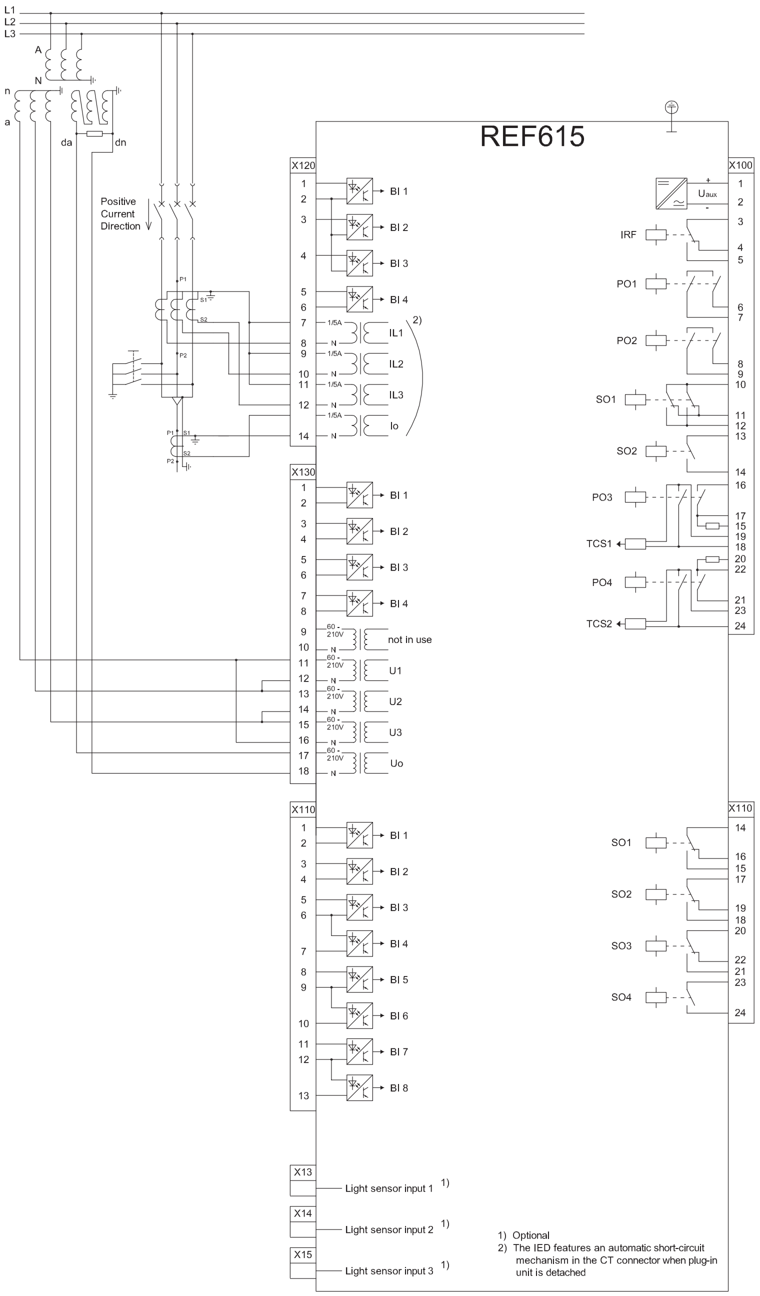


Figure 13: Connection diagram for the E and F configurations

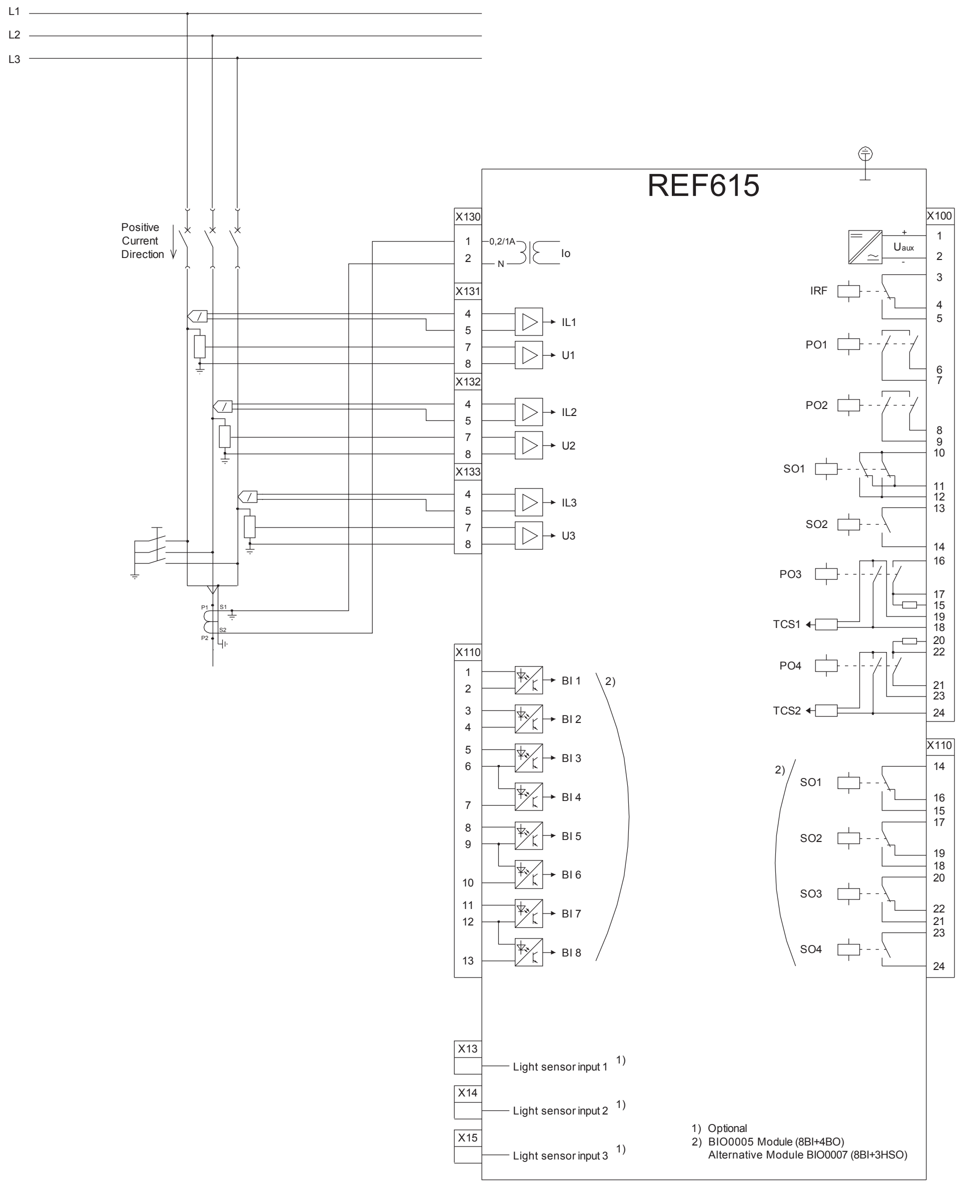


Figure 14: Connection diagram for the G and L configurations with SIM0002 module

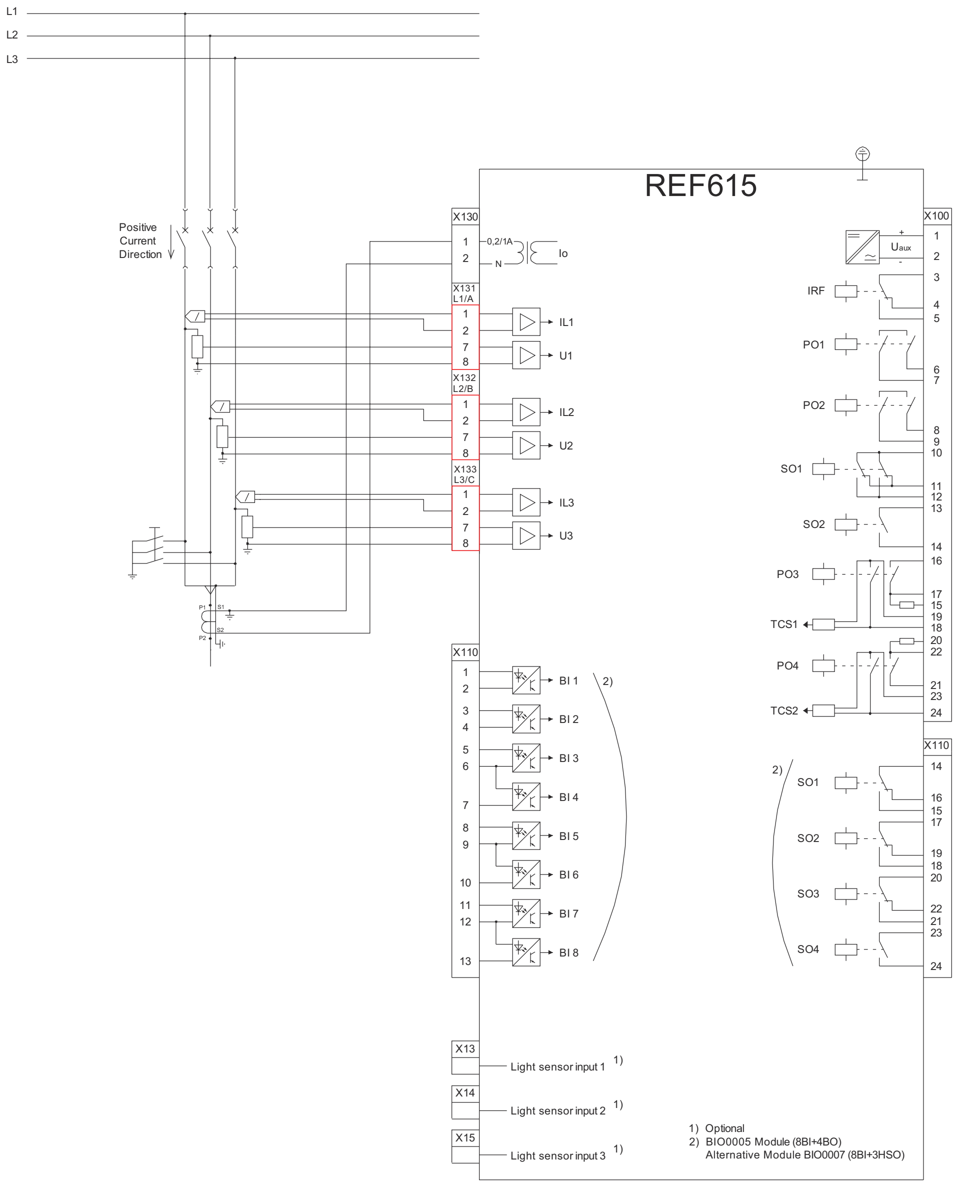


Figure 15: Connection diagram for the G and L configurations with SIM0005 module

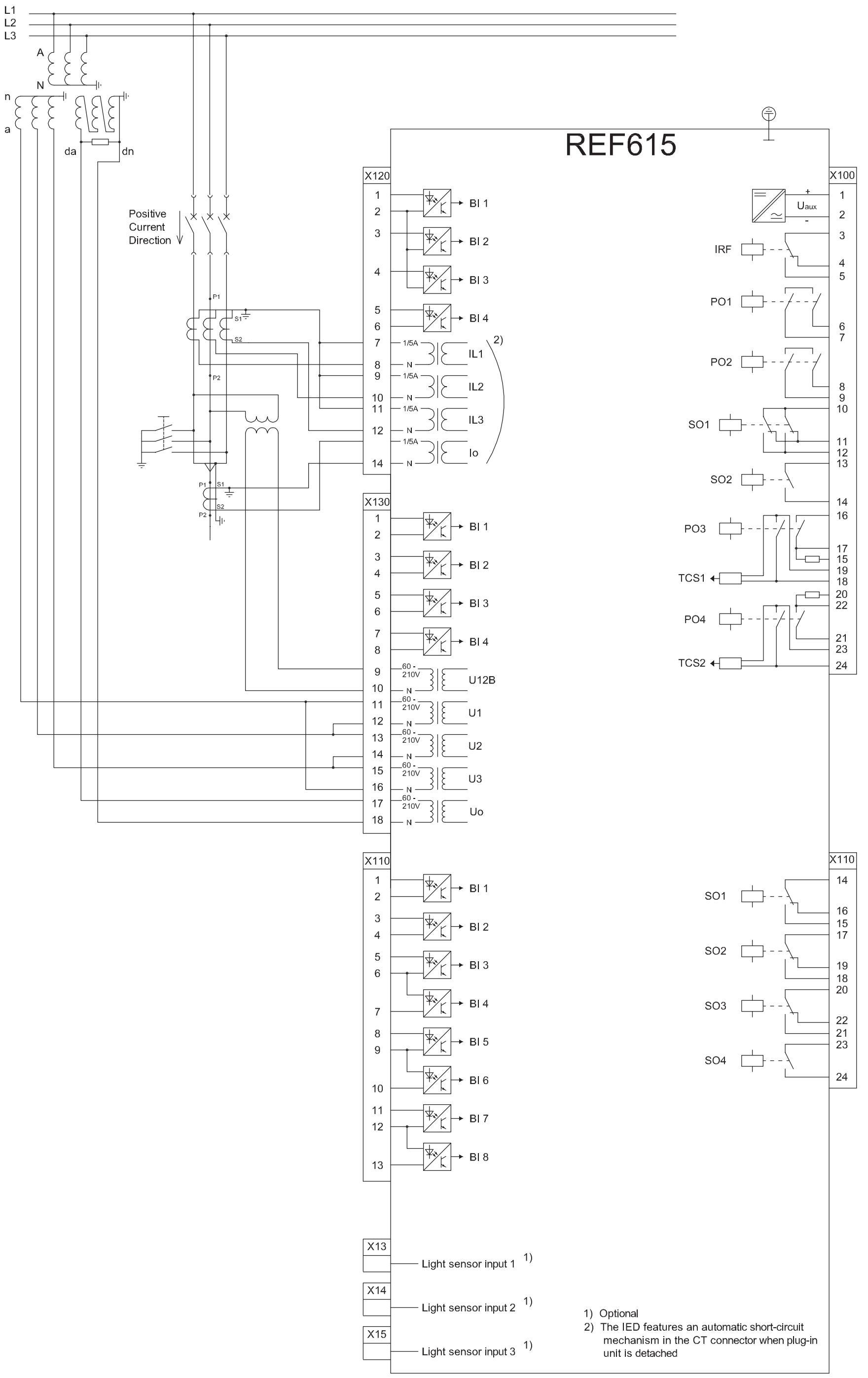


Figure 16: Connection diagram for the H, J and N configurations

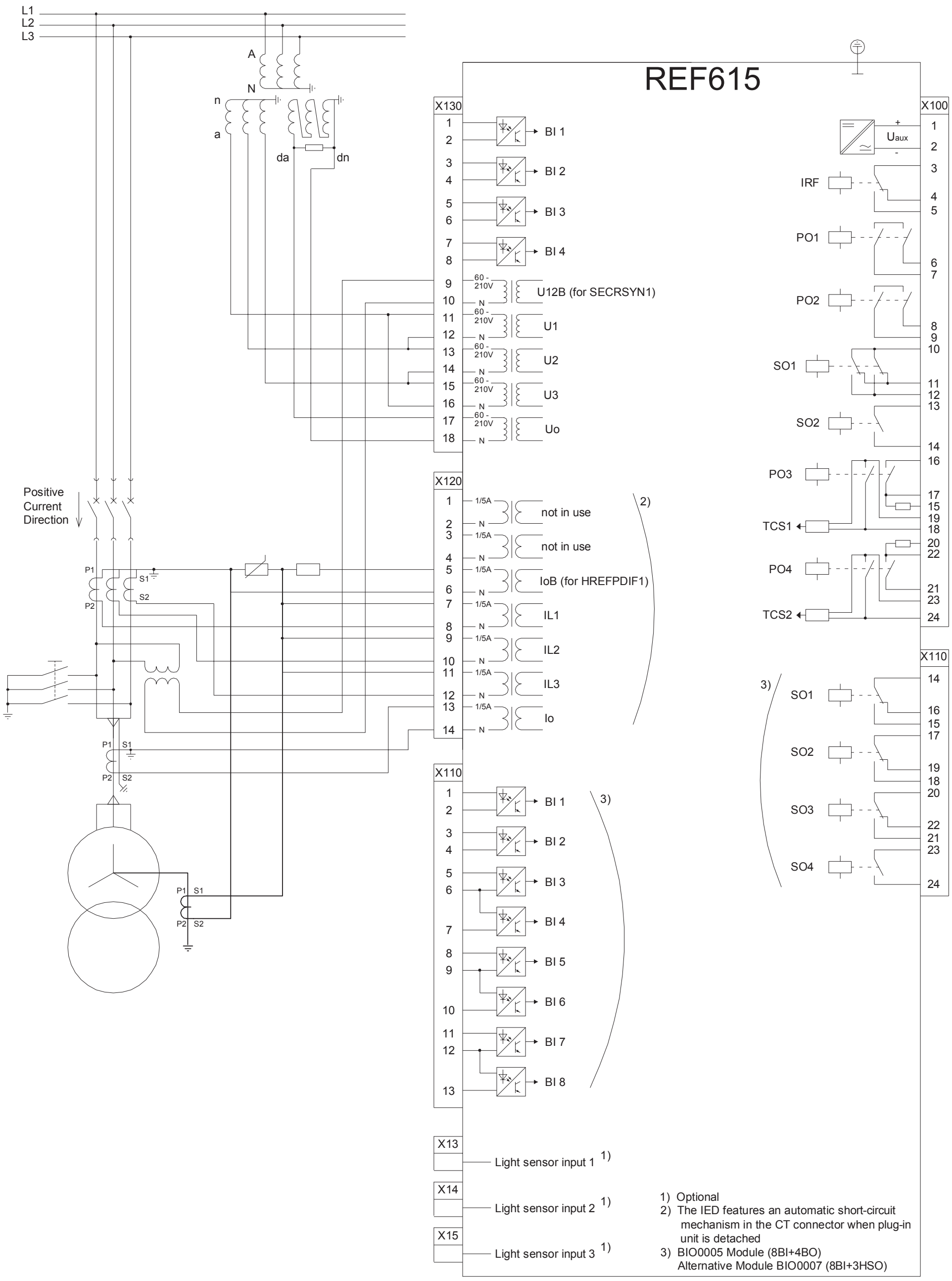


Figure 17: Connection diagram for the K configuration

3.3 Standard configuration A

3.3.1 Applications

The standard configuration for non-directional overcurrent and directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance or wattmetric-based 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.

3.3.2 Functions

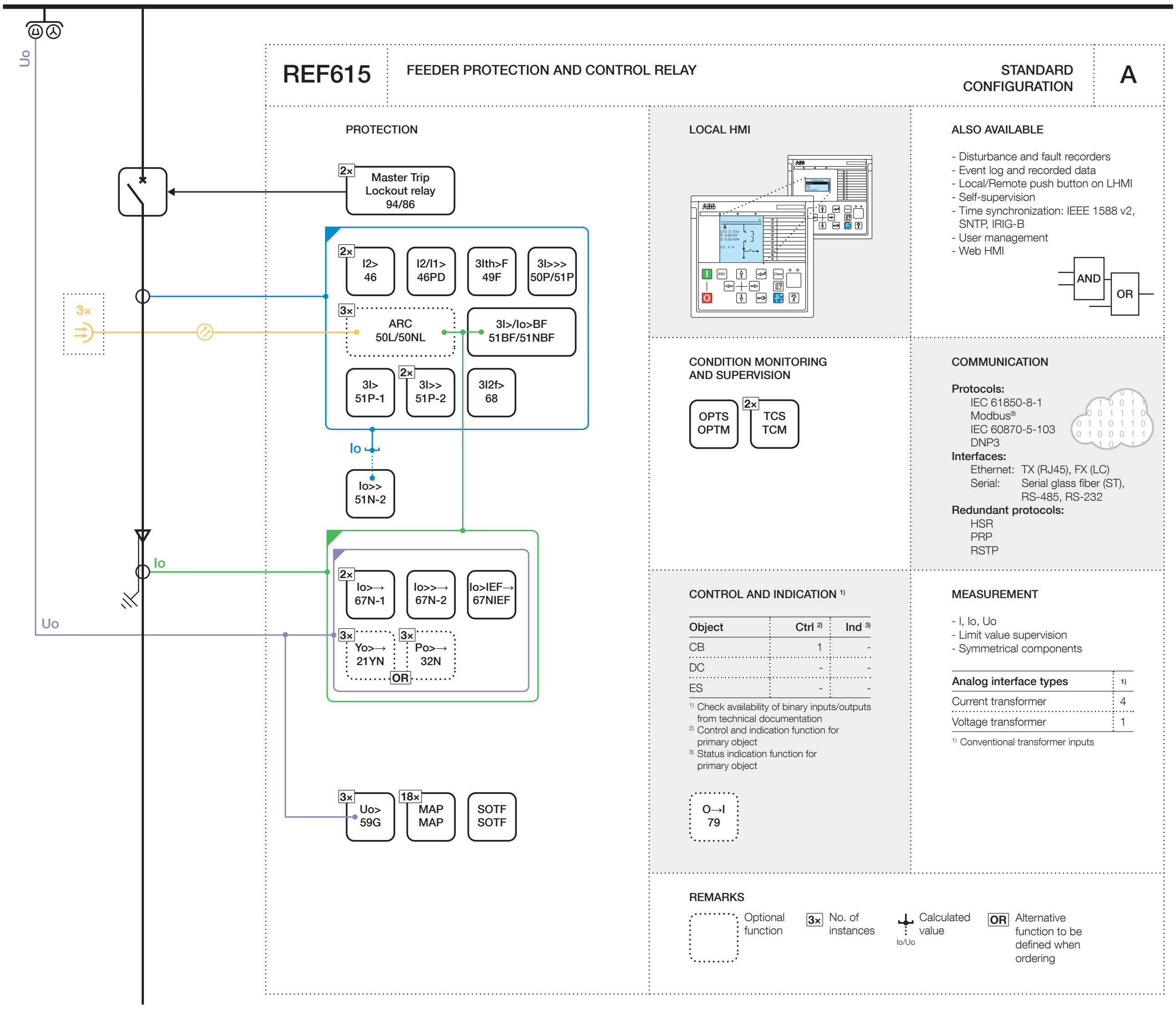


Figure 18: Functionality overview for standard configuration A

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
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed position indication
X120-BI3	Circuit breaker open position indication

Table 12: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Circuit breaker failure protection trip to upstream breaker
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X100-SO1	General start indication
X100-SO2	General operate indication

Table 13: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Directional or intermittent earth-fault operate
3	Double (cross country) earth-fault or residual overvoltage operate
4	Negative sequence overcurrent or phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	–
9	Trip circuit supervision alarm
10	Arc protection operate
11	Autoreclose in progress

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	Uo
6	–
7	–
8	–
9	–
10	–
11	–
12	–

Table 15: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
	EFPADM1 - start	
	WPWDE1 - start	
8	DEFLPDEF2 - start	Positive or Rising
	EFPADM2 - start	
	WPWDE2 - start	
9	EFPADM3 - start	Positive or Rising
	WPWDE3 - start	
10	INTRPTEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	ROVPTOV1 - start	Positive or Rising
15	ROVPTOV2 - start	Positive or Rising
16	ROVPTOV3 - start	Positive or Rising
17	CCBRBRF1 - trret	Level trigger off
18	CCBRBRF1 - trbu	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
19	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
20	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
21	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1- operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
22	INTRPTEF1 - operate	Level trigger off
23	EFHPTOC1 - operate	Level trigger off
24	PDNSPTOC1 - operate	Level trigger off
25	INRPHAR1 - blk2h	Level trigger off
26	T1PTTR1 - operate	Level trigger off
27	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
28	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
29	ARCSARC1 - operate	Positive or rising
30	ARCSARC2 - operate	Positive or rising
31	ARCSARC3 - operate	Positive or rising
32	DARREC1 - inpro	Level trigger off
33	DARREC1 - close CB	Level trigger off
34	DARREC1 - unsuc recl	Level trigger off
35	X120BI1 - ext OC blocking	Level trigger off
36	X120BI2 - CB closed	Level trigger off
37	X120BI3 - CB opened	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 residual voltage to the protection relay is fed from either the 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.

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 IEDs protection functionality in detail and according to the factory set default connections.

Four overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional instantaneous stage PHIPTOC1 can be blocked by energizing the binary input X120:BI1.

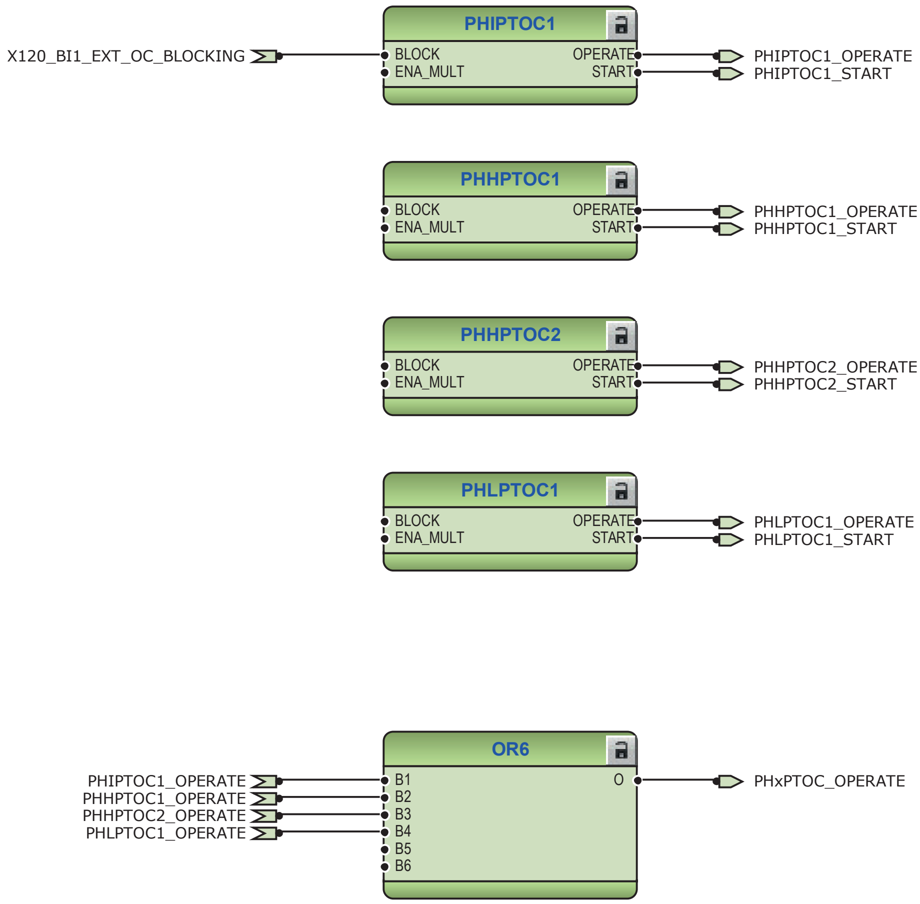


Figure 19: Overcurrent protection functions

The output INRPHAR1_BLK2H of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

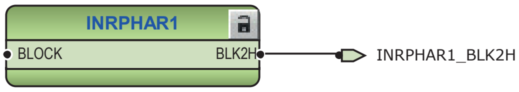


Figure 20: Inrush detector function

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.

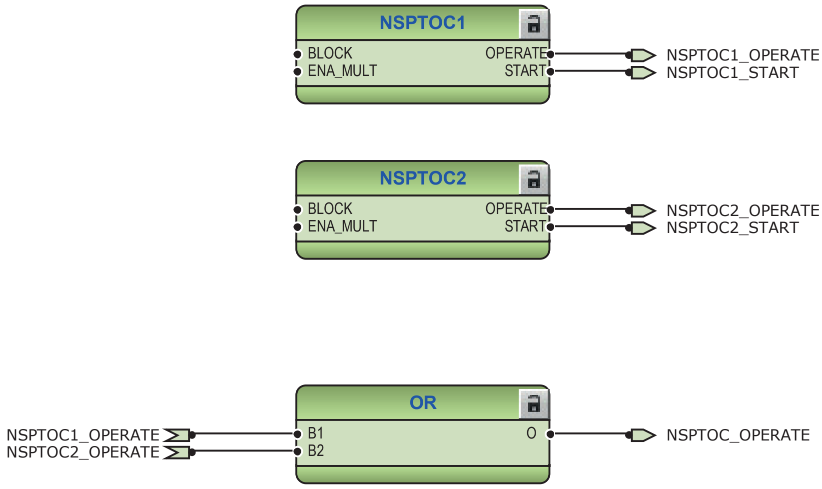


Figure 21: Negative-sequence overcurrent protection function

Three stages are provided for directional earth-fault protection. According to the IED's order code, the directional earth-fault protection method is based on conventional directional earth-fault DEFxPDEF only or used alternatively together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE. 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.

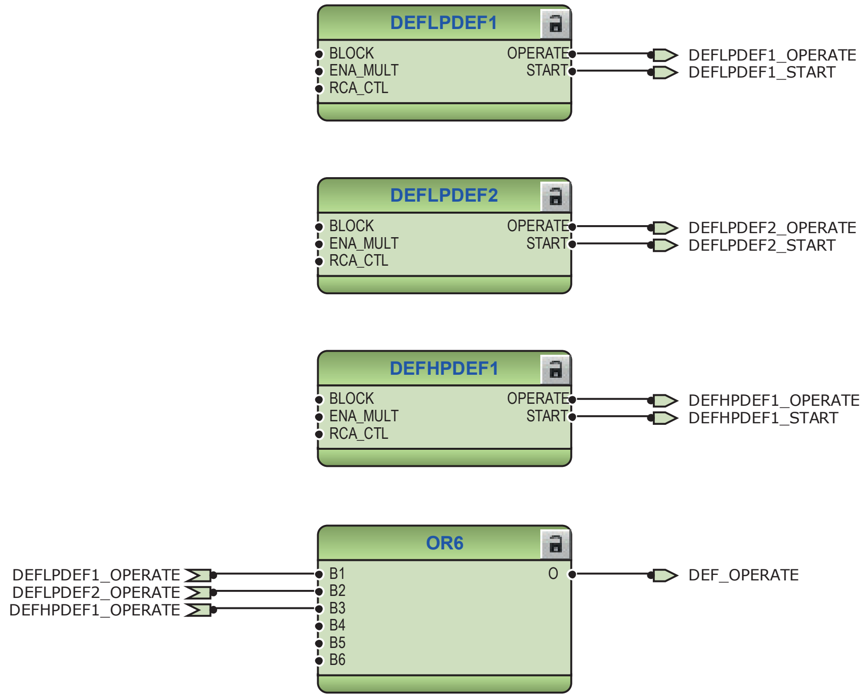


Figure 22: Directional earth-fault protection functions

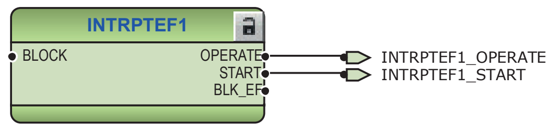


Figure 23: Transient or intermittent earth-fault protection functions

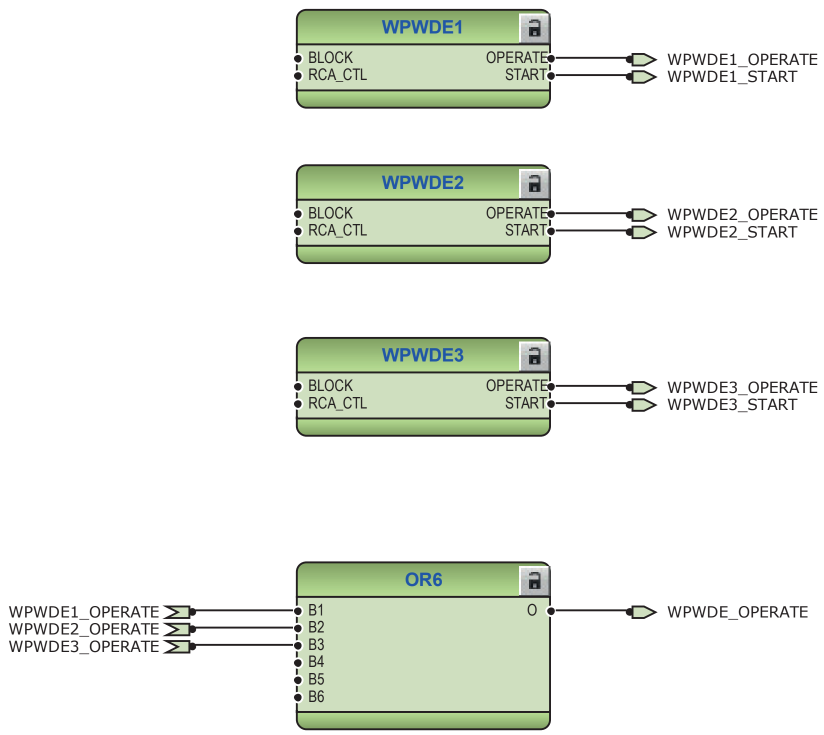


Figure 24: Wattmetric protection function

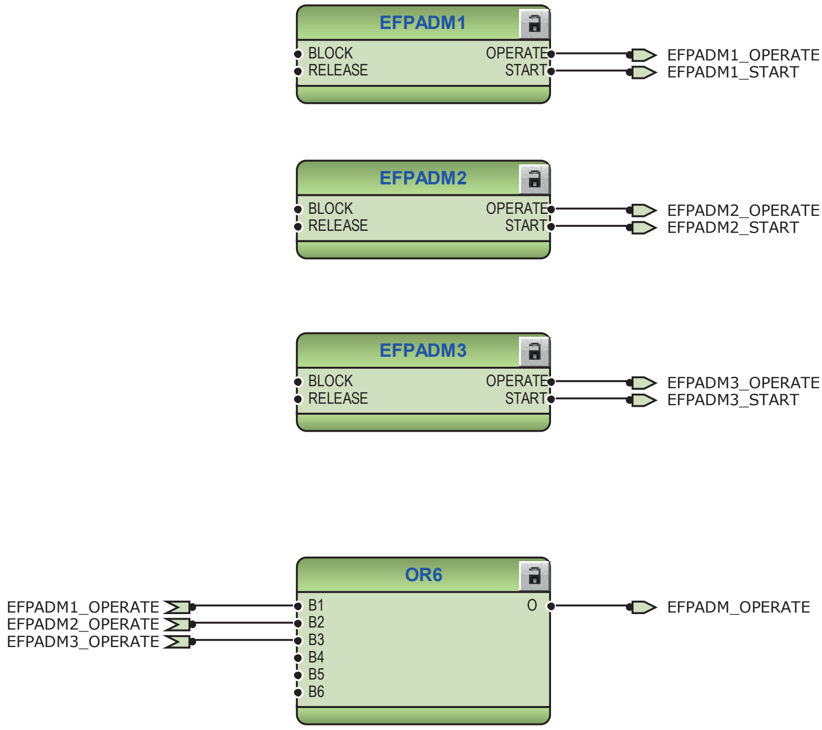


Figure 25: Admittance-based earth-fault protection function

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.

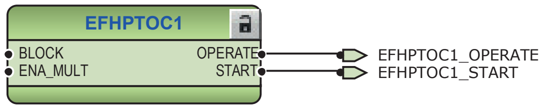


Figure 26: Non-directional earth-fault protection

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

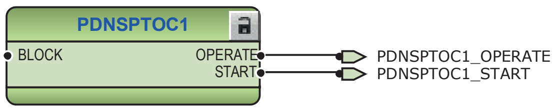


Figure 27: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions.

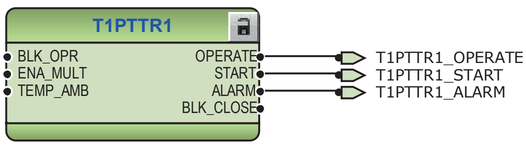


Figure 28: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by number of different protection functions available in the IED. The 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.

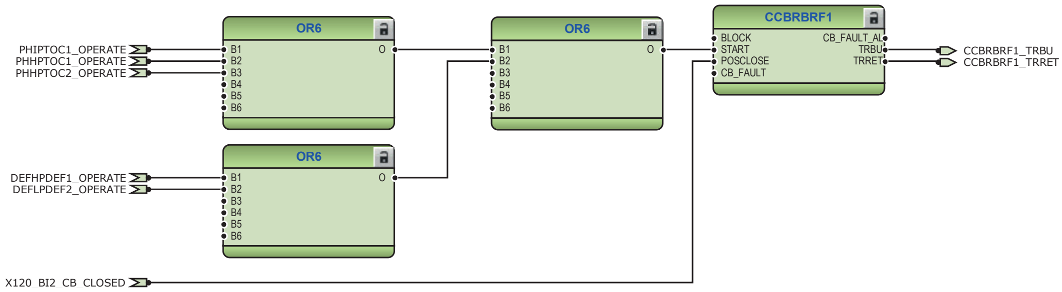


Figure 29: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2.

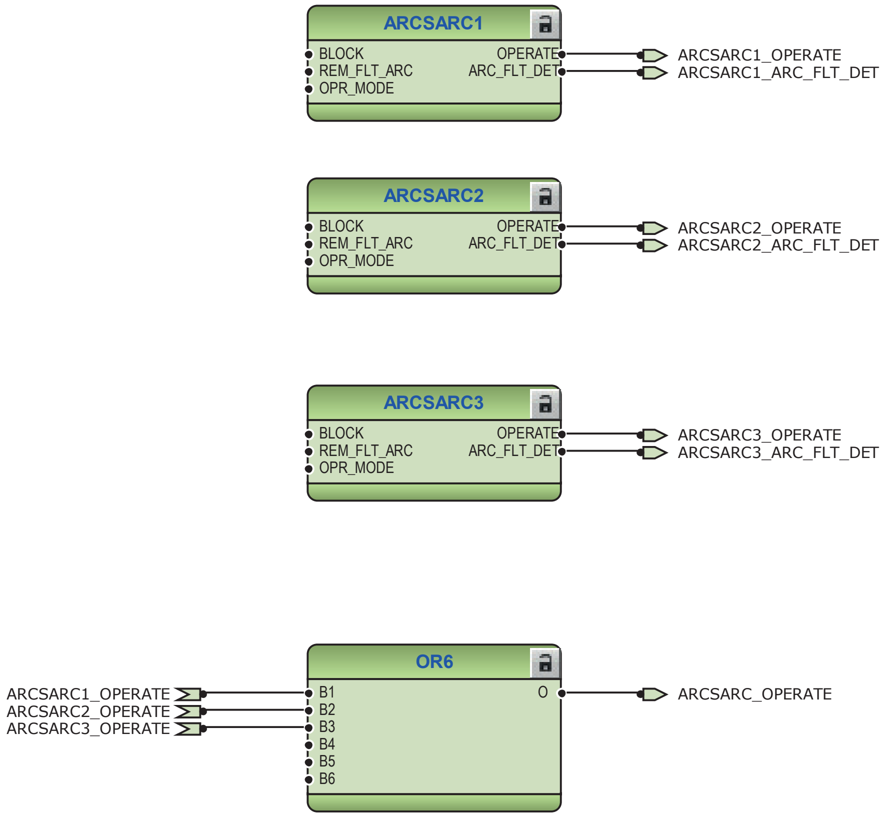


Figure 30: Arc protection

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. This signal is not connected in the 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.

Set the parameters for DARREC1 properly.

Check the initialization signals of DARREC1.

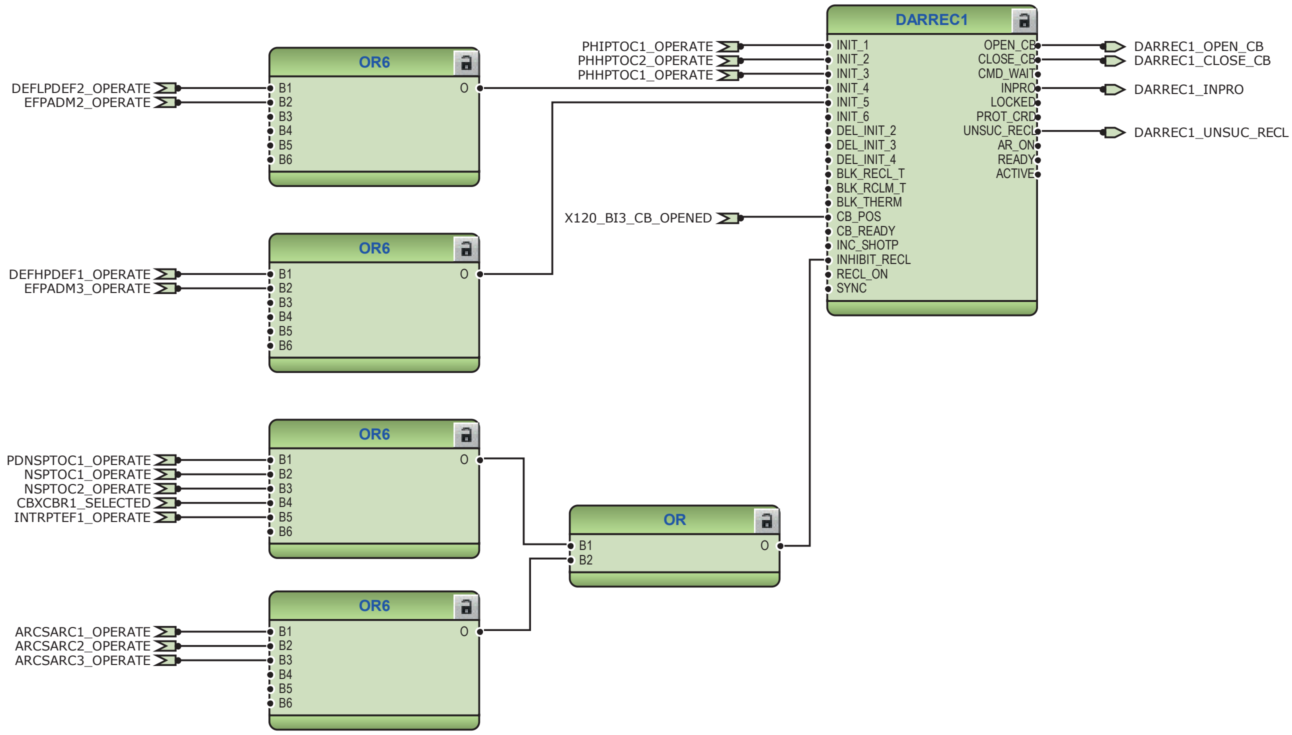


Figure 31: Autoreclosing function

Residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage. This can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality.

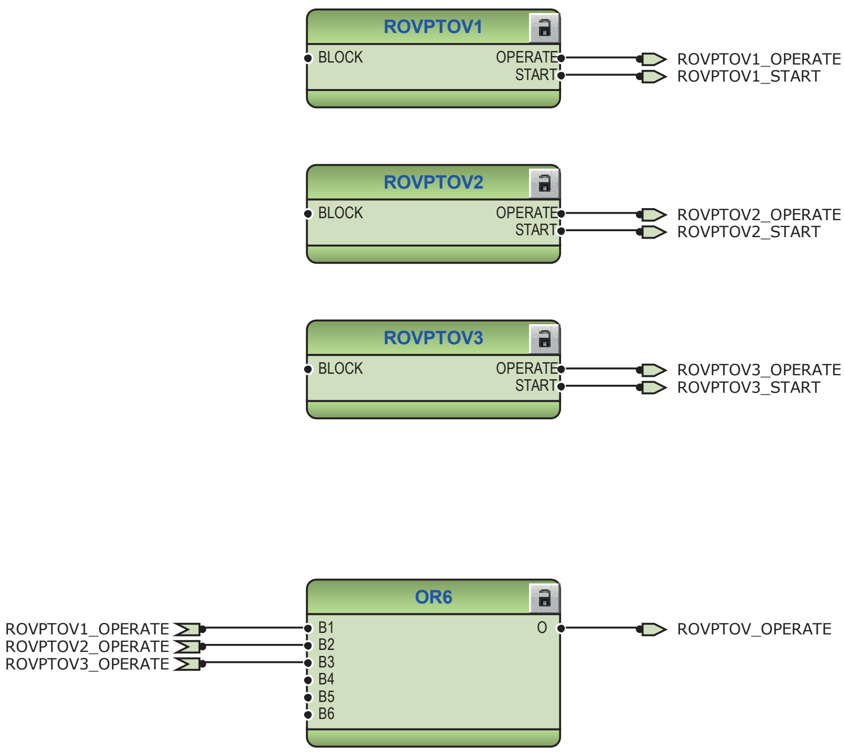


Figure 32: Residual voltage protection function

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 is connected to binary outputs.

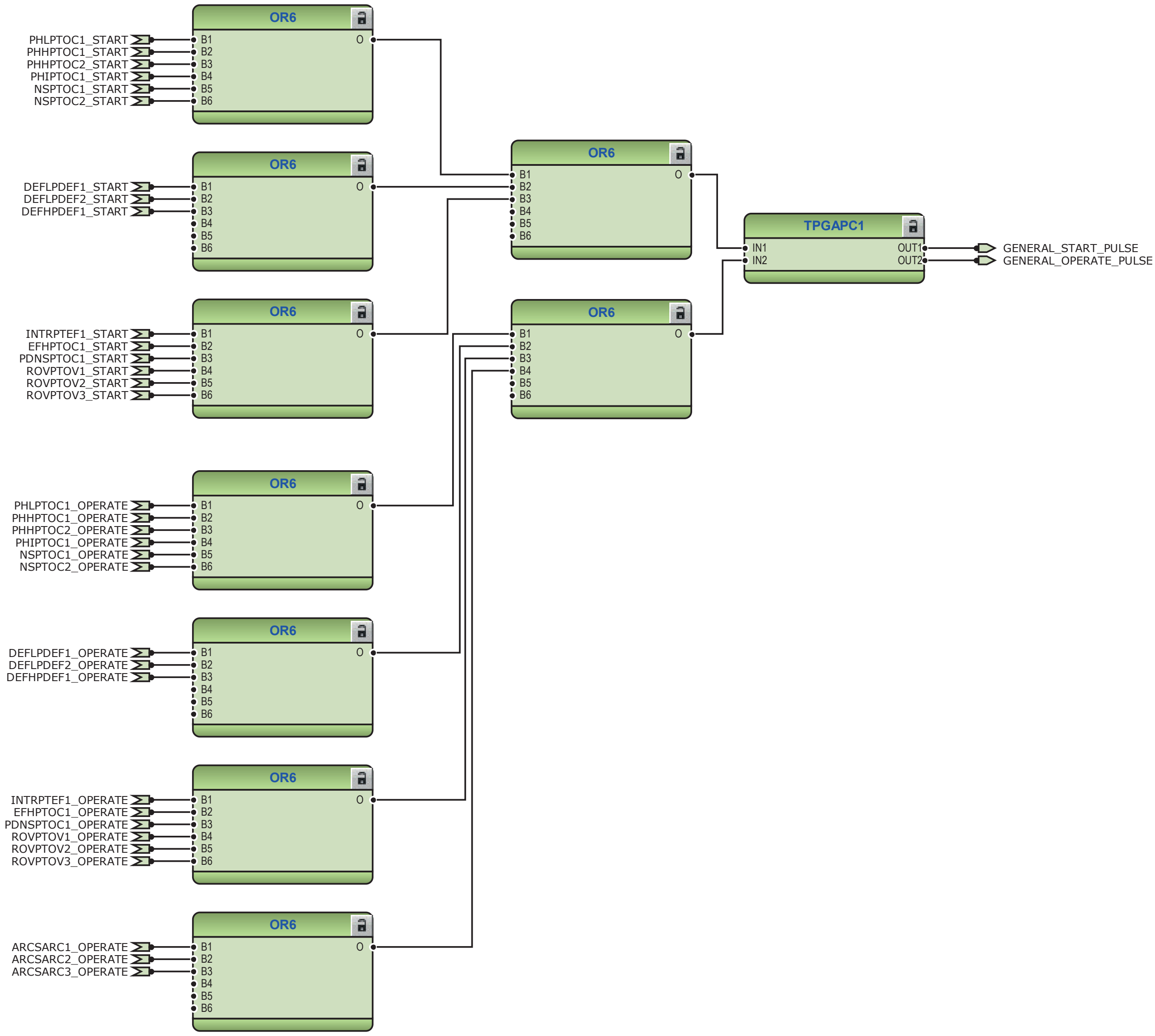


Figure 33: General start and operate signals

The operate signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions are available at binary outputs X100:PO3 and X100:PO4. Both the trip logic functions are provided with lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

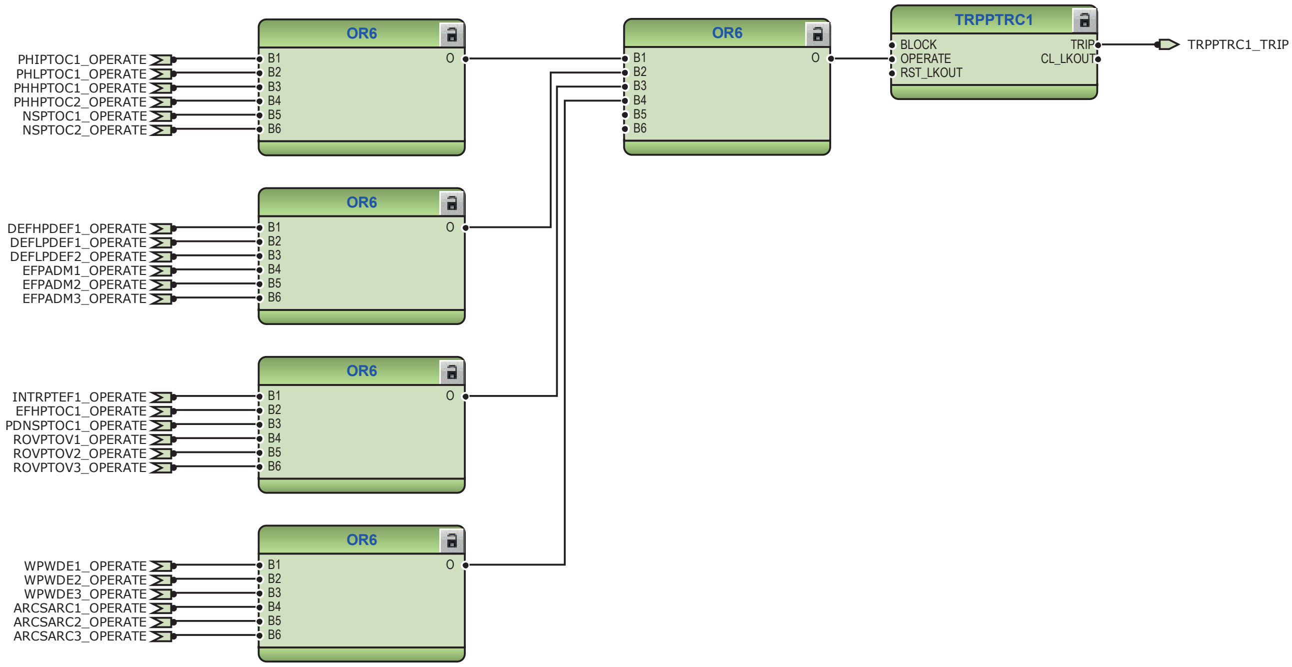


Figure 34: Trip logic TRPPTRC1

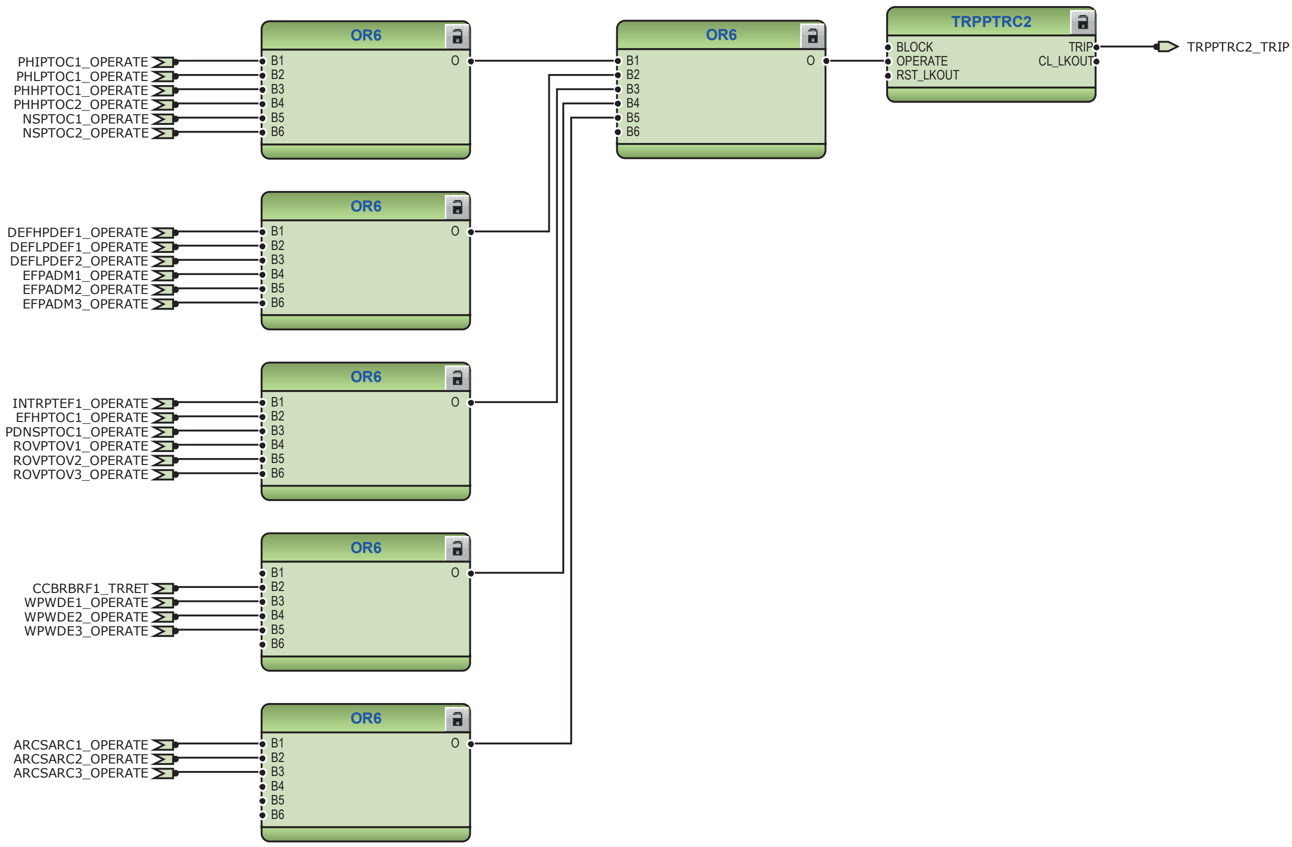


Figure 35: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

The START and 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.

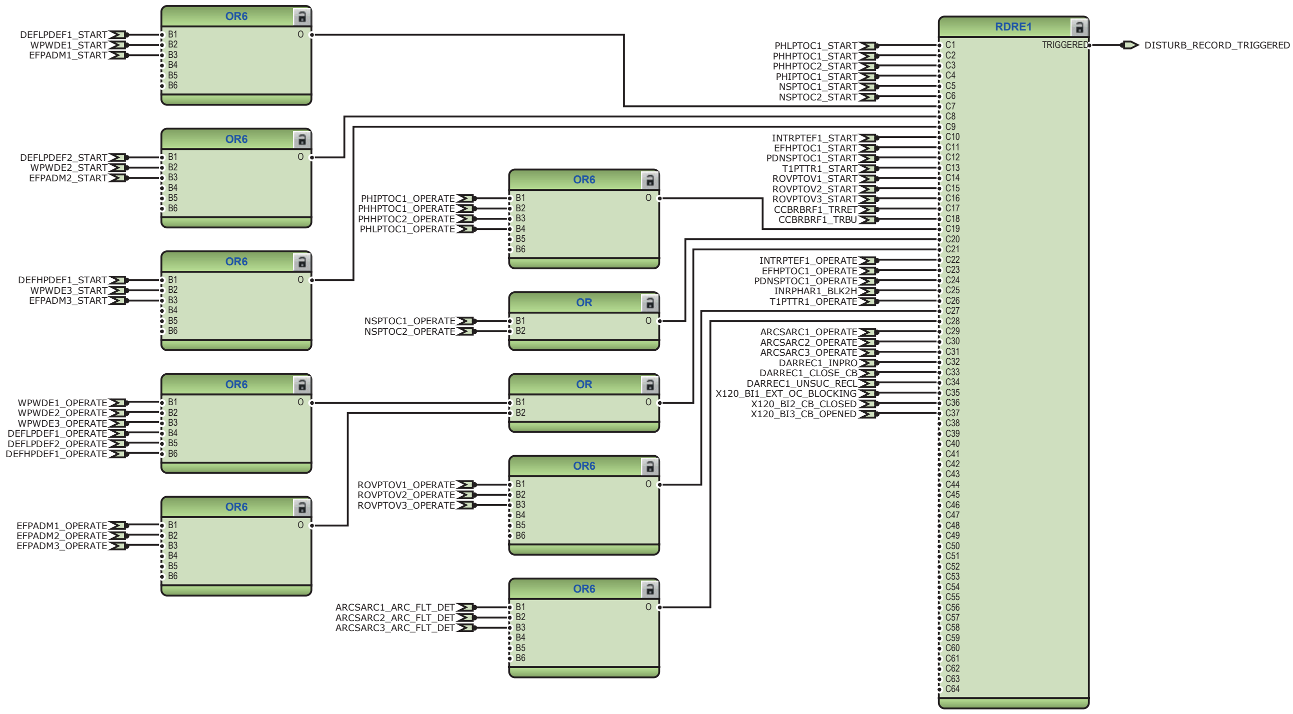


Figure 36: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

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

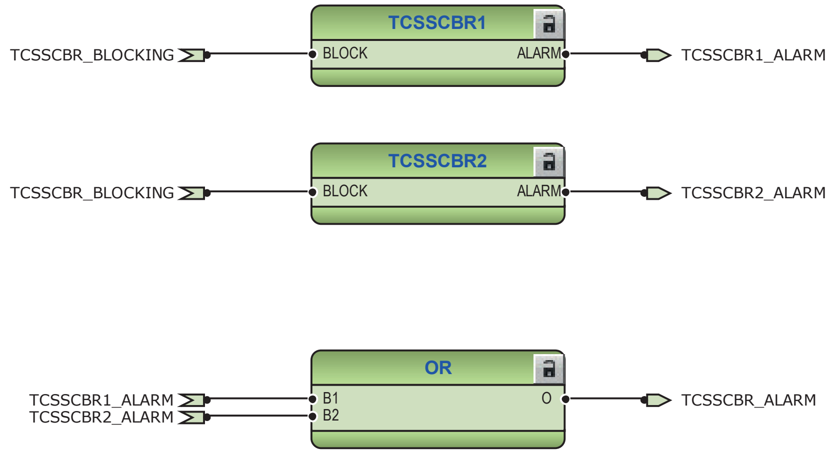


Figure 37: Trip circuit supervision function

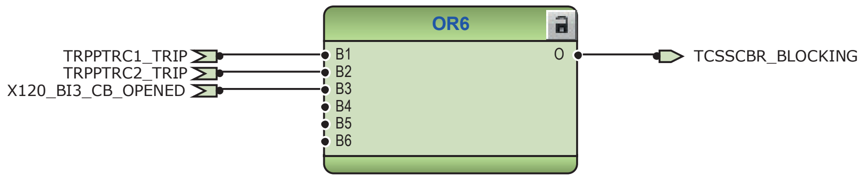


Figure 38: Logic for blocking of trip circuit supervision

3.3.3.4 Functional diagrams for control and interlocking

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated using the configuration logic, which is based on the status of the trip logics. However, other signals can be connected based on the application needs.

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

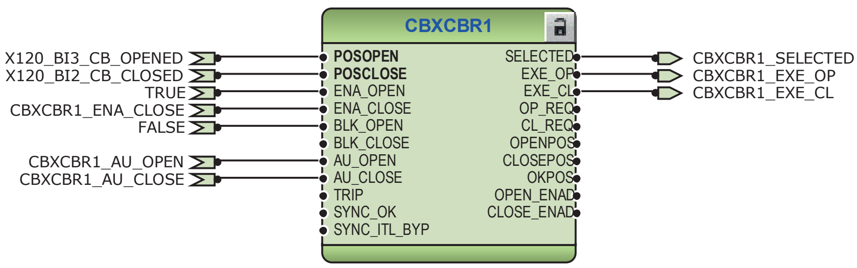


Figure 39: Circuit breaker control logic: Circuit breaker 1

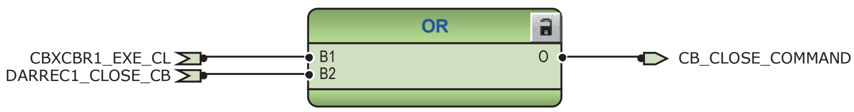


Figure 40: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

Figure 41: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

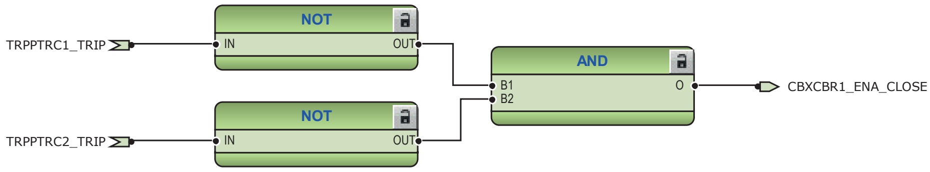


Figure 42: Circuit breaker close enable logic

The configuration includes the 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.

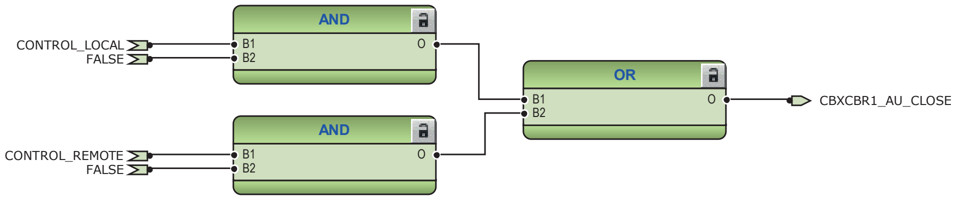


Figure 43: External closing command for circuit breaker

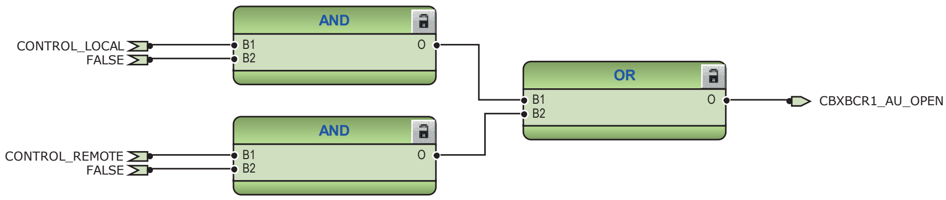


Figure 44: External opening command for circuit breaker

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

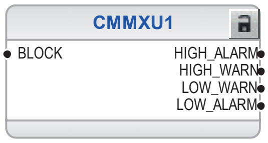


Figure 45: Current measurement: Three phase current measurement

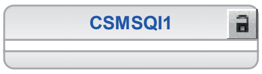


Figure 46: Current measurement: Sequence current measurements

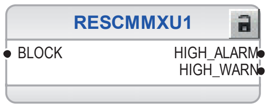


Figure 47: Current measurement: Residual current measurements

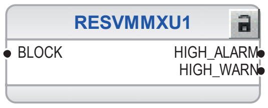


Figure 48: Voltage measurement: Residual voltage measurements

Figure 49: Other measurement: Data monitoring

3.3.3.6 Functional diagrams for I/O and alarm LEDs

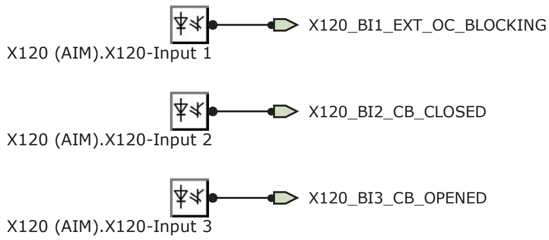


Figure 50: Default binary inputs - X120

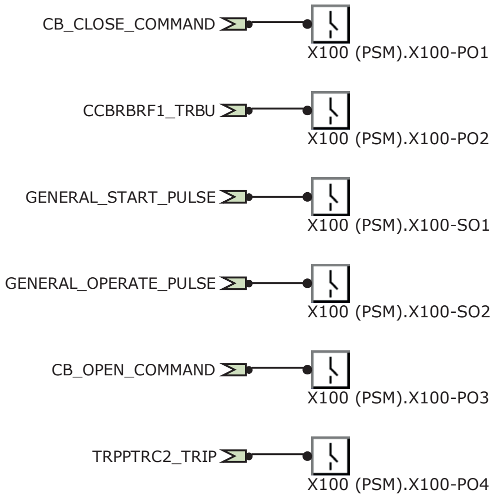
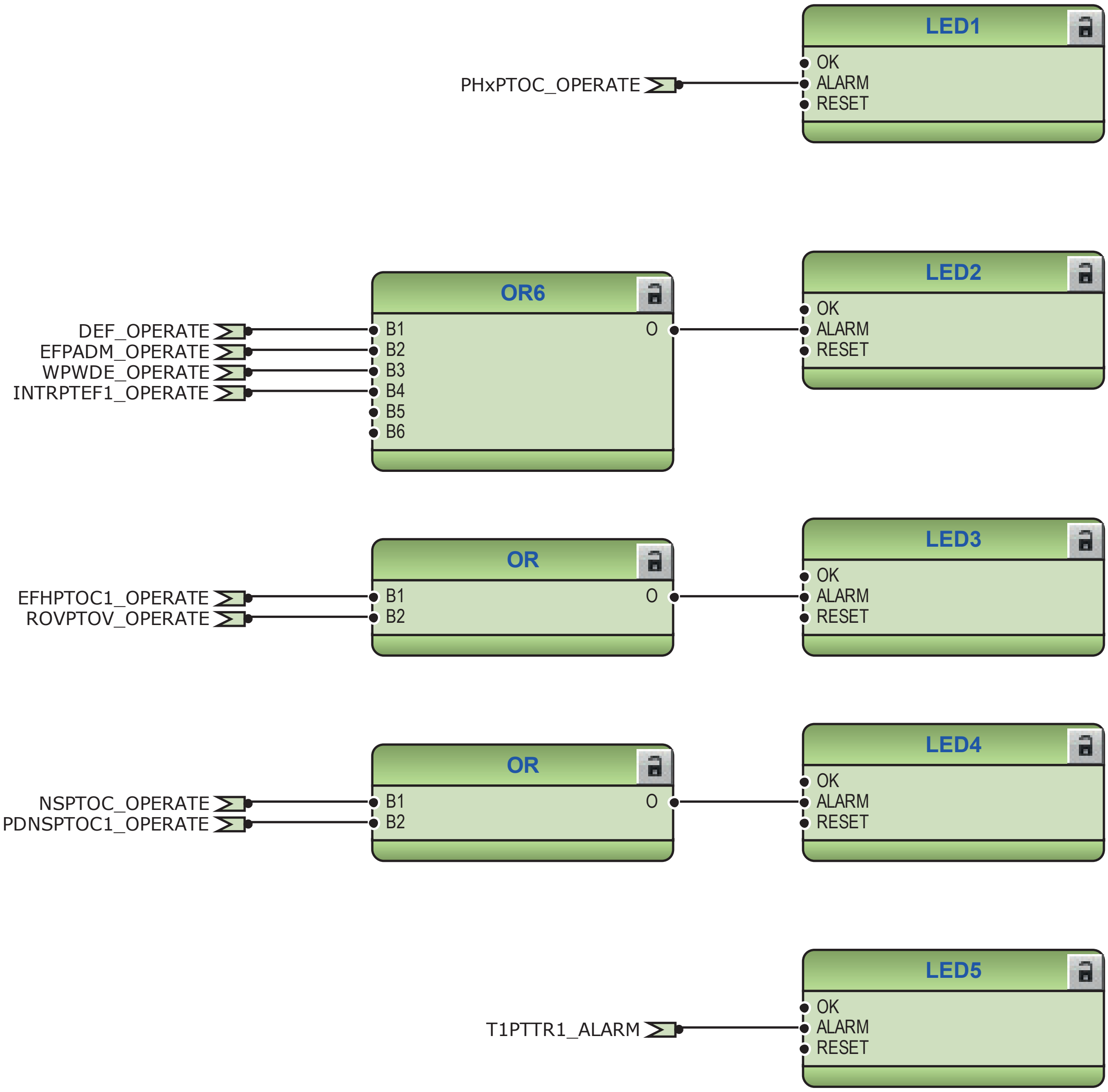


Figure 51: Default binary outputs - X100


LED1
PHxPTOC_OPERATE
OK
ALARM
RESET
OR6
DEF_OPERATE
EFPADM_OPERATE
WPWDE_OPERATE
INTRPTEF1_OPERATE
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
OR
EFHPTOC1_OPERATE
ROVPTOV_OPERATE
B1
B2
O
LED3
OK
ALARM
RESET
OR
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
B1
B2
O
LED4
OK
ALARM
RESET
LED5
T1PTTR1_ALARM
OK
ALARM
RESET

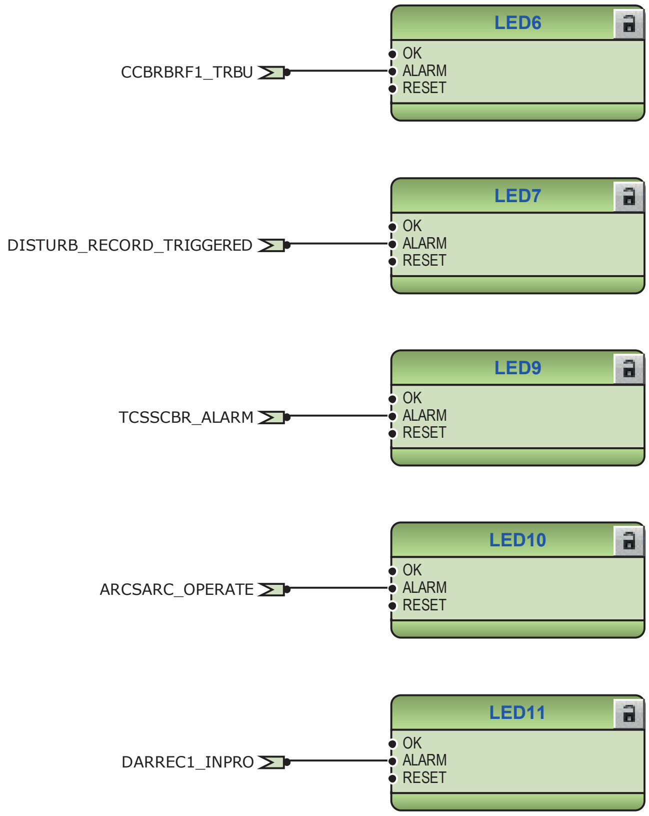


Figure 52: Default LED connection

3.3.3.7 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, runtime counter for machines and devices MDSOPT and different types of timer 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 non-directional overcurrent and directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance, wattmetric or harmonic-based 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

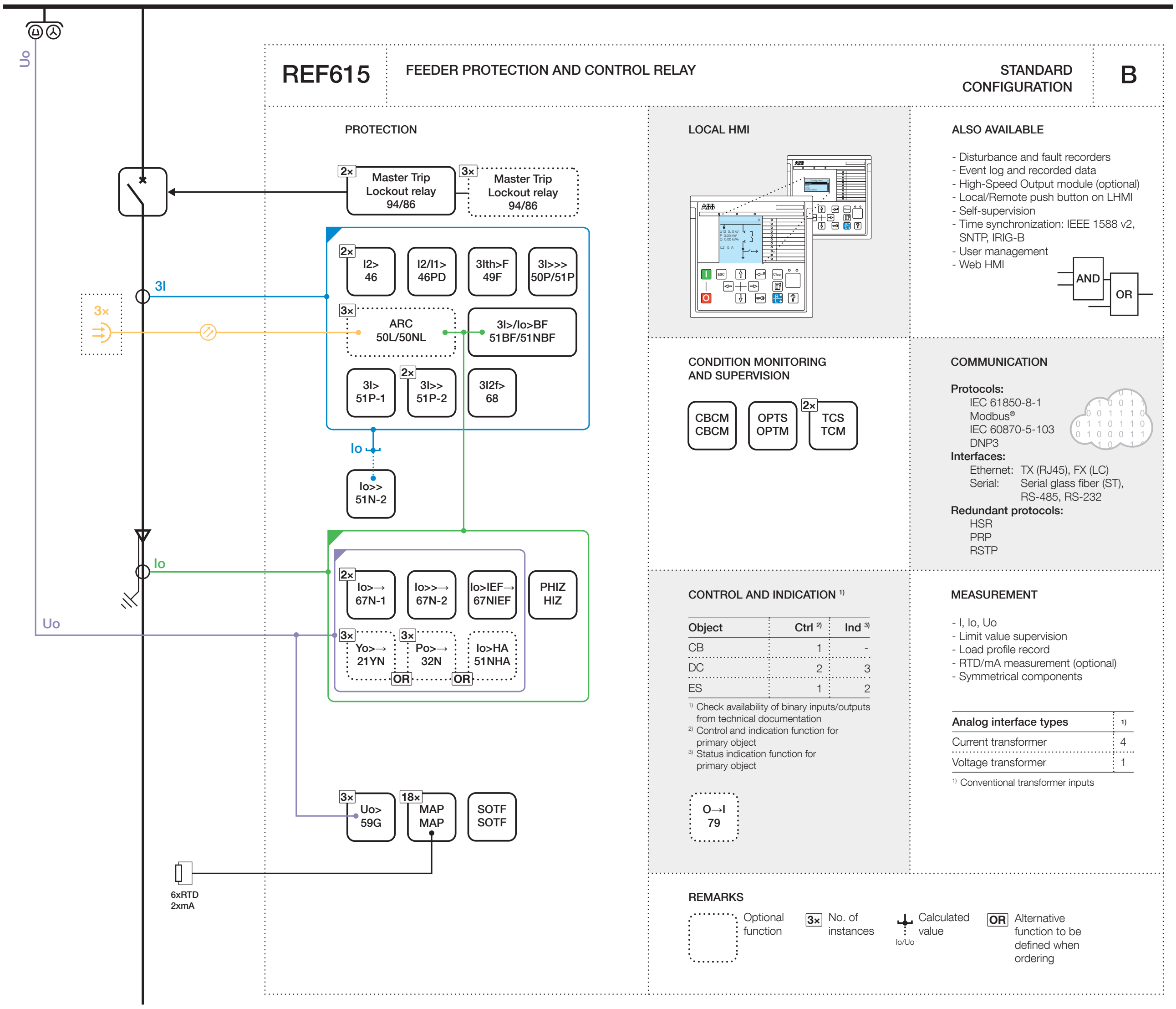


Figure 53: Functionality overview for standard configuration B

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-BI2	Directional earth-fault protection's basic angle control
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication

Table 17: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Circuit breaker failure protection trip to upstream breaker
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X100-SO1	General start indication
X100-SO2	General operate indication
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 18: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Directional/intermittent earth-fault operate
3	Double (cross country) earth-fault or residual overvoltage operate
4	Negative sequence overcurrent or phase discontinuity operate
5	Thermal overload alarm

Table continues on the next page

LED	Description
6	Breaker failure operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Trip circuit supervision alarm
10	Arc protection operate
11	Autoreclose in progress

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	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
	EFPADM1 - start	
	WPWDE1 - start	
8	DEFLPDEF2 - start	Positive or Rising
	EFPADM2 - start	
	WPWDE2 - start	
9	EFPADM3 - start	Positive or Rising
	WPWDE3 - start	

Table continues on the next page

Channel	ID text	Level trigger mode
10	INTRPTEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	ROVPTOV1 - start	Positive or Rising
15	ROVPTOV2 - start	Positive or Rising
16	ROVPTOV3 - start	Positive or Rising
17	CCBRBRF1 - trret	Level trigger off
18	CCBRBRF1 - trbu	Level trigger off
19	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
20	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
21	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1 - operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
22	INTRPTEF1 - operate	Level trigger off
23	EFHPTOC1 - operate	Level trigger off
24	PDNSPTOC1 - operate	Level trigger off
25	INRPHAR1 - blk2h	Level trigger off
26	T1PTTR1 - operate	Level trigger off
27	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
28	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
29	ARCSARC1 - operate	Positive or rising
30	ARCSARC2 - operate	Positive or rising
31	ARCSARC3 - operate	Positive or rising
32	DARREC1 - inpro	Level trigger off
33	DARREC1 - close CB	Level trigger off
34	DARREC1 - unsuc recl	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
34	X120BI1 - ext OC blocking	Level trigger off
35	X120BI2 - CB closed	Level trigger off
36	X120BI3 - CB opened	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 the 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.

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 IEDs protection functionality in detail and according to the factory set default connections.

Four 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.

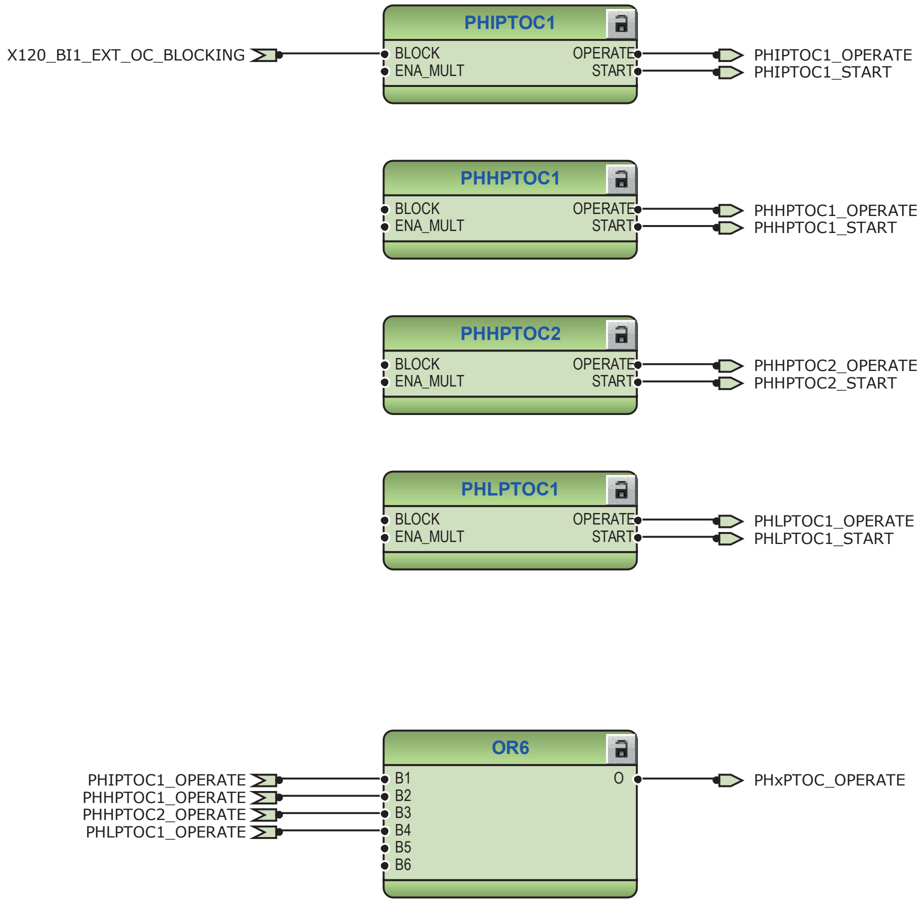


Figure 54: Overcurrent protection functions

The upstream blocking from the start of the second high stage of three-phase non-directional overcurrent protection PHHPTOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

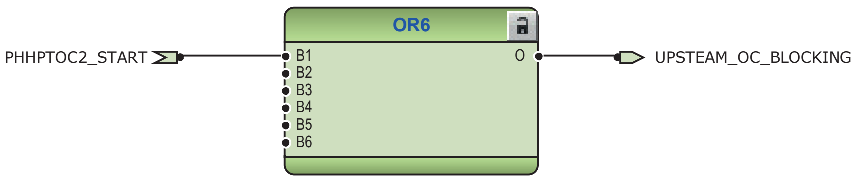


Figure 55: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

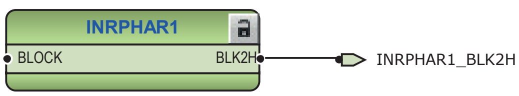


Figure 56: Inrush detector function

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.

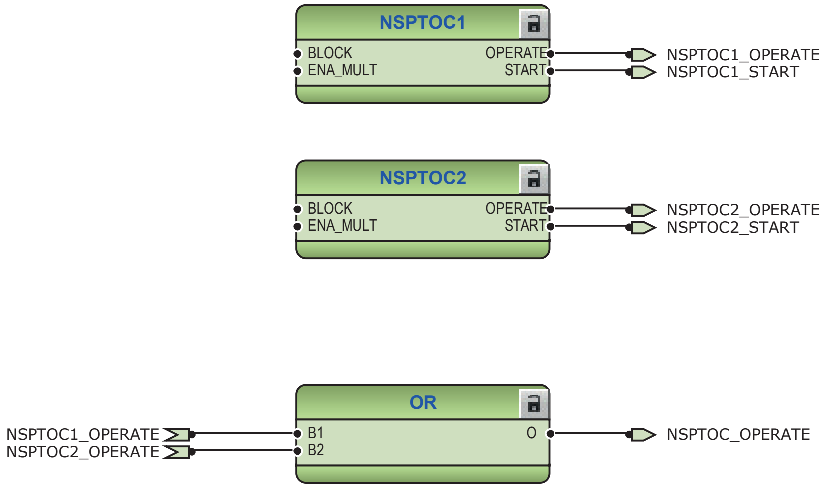


Figure 57: Negative-sequence overcurrent protection function

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 used together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE or harmonics-based earth-fault protection HAEFPTOC1. 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.

The binary input X110:BI2 is used for controlling directional earth-fault protection block's relay characteristic angle (RCA: 0°, -90°) or operation mode (IoSinϕ, IoCosϕ) change. The same input is also available for wattmetric protection.

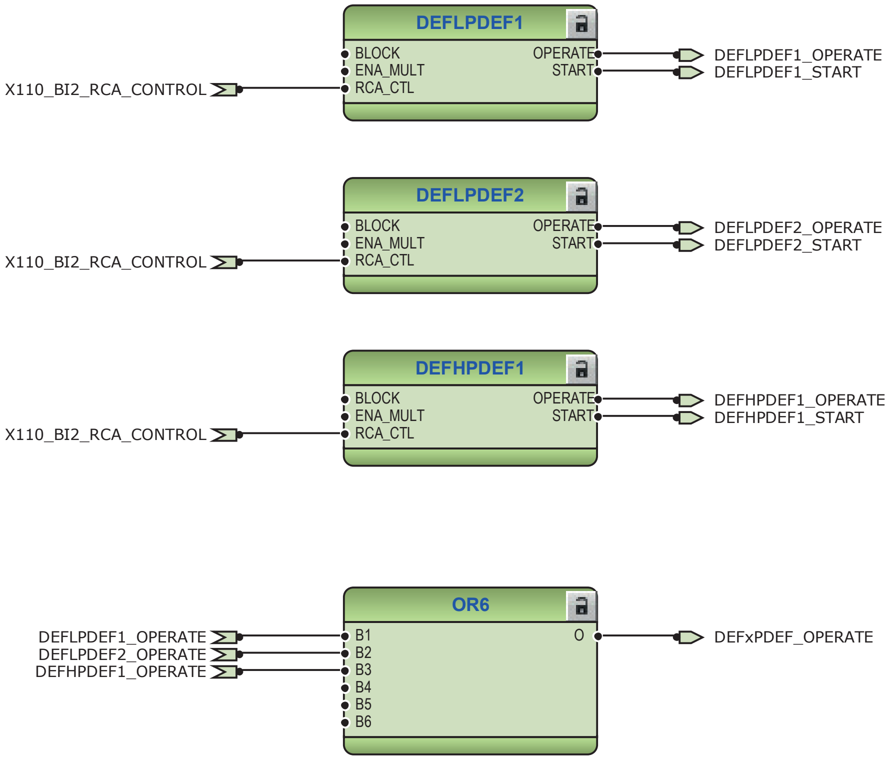


Figure 58: Directional earth-fault protection functions

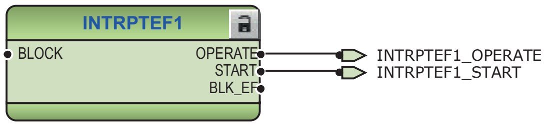


Figure 59: Transient or intermittent earth-fault protection functions

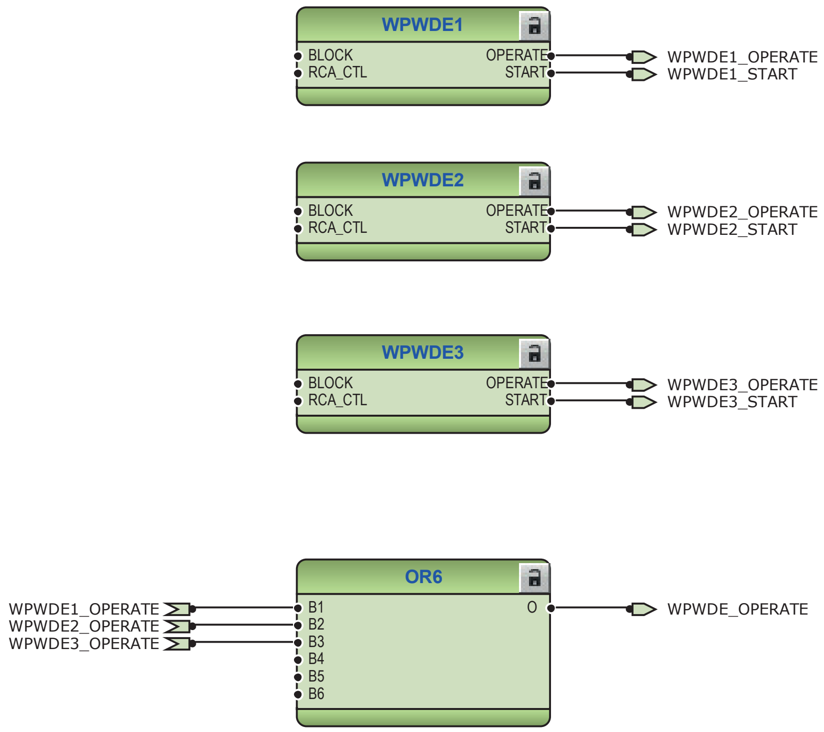


Figure 60: Wattmetric protection function

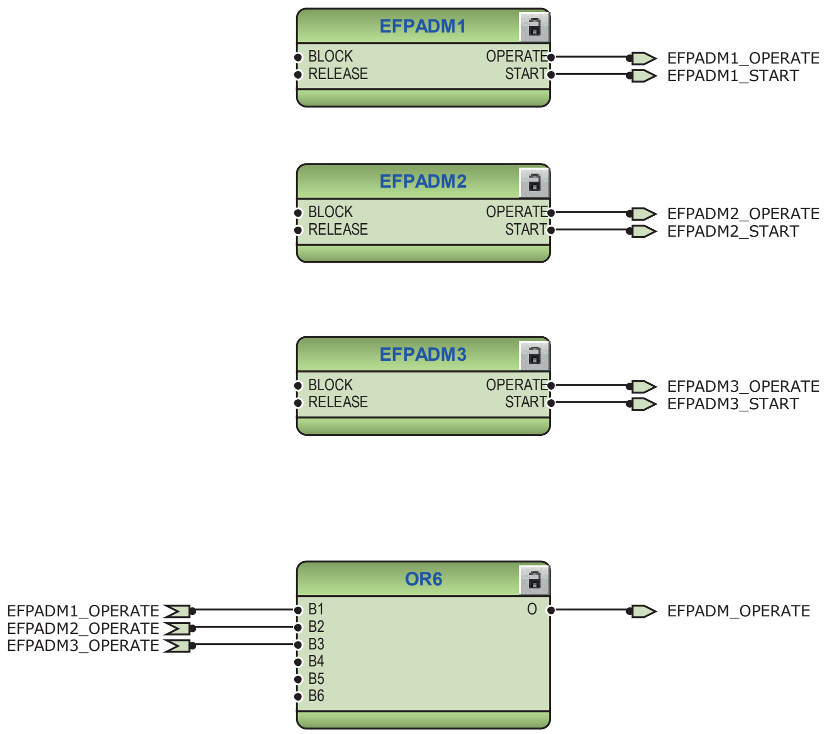


Figure 61: Admittance-based earth-fault protection function

A dedicated non-directional earth-fault protection block EFHPTOC protects from double earth-fault situations in isolated or compensated networks. The protection function uses the calculated residual current originating from the phase currents.

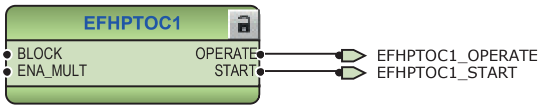


Figure 62: Non-directional earth-fault protection

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

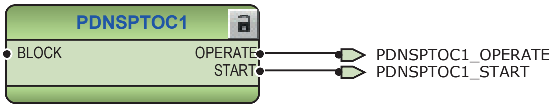


Figure 63: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions.

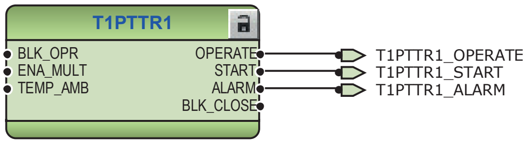


Figure 64: Thermal overcurrent protection function

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

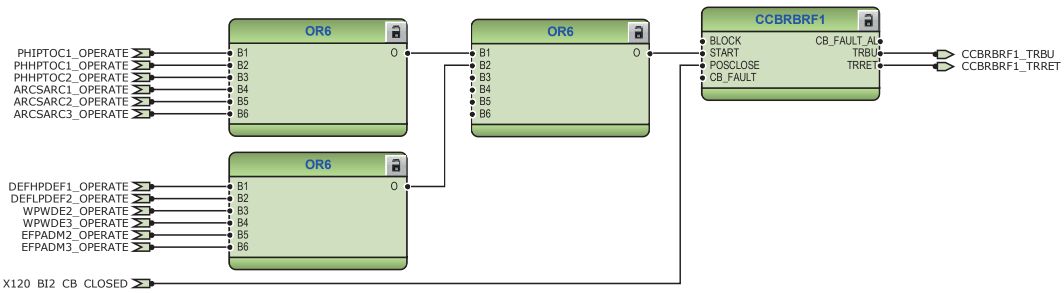


Figure 65: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1..3 are connected to dedicated trip logic

TRPPTRC3...5. The outputs of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2, and X110:HSO3 respectively.

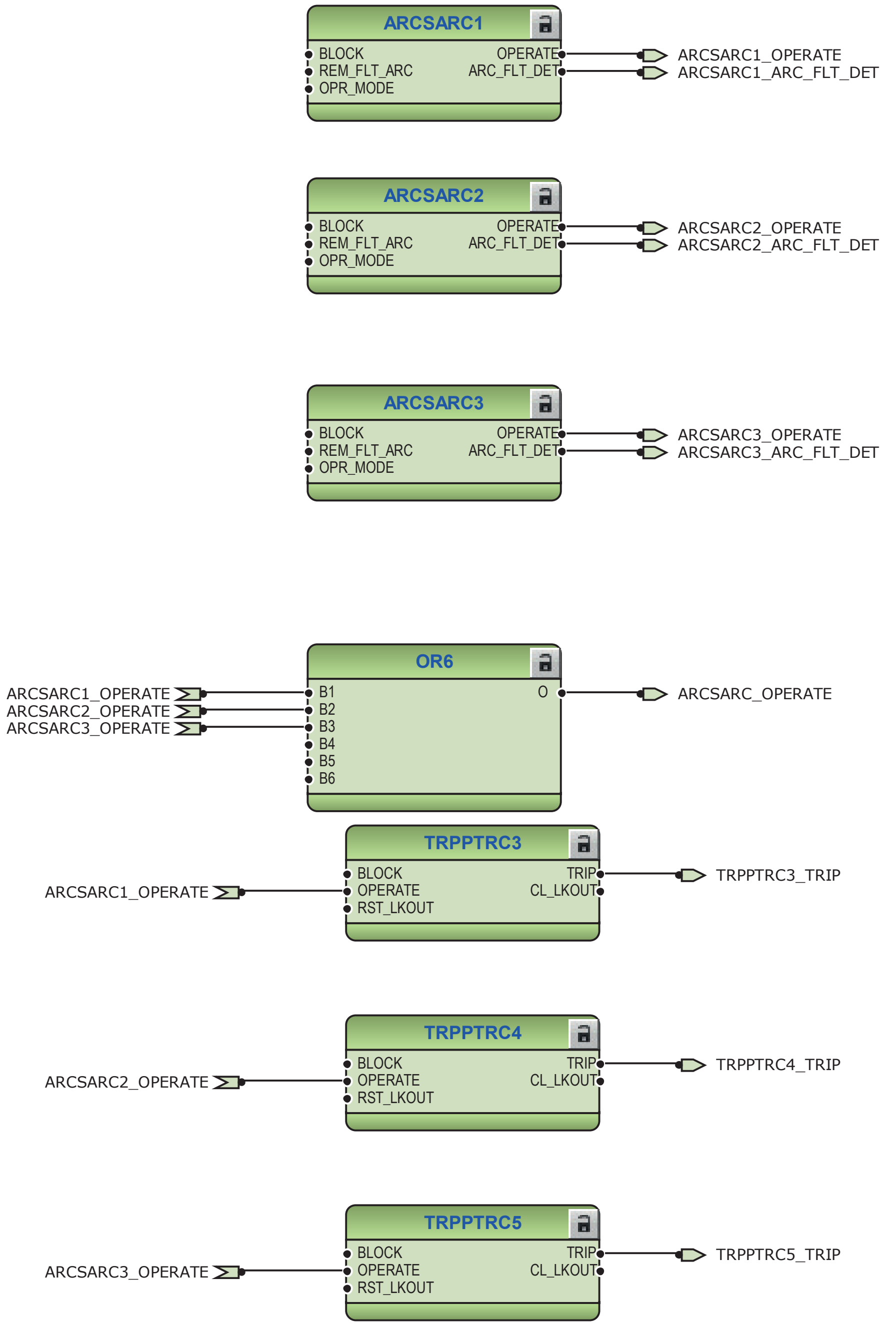


Figure 66: Arc protection with dedicated HSO

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 `CBXCBR-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 the binary output X100:PO3, whereas the close command is connected directly to the binary output X100:PO1.

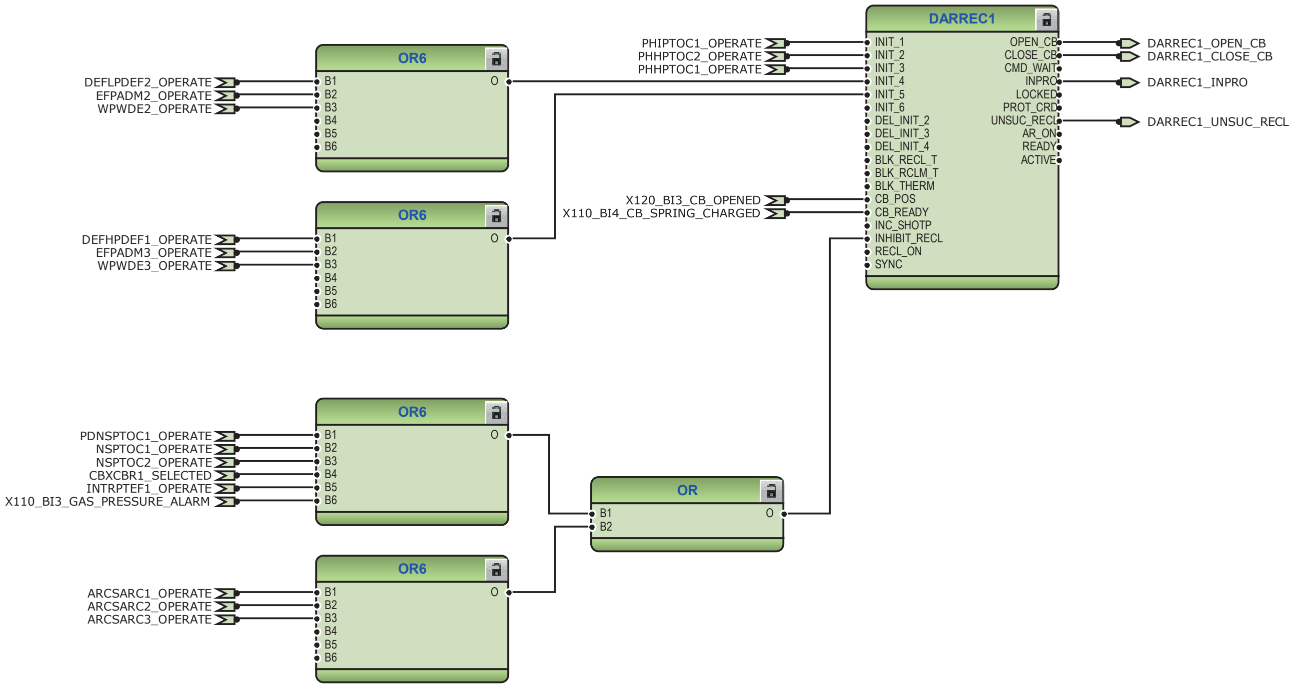


Figure 67: Autoreclosing function

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

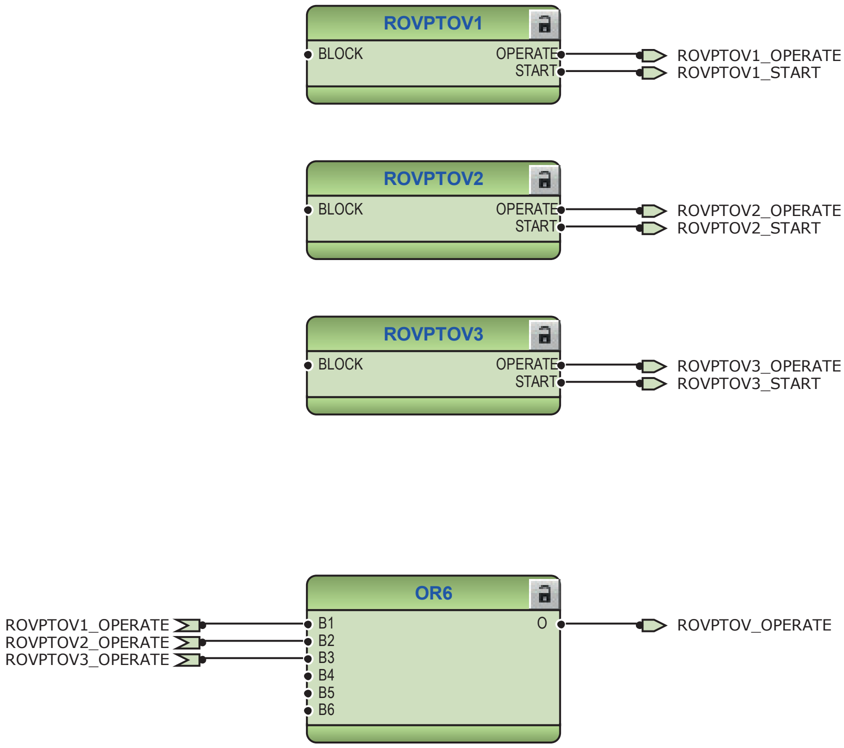


Figure 68: Residual voltage protection function

General `start` and `operate` from all the functions are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

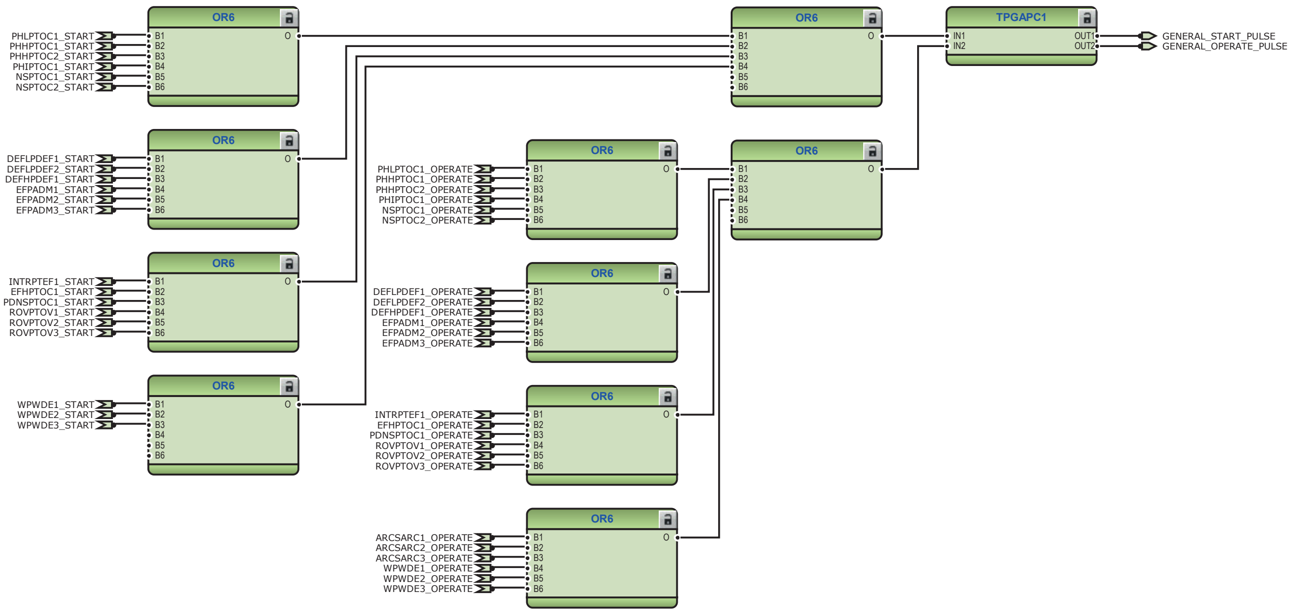


Figure 69: General start and operate signals

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, the binary input has been assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button. Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

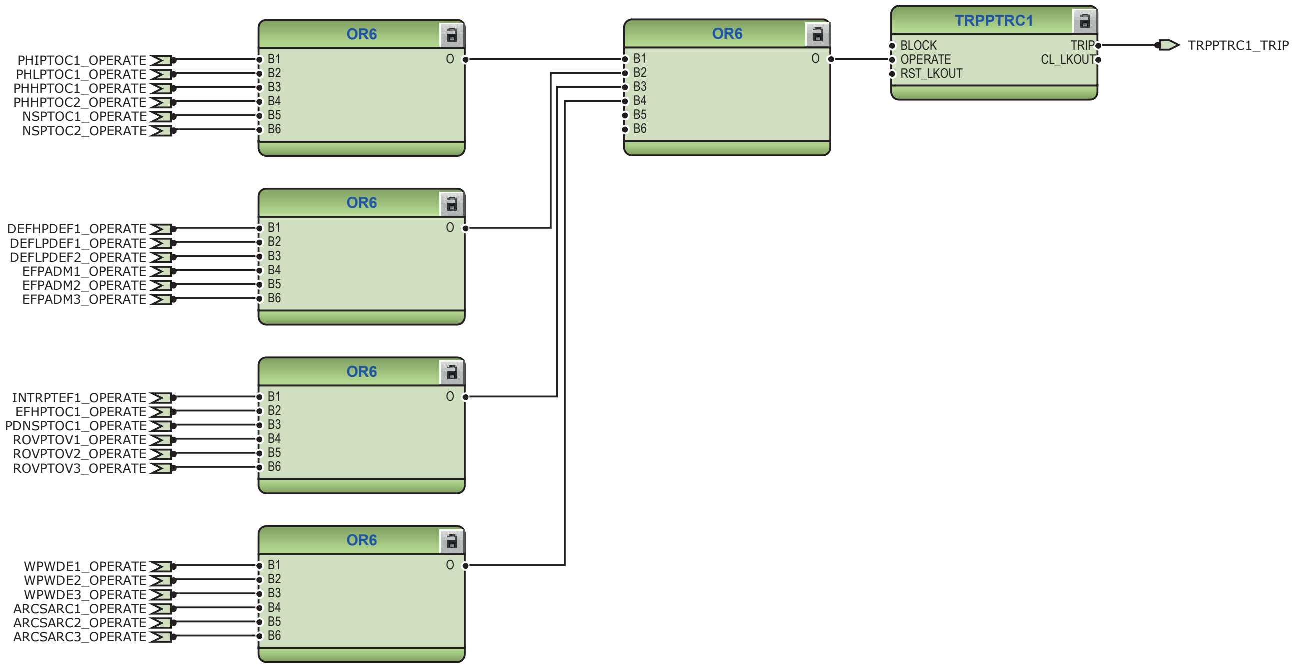


Figure 70: Trip logic TRPPTRC1

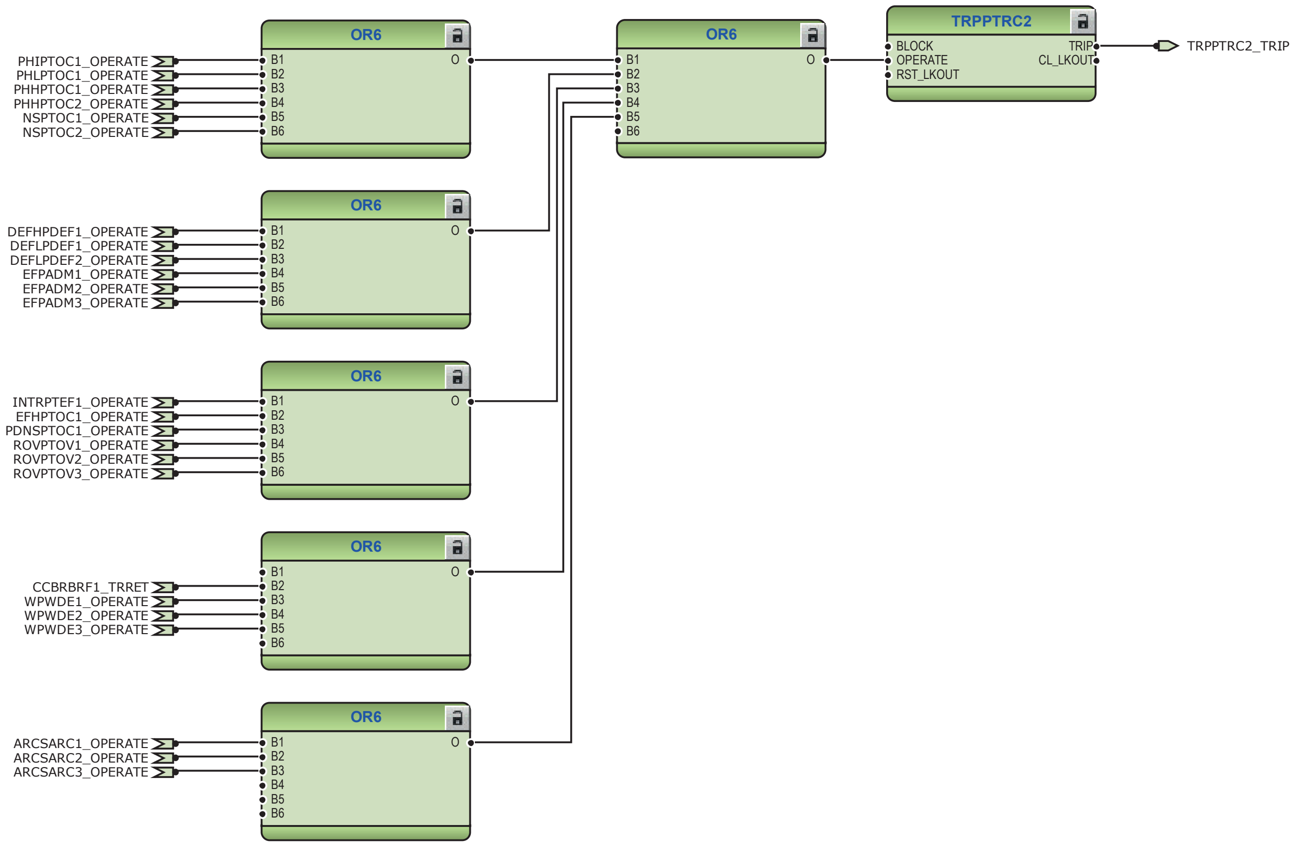


Figure 71: Trip logic TRPPTRC2

3.4.3.2 Functional diagrams for disturbance recorder

The START and 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 few binary inputs are also connected.

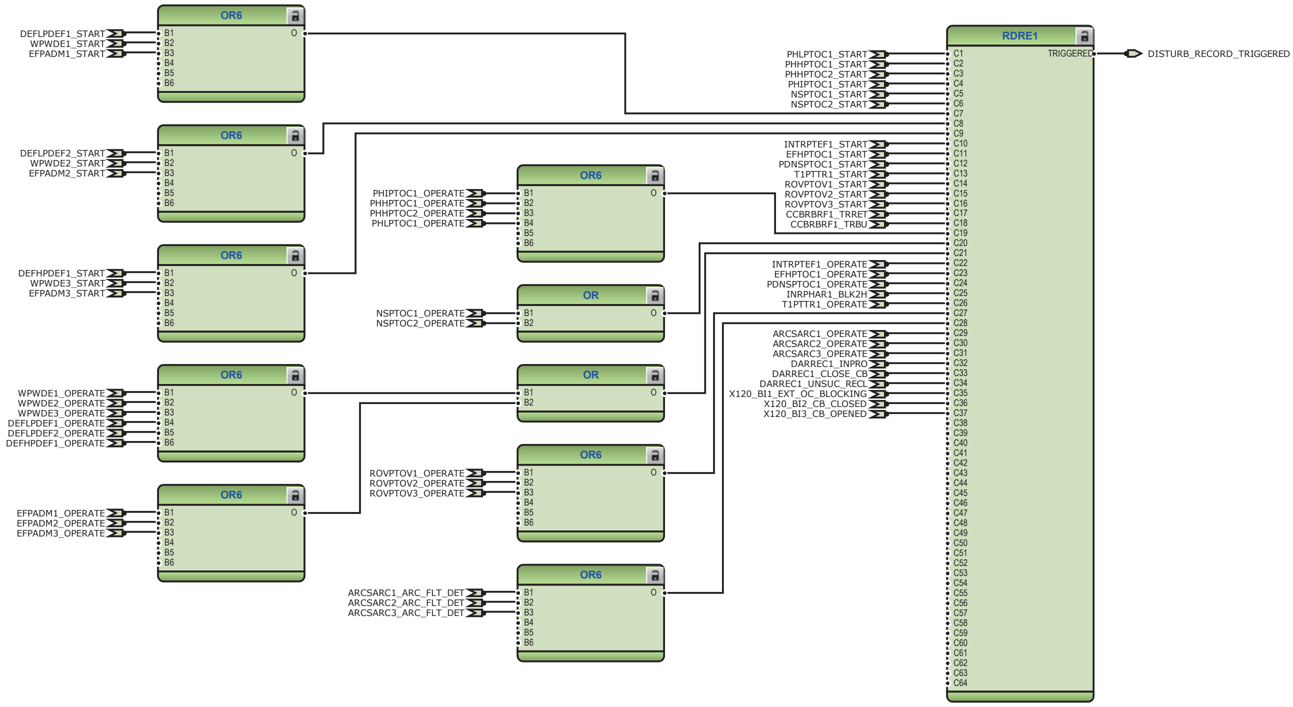


Figure 72: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

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.

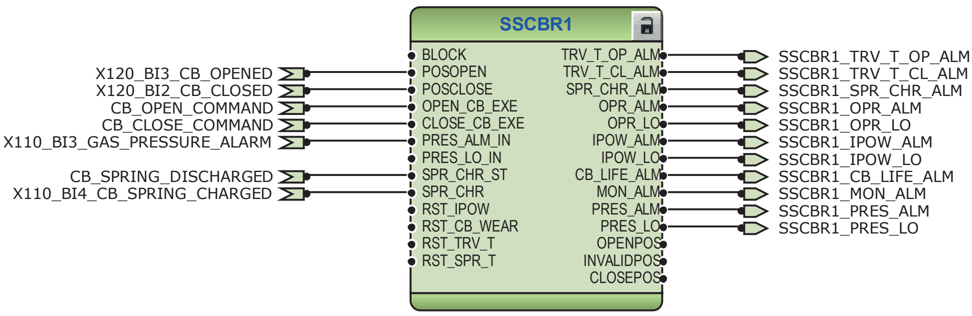


Figure 73: Circuit-breaker condition monitoring function

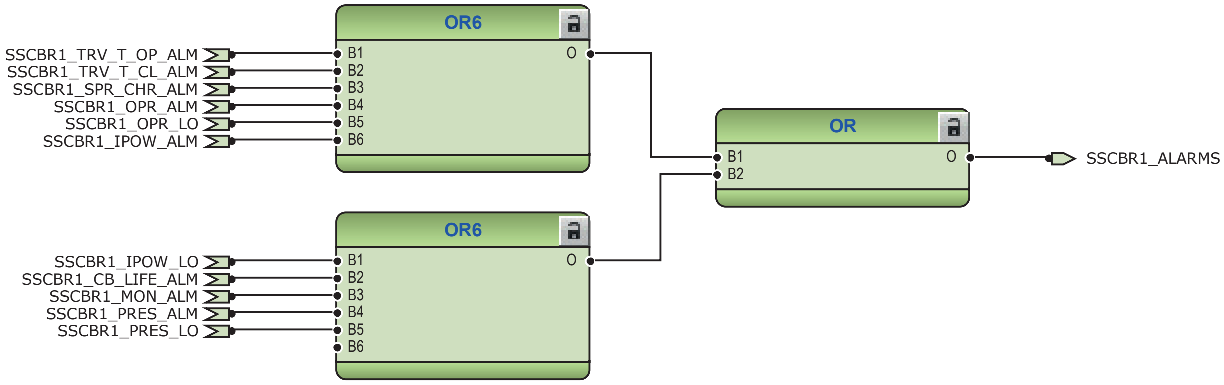


Figure 74: Logic for circuit breaker monitoring alarm

Figure 75: 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. Both 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.

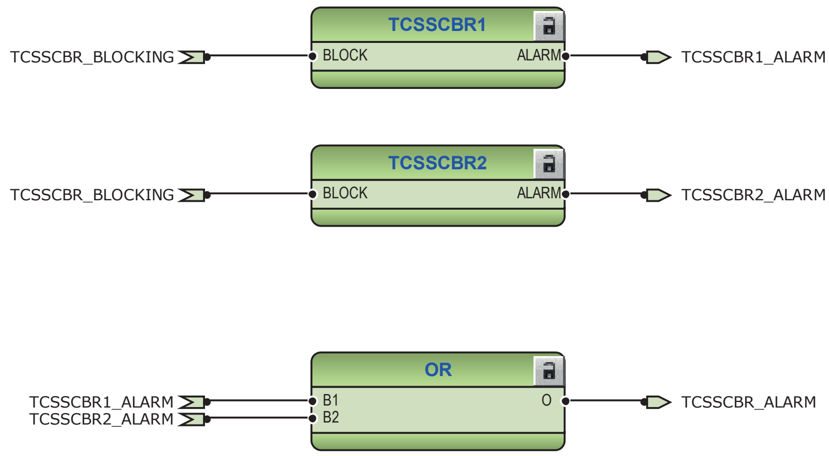


Figure 76: Trip circuit supervision function

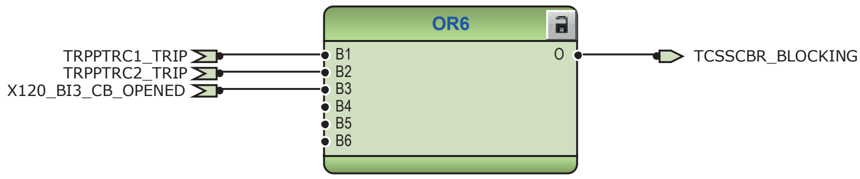


Figure 77: Logic for blocking of trip circuit supervision function

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 standard configuration. The disconnector (CB truck) and line side earthing switch status information are connected to DCSXSWI1 and ESSXSI1 respectively.

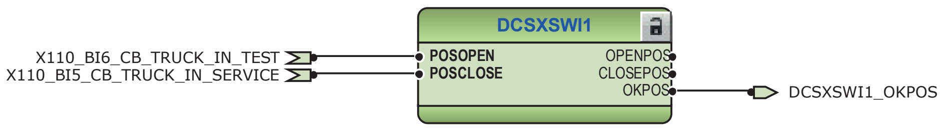


Figure 78: Disconnector control logic

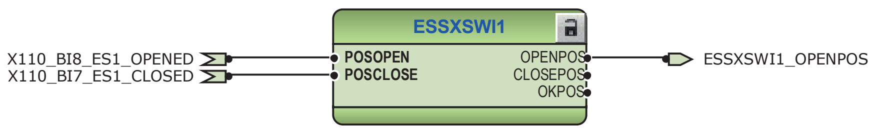


Figure 79: Earthing switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit-breaker spring charging status.

The `OKPOS` output from DCSXSWI defines whether the disconnector or 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 circuit breaker is always enabled.

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

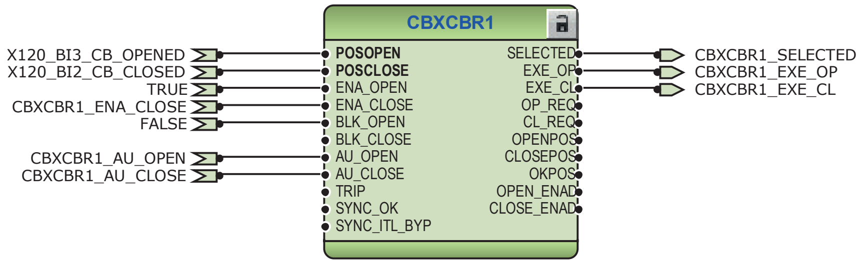


Figure 80: Circuit-breaker control logic: Circuit breaker 1

Connect the additional signals required for the application for closing and opening of circuit breaker.

Figure 81: Circuit-breaker control logic: Signals for closing coil of circuit breaker

Figure 82: Circuit-breaker control logic: Signals for opening coil of circuit breaker

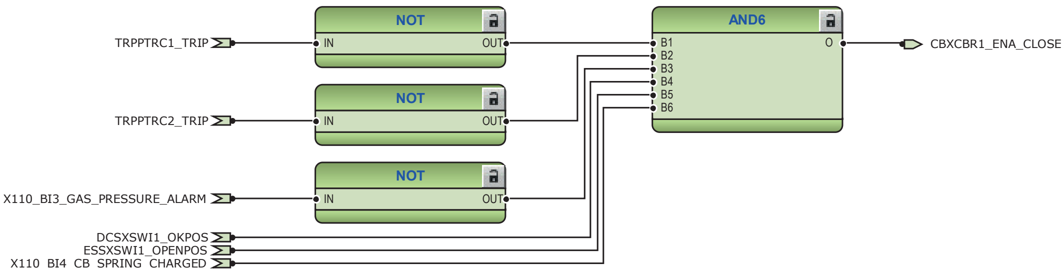


Figure 83: Circuit breaker close enable logic

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

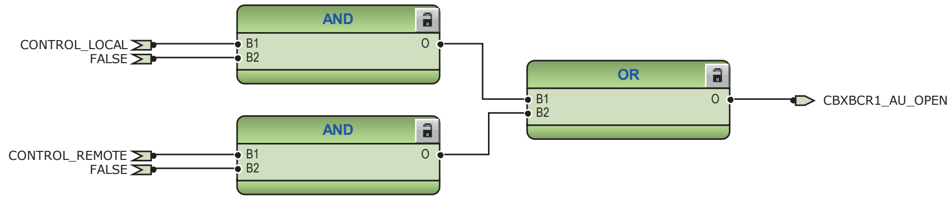


Figure 84: External opening command for circuit breaker

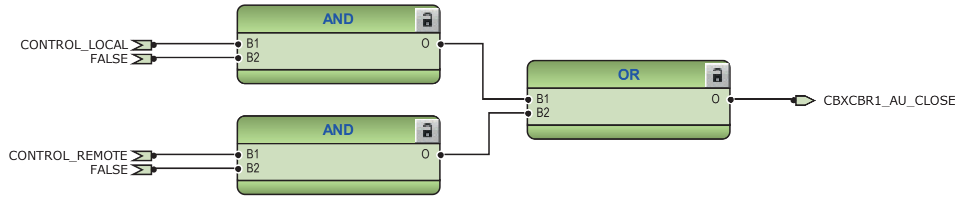


Figure 85: External closing command for circuit breaker

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

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

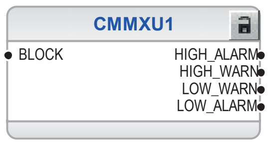


Figure 86: Current measurement: Three phase current measurement

Figure 87: Current measurement: Sequence current measurements

Figure 88: Current measurement: Residual current measurements

Figure 89: Voltage measurement: Residual voltage measurements

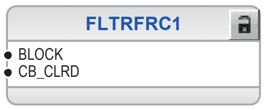


Figure 90: Other measurement: Data monitoring

Figure 91: Other measurement: Load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

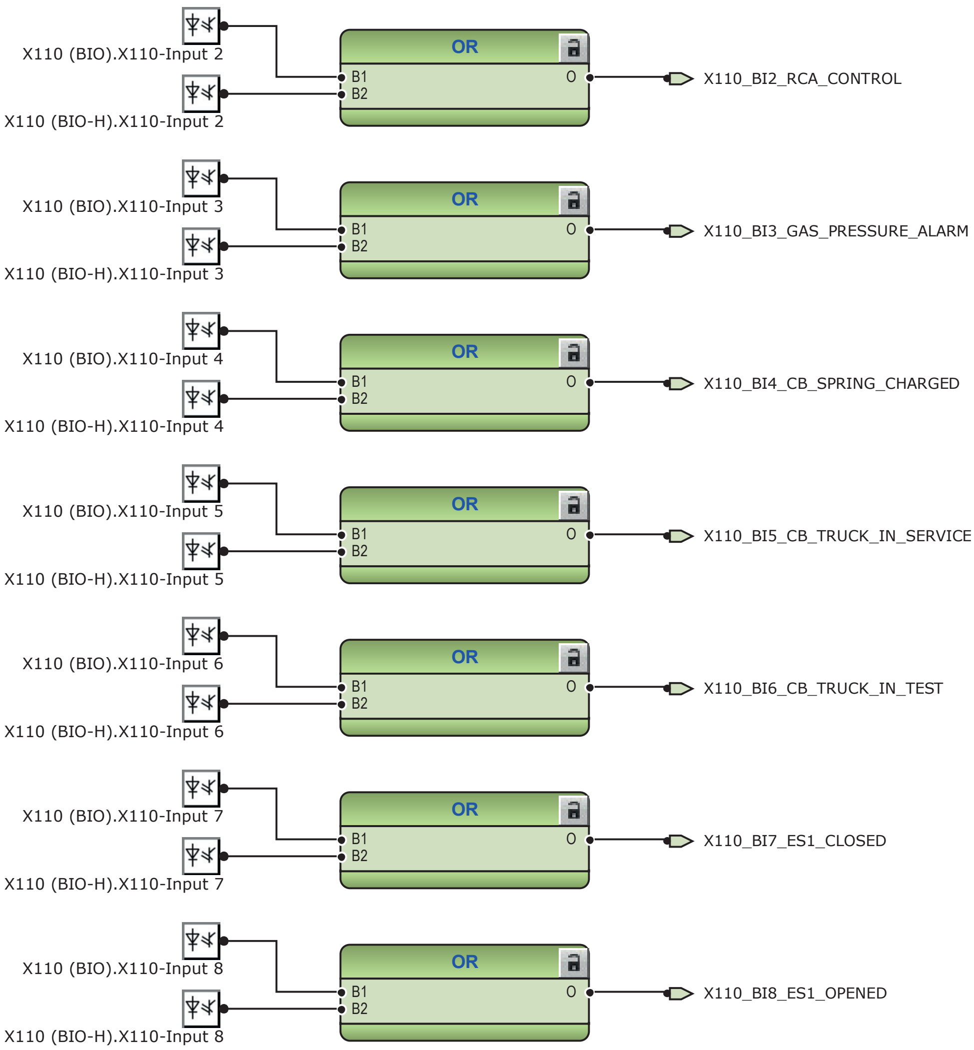


Figure 92: Binary inputs - X110 terminal block

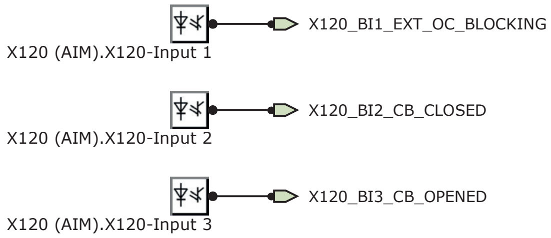


Figure 93: Binary inputs - X120 terminal block

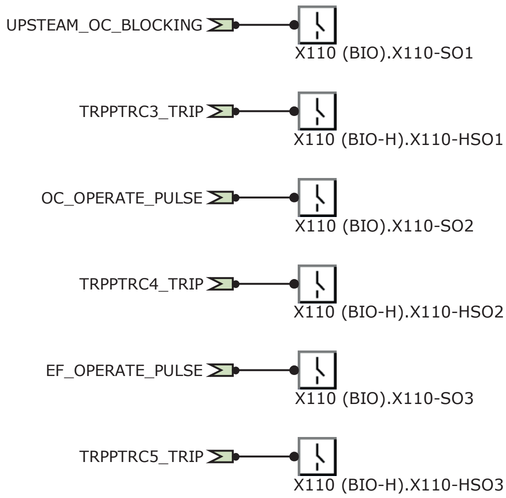


Figure 94: Default binary outputs - X110

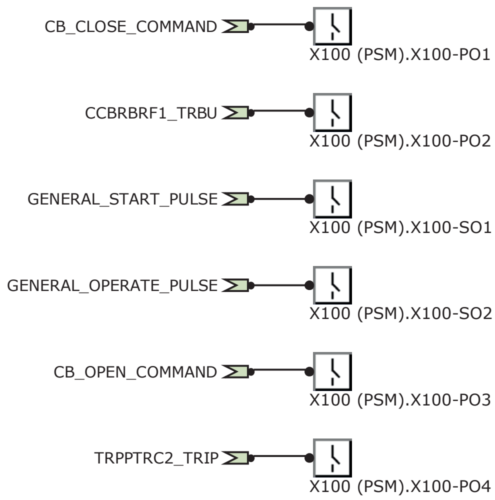
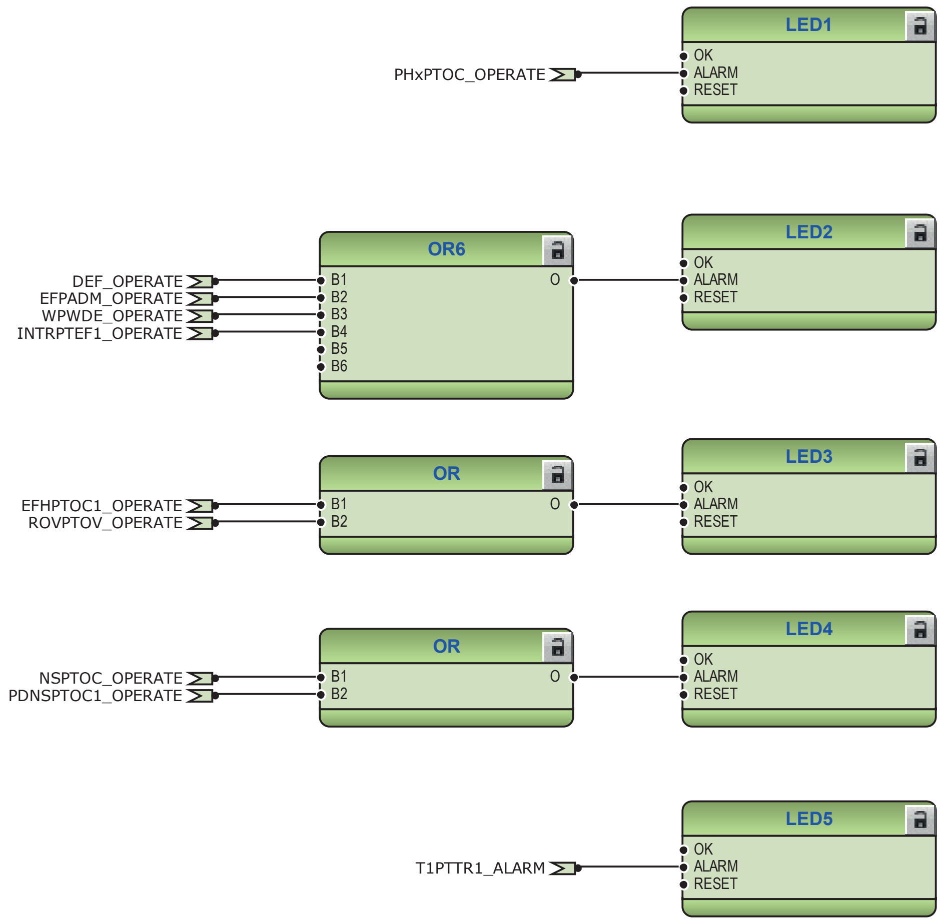


Figure 95: Default binary outputs - X100


LED1
PHxPTOC_OPERATE
OK
ALARM
RESET
OR6
DEF_OPERATE
EFPADM_OPERATE
WPWDE_OPERATE
INTRPTEF1_OPERATE
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
OR
EFHPTOC1_OPERATE
ROVPTOV_OPERATE
B1
B2
O
LED3
OK
ALARM
RESET
OR
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
B1
B2
O
LED4
OK
ALARM
RESET
LED5
T1PTTR1_ALARM
OK
ALARM
RESET

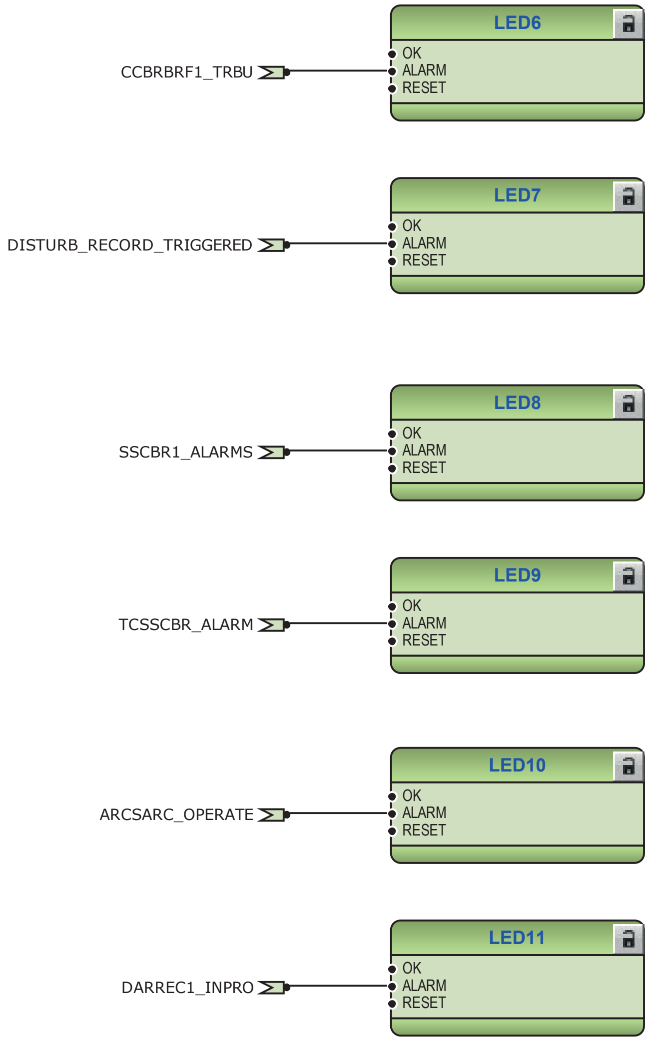


Figure 96: Default LED connection

3.4.3.7 Functional diagrams for other timer logics

The configuration also includes the overcurrent operate and earth-fault operate logic. The operate logics are connected to the minimum pulse timer TPGAPC2 for setting the minimum pulse length for the outputs. The output from TPGAPC2 is connected to binary outputs.

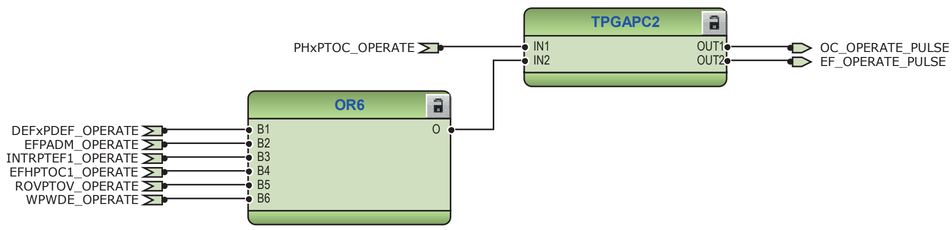


Figure 97: Timer logic for overcurrent and earth-fault operate pulse

3.4.3.8 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, 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.

3.5 Standard configuration C

3.5.1 Applications

The standard configuration for non-directional overcurrent and non-directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in directly or resistance-earthed distribution networks.

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

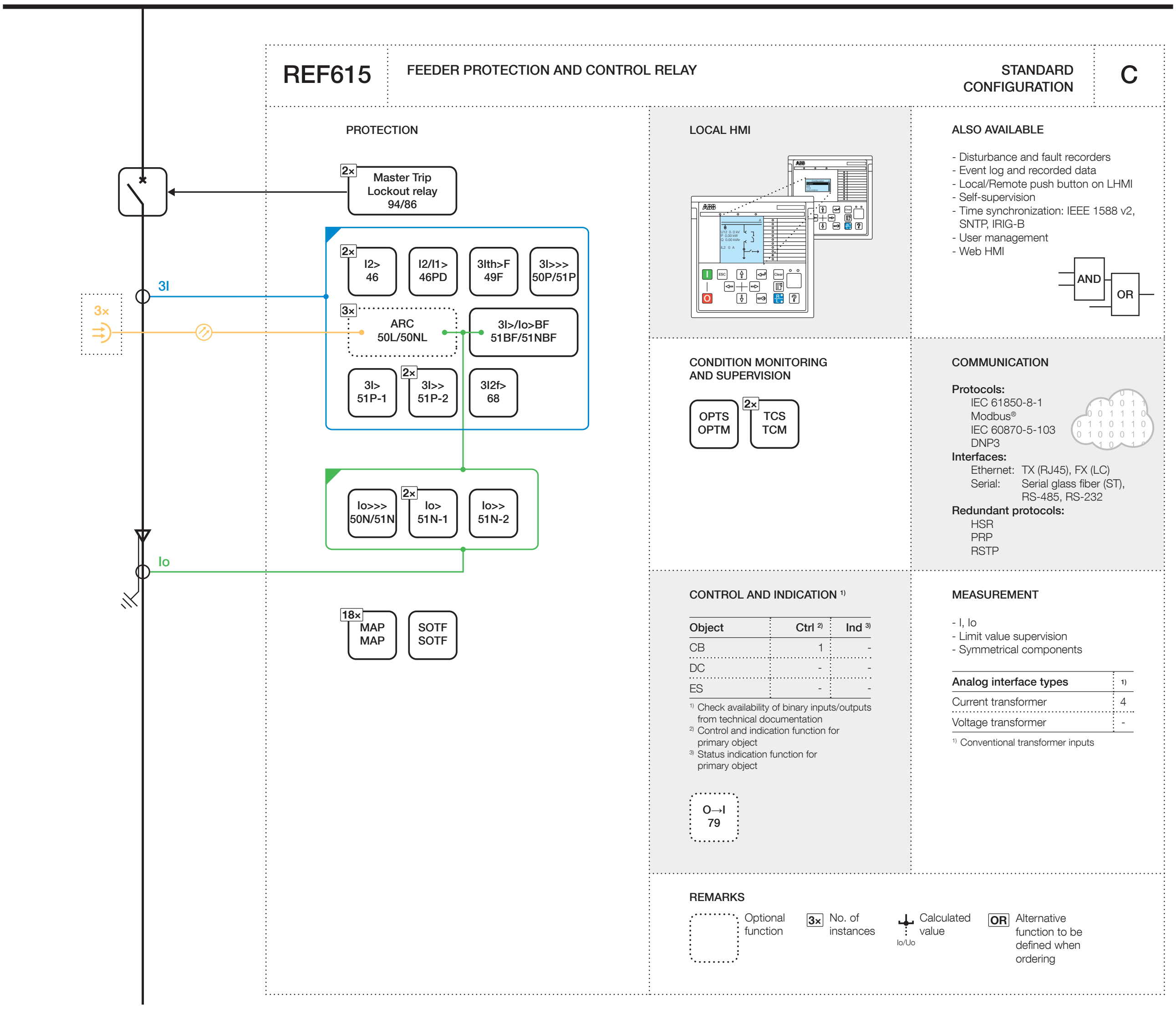


Figure 98: Functionality overview for standard configuration C

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
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Reset of master trip lockout

Table 22: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Circuit breaker failure protection trip to upstream breaker
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X100-SO1	General start indication
X100-SO2	General operate indication

Table 23: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Non-directional earth-fault operate
3	Sensitive earth-fault operate
4	Negative sequence overcurrent or phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	–
9	Trip circuit supervision alarm
10	Arc protection operate
11	Autoreclose in progress

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

Table continues on the next page

Channel	ID text	Level trigger mode
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
19	–	–
20	EFLPTOC2 - operate	Level trigger off
21	PDNSPTOC1 - operate	Level trigger off
22	INRPHAR1 - blk2h	Level trigger off
23	T1PTTR1 - operate	Level trigger off
24	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
25	ARCSARC1 - operate	Positive or Rising
26	ARCSARC2 - operate	Positive or Rising
27	ARCSARC3 - operate	Positive or Rising
28	DARREC1 - inpro	Level trigger off
29	DARREC1 - close CB	Level trigger off
30	DARREC1 - unsuc recl	Level trigger off
31	X120BI1 - ext OC blocking	Level trigger off
32	X120BI2 - CB closed	Level trigger off
33	X120BI3 - CB opened	Level trigger off
34 - 64	-	-

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.

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 IEDs protection functionality in detail and according to the factory set default connections.

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.

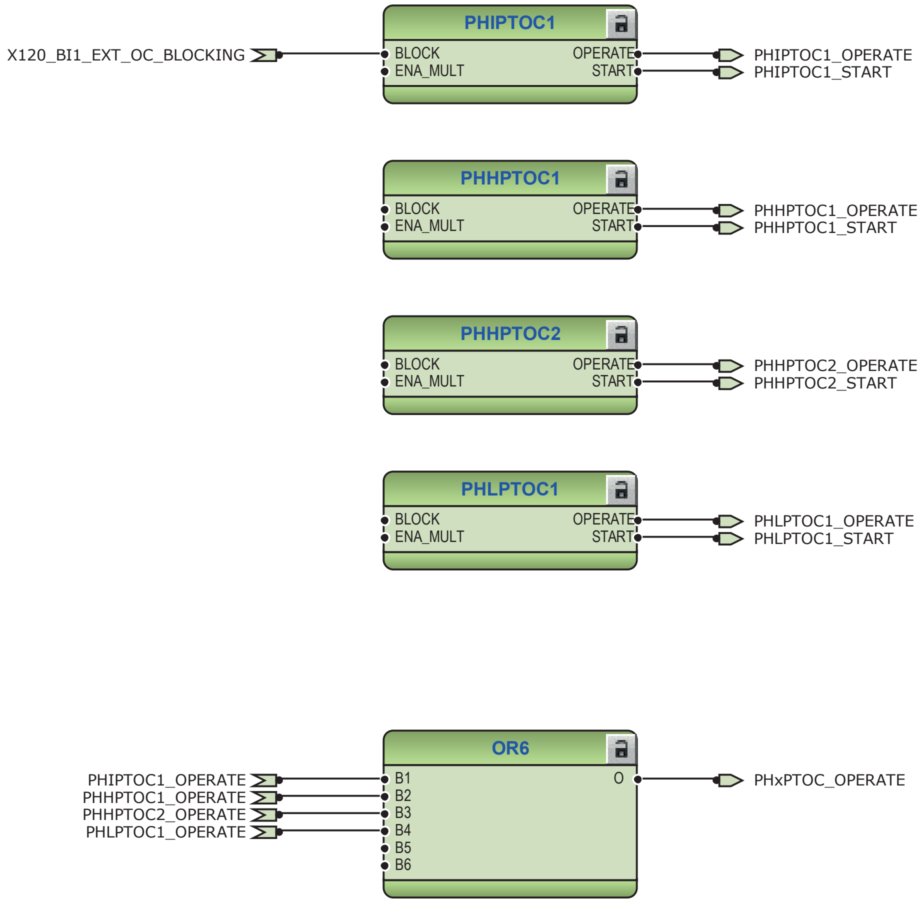


Figure 99: Overcurrent protection functions

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

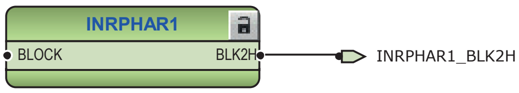


Figure 100: Inrush detector function

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.

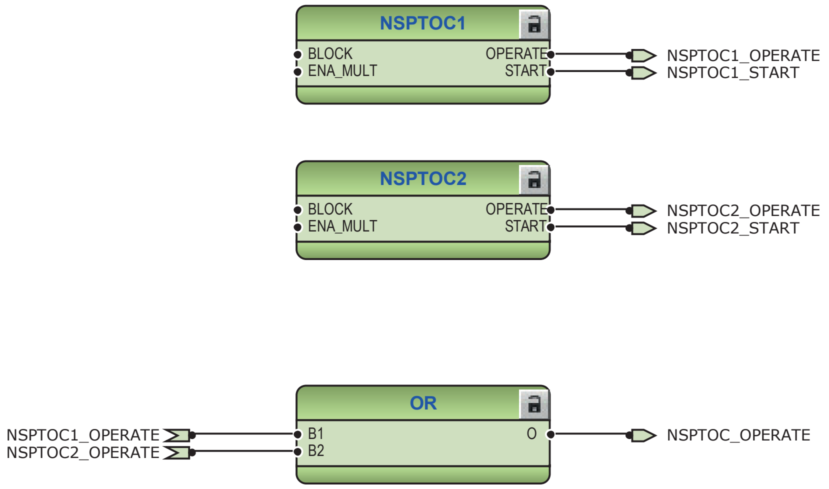


Figure 101: Negative sequence overcurrent protection function

Four stages are provided for non-directional earth-fault protection. One stage is dedicated to sensitive earth-fault protection EFLPTOC2.

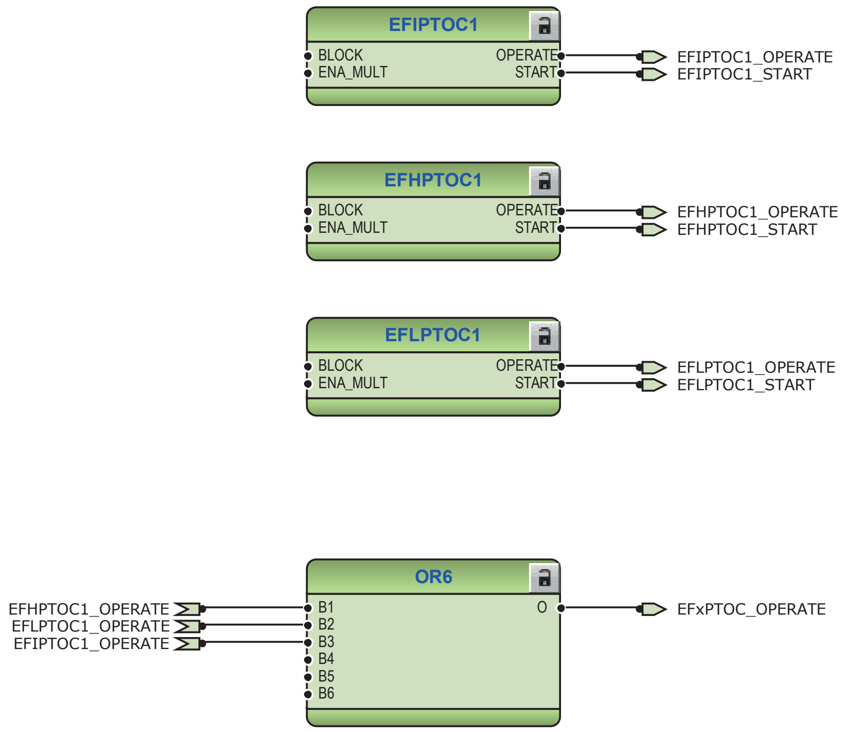


Figure 102: Earth-fault protection functions

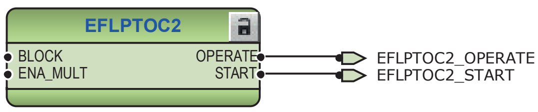


Figure 103: Sensitive earth-fault protection function

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

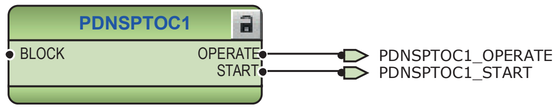


Figure 104: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions.

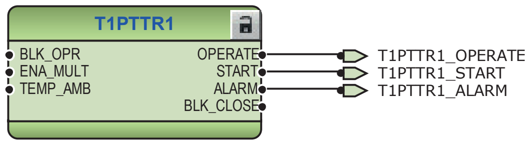


Figure 105: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The 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.

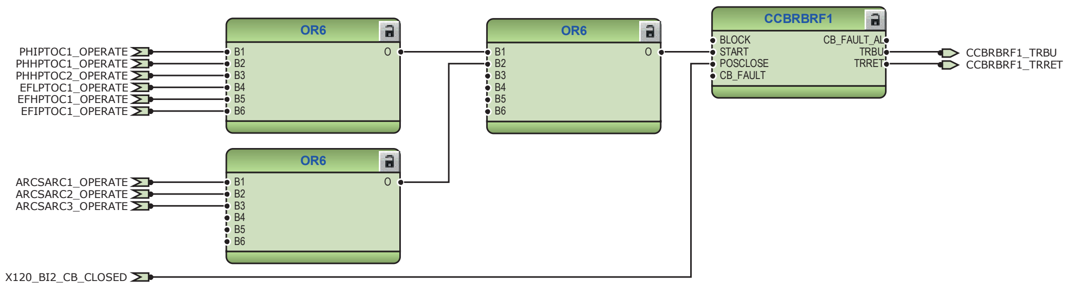


Figure 106: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2.

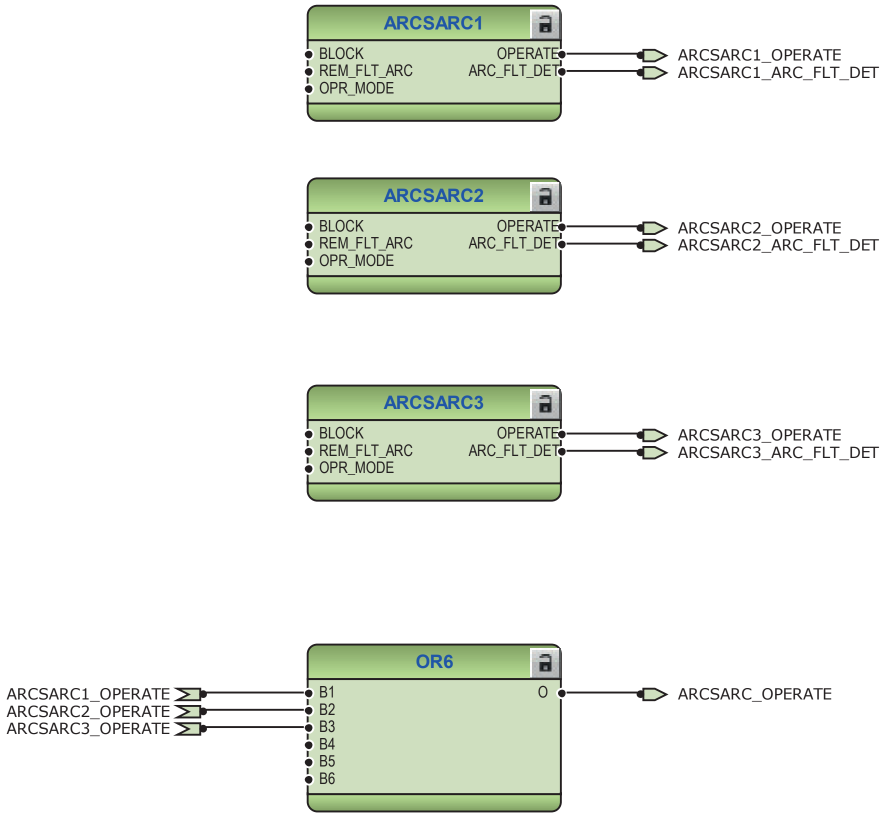


Figure 107: Arc protection

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. This signal is not connected in the configuration. The open command from the autorecloser is directly connected to binary output X100:PO3, whereas close command is connected directly to binary output X100:PO1.

Set the parameters for DARREC1 properly.

Check the initialization signals of the DARREC1.

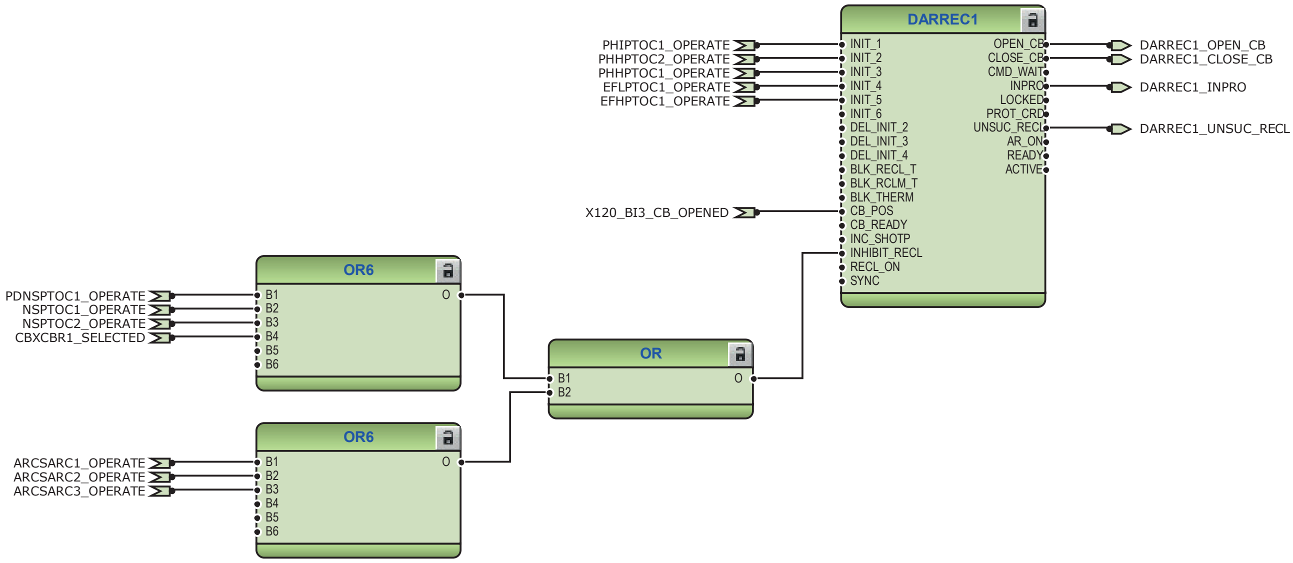


Figure 108: Autoreclosing

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

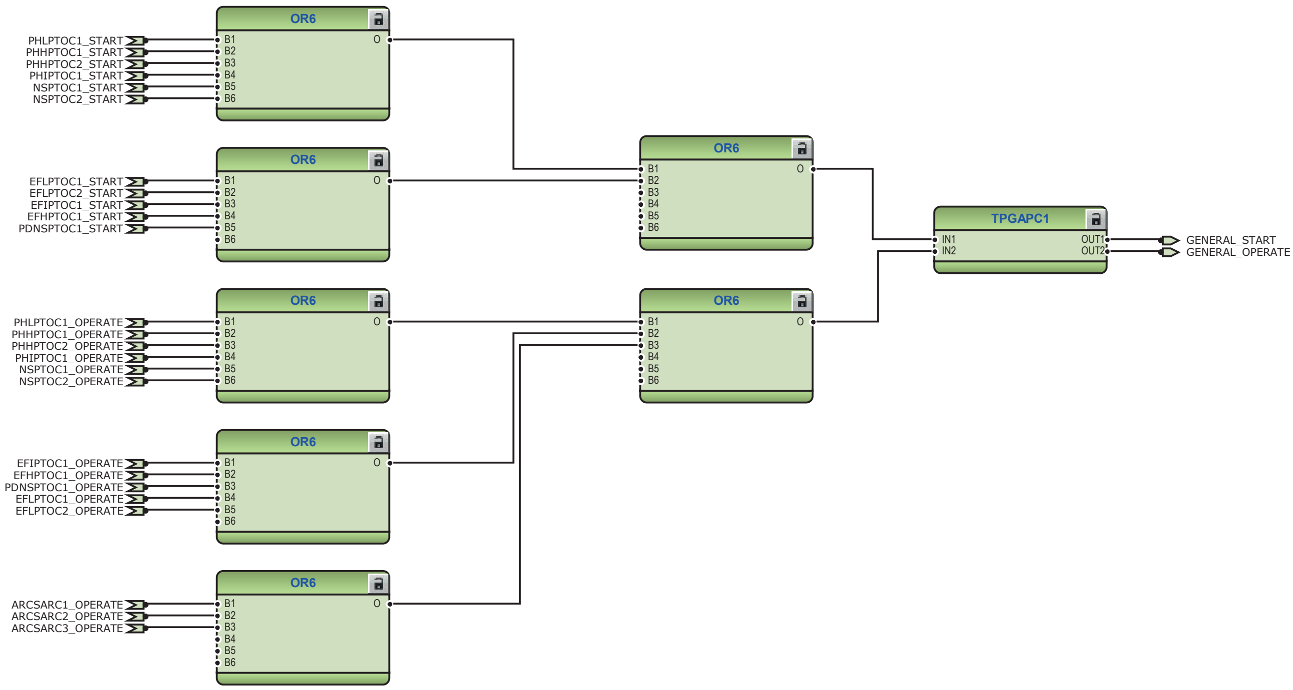


Figure 109: General start and operate signals

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 lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, the binary input X120:BI4 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

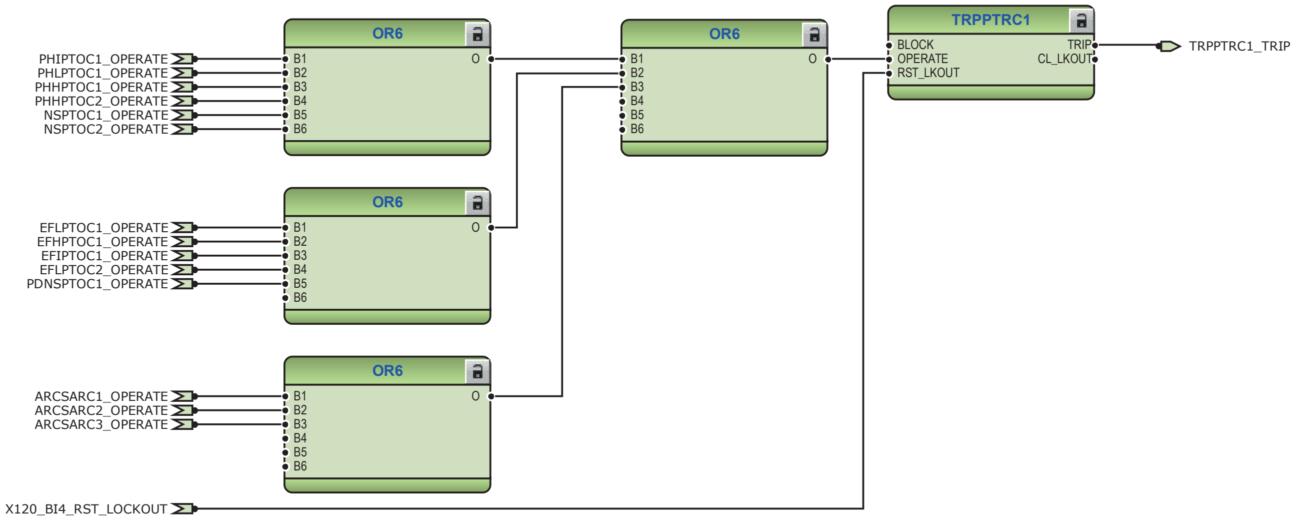


Figure 110: Trip logic TRPPTRC1

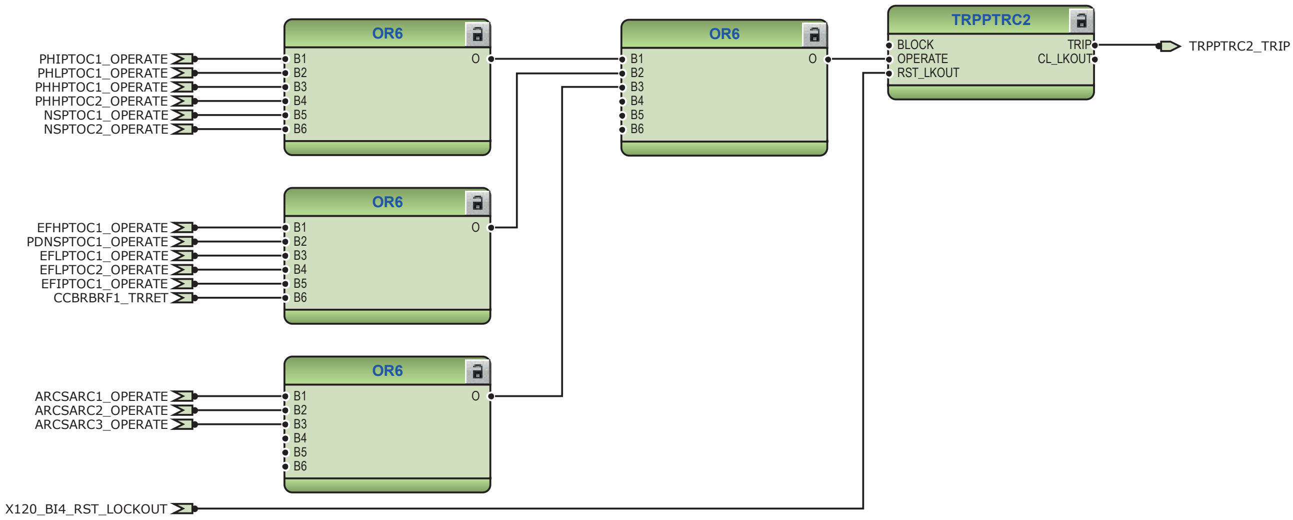


Figure 111: Trip logic TRPPTRC2

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 few binary inputs are also connected to the disturbance recorder.

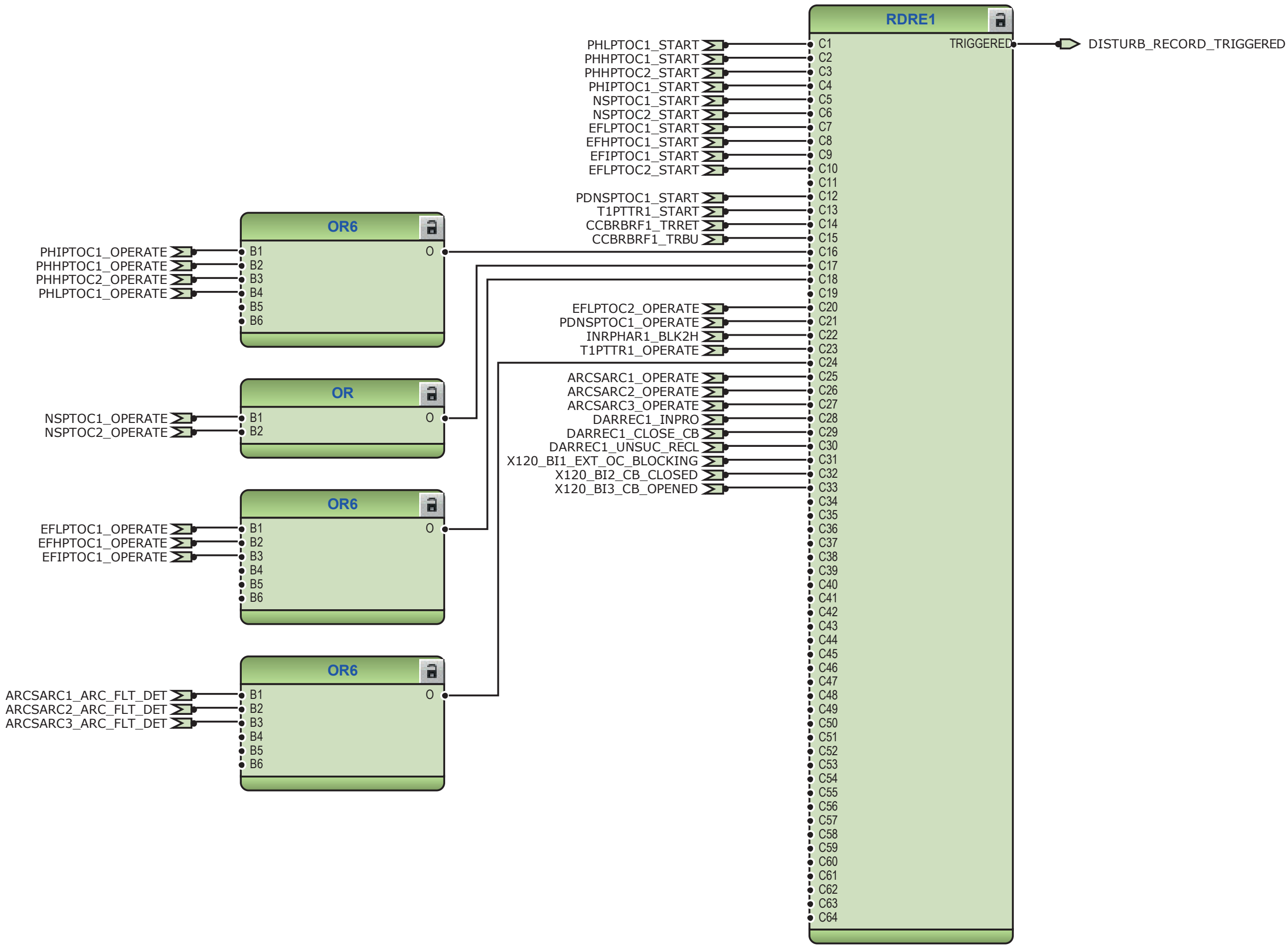


Figure 112: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

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.

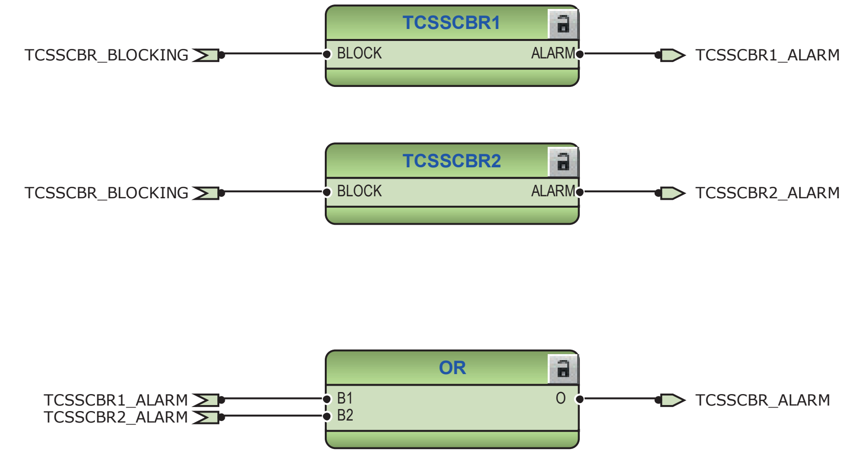


Figure 113: Trip circuit supervision function

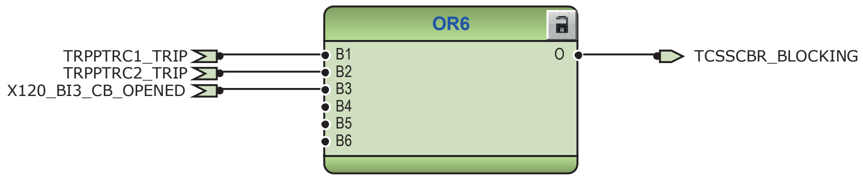


Figure 114: Logic for trip circuit supervision function

3.5.3.4 Functional diagrams for control and interlocking

The circuit breaker closing is enabled when the `ENA_CLOSE` input is activated. The input can be activated using the configuration logic, which is based on the status of the trip logics. However, other signals can be connected based on the application needs.

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

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

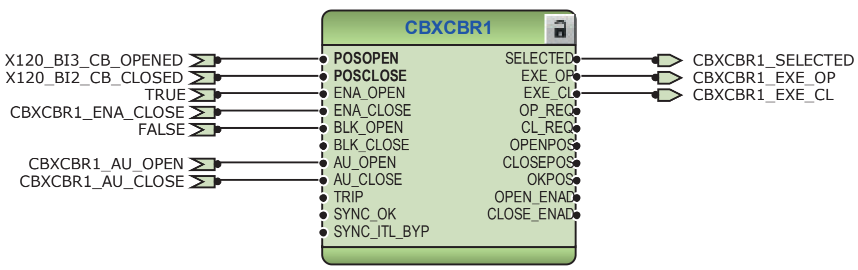


Figure 115: Circuit breaker control logic: Circuit breaker 1

Figure 116: Circuit breaker control logic: Signal for closing of circuit breaker 1

Figure 117: Circuit breaker control logic: Signal for opening of circuit breaker 1

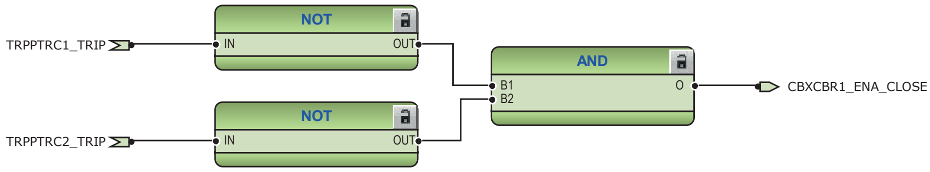


Figure 118: Circuit breaker close enable logic

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 any additional signal applicable for the configuration for closing and opening of circuit breaker in local or remote mode.

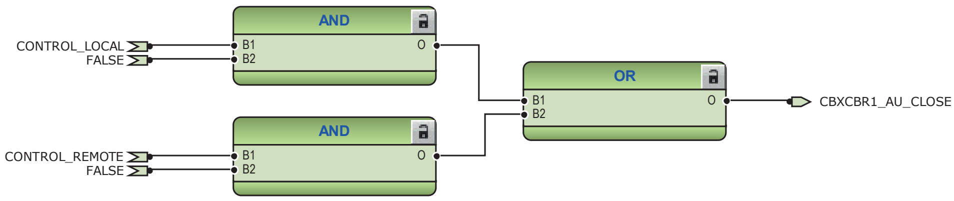


Figure 119: External closing command for circuit breaker

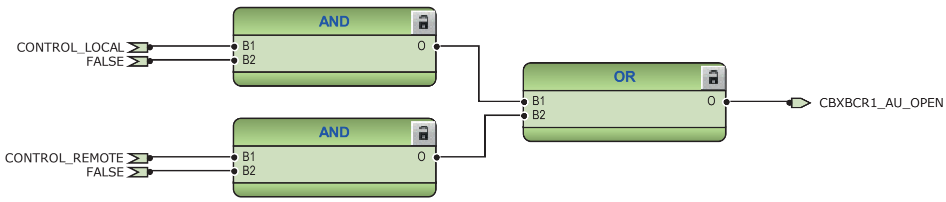


Figure 120: External opening command for circuit breaker

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. Similarly, the sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

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

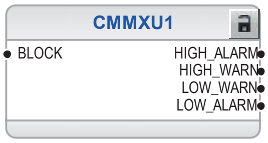


Figure 121: Current measurement: Three phase current measurement

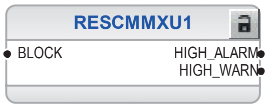


Figure 122: Current measurement: Residual current measurement

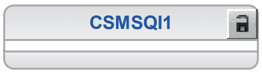


Figure 123: Current measurement: Sequence current measurement

Figure 124: Other measurements: Data monitoring

3.5.3.6 Functional diagrams for I/O and alarm LEDs

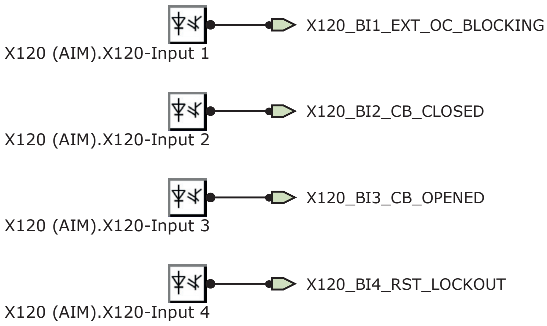


Figure 125: Default binary inputs X120

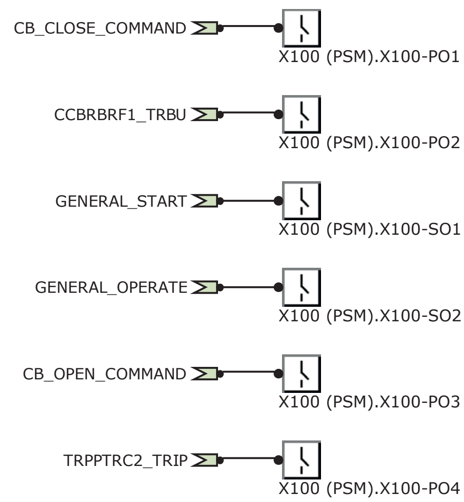
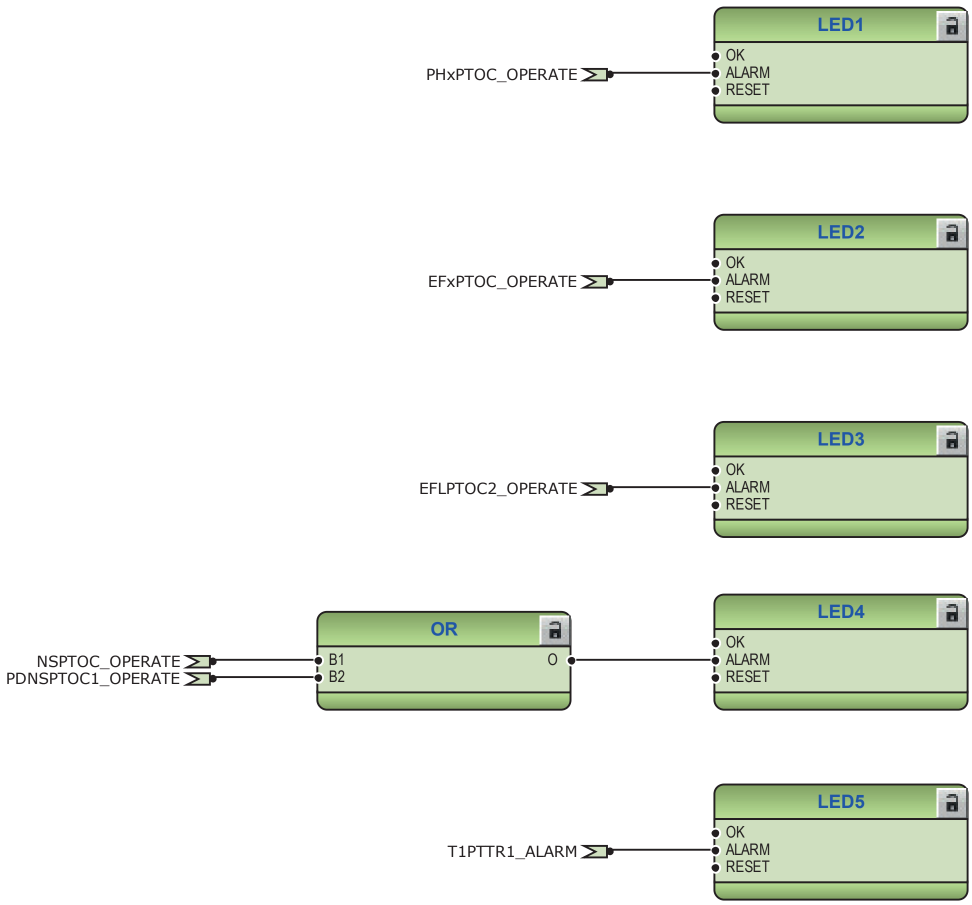


Figure 126: Default binary outputs X100



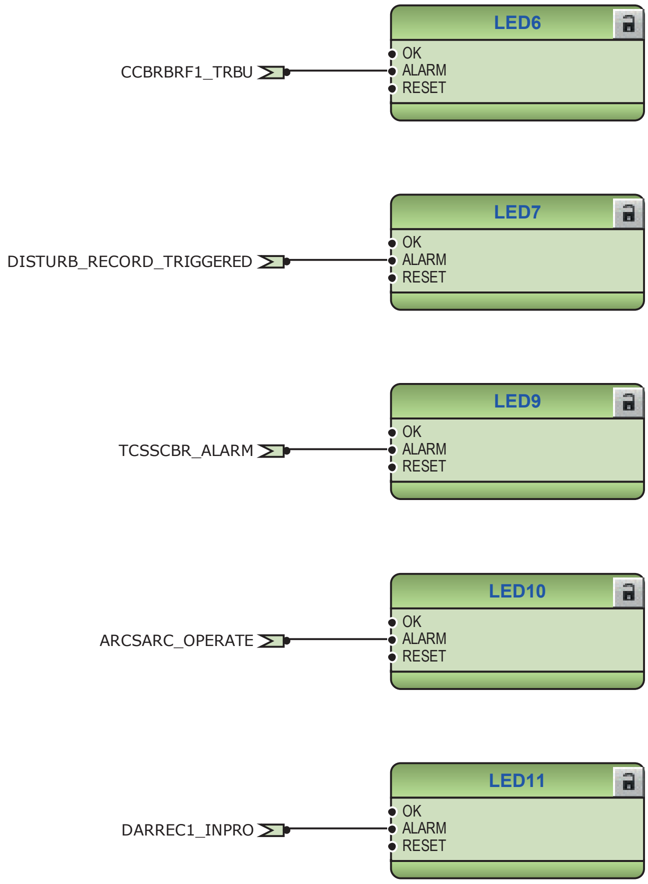


Figure 127: Default LED connection

3.5.3.7 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, runtime counter for machines and devices MDSOPT and different types of timer 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 for non-directional overcurrent and non-directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in directly or resistance earthed distribution networks.

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

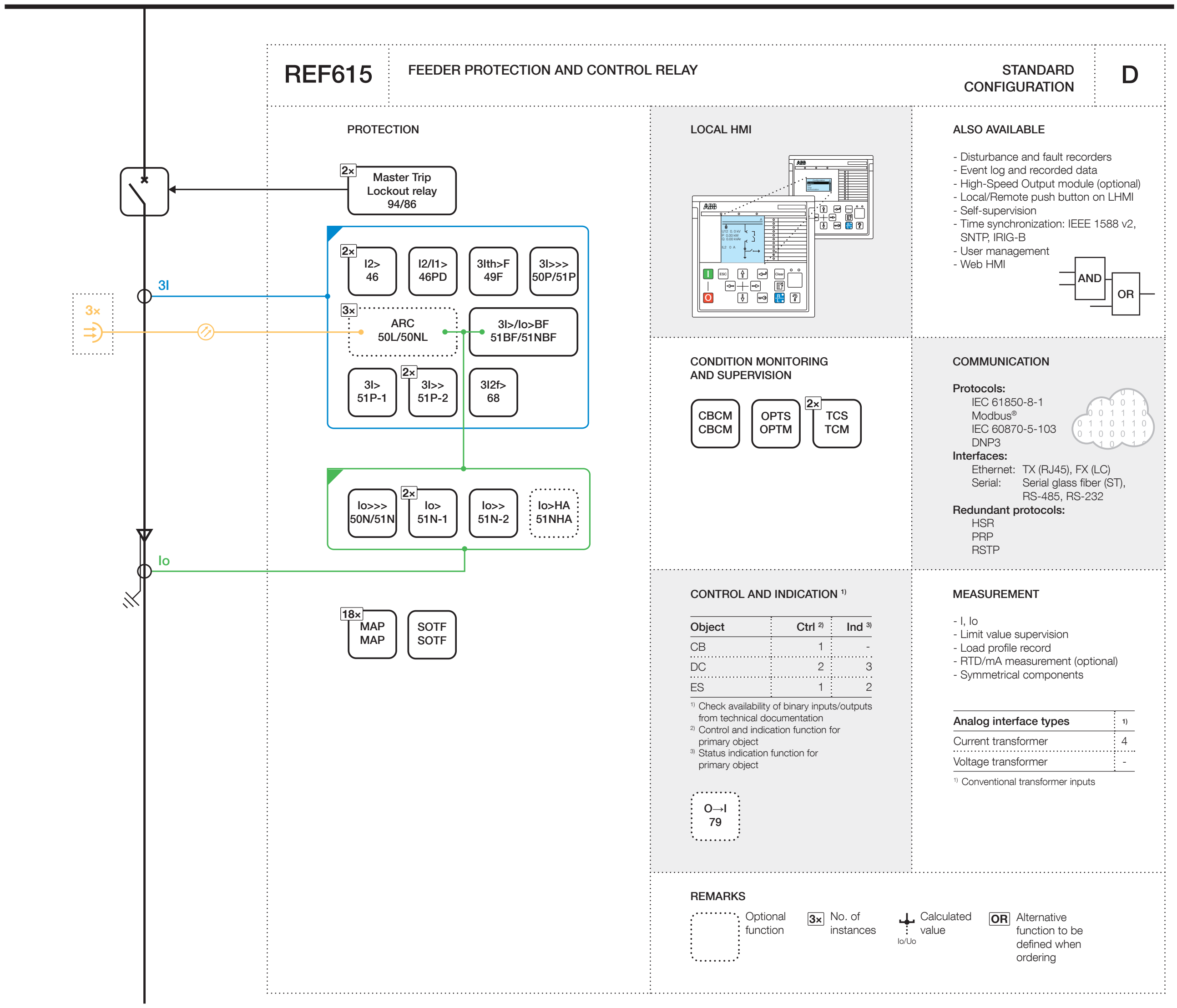


Figure 128: Functionality overview for standard configuration D

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

Binary input	Description
X110-BI2	Autoreclose external start command
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Reset of master trip lockout

Table 27: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Circuit breaker failure protection trip to upstream breaker
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X100-SO1	General start indication
X100-SO2	General operate indication
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 28: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Non-directional earth-fault operate
3	Sensitive earth-fault operate
4	Negative sequence overcurrent or phase discontinuity operate

Table continues on the next page

LED	Description
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Trip circuit supervision alarm
10	Arc protection operate
11	Autoreclose in progress

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	–
6	–
7	–
8	–
9	–
10	–
11	–
12	–

Table 30: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	EFLPTOC1 - start	Positive or Rising
8	EFHPTOC1 - start	Positive or Rising
9	EFIPTOC1 - start	Positive or Rising
10	EFLPTOC2 - start	Positive or Rising
11	–	–
12	PDNSPTOC1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
13	T1PTTR1 - start	Positive or Rising
14	CCBRBRF1 - trret	Level trigger off
15	CCBRBRF1 - trbu	Level trigger off
16	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
17	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
18	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
19	X110BI2 - ext start AutoReclose	Level trigger off
20	EFLPTOC2 - operate	Level trigger off
21	PDNSPTOC1 - operate	Level trigger off
22	INRPHAR1 - blk2h	Level trigger off
23	T1PTTR1 - operate	Level trigger off
24	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
25	ARCSARC1 - operate	Positive or Rising
26	ARCSARC2 - operate	Positive or Rising
27	ARCSARC3 - operate	Positive or Rising
28	DARREC1 - inpro	Level trigger off
29	DARREC1 - close CB	Level trigger off
30	DARREC1 - unsuc recl	Level trigger off
31	X120BI1 - ext OC blocking	Level trigger off
32	X120BI2 - CB closed	Level trigger off
33	X120BI3 - CB opened	Level trigger off
34 - 64	-	-

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

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

3.6.3.1 Functional diagrams for protection

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

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.

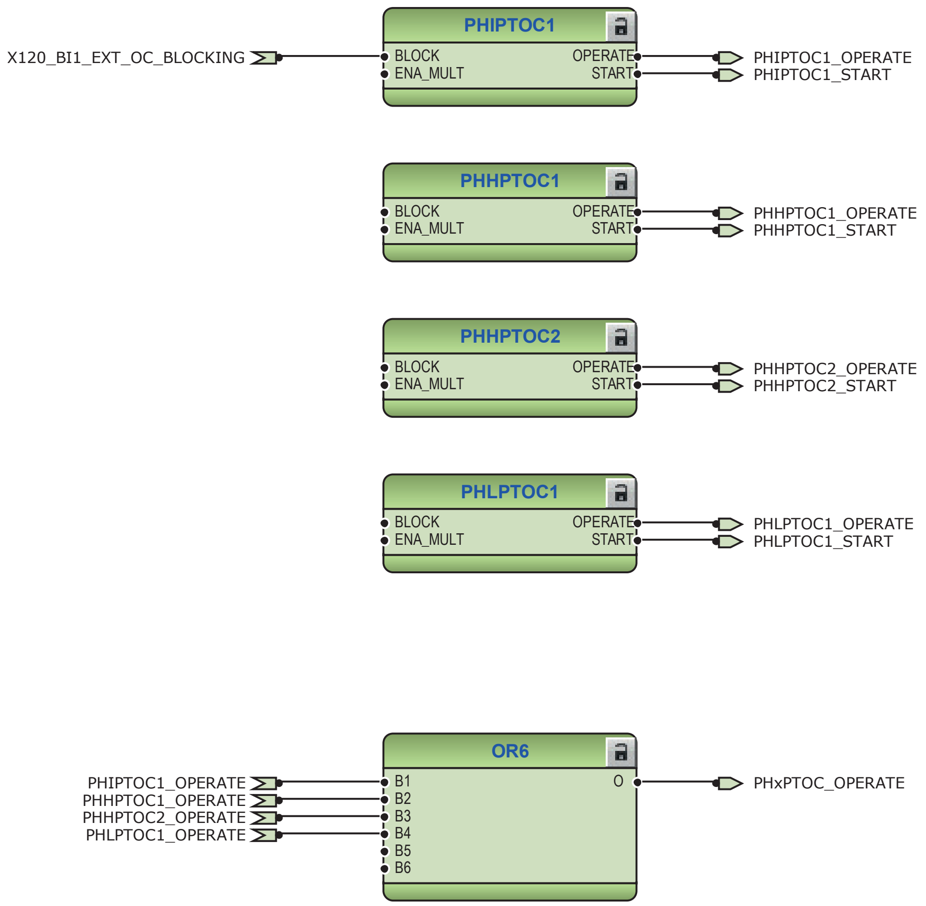


Figure 129: Overcurrent protection functions

The upstream blocking from the start of the second high stage of three-phase non-directional overcurrent protection PHHPTOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

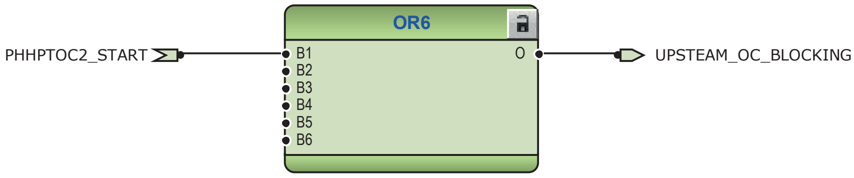


Figure 130: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

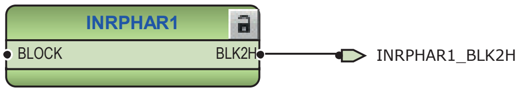


Figure 131: Inrush detector function

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.

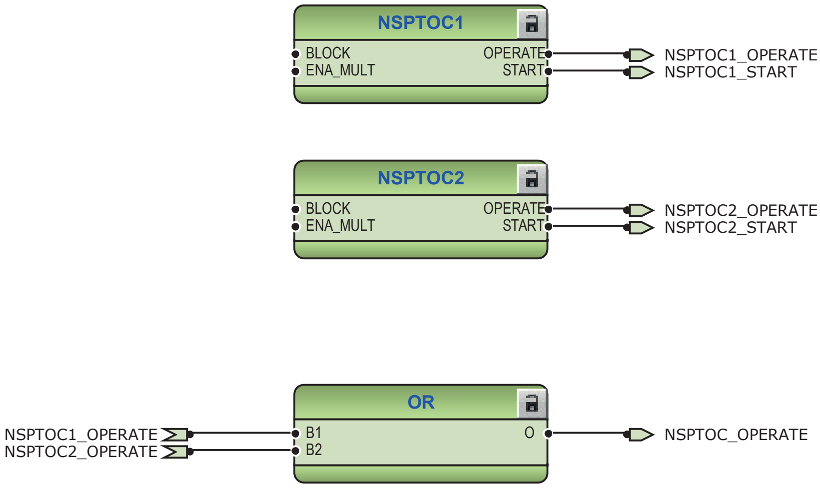


Figure 132: Negative-sequence overcurrent protection function

Four stages are provided for non-directional earth-fault protection. EFLPTOC2 stage is dedicated to sensitive earth-fault protection. According to the IED's order code, the configuration can also include harmonics-based earth-fault protection HAEFPTOC.

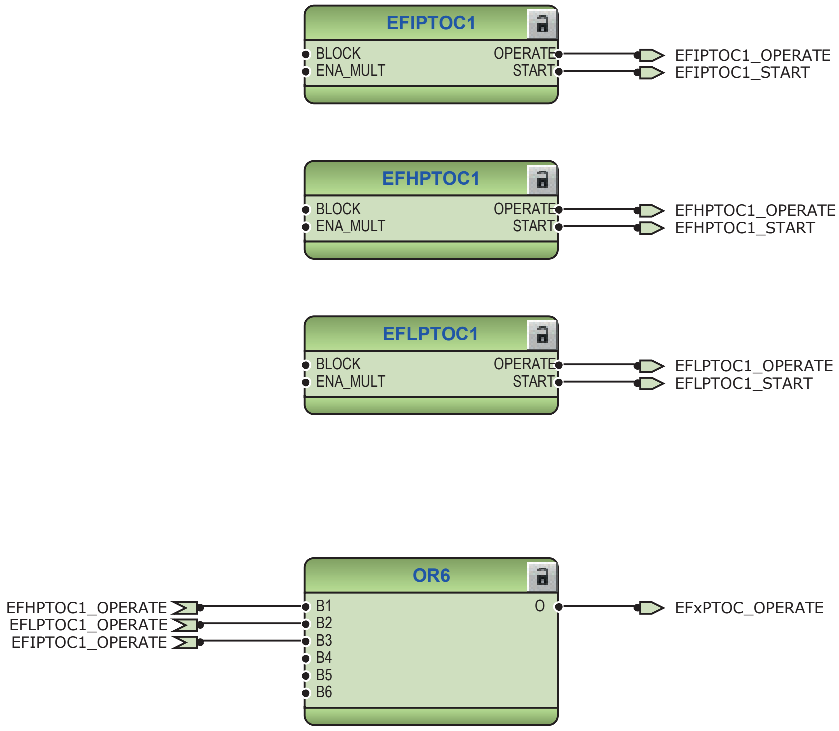


Figure 133: Earth-fault protection functions

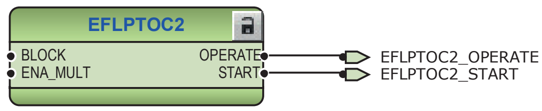


Figure 134: Sensitive earth-fault protection functions

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

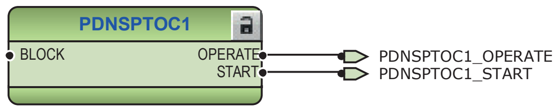


Figure 135: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The output BLK_CLOSE is used to block the closing operation of circuit breaker.

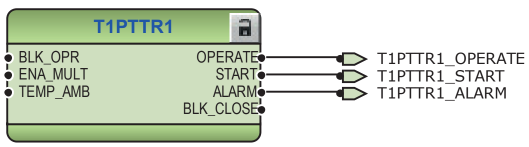


Figure 136: Thermal overcurrent protection function

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

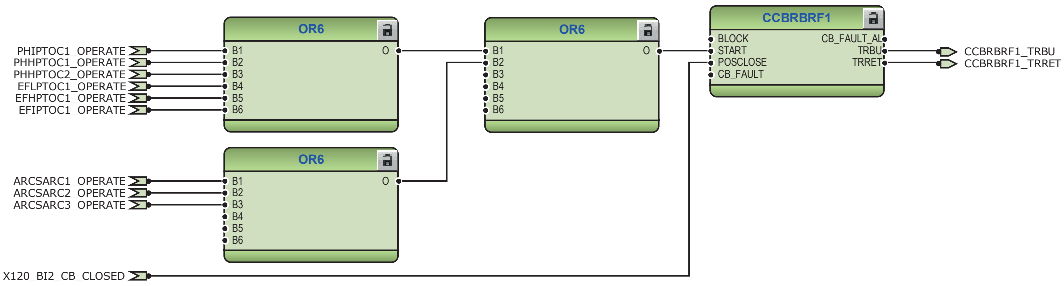


Figure 137: Circuit breaker failure protection function

Three protection S1...3 stages are included as an optional function. The protection offers individual function blocks for three sensors that can be connected to the IED. Each protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals S1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from S1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

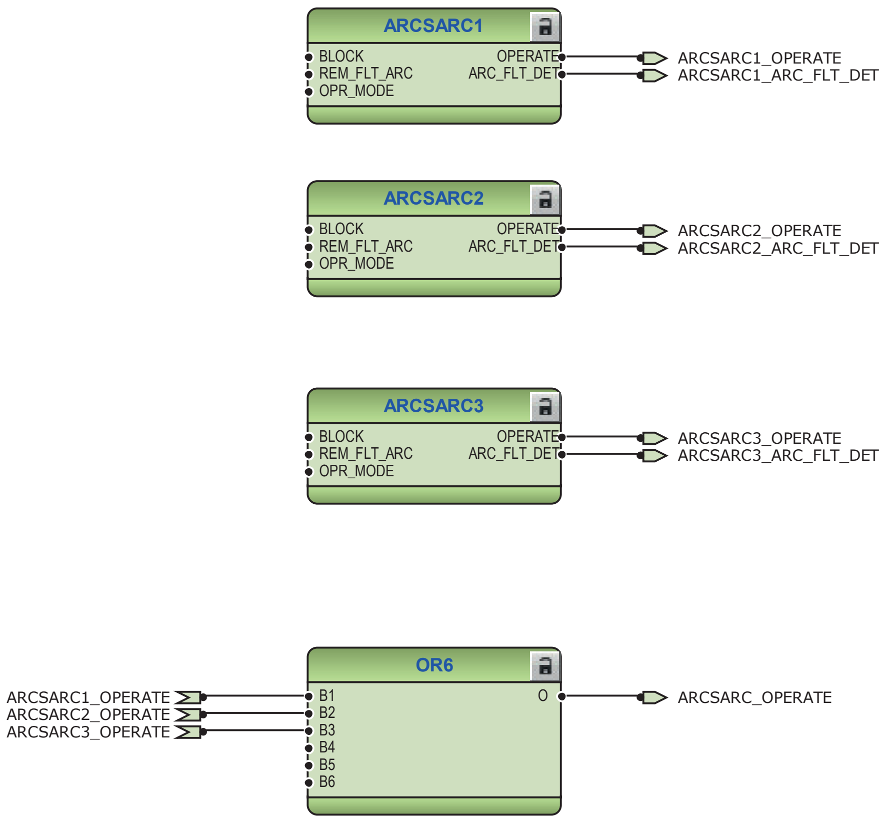


Figure 138: Arc protection function

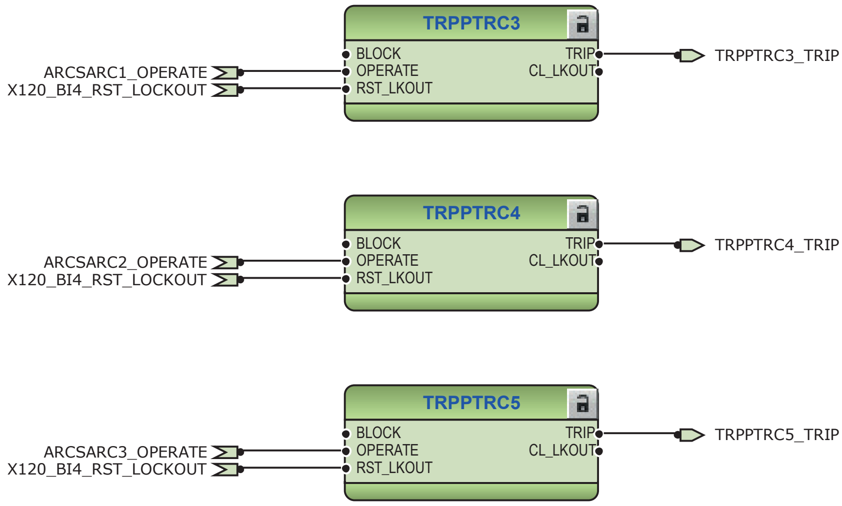


Figure 139: Arc protection with dedicated HSO

The optional autoreclosing function is configured to be initiated by operate signals from a number of protection stages through the `INIT_1...5` inputs. The `INIT_6` input in the autoreclosing function block is controlled by a binary input X110: BI2 enabling the use of the external autoreclosing start command. 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 autoreclosure 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.

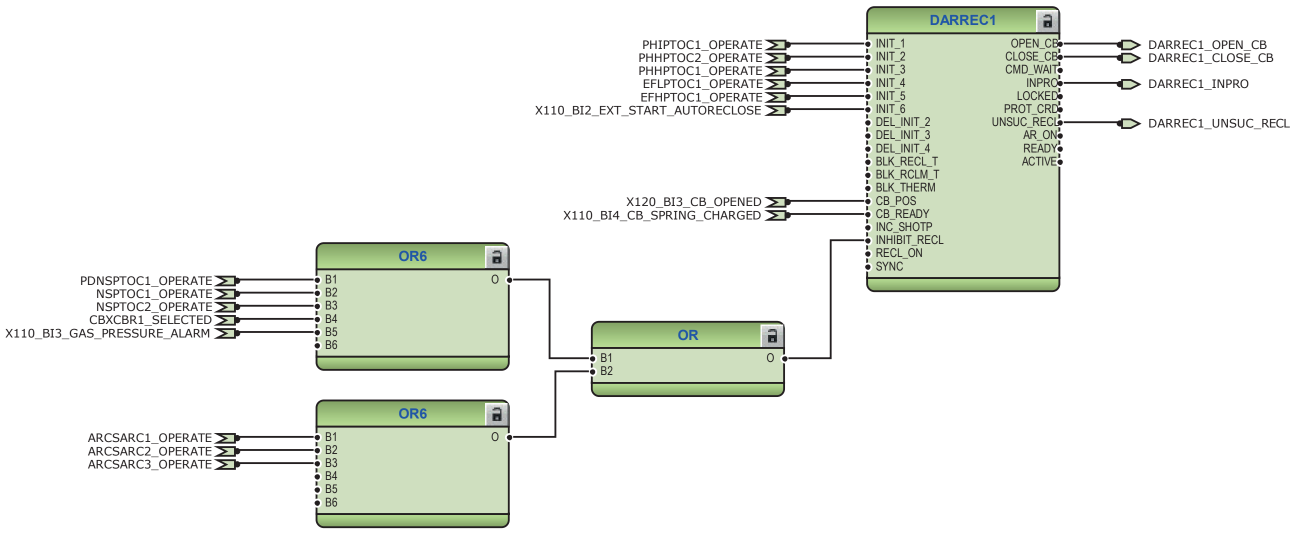


Figure 140: Autoreclosing function

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

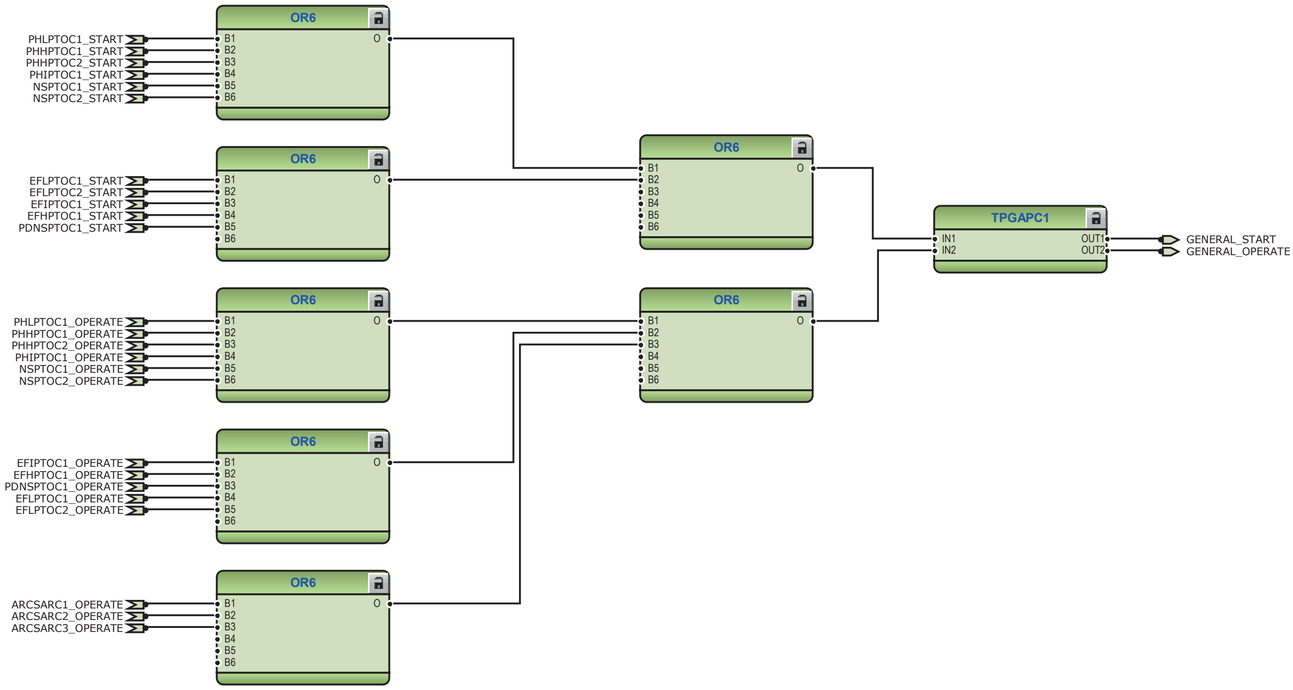


Figure 141: General start and operate signals

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 has been assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

Other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

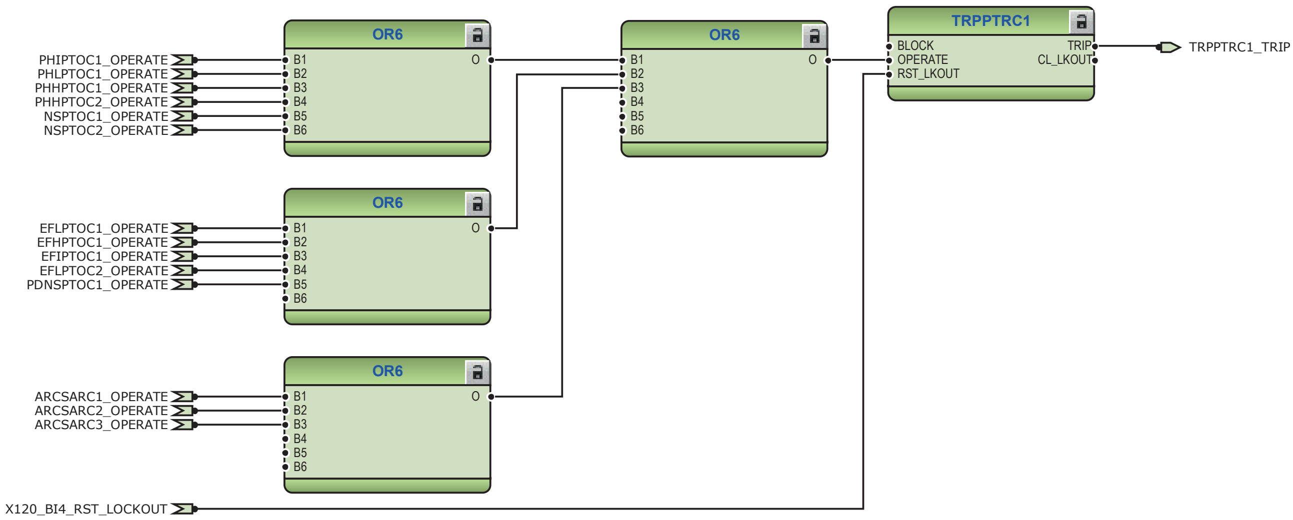


Figure 142: Trip logic TRPPTRC1

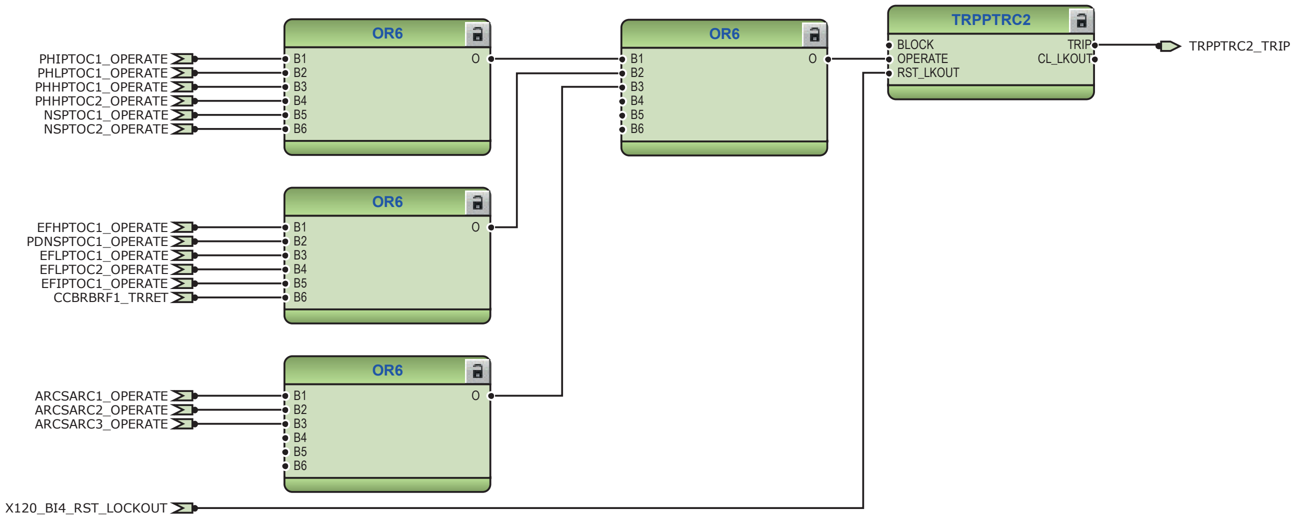


Figure 143: Trip logic TRPPTRC2

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.

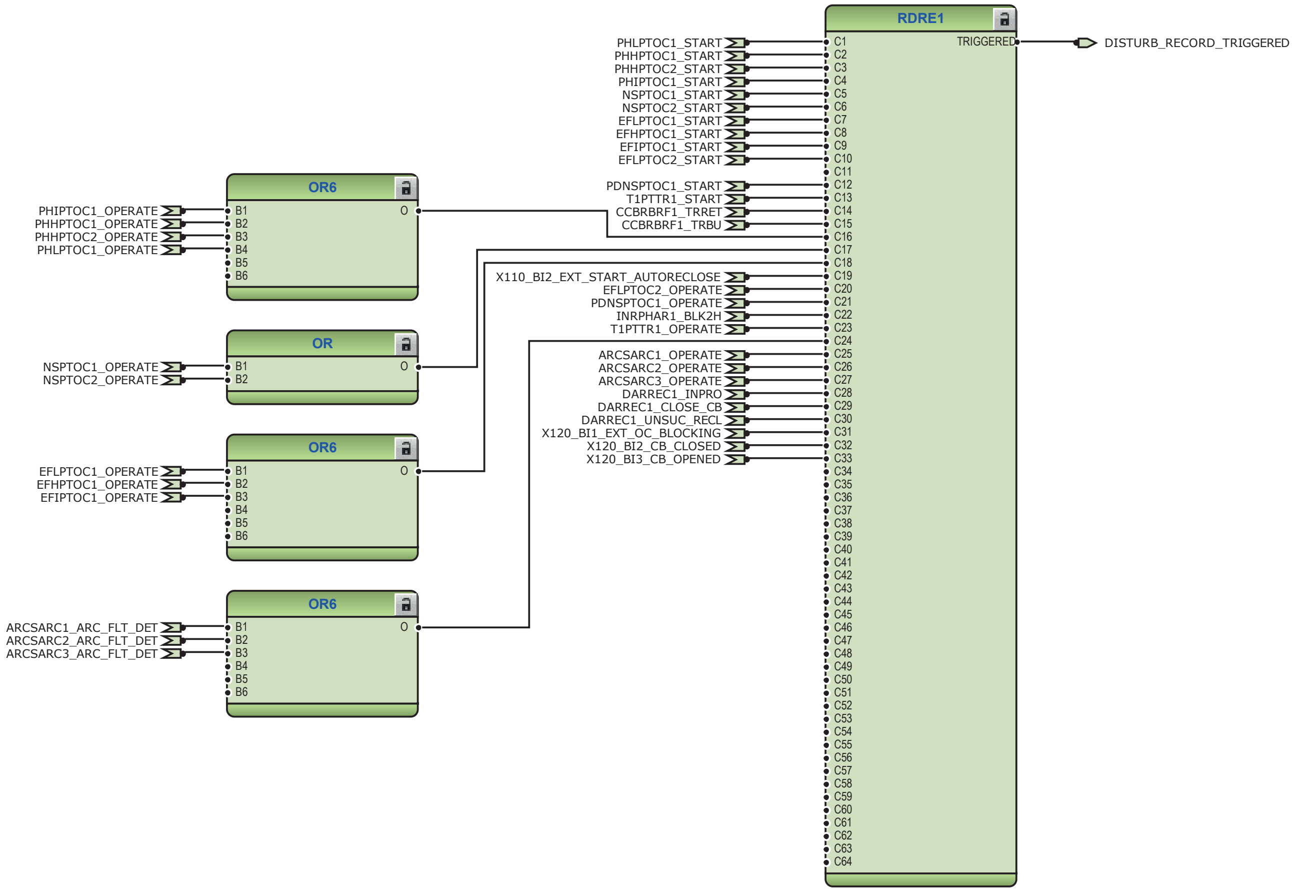


Figure 144: Disturbance recorder

3.6.3.3 Functional diagrams for condition monitoring

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 SSCBR properly.

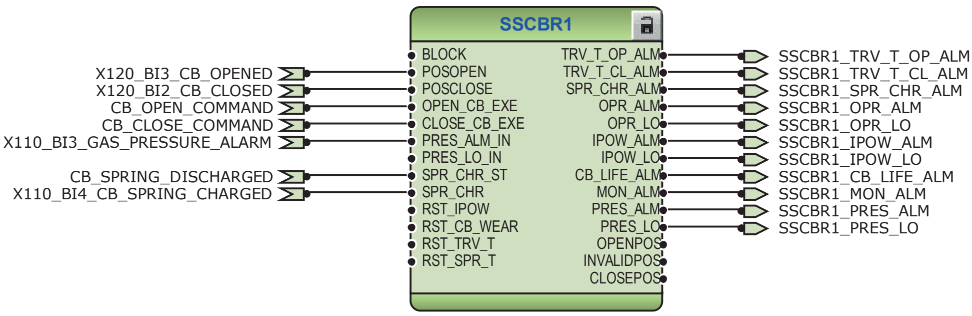


Figure 145: Circuit breaker condition monitoring function

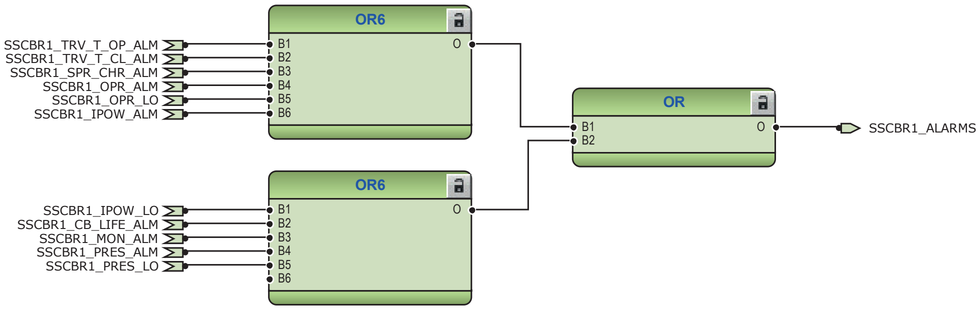


Figure 146: Logic for circuit breaker monitoring alarm

Figure 147: 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. 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 TCSSCBR properly.

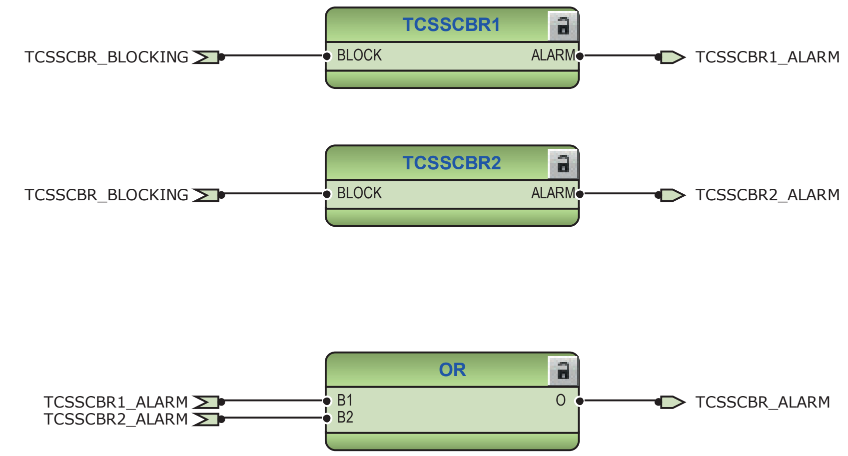


Figure 148: Trip circuit supervision function

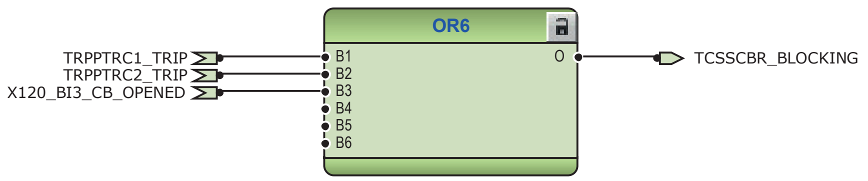


Figure 149: Logic for blocking of trip circuit supervision

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.

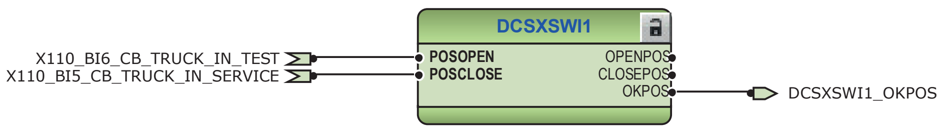


Figure 150: Disconnector 1

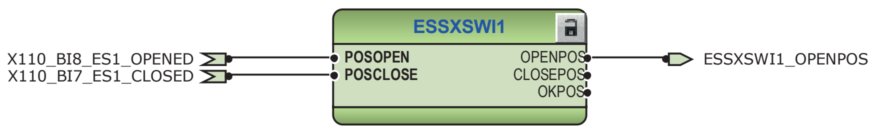


Figure 151: Earthing switch 1

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status.

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely 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 circuit breaker is always enabled.

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

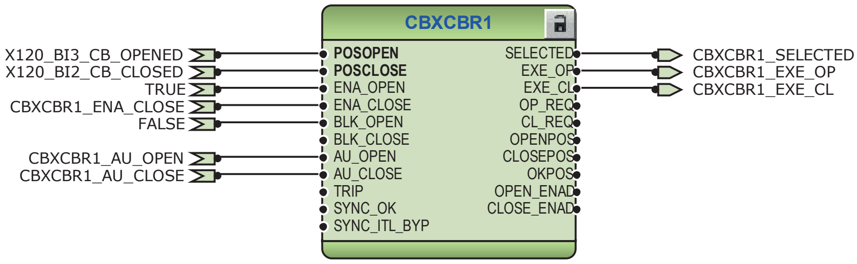


Figure 152: Circuit breaker 1

Connect the additional signals required by the application for closing and opening of the circuit breaker.

Figure 153: Signals for closing coil of circuit breaker 1

Figure 154: Signals for opening coil of circuit breaker 1

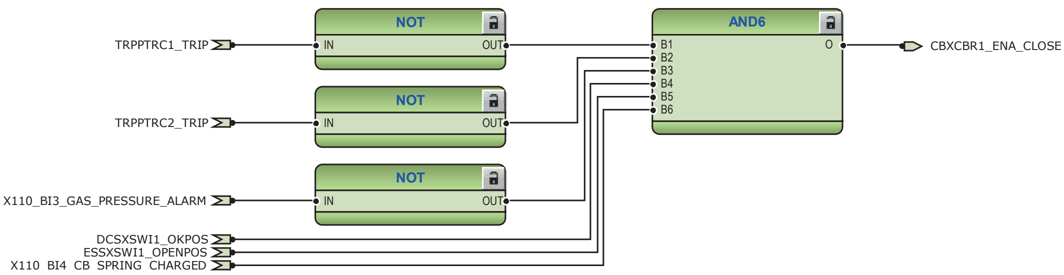


Figure 155: Circuit breaker 1 close enable logic

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

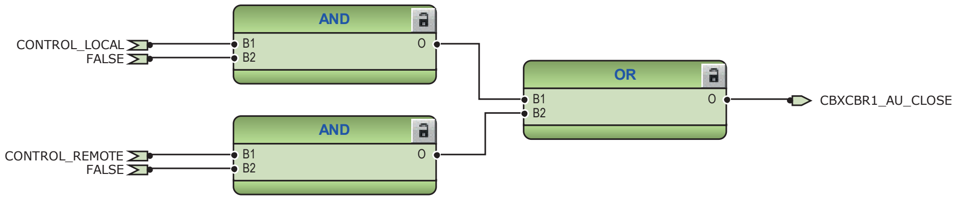


Figure 156: External closing command for circuit breaker 1

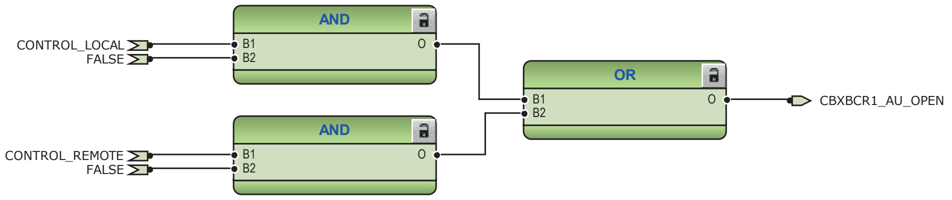


Figure 157: External opening command for circuit breaker 1

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 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.

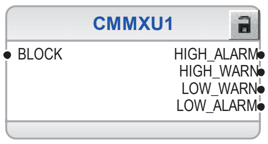


Figure 158: Current measurement: Three-phase current measurement

Figure 159: Current measurement: Sequence current measurement

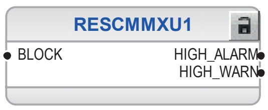


Figure 160: Current measurement: Residual current measurement

Figure 161: Other measurement: Data monitoring

Figure 162: Other measurement: Load profile record

3.6.3.6 Functional diagrams for I/O and alarm LEDs

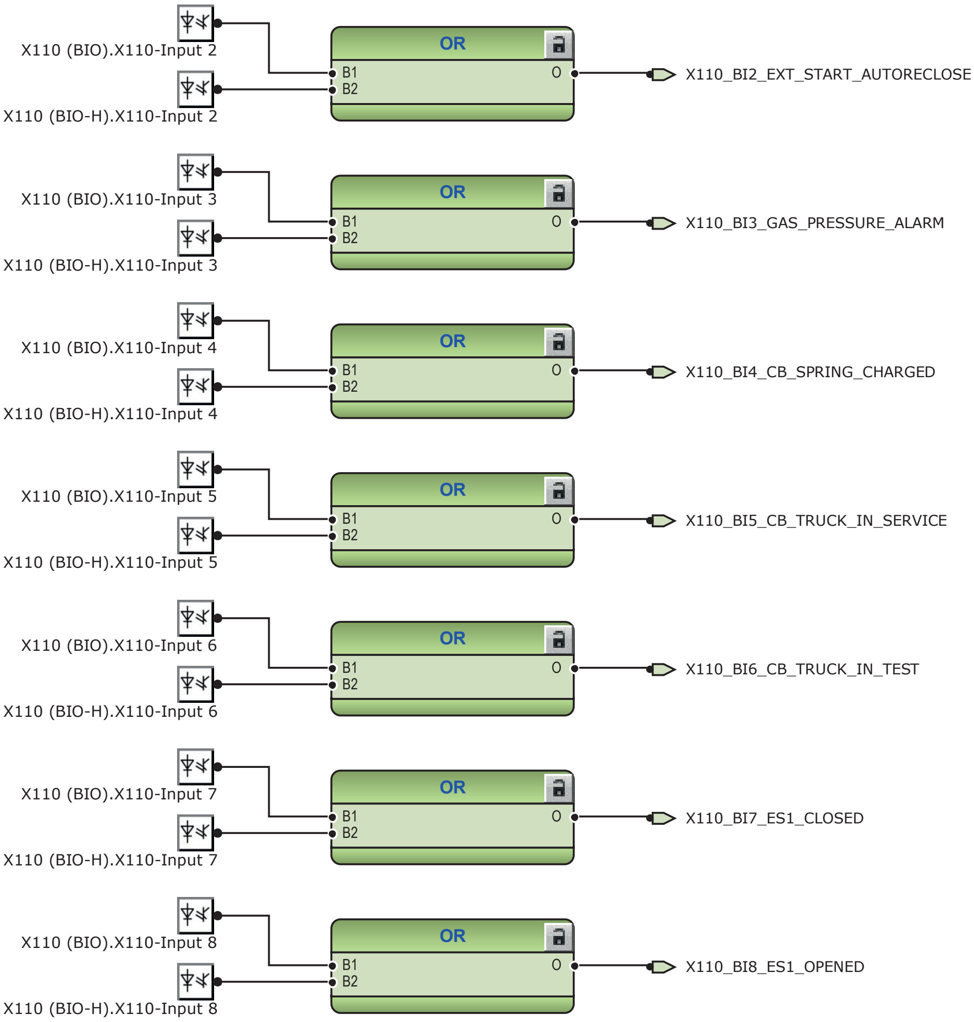


Figure 163: Binary inputs - X110 terminal block

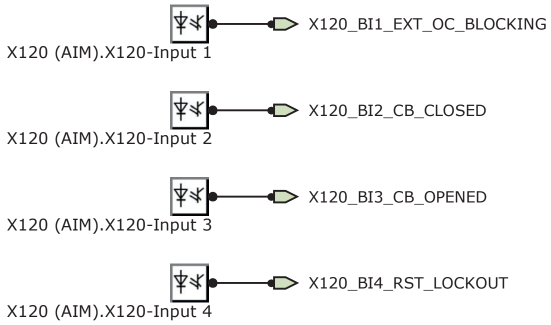


Figure 164: Binary inputs - X120 terminal block

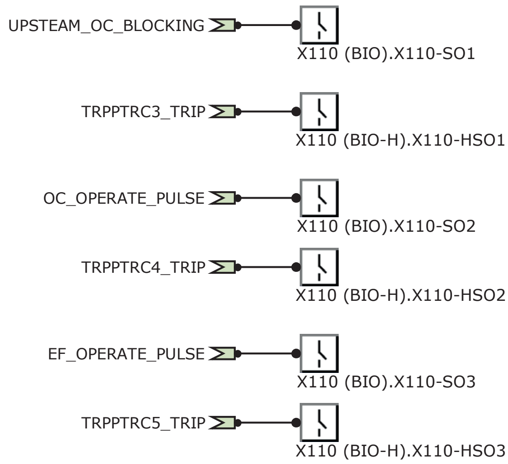


Figure 165: Binary outputs - X110 terminal block

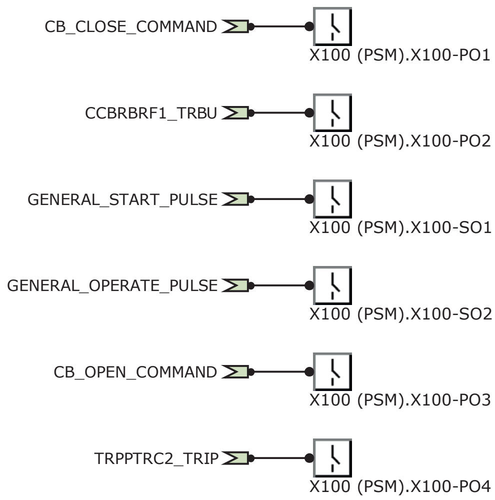
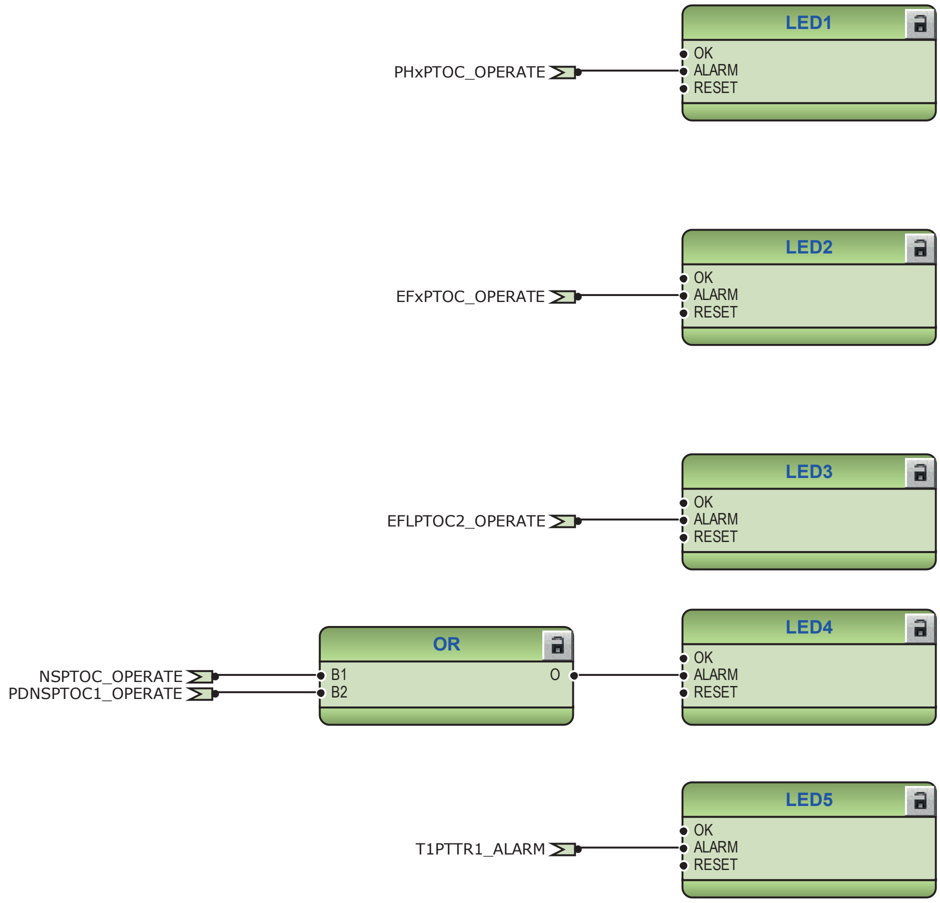


Figure 166: Binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
PHxPTOC_OPERATE
LED2
OK
ALARM
RESET
EFxPTOC_OPERATE
LED3
OK
ALARM
RESET
EFLPTOC2_OPERATE
OR
B1
B2
O
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
LED4
OK
ALARM
RESET
LED5
OK
ALARM
RESET
T1PTTR1_ALARM

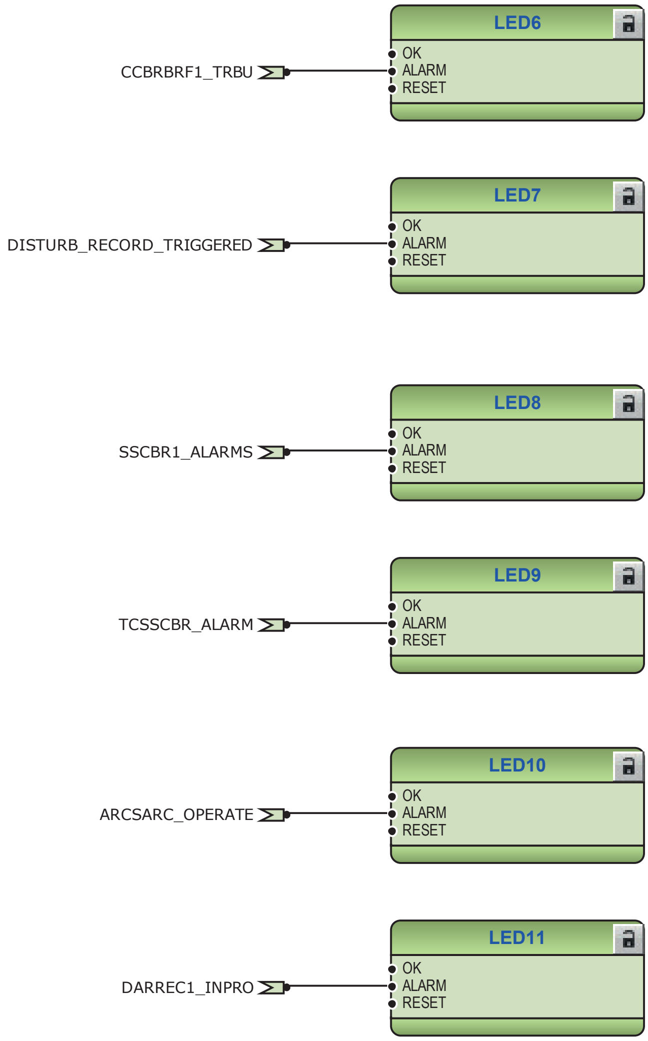


Figure 167: Default LED connection

3.6.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate and earth-fault operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

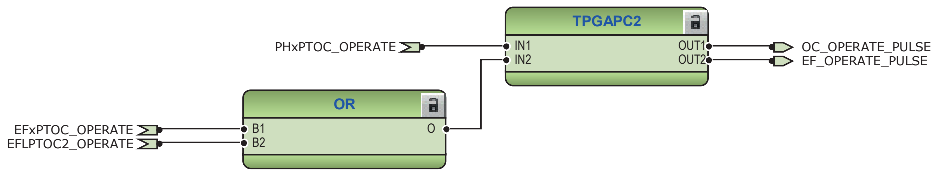


Figure 168: Timer logic for overcurrent and earth-fault operate pulse

3.6.3.8 Other functions

The configuration includes few instances of multi-purpose protection function MAPGAPC, high impedance fault detection function PHIZ, runtime counter 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 for non-directional overcurrent and directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance or wattmetric-based 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.

3.7.2 Functions

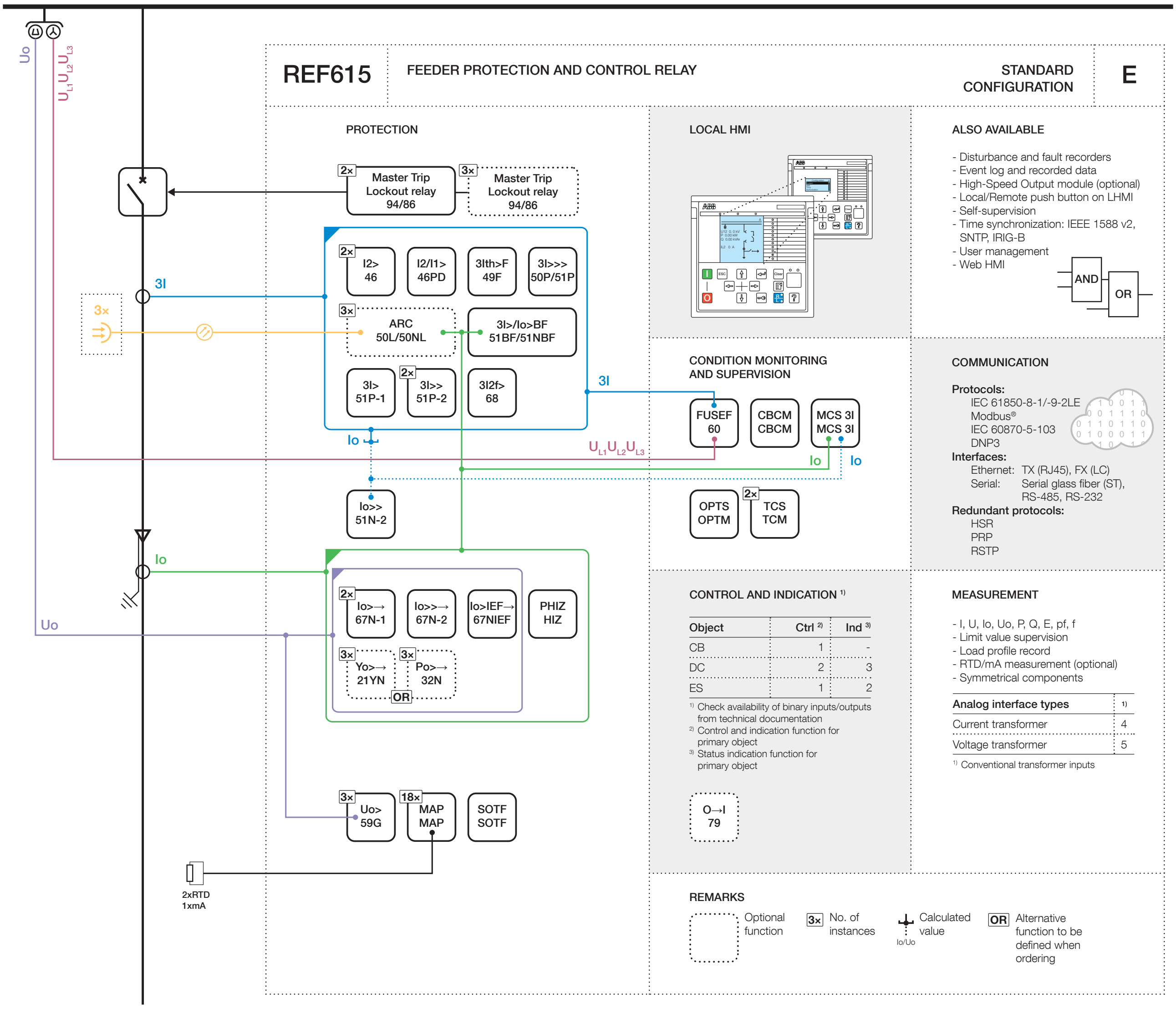


Figure 169: Functionality overview for standard configuration E

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	MCB open
X110-BI2	Directional earth-fault protection's basic angle control
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 (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Lock-out reset

Table 32: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 33: Default connections for LEDs

LED	Description
1	Non-directional overcurrent protection operated
2	Directional earth-fault protection operated

Table continues on the next page

LED	Description
3	Double (cross country) earth-fault or residual overvoltage protection operated
4	Negative sequence overcurrent or phase discontinuity protection operated
5	Thermal overload alarm
6	Circuit breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

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	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
	EFPADM1 - start	

Table continues on the next page

Channel	ID text	Level trigger mode
	WPWDE1 - start	
8	DEFLPDEF2 - start	Positive or Rising
	EFPADM2 - start	
	WPWDE2 - start	
9	EFPADM3 - start	Positive or Rising
	WPWDE3 - start	
10	INTRPTEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	ROVPTOV1 - start	Positive or Rising
15	ROVPTOV2 - start	Positive or Rising
16	ROVPTOV3 - start	Positive or Rising
17	CCBRBRF1 - trret	Level trigger off
18	CCBRBRF1 - trbu	Level trigger off
19	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
20	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
21	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1 - operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
22	INTRPTEF1 - operate	Level trigger off
23	EFHPTOC1 - operate	Level trigger off
24	PDNSPTOC1 - operate	Level trigger off
25	INRPHAR1 - blk2h	Level trigger off
26	T1PTTR1 - operate	Level trigger off
27	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
28	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	

Table continues on the next page

Channel	ID text	Level trigger mode
29	ARCSARC1 - operate	Positive or Rising
30	ARCSARC2 - operate	Positive or Rising
31	ARCSARC3 - operate	Positive or Rising
32	DARREC1 - close CB	Level trigger off
	DARREC1 - unsuc recl	
33	DARREC1 - inpro	Level trigger off
34	X120BI1 - ext OC blocking	Level trigger off
35	X120BI2 - CB closed	Level trigger off
36	X120BI3 - CB opened	Level trigger off
37	SEQSPVC1 - fusef3ph	Level trigger off
38	SEQSPVC1 - fusefu	Level trigger off
39	CCSPVC1 - fail	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 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.

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

Four 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.

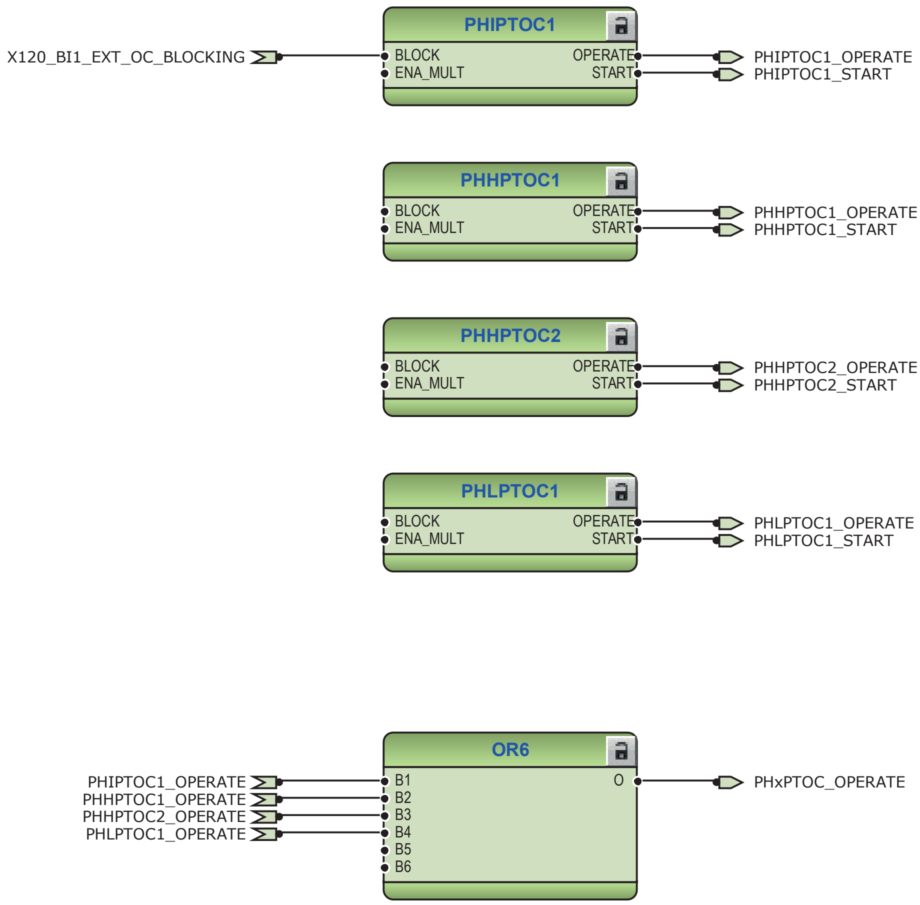


Figure 170: Overcurrent protection functions

The upstream blocking from the start of the second high stage of three-phase non-directional overcurrent protection PHHPTOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

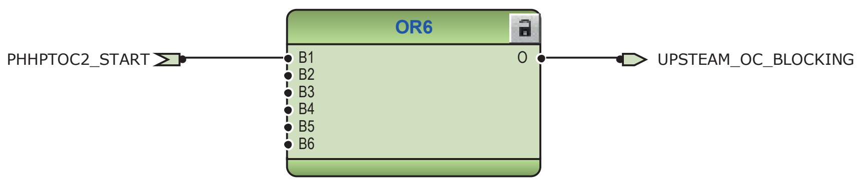


Figure 171: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

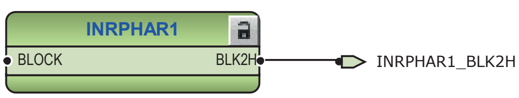


Figure 172: Inrush detector function

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 negative sequence overcurrent protections are blocked in case of detection of a failure in secondary circuit of current transformer.

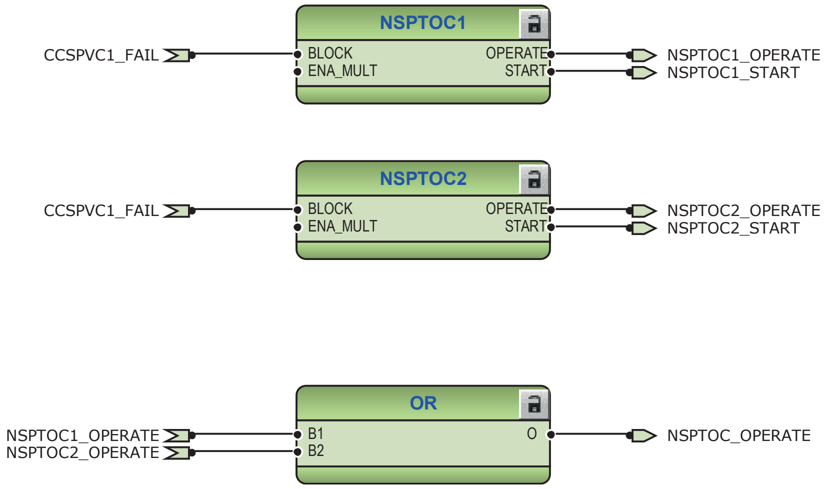


Figure 173: Negative sequence overcurrent protection function

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 used together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE. 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.

The binary input X110:BI2 is intended for controlling directional earth-fault protection blocks' relay characteristic angle (RCA: 0°, -90°) or operation mode (IoSinφ, IoCosφ) change. The same input is also available for wattmetric protection.

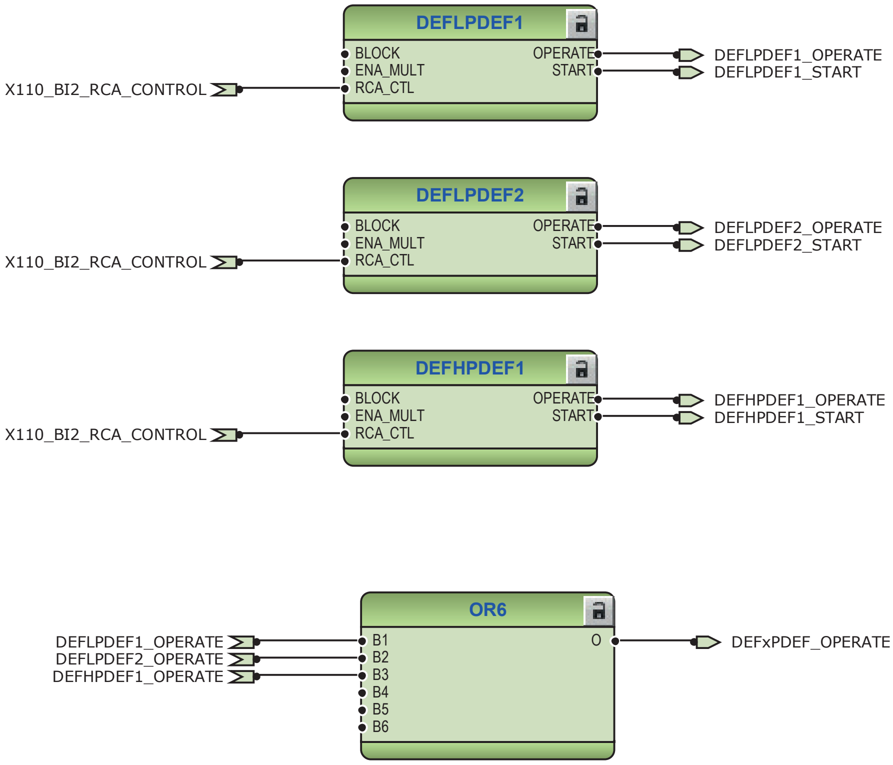


Figure 174: Directional earth-fault protection function

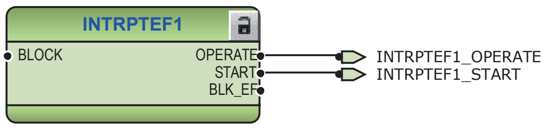


Figure 175: Transient or intermittent earth-fault protection function

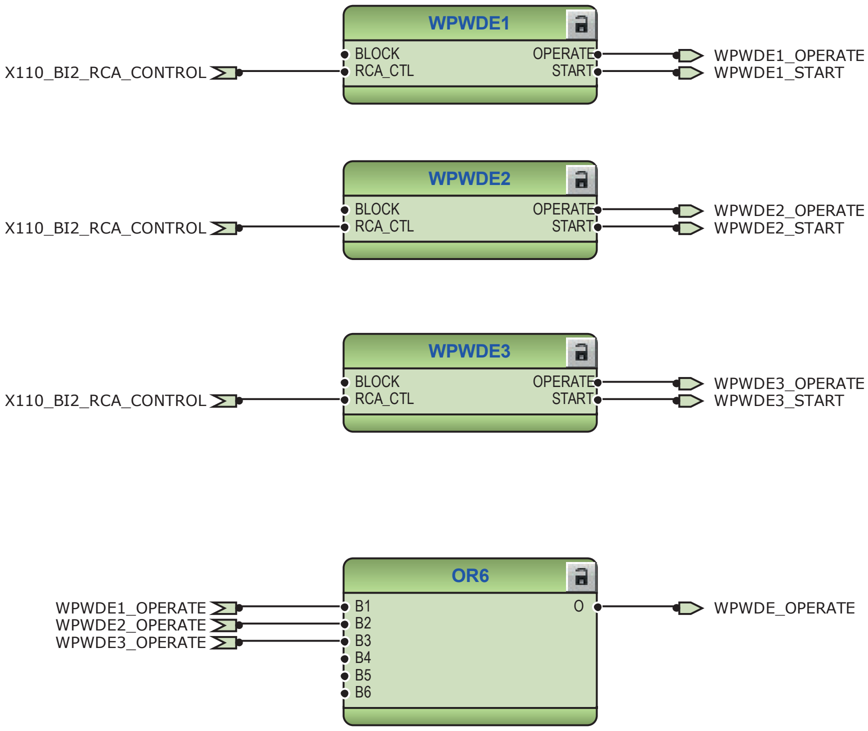


Figure 176: Wattmetric protection function

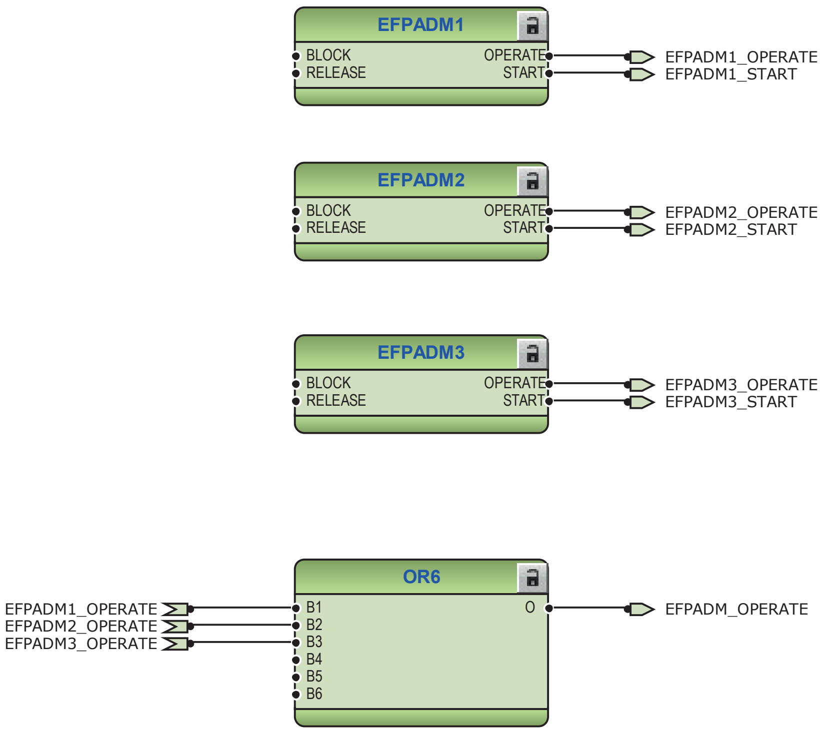


Figure 177: Admittance-based earth-fault protection function

Non-directional earth-fault protection 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. The function is blocked in case of detection of a failure in secondary circuit of current transformer.

Figure 178: Non-directional earth-fault protection

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 of a failure in secondary circuit of voltage transformer.

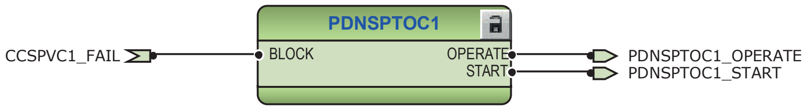


Figure 179: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

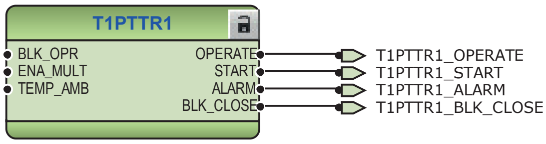


Figure 180: Thermal overcurrent protection function

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

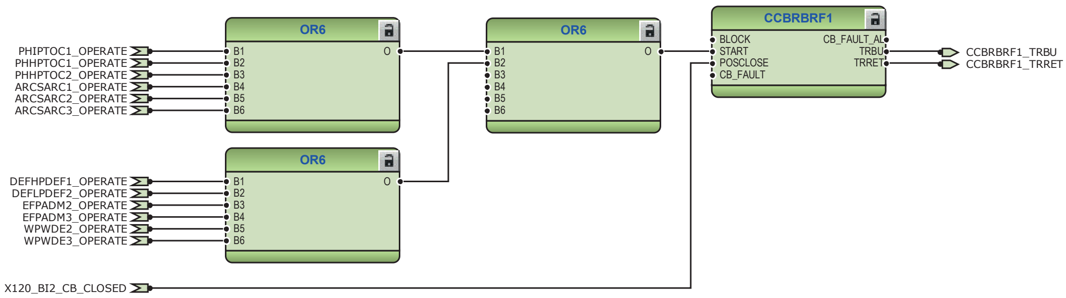


Figure 181: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

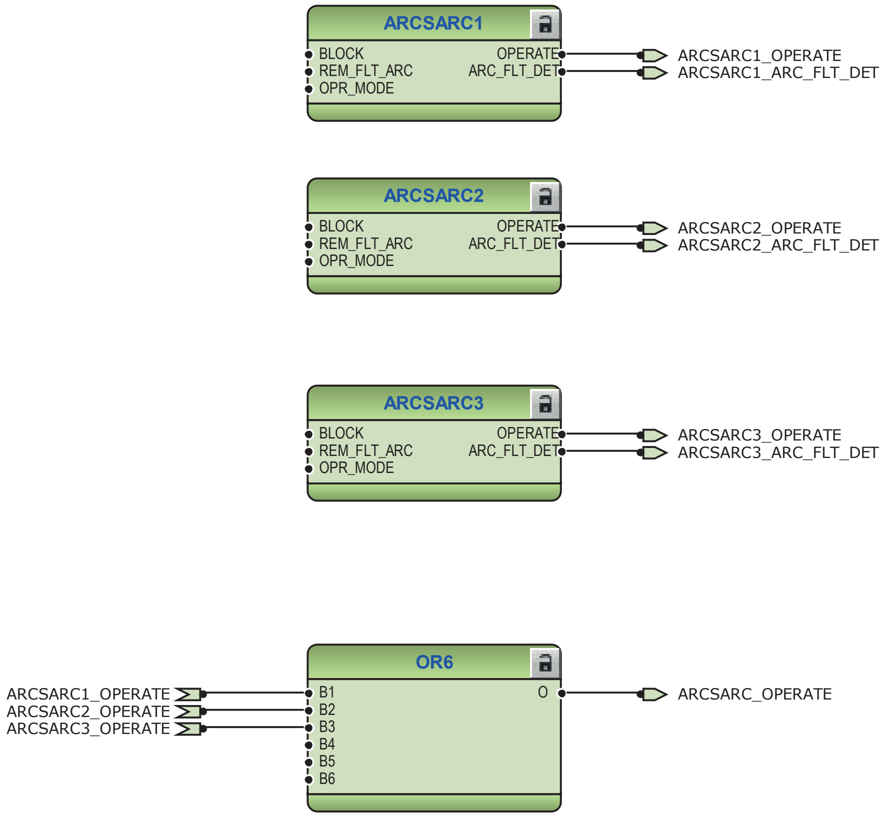


Figure 182: Arc protection function

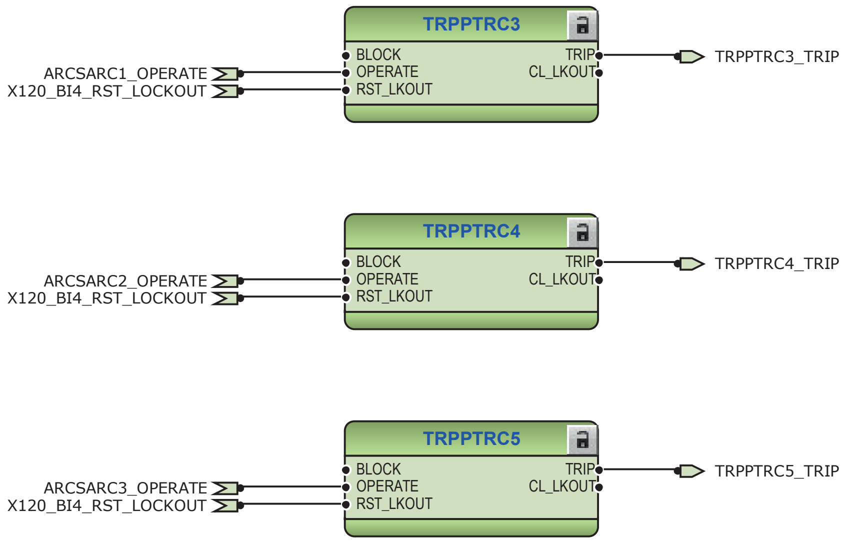


Figure 183: Arc protection with dedicated HSO

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. 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.

Set the parameters for DARREC1 properly.

Check this initialization signals of the DARREC1.

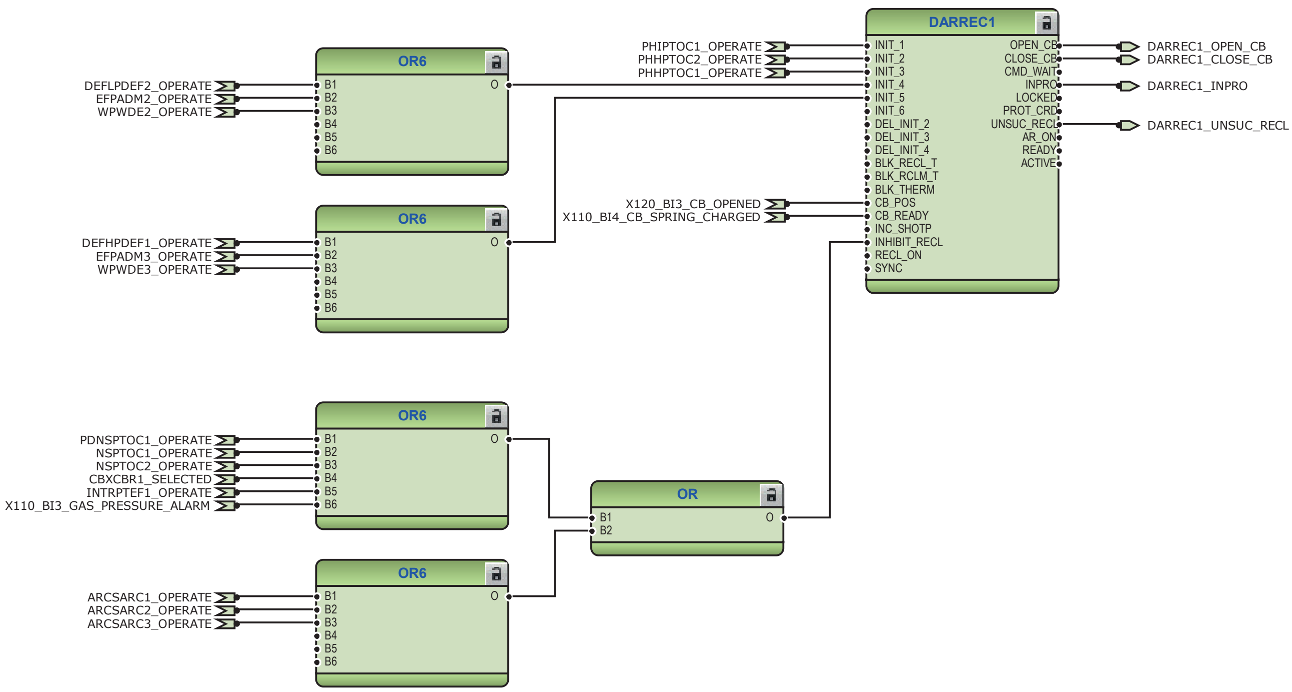


Figure 184: Autoreclosing function

The residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage. This can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality.

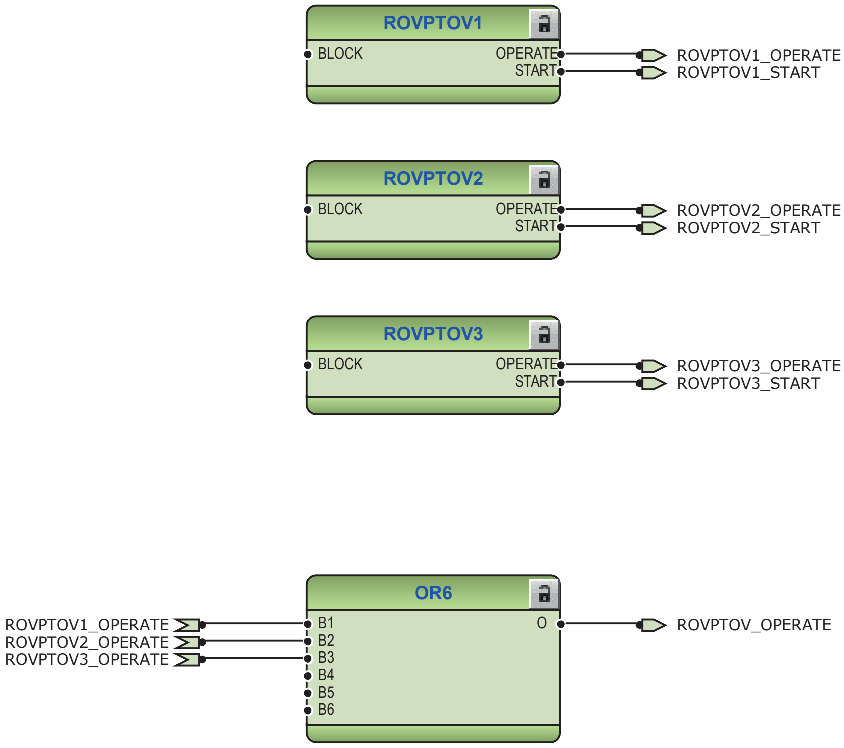


Figure 185: Residual voltage protection function

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 is connected to binary outputs.

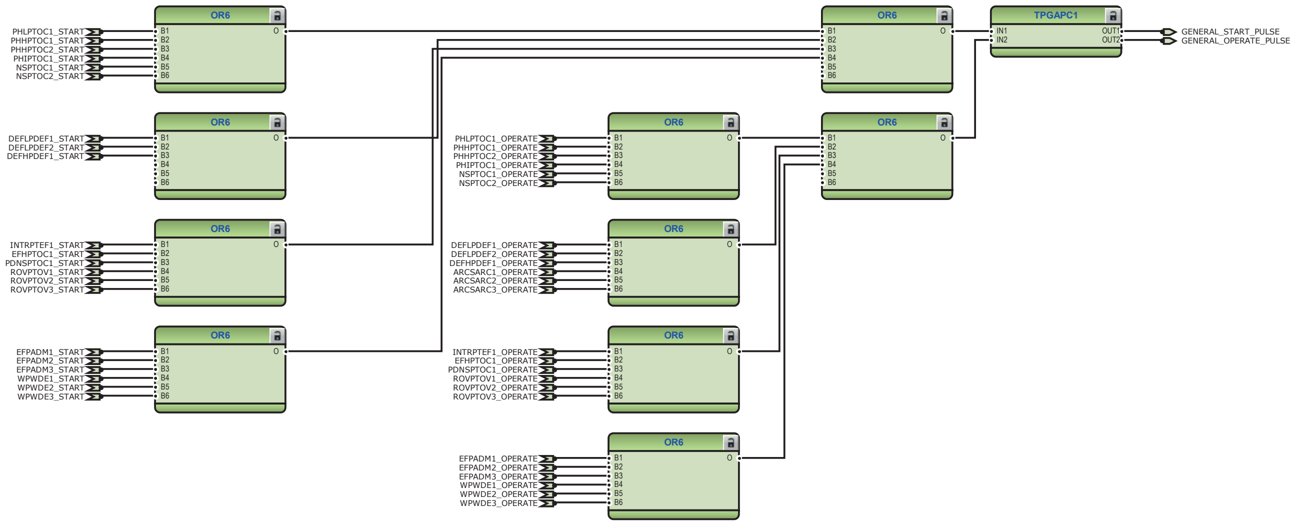


Figure 186: General start and operate signals

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 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

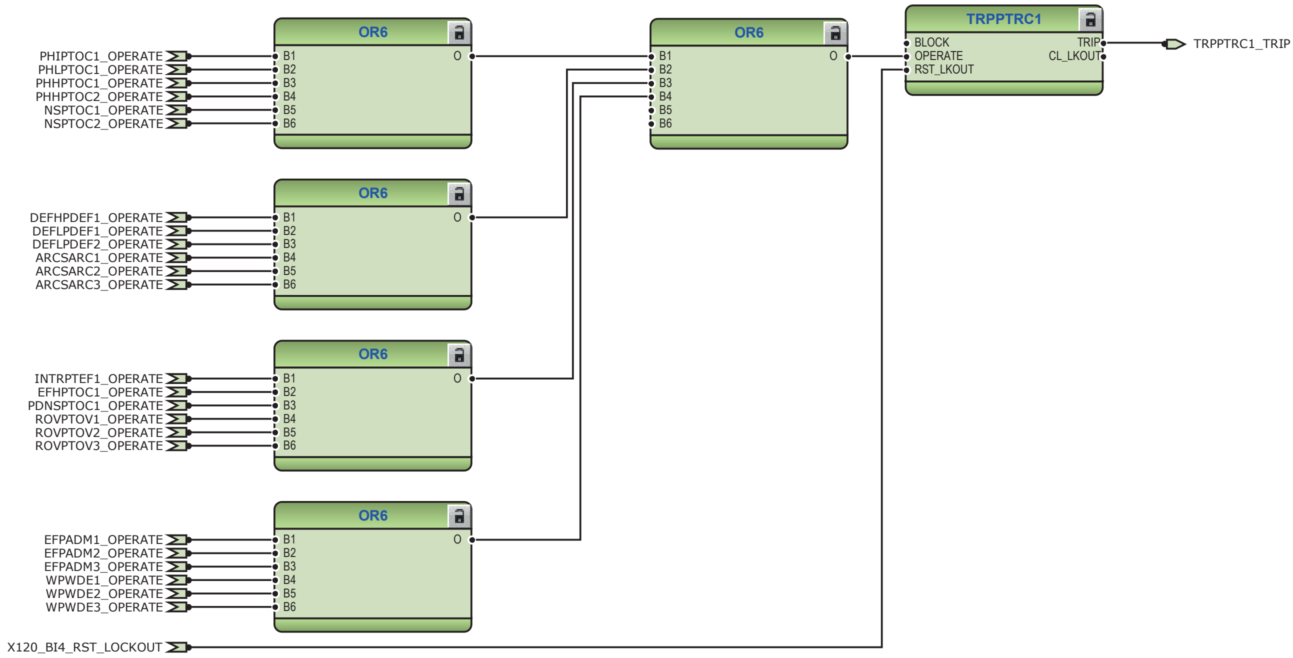


Figure 187: Trip logic TRPPTRC1

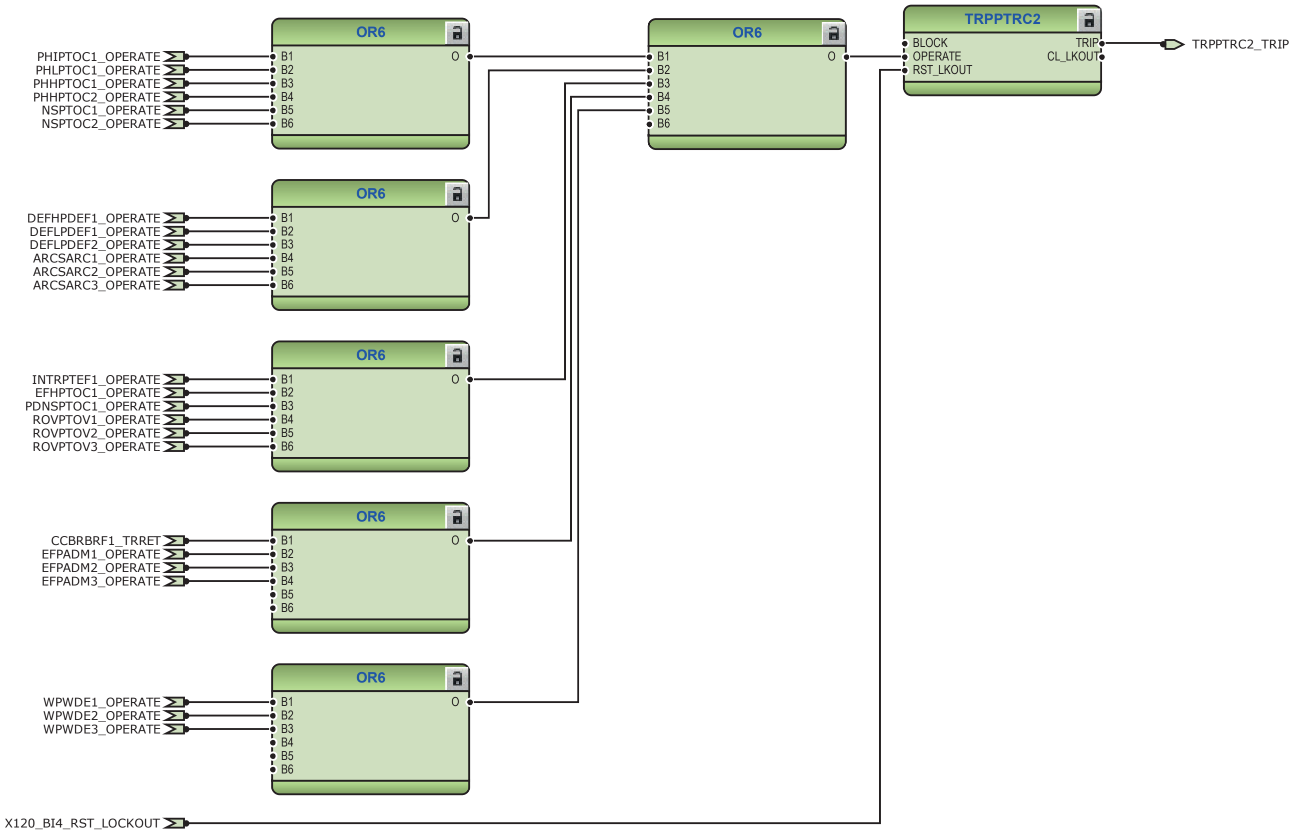


Figure 188: Trip logic TRPPTRC2

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.

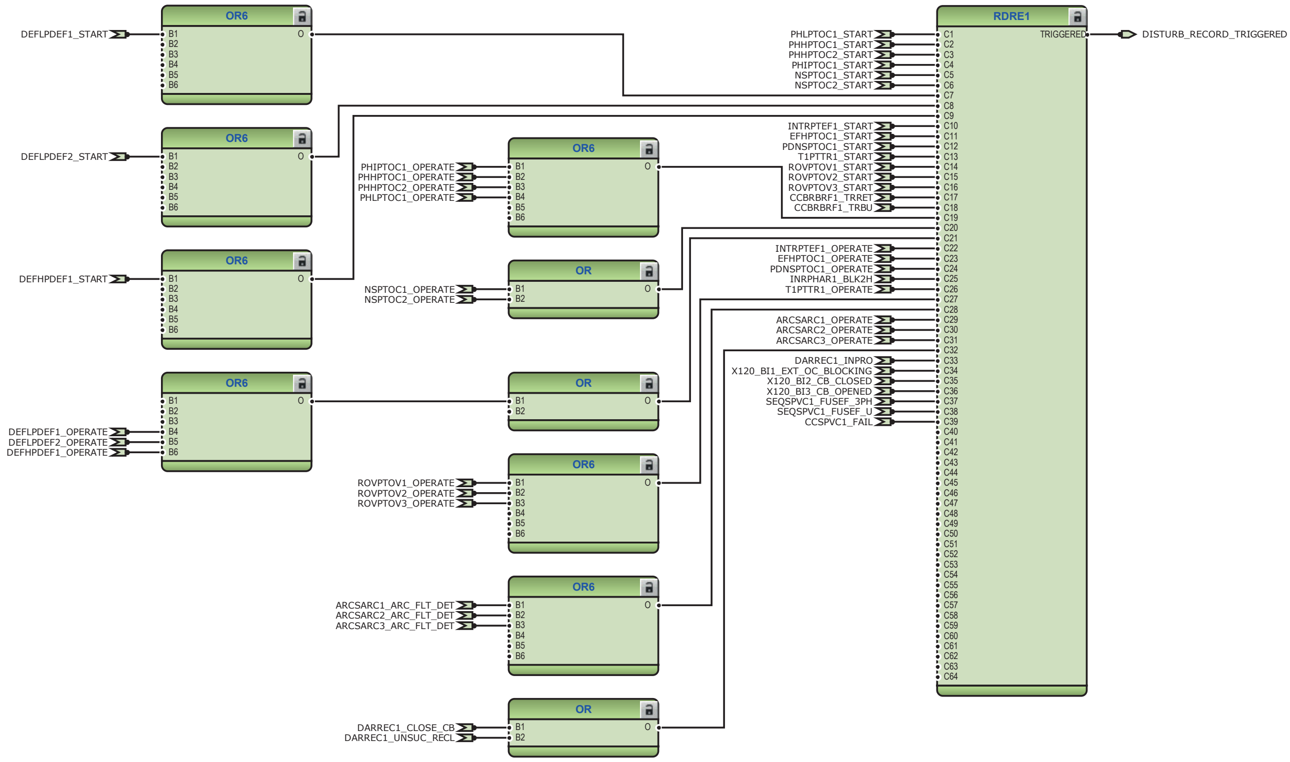


Figure 189: Disturbance recorder

3.7.3.3 Functional diagrams for condition monitoring

Failures in the current measuring circuits are detected by CCSPVC1. When a failure is detected, it is used to block current protection functions which measure the calculated sequence component currents or residual current to avoid unnecessary operation.

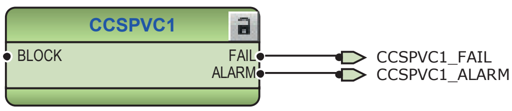


Figure 190: Current circuit supervision function

The fuse failure supervision function SEQSPVC1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

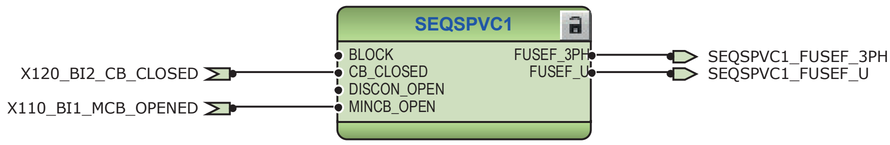


Figure 191: Fuse failure supervision function

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.

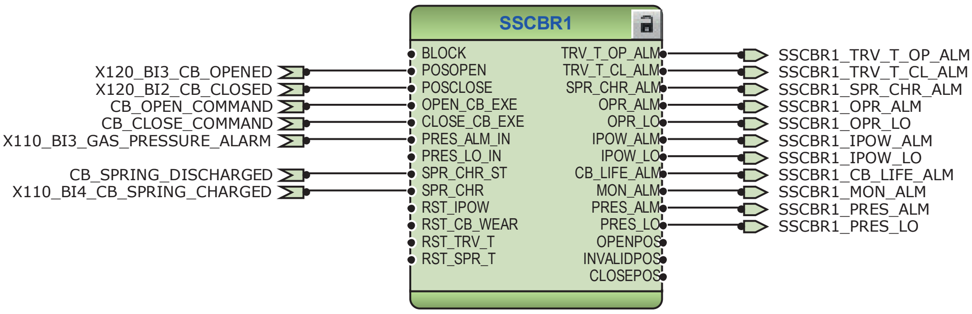


Figure 192: Circuit-breaker condition monitoring function

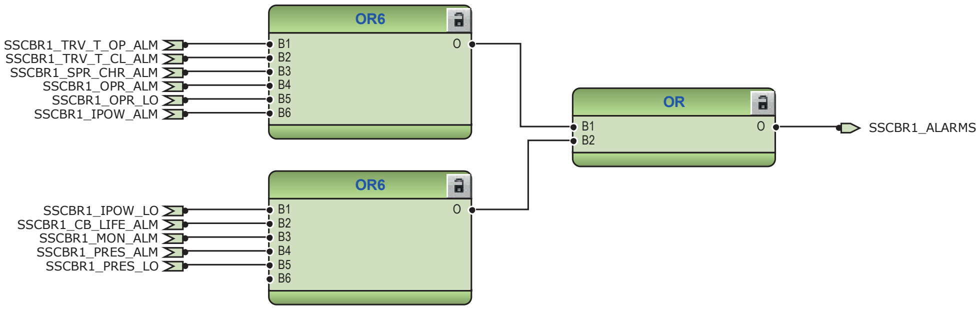


Figure 193: Logic for circuit-breaker monitoring alarm

Figure 194: 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. 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.

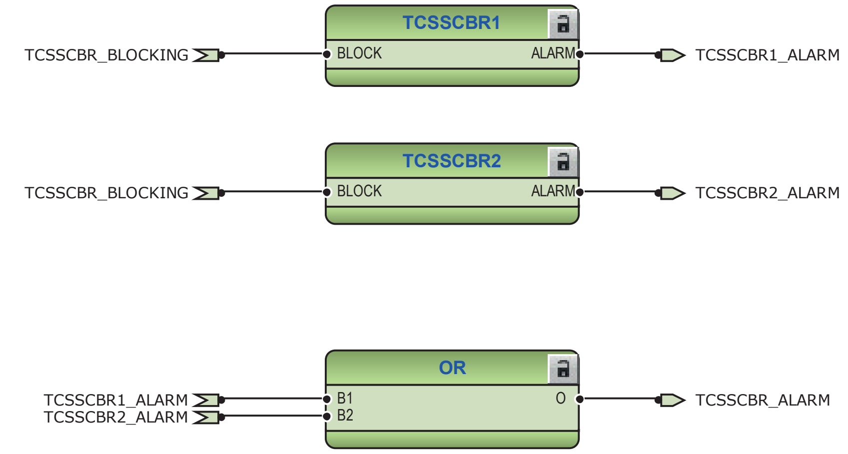


Figure 195: Trip circuit supervision function

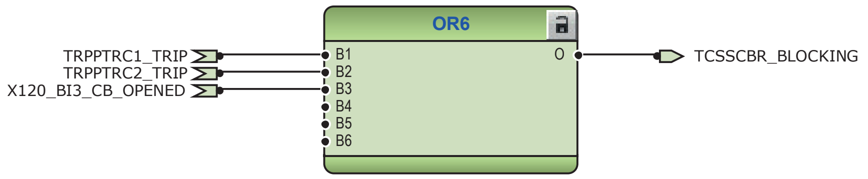


Figure 196: Logic for blocking of trip circuit supervision function

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 standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

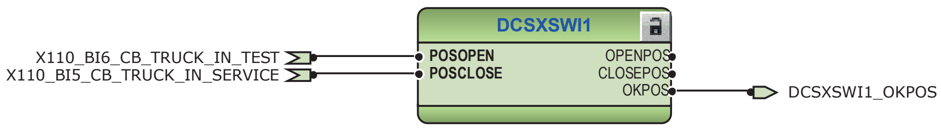


Figure 197: Disconnector 1

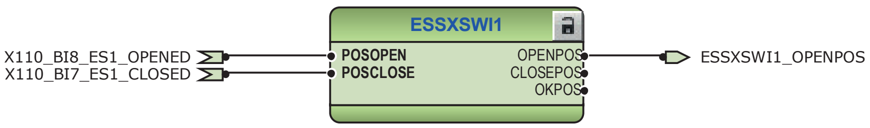


Figure 198: Earthing switch 1

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit-breaker spring charging status.

The `OKPOS` output from DCSXSWI defines if the disconnector or breaker truck is definitely 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 circuit breaker is always enabled.

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

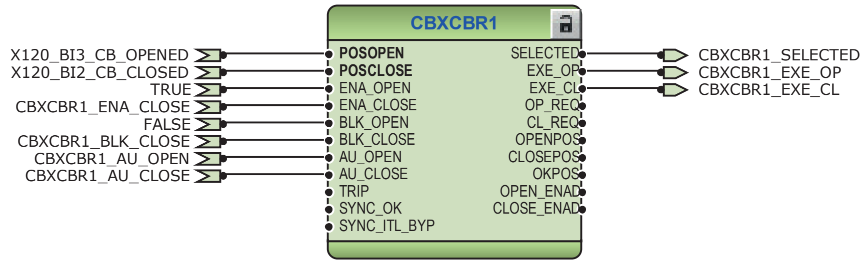


Figure 199: Circuit breaker control logic: Circuit breaker 1

Connect the additional signals required for the application for closing and opening of circuit breaker.

Figure 200: Circuit breaker control logic: Signals for closing coil of circuit breaker 1

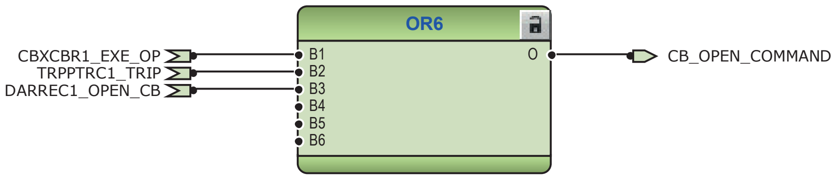


Figure 201: Circuit breaker control logic: Signals for opening coil of circuit breaker 1

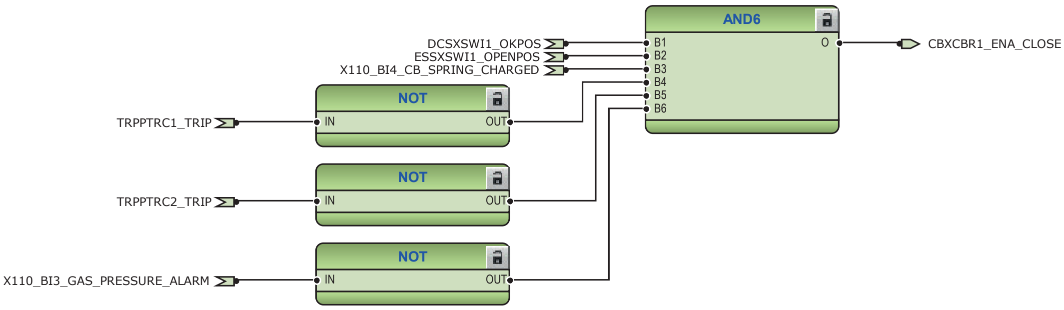


Figure 202: Circuit breaker close enable logic

Connect the higher-priority conditions which must be set before enabling the closing of circuit breaker. These conditions cannot be bypassed using bypass feature of the function.

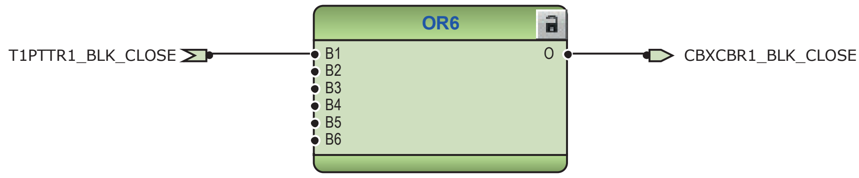


Figure 203: Circuit breaker close blocking logic

The configuration includes the logic for generating circuit breaker external closing and opening commands 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 additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration

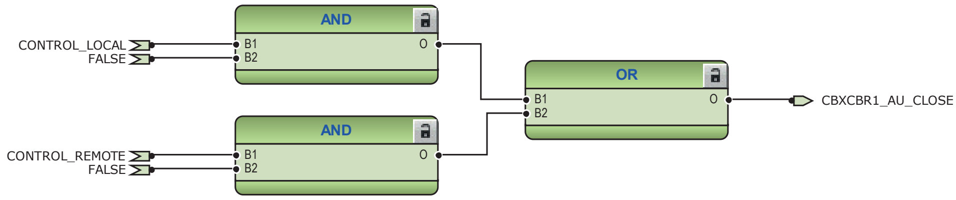


Figure 204: External closing command for circuit breaker 1

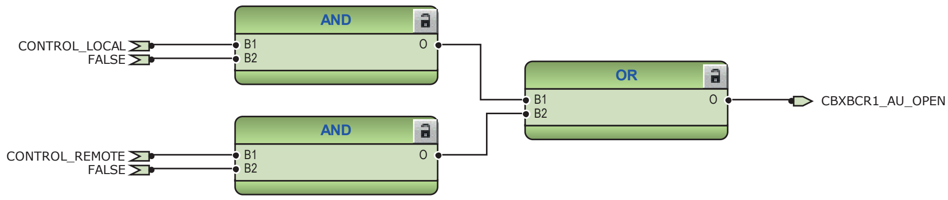


Figure 205: External opening command for circuit breaker 1

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 three-phase voltage measurement VMMXU1. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESVMMXU1 measures the residual voltage.

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

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

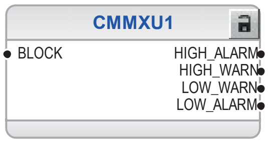


Figure 206: Current measurement: Three-phase current measurement

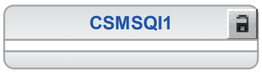


Figure 207: Current measurement: Sequence current measurement

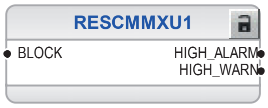


Figure 208: Current measurement: Residual current measurement

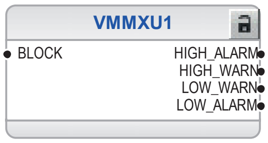


Figure 209: Voltage measurement: Three-phase voltage measurement

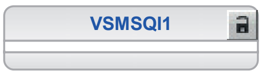


Figure 210: Voltage measurement: Sequence voltage measurement

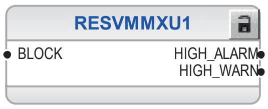


Figure 211: Voltage measurement: Residual voltage measurement

Figure 212: Other measurement: Frequency measurement

Figure 213: Other measurement: Three-phase power and energy measurement

Figure 214: Other measurement: Data monitoring

Figure 215: Other measurement: Load record profile

3.7.3.6 Functional diagrams for I/O and alarm LEDs

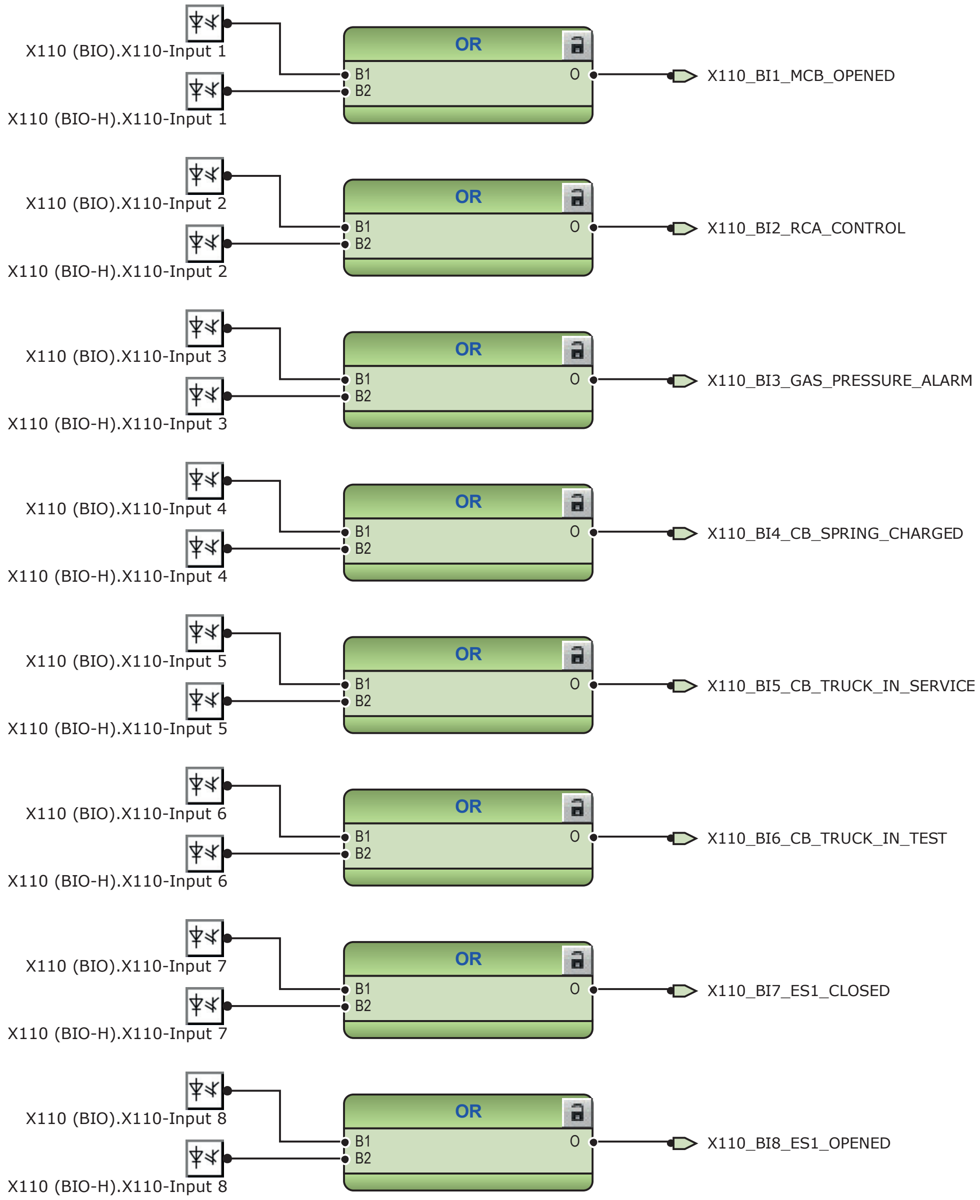


Figure 216: Binary inputs - X110 terminal block

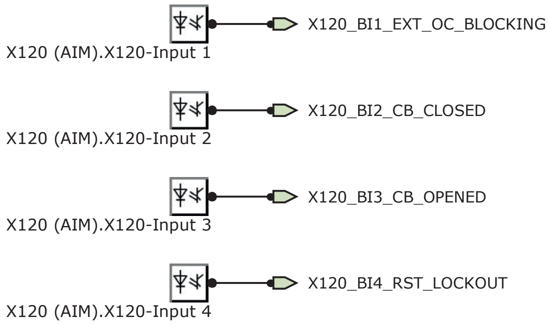


Figure 217: Binary inputs - X120 terminal block

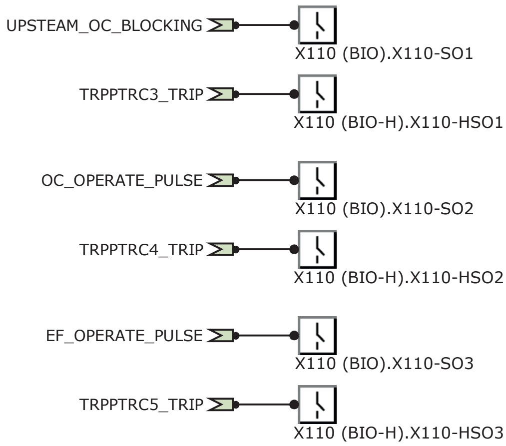


Figure 218: Default binary outputs - X110 terminal block

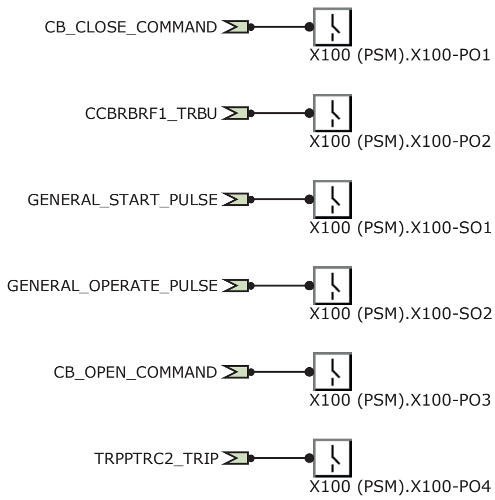
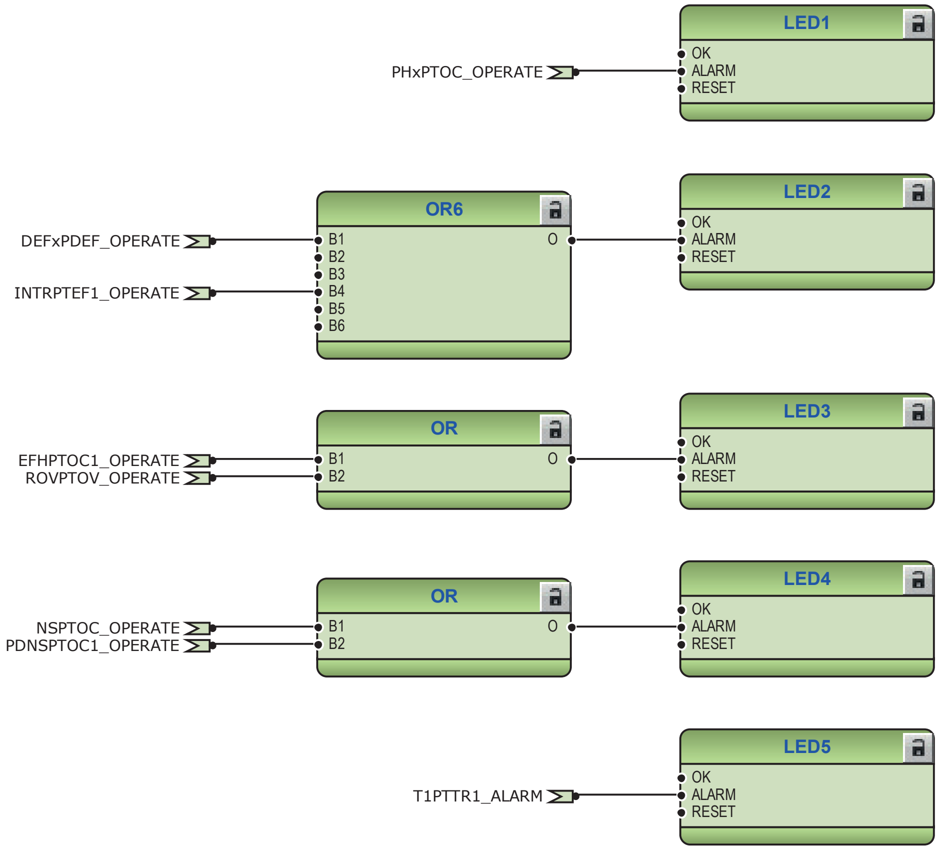


Figure 219: Default binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
PHxPTOC_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
DEFxPDEF_OPERATE
INTRPTEF1_OPERATE
LED2
OK
ALARM
RESET
OR
B1
B2
O
EFHPTOC1_OPERATE
ROVPTOV_OPERATE
LED3
OK
ALARM
RESET
OR
B1
B2
O
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
LED4
OK
ALARM
RESET
LED5
OK
ALARM
RESET
T1PTTR1_ALARM

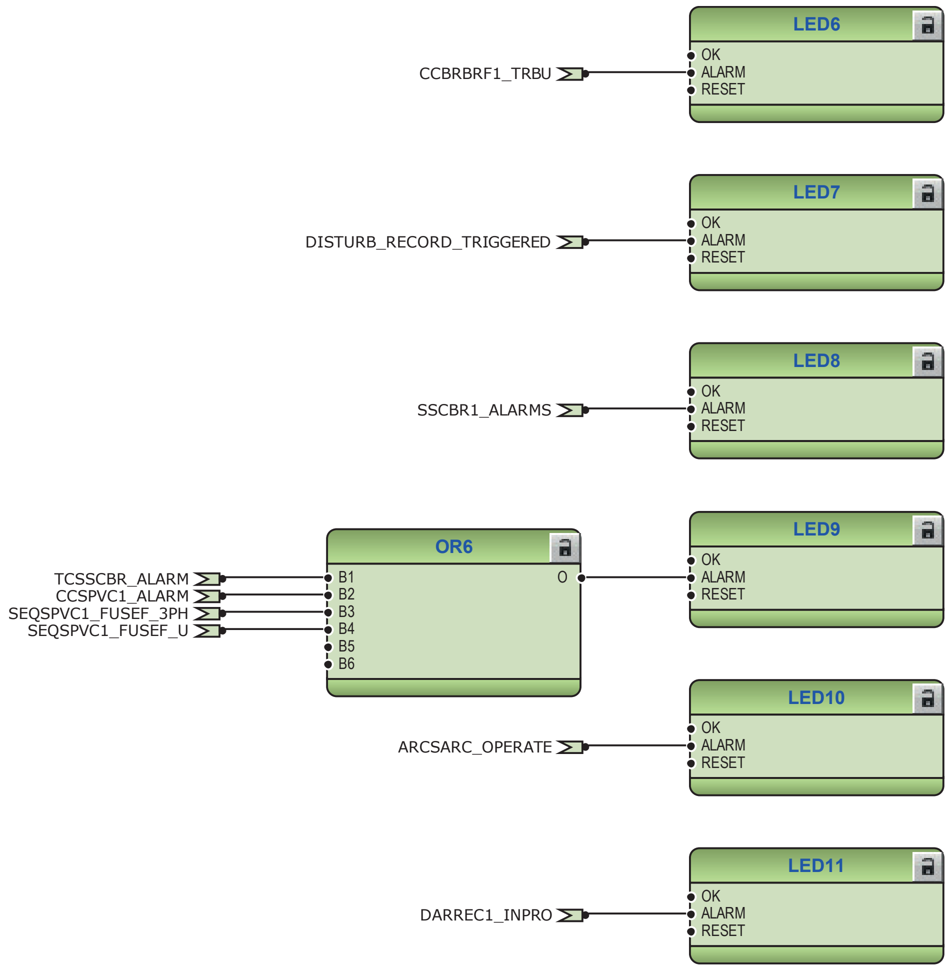


Figure 220: Default LED connection

3.7.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate and earth-fault operate logic. The operate logics are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

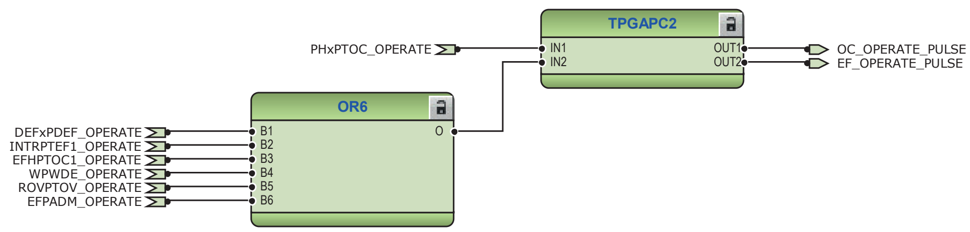


Figure 221: Timer logic for overcurrent and earth-fault operate pulse

3.7.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, high -impedance fault detection PHIZ, runtime counter for machines and devices

MDSOPT and 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.

3.8 Standard configuration F

3.8.1 Applications

The standard configuration includes directional overcurrent and directional earth-fault protection with phase voltage based measurement, undervoltage and overvoltage protection and measurement function. The configuration is mainly intended for cable and overhead-line feeder applications in directly or resistance earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance, wattmetric or harmonic-based 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.

3.8.2 Functions

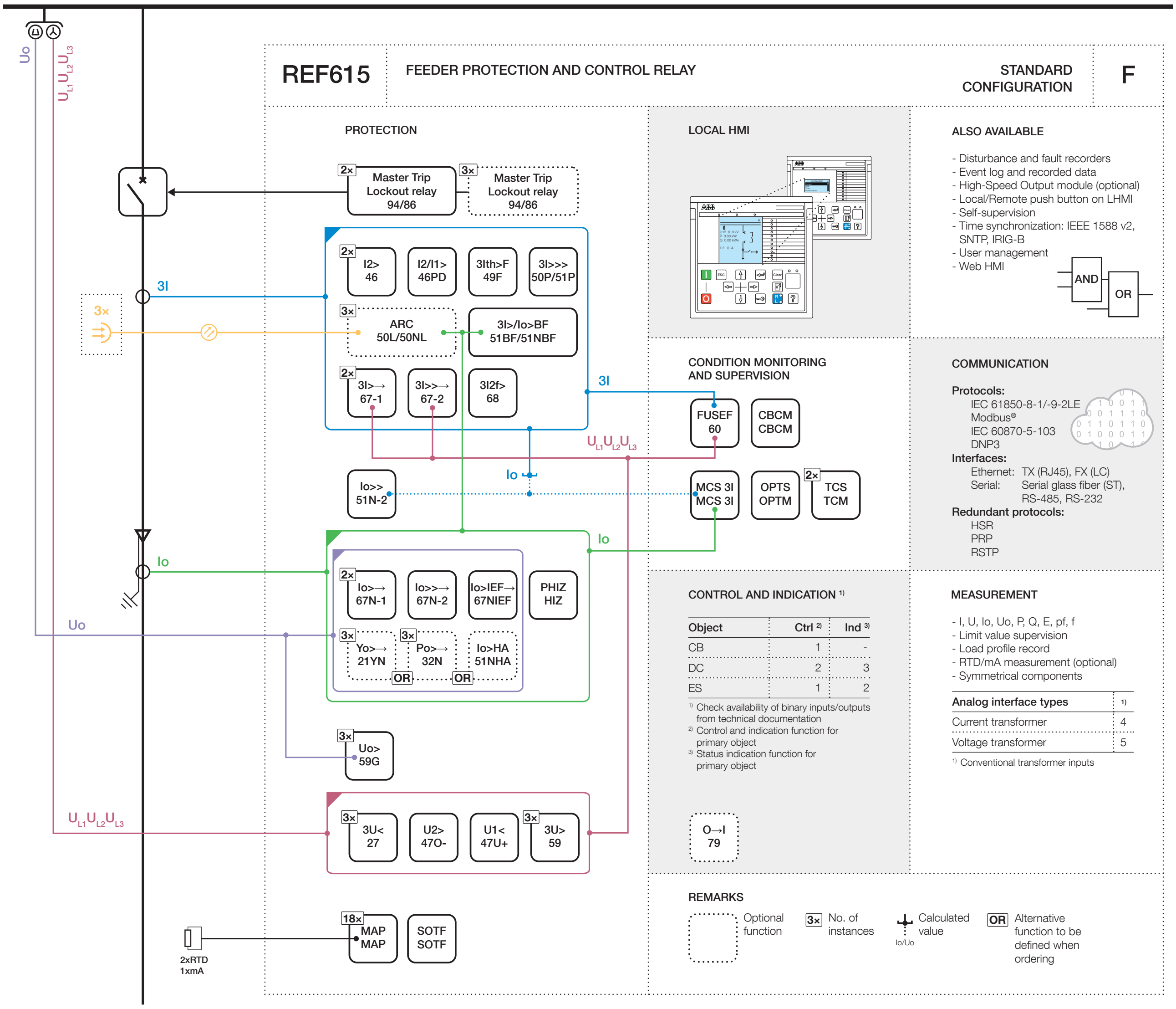


Figure 222: Functionality overview for standard configuration F

3.8.2.1 Default I/O connections

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

Table 36: Default connections for binary inputs

Binary input	Description
X110-BI1	MCB open
X110-BI2	Directional earth-fault protection's basic angle control
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Lock-out reset

Table 37: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-SO4	Voltage protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 38: Default connections for LEDs

LED	Description
1	Overcurrent protection operated
2	Earth-fault protection operated

Table continues on the next page

LED	Description
3	Voltage protection operated
4	Negative sequence overcurrent or phase discontinuity protection operated
5	Thermal overload alarm
6	Circuit breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.8.2.2 Default disturbance recorder settings

Table 39: 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 40: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	DPHLPDOC1 - start	Positive or Rising
2	DPHLPDOC2 - start	Positive or Rising
3	DPHHPDOC1 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
	EFPADM1 - start	
	WPWDE1 - start	

Table continues on the next page

Channel	ID text	Level trigger mode
8	DEFLPDEF2 - start	Positive or Rising
	EFPADM2 - start	
	WPWDE2 - start	
9	EFPADM3 - start	Positive or Rising
	WPWDE3 - start	
10	INTRPTEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	PHPTOV1 - start	Positive or Rising
15	PHPTOV2 - start	Positive or Rising
16	PHPTOV3 - start	Positive or Rising
17	PSPTUV1 - trret	Positive or Rising
18	NSPTOV1 - trbu	Positive or Rising
19	PHPTUV1 - start	Positive or Rising
20	PHPTUV2 - start	Positive or Rising
21	PHPTUV3 - start	Positive or Rising
22	ROVPTOV1 - start	Positive or Rising
23	ROVPTOV2 - start	Positive or Rising
24	ROVPTOV3 - start	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHIPTOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
28	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
29	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1 - operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
30	INTRPTEF1 - operate	Level trigger off
31	EFHPTOC1 - operate	Level trigger off
32	PDNSPTOC1 - operate	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
34	T1PTTR1 - operate	Level trigger off
35	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
	PHPTOV3 - operate	
36	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
	PHPTUV3 - operate	
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
	PSPTUV1 - operate	
	NSPTOV2 - operate	
38	SEQSPVC1 - fusef3ph	Level trigger off
39	SEQSPVC1 - fusefu	Level trigger off
40	CCSPVC1 - fail	Level trigger off
41	X120BI1 - ext OC blocking	Level trigger off
42	X120BI2 - CB closed	Level trigger off
43	X120BI3 - CB opened	Level trigger off
44	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
45	DARREC1 - close CB	Level trigger off
	DARREC1 - unsuc recl	
46	ARCSARC1 - operate	Positive or Rising
47	ARCSARC2 - operate	Positive or Rising
48	ARCSARC3 - operate	Positive or Rising
49	DARREC1 - inpro	Level trigger off

3.8.3 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.

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

3.8.3.1 Functional diagrams for protection

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

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.

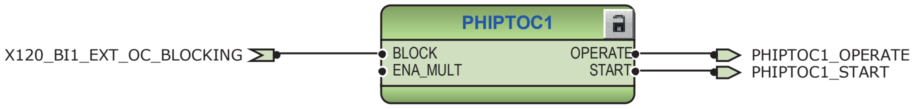


Figure 223: Overcurrent protection function

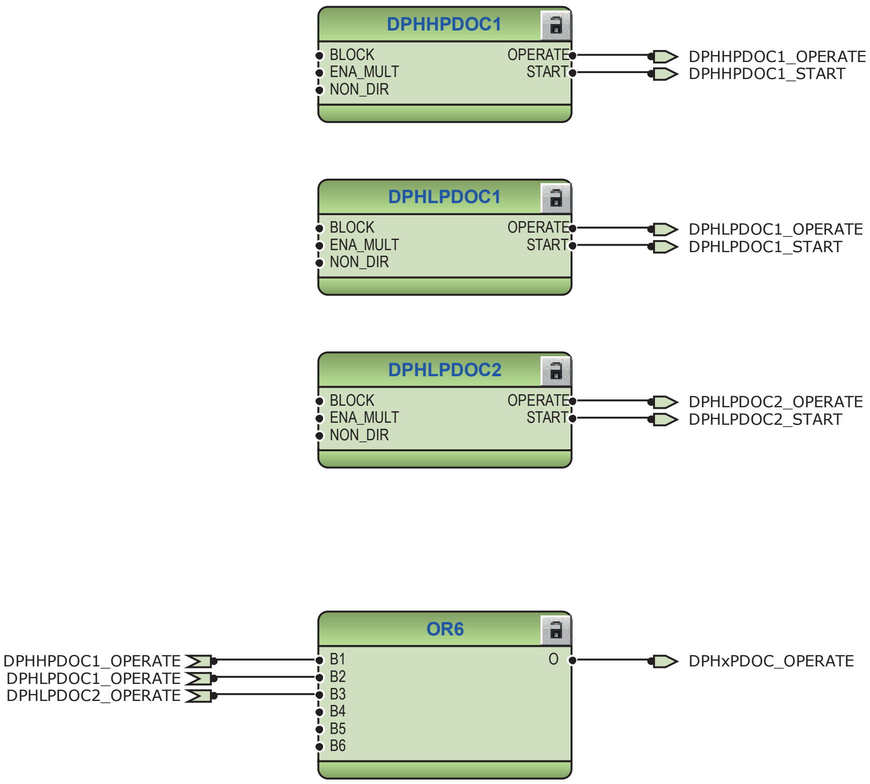


Figure 224: Directional overcurrent protection function

The upstream blocking from the start of the second low stage of three-phase directional overcurrent protection DPHLPDOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

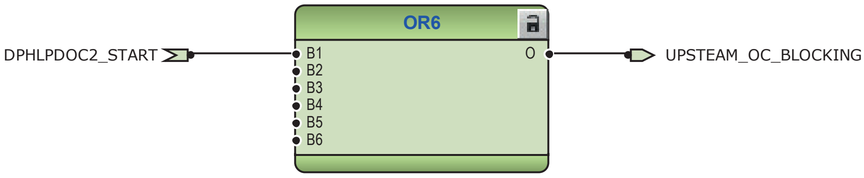


Figure 225: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

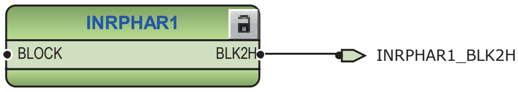


Figure 226: Inrush detector function

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 protections are blocked in case of detection in failure in secondary circuit of current transformer.

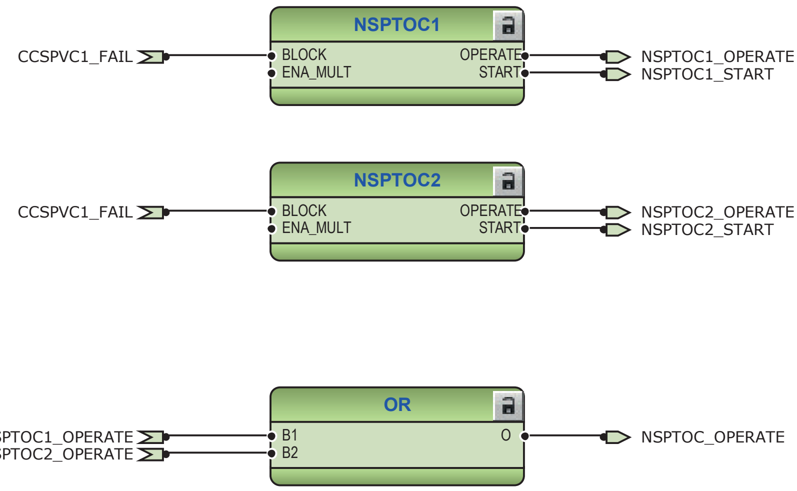


Figure 227: Negative-sequence overcurrent protection function

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 used together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE or harmonics-based earth-fault protection HAEFPTOC. A dedicated protection stage INTRPTEF is used either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

The binary input X110:BI2 is intended for controlling directional earth-fault protection blocks' relay characteristic angle (RCA: 0°, -90°) or operation mode (IoSinφ, IoCosφ) change. The same input is also available for wattmetric protection.

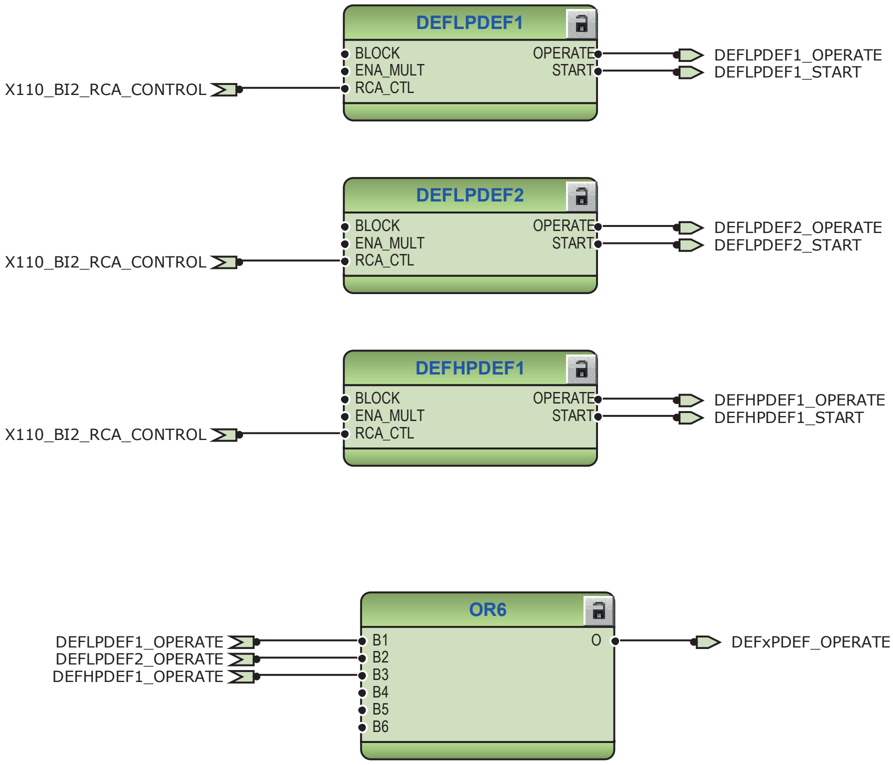


Figure 228: Directional earth-fault protection function

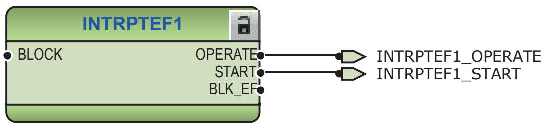


Figure 229: Transient or intermittent earth-fault protection function

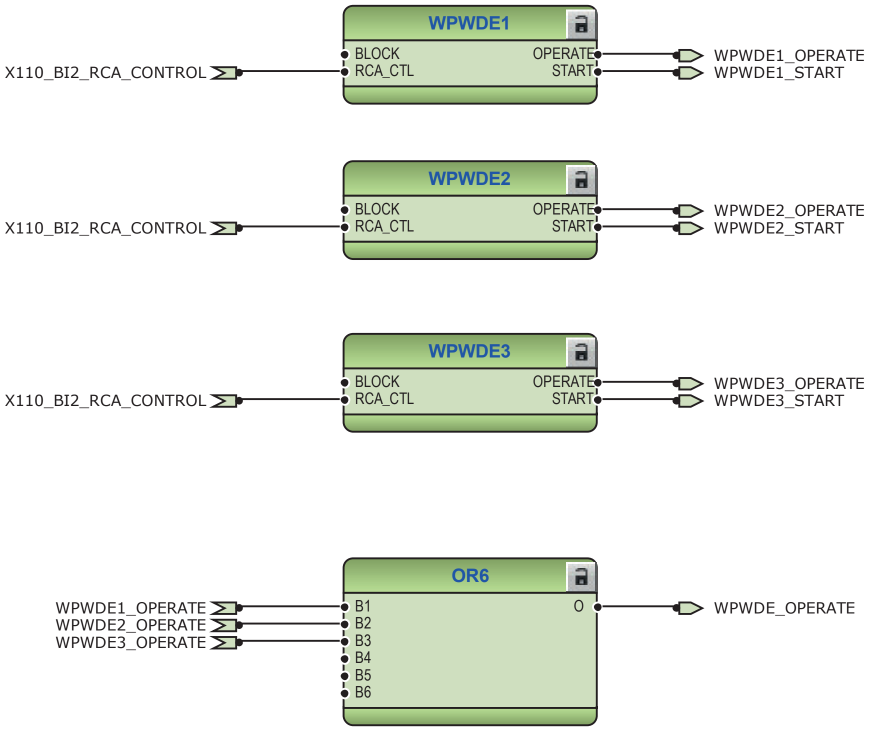


Figure 230: Wattmetric protection function

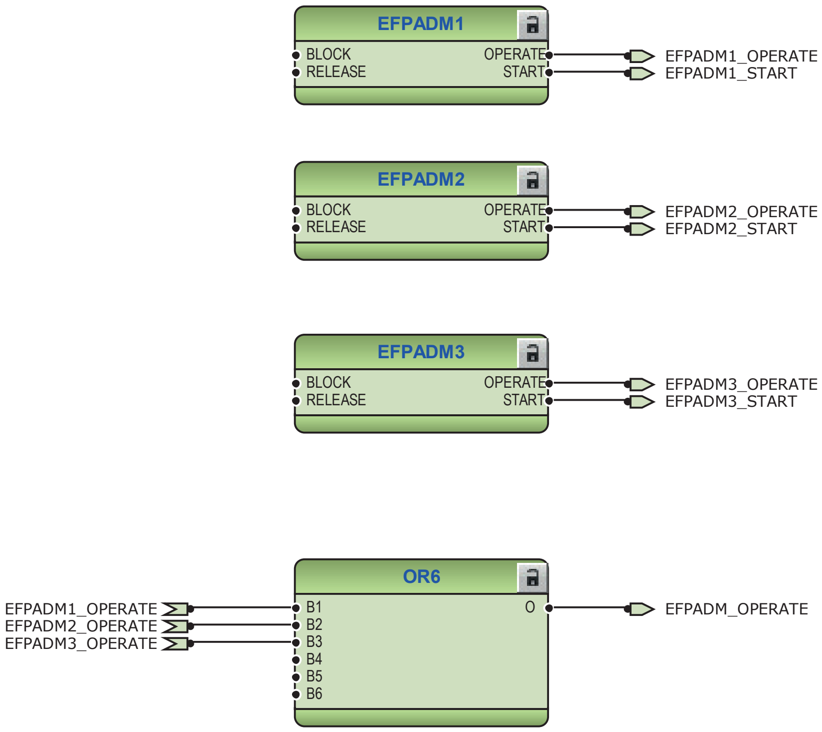


Figure 231: Admittance-based earth-fault protection function

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. The function is blocked in case of detection of a failure in secondary circuit of current transformer.

Figure 232: Earth-fault protection function

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

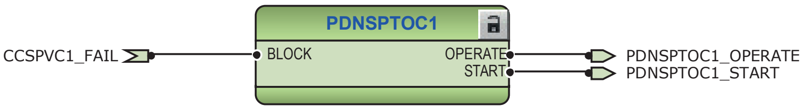


Figure 233: Phase discontinuity protection function

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

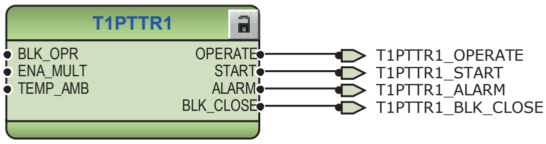


Figure 234: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by a number of different protection functions available in the IED. The 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.

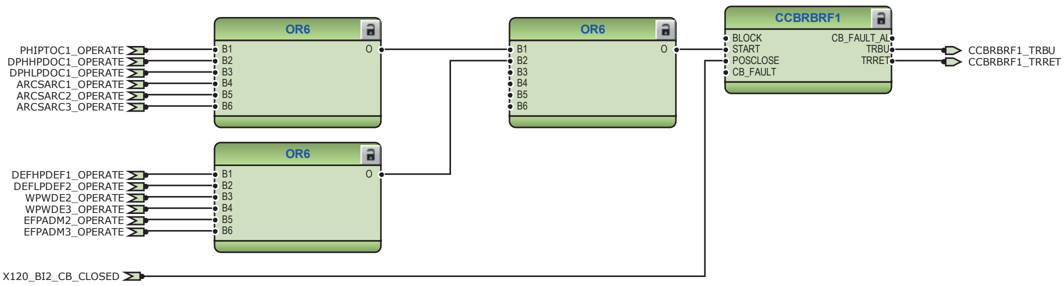


Figure 235: Circuit breaker failure protection function

Three arc protection stages ARCSARC1...3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

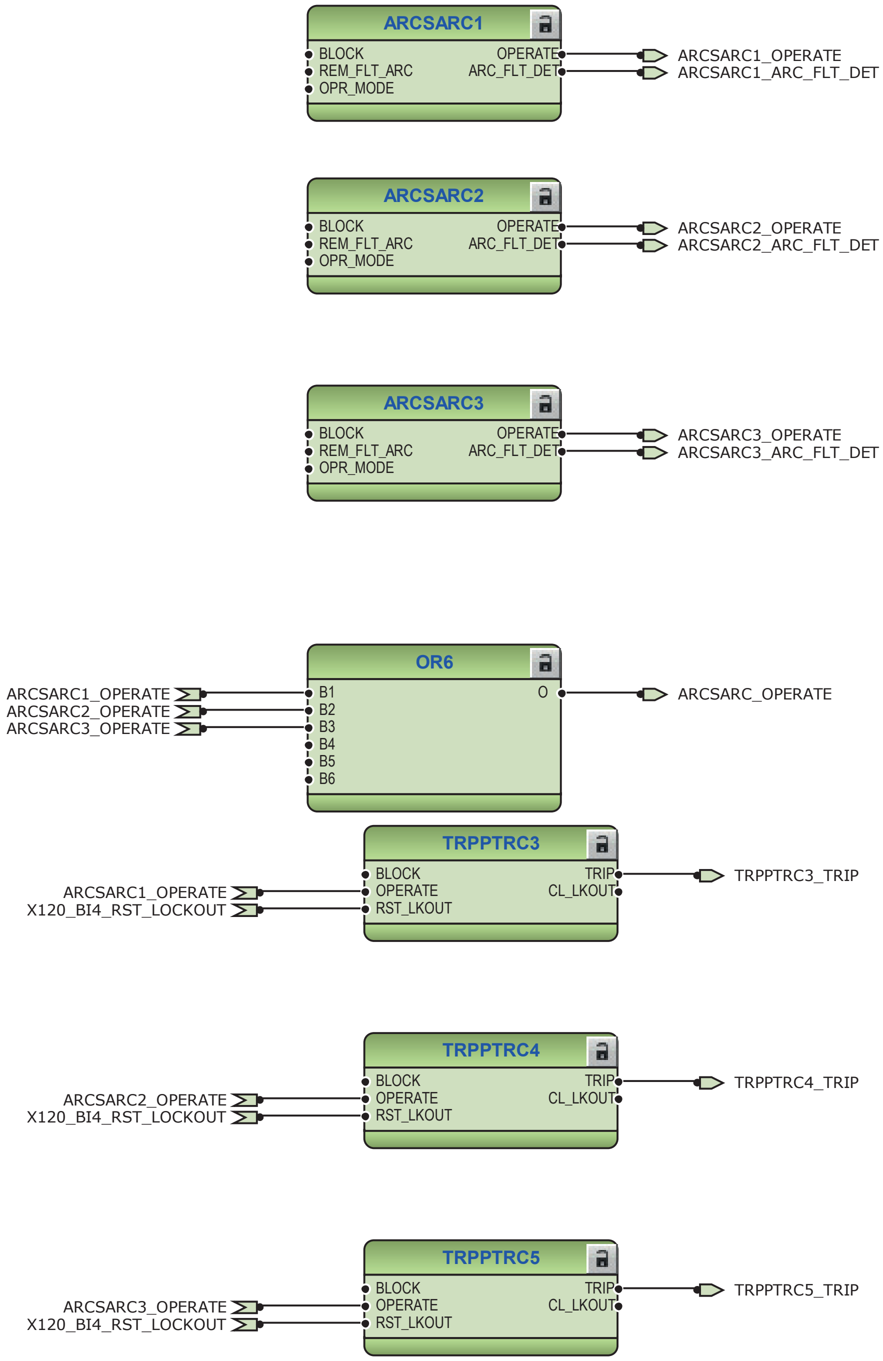


Figure 236: Arc protection with dedicated HSO

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.

Set the parameters for DARREC1 properly.

Check the initialization signals of DARREC1.

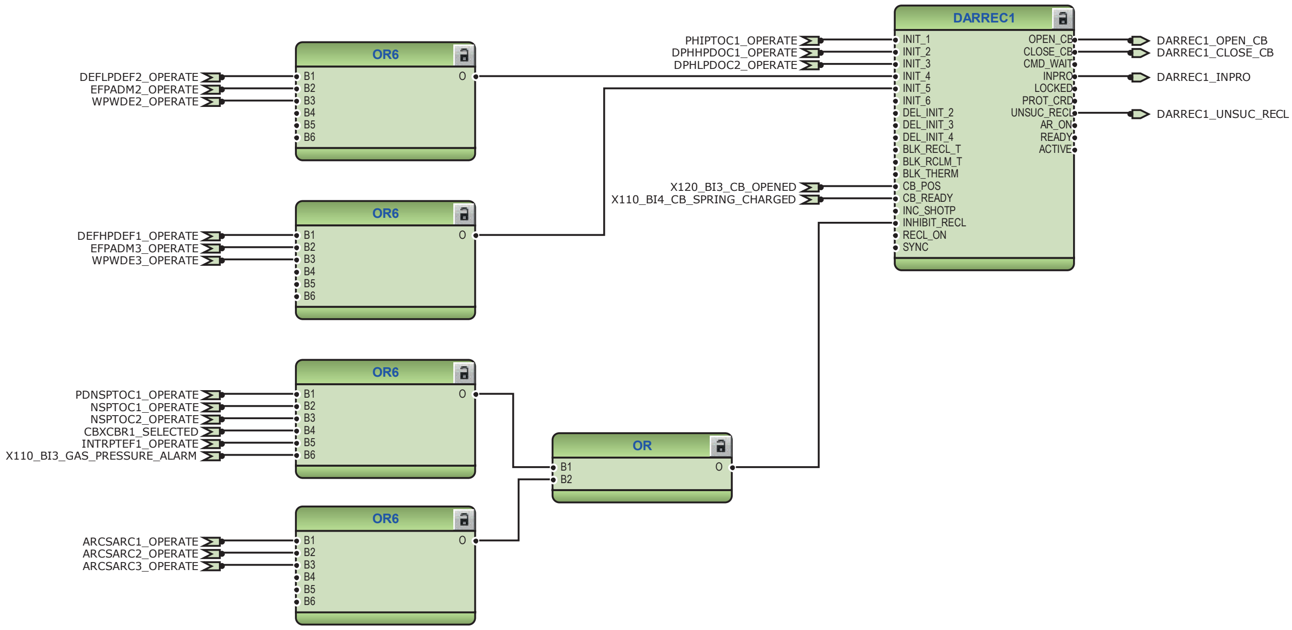


Figure 237: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV and negative-sequence overvoltage protection NSPTOV enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function. The activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

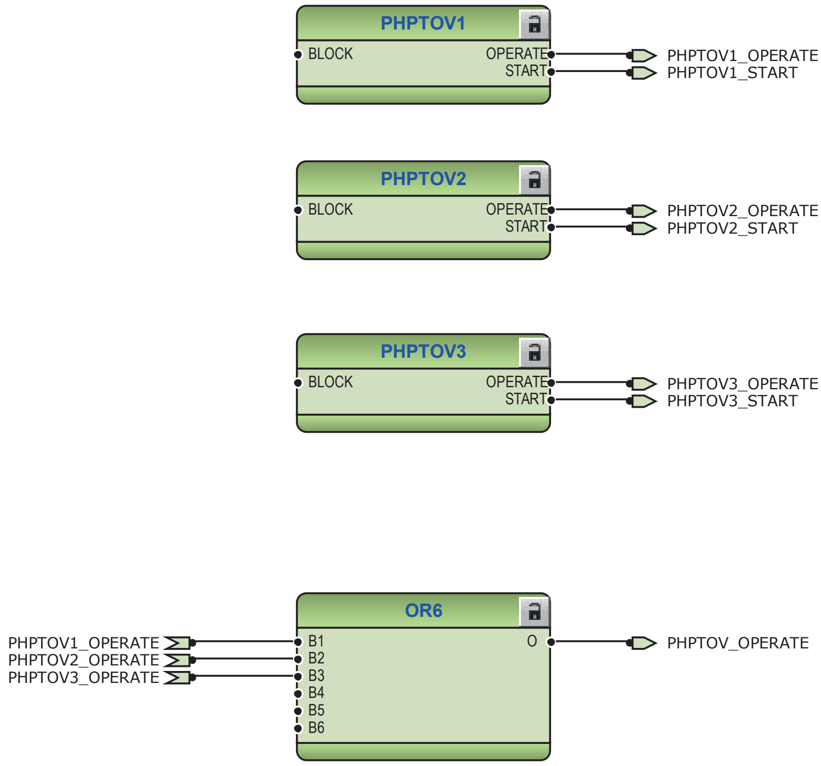


Figure 238: Overvoltage protection function

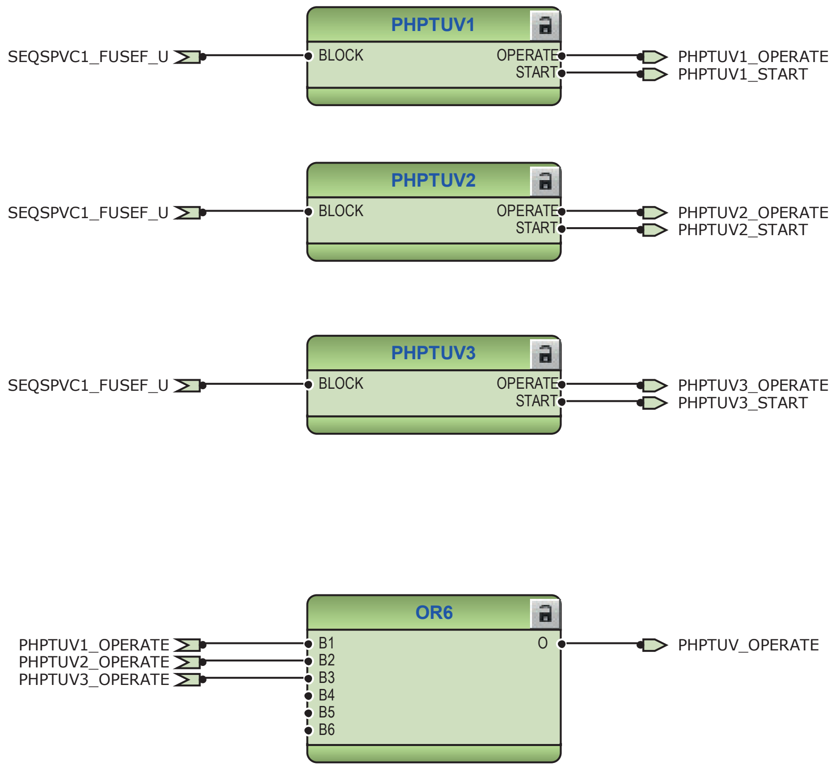


Figure 239: Undervoltage protection function

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.

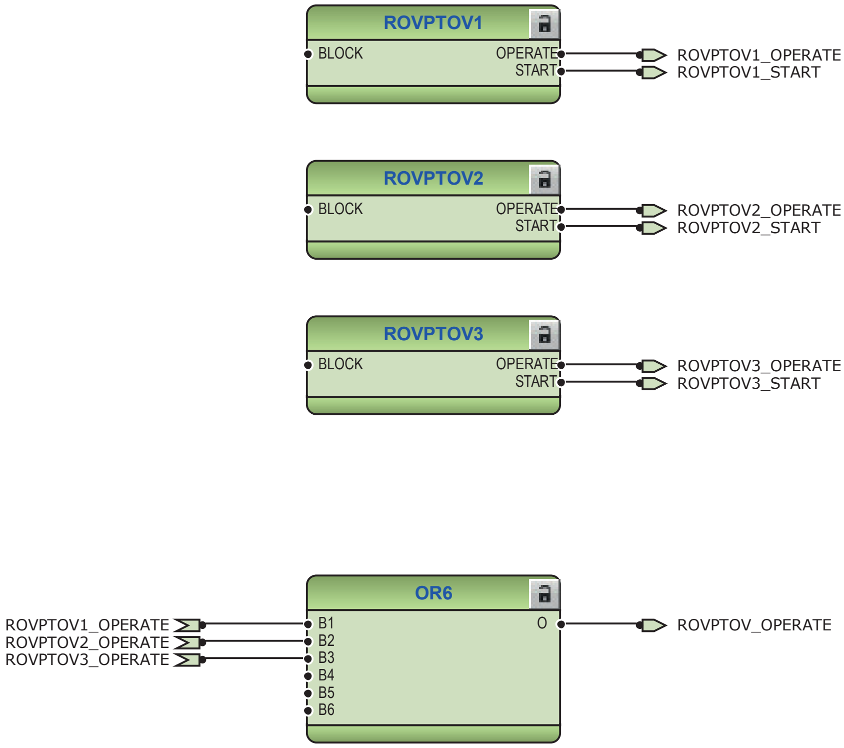


Figure 240: Residual voltage protection function

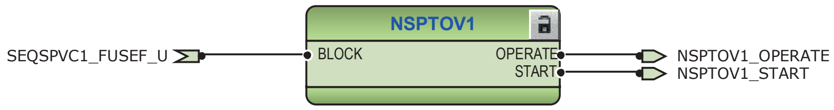


Figure 241: Negative-sequence overvoltage protection function

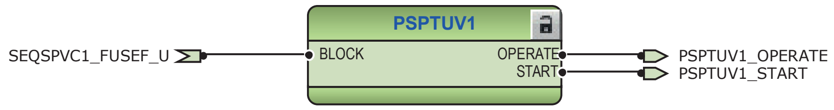


Figure 242: Positive-sequence undervoltage protection function

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 is connected to binary outputs

If a new protection function block to the configuration is added, check the activation logic and add the connections.

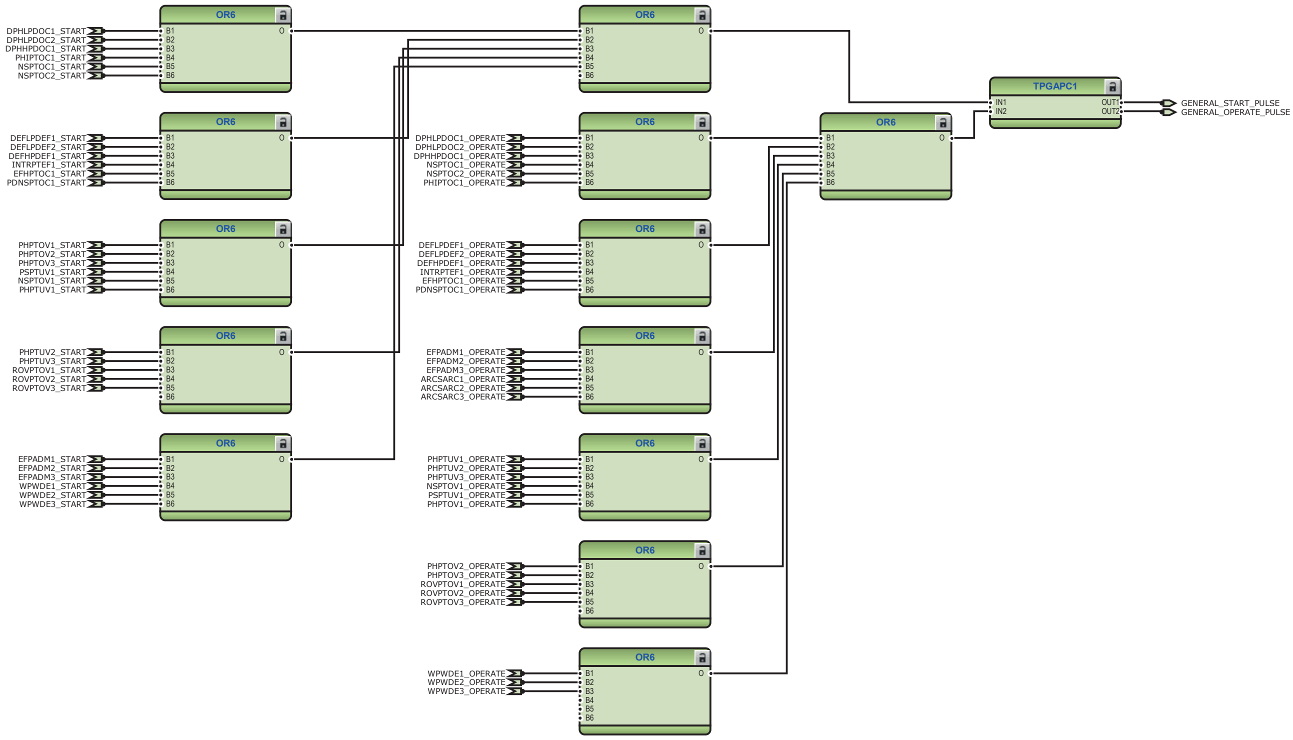


Figure 243: General start and operate signals

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 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

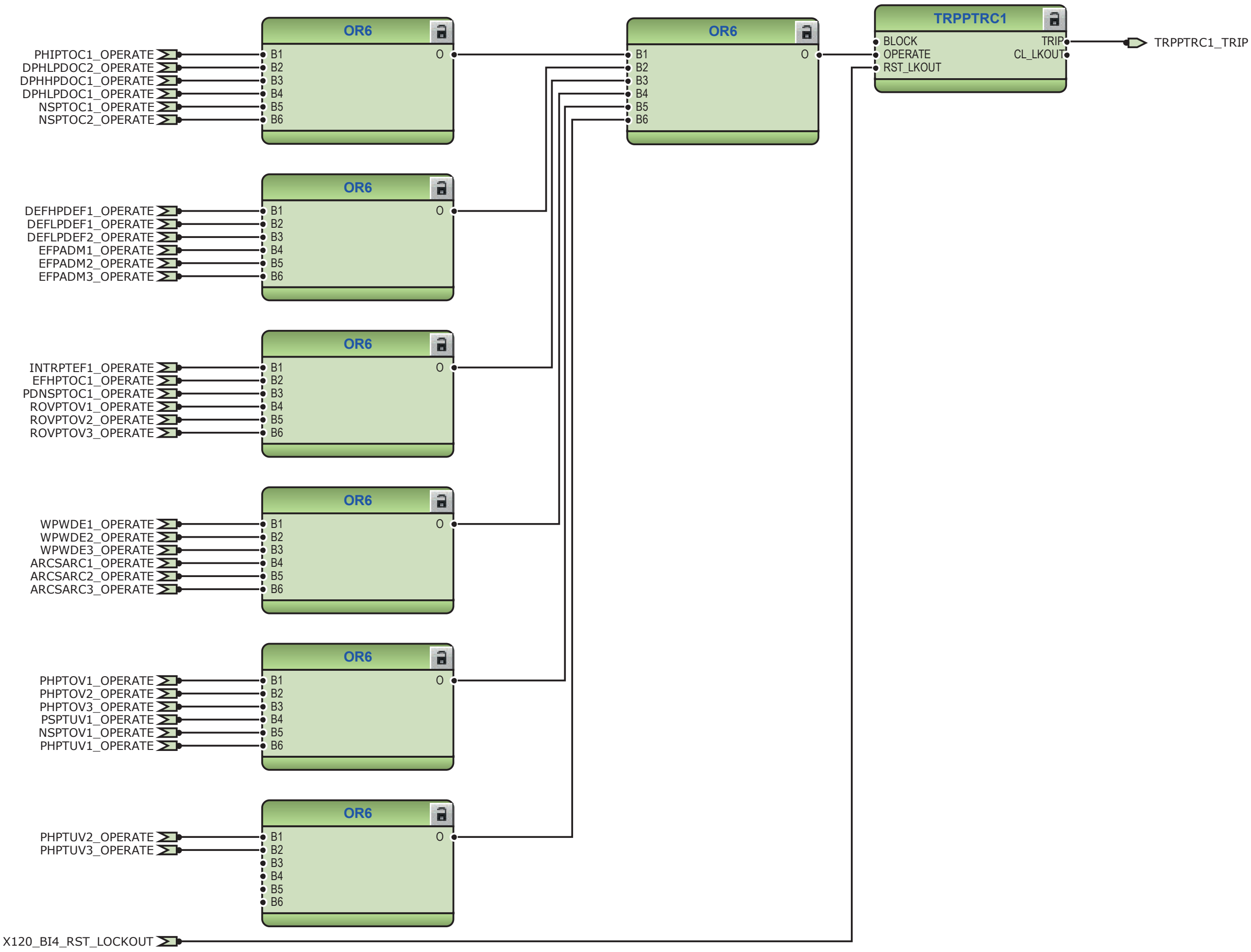


Figure 244: Trip logic TRPPTRC1

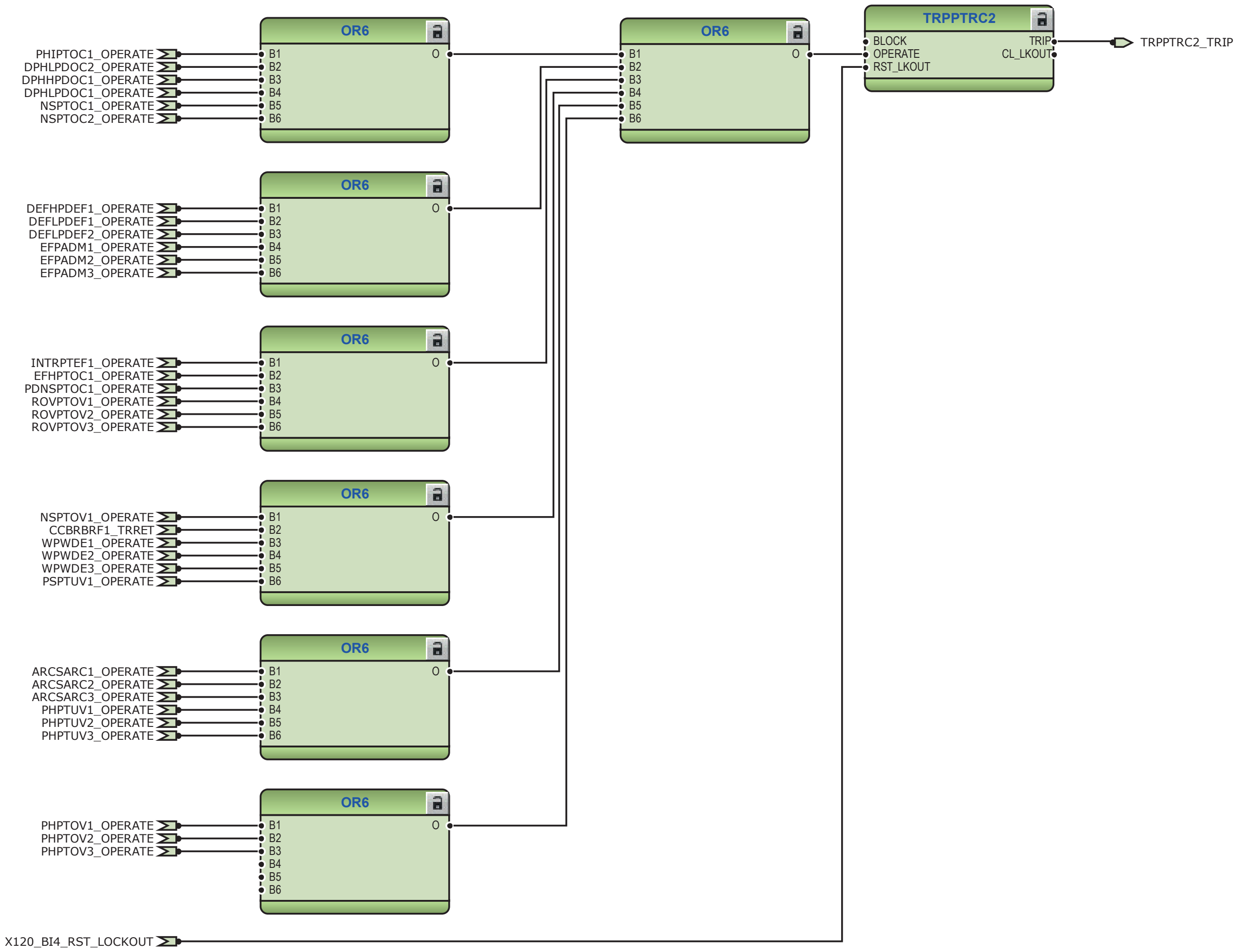


Figure 245: Trip logic TRPPTRC2

3.8.3.2 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.

The disturbance recorder main application sheet contains the disturbance recorder function block and the connections to variables.

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

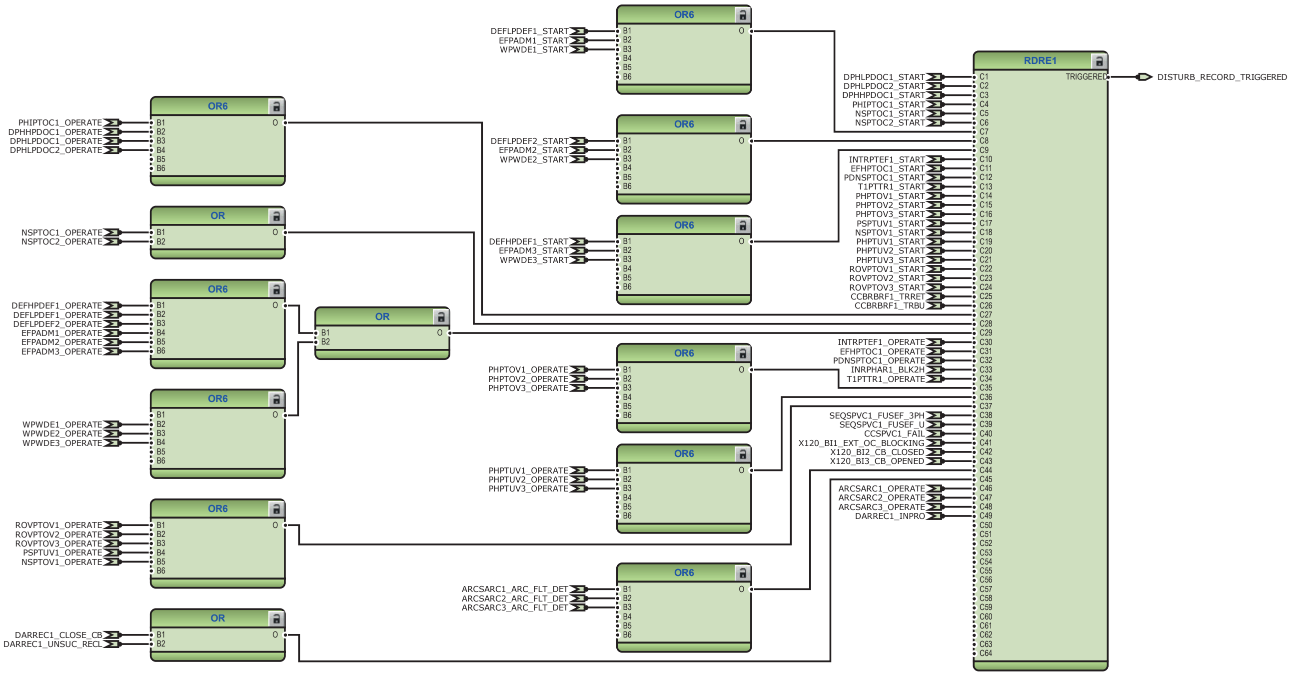


Figure 246: Disturbance recorder

3.8.3.3 Functional diagrams for condition monitoring

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

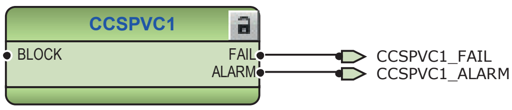


Figure 247: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

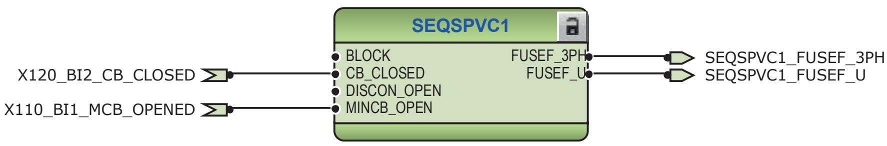


Figure 248: Fuse failure supervision function

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.

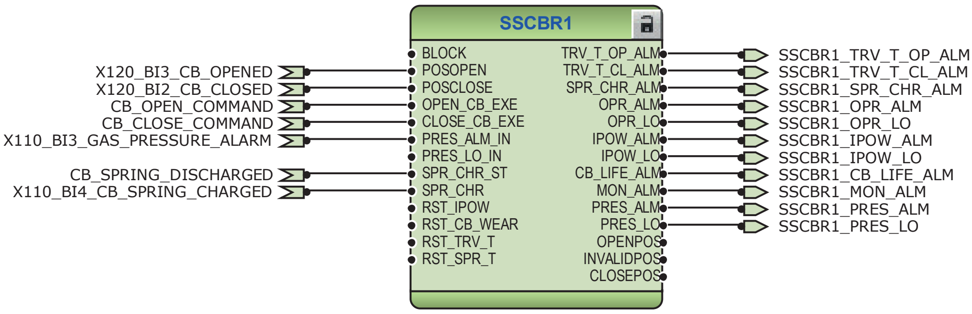


Figure 249: Circuit-breaker condition monitoring function

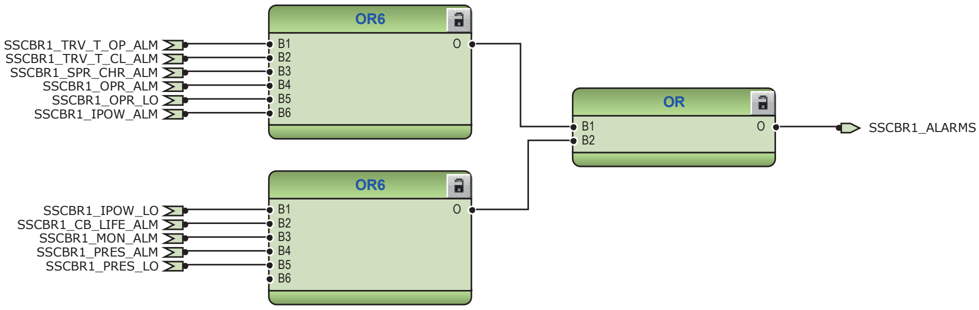


Figure 250: Logic for circuit breaker monitoring alarm

Figure 251: 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. 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.

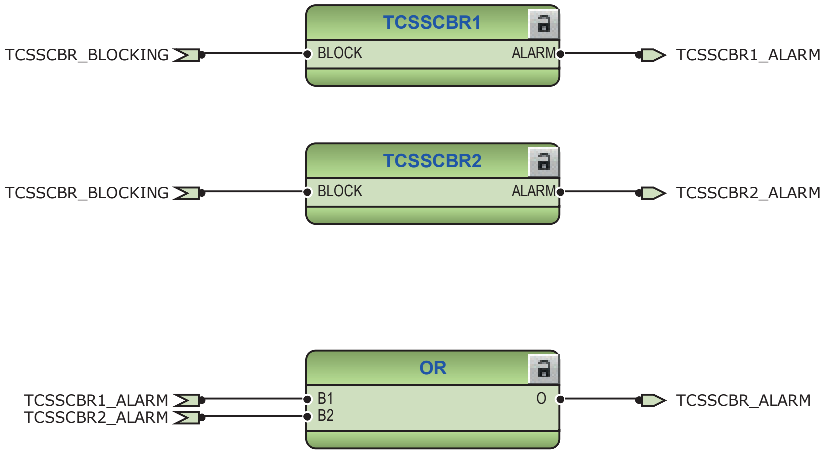


Figure 252: Trip circuit supervision function

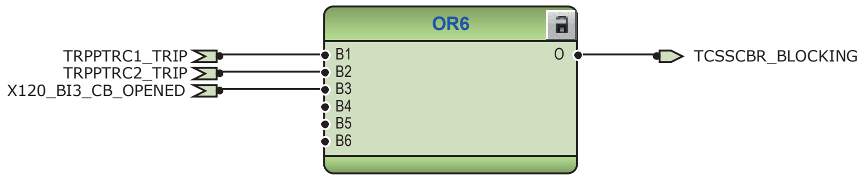


Figure 253: Logic for blocking of trip circuit supervision

3.8.3.4 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.

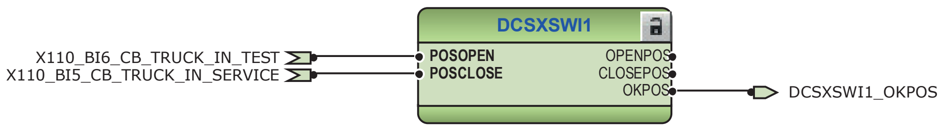


Figure 254: Disconnector control logic

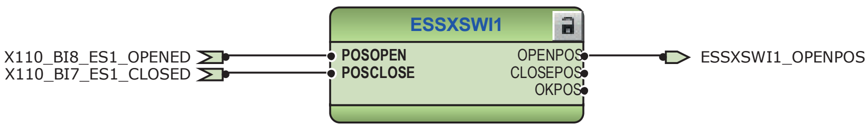


Figure 255: Earth-switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and the circuit breaker spring charging status.

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely 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 circuit breaker is always enabled.

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

Connect the additional signals required for the application for closing and opening of circuit breaker.

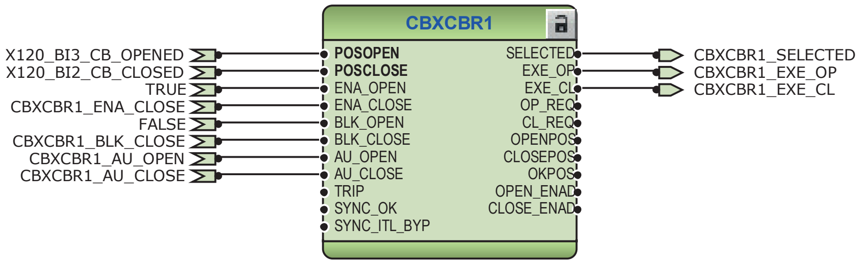


Figure 256: Circuit breaker 1 control logic

Figure 257: Signal for closing coil of circuit breaker 1

Figure 258: Signal for opening coil of circuit breaker 1

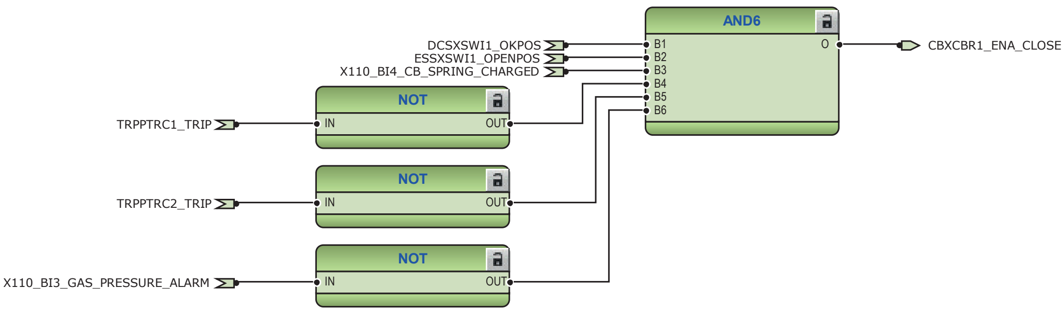


Figure 259: Circuit breaker 1 close enable logic

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

Figure 260: Circuit breaker 1 close blocking logic

The configuration includes the logic for generating the 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 additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration.

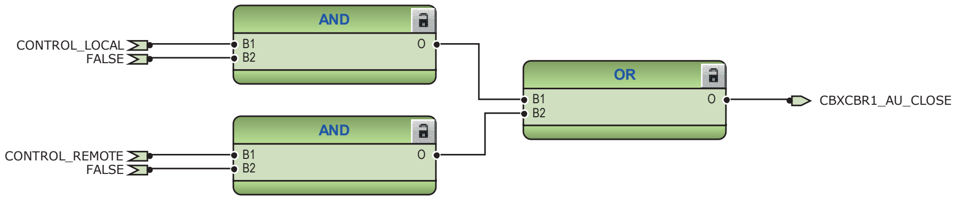


Figure 261: External closing command for circuit breaker 1

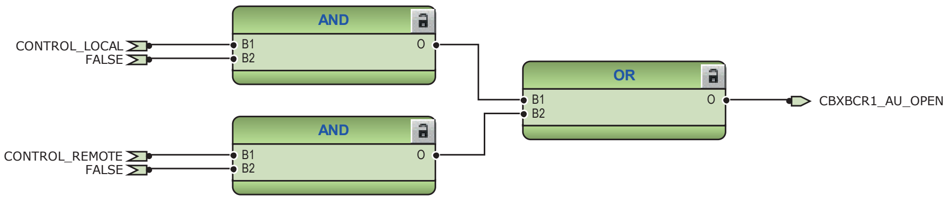


Figure 262: External opening command for circuit breaker 1

3.8.3.5 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.

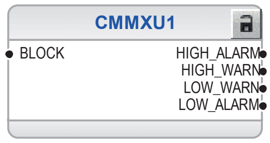


Figure 263: Current measurement: Three-phase current measurement

Figure 264: Current measurement: Sequence current measurement

Figure 265: Current measurement: Residual current measurement

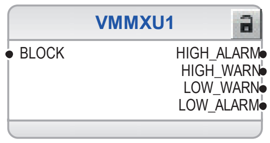


Figure 266: Voltage measurement: Three-phase voltage current

Figure 267: Voltage measurement: Sequence voltage measurement

Figure 268: Other measurement: Frequency measurement

Figure 269: Other measurement: Three-phase power and energy measurement

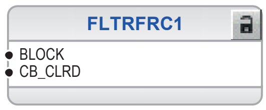


Figure 270: Other measurement: Data monitoring

Figure 271: Other measurement: Load profile record

3.8.3.6 Functional diagrams for I/O and alarm LEDs

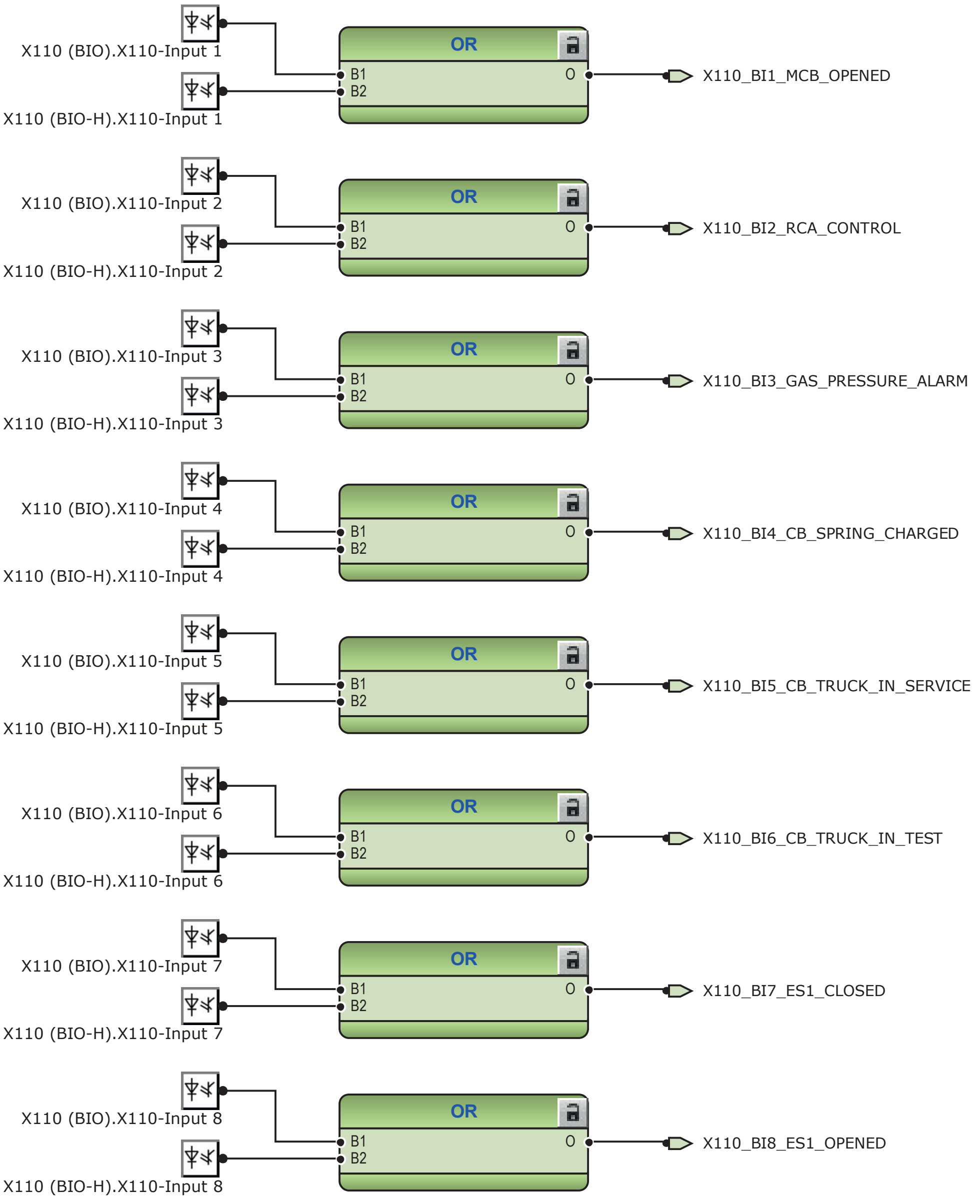


Figure 272: Default binary inputs - X110

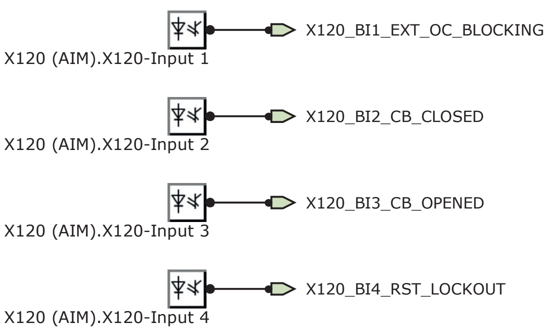


Figure 273: Default binary inputs - X120

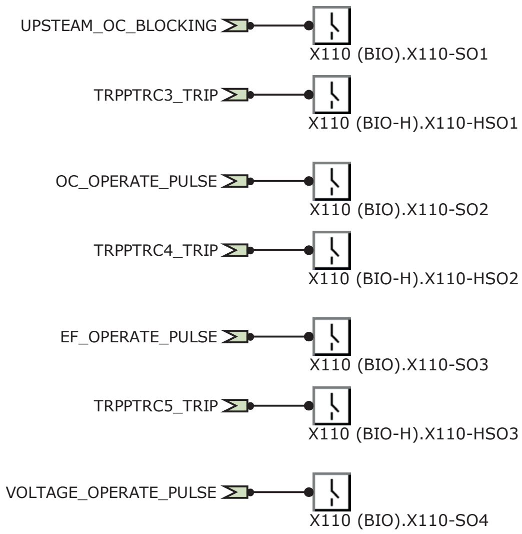


Figure 274: Default binary outputs - X110

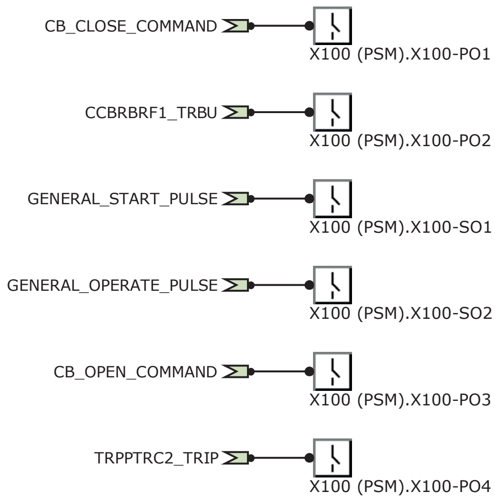
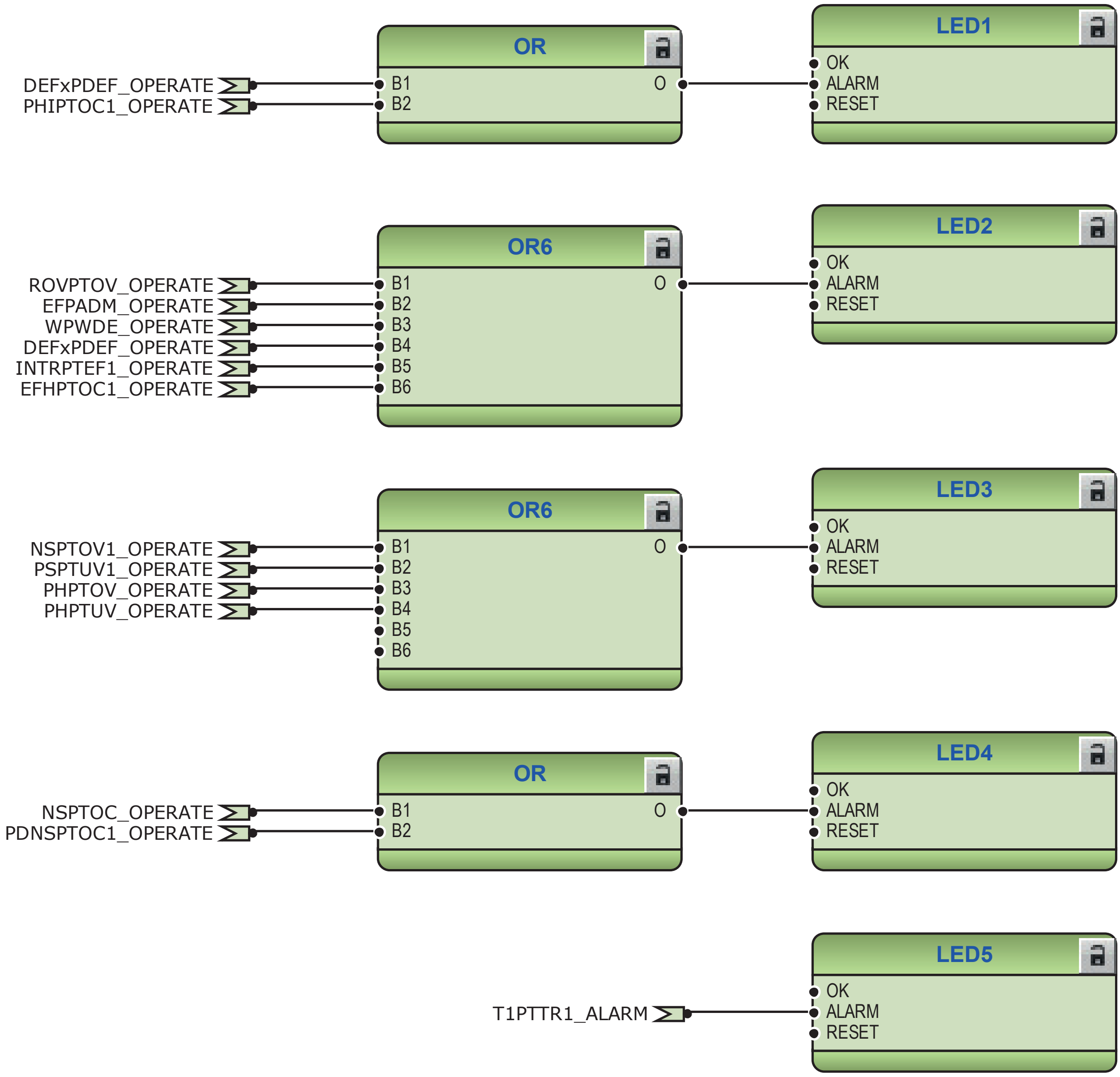


Figure 275: Default binary outputs - X100


DEFxPDEF_OPERATE
PHIPTOC1_OPERATE
OR
B1
B2
O
LED1
OK
ALARM
RESET
ROVPTOV_OPERATE
EFPADM_OPERATE
WPWDE_OPERATE
DEFxPDEF_OPERATE
INTRPTEF1_OPERATE
EFHPTOC1_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
NSPTOV1_OPERATE
PSPTUV1_OPERATE
PHPTOV_OPERATE
PHPTUV_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
OR
B1
B2
O
LED4
OK
ALARM
RESET
T1PTTR1_ALARM
LED5
OK
ALARM
RESET

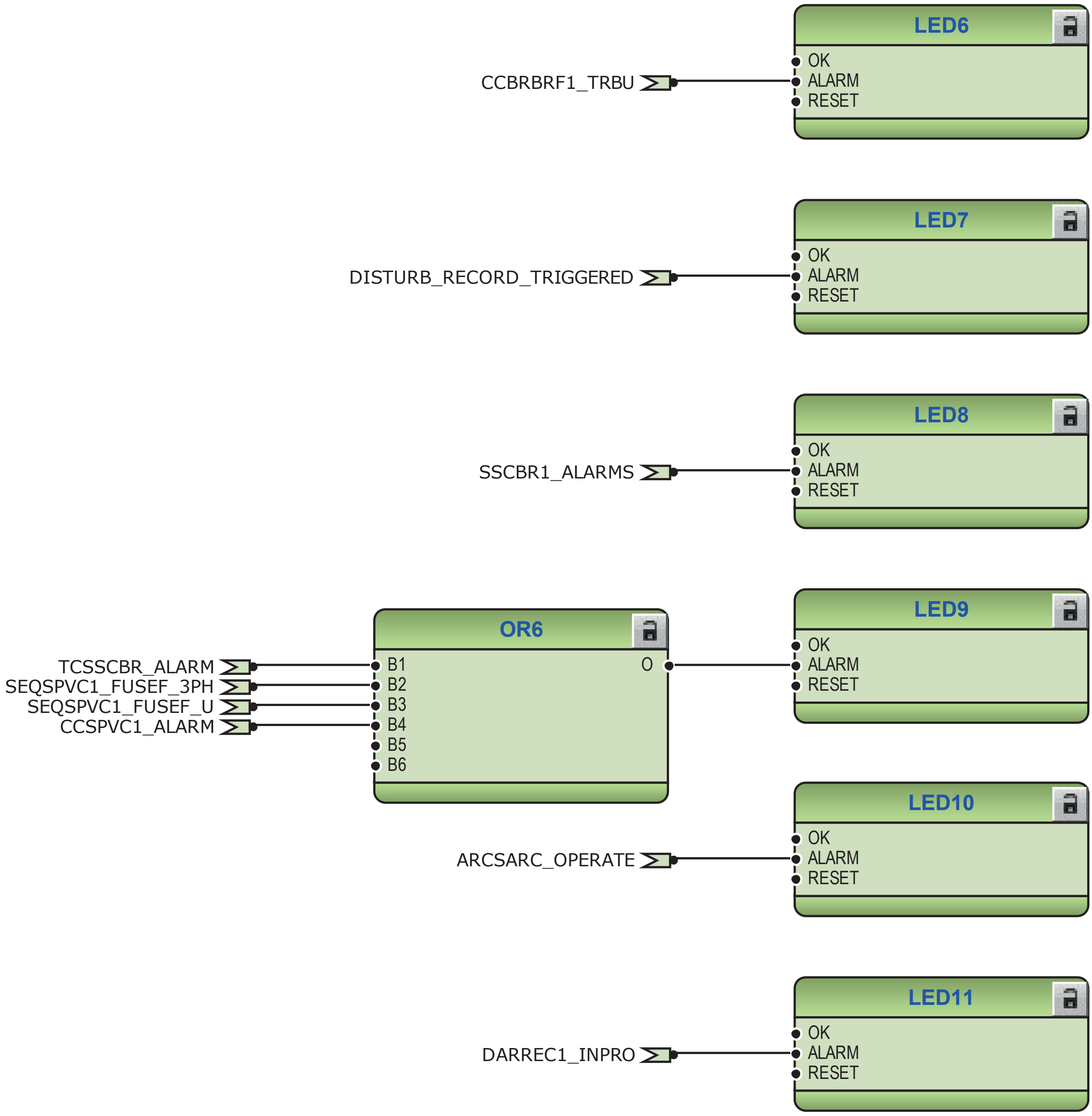


Figure 276: Default LED connection

3.8.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and voltage operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

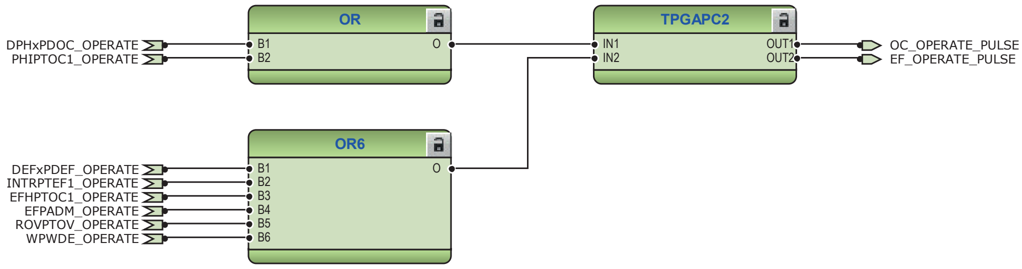


Figure 277: Timer logic for overcurrent and earth-fault operate pulse

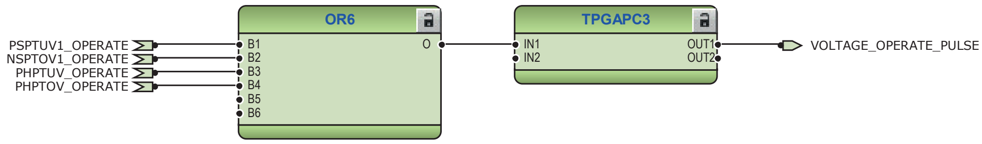


Figure 278: Timer logic for voltage operate pulse

3.8.3.8 Other functions

The configuration includes few instances of multi-purpose protection function MAPGAPC, high impedance fault detection function PHIZ, runtime counter 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.

3.9 Standard configuration G

3.9.1 Applications

The standard configuration includes directional overcurrent and directional earth-fault protection, undervoltage and overvoltage protection, frequency protection and measurement function. The configuration is mainly intended for cable and overhead-line feeder applications in direct or resistance-earthed distributed networks. The configuration also includes additional options for selecting earth-fault protection based on admittance and wattmetric 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.

3.9.2 Functions

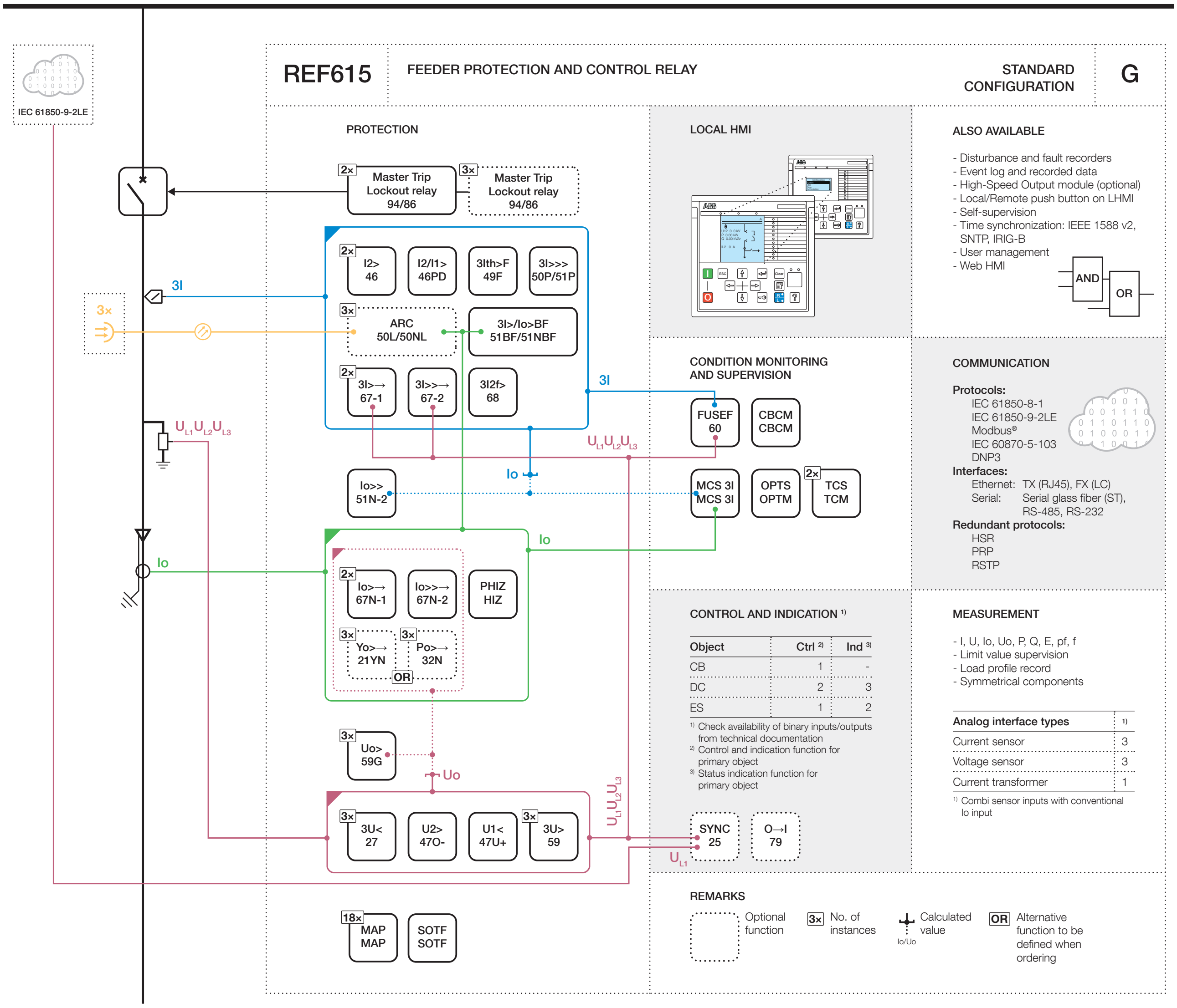


Figure 279: Functionality overview for standard configuration G

3.9.2.1 Default I/O connections

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

Table 41: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker closed indication
X110-BI2	Circuit breaker open indication
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication

Table 42: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-SO4	Voltage protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 43: Default connections for LEDs

LED	Description
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Voltage protection operated
4	Negative sequence overcurrent or phase discontinuity protection operat-ed
5	Thermal overload alarm
6	Circuit breaker failure protection backup protection operated
7	Disturbance recorder triggered

Table continues on the next page

LED	Description
8	Circuit breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.9.2.2 Default disturbance recorder settings

Table 44: Default disturbance recorder analog channels

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

Table 45: Default disturbance recorder binary channels

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

Table continues on the next page

Channel	ID text	Level trigger mode
12	T1PTTR1 - start	Positive or Rising
13	PHPTOV1 - start	Positive or Rising
14	PHPTOV2 - start	Positive or Rising
15	PHPTOV3 - start	Positive or Rising
16	PSPTUV1 - trret	Positive or Rising
17	NSPTOV1 - trbu	Positive or Rising
18	PHPTUV1 - start	Positive or Rising
19	PHPTUV2 - start	Positive or Rising
20	PHPTUV3 - start	Positive or Rising
21	ROVPTOV1 - start	Positive or Rising
22	ROVPTOV2 - start	Positive or Rising
23	ROVPTOV3 - start	Positive or Rising
24	CCBRBRF1 - trret	Level trigger off
25	CCBRBRF1 - trbu	Level trigger off
26	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
27	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
28	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1 - operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
29	EFHPTOC1 - operate	Level trigger off
30	PDNSPTOC1 - operate	Level trigger off
31	INRPHAR1 - blk2h	Level trigger off
32	T1PTTR1 - operate	Level trigger off
33	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
	PHPTOV3 - operate	
34	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
	PHPTUV3 - operate	
35	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	

Table continues on the next page

Channel	ID text	Level trigger mode
	ROVPTOV3 - operate	
	PSPTUV1 - operate	
	NSPTOV2 - operate	
36	SEQSPVC1 - fusef3ph	Level trigger off
37	SEQSPVC1 - fusefu	Level trigger off
38	CCSPVC1 - fail	Level trigger off
39	X110BI1 - CB closed	Level trigger off
40	X110BI2 - CB opened	Level trigger off
41	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
42	ARCSARC1 - operate	Level trigger off
43	ARCSARC2 - operate	Level trigger off
44	ARCSARC3 - operate	Level trigger off
45	DARREC1 - inpro	Level trigger off
46	DARREC1 - close CB	Positive or Rising
47	DARREC1 - unsuc recl	Positive or Rising

3.9.3 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.

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

3.9.3.1 Functional diagrams for protection

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

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC.

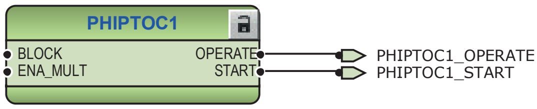


Figure 280: Overcurrent protection function

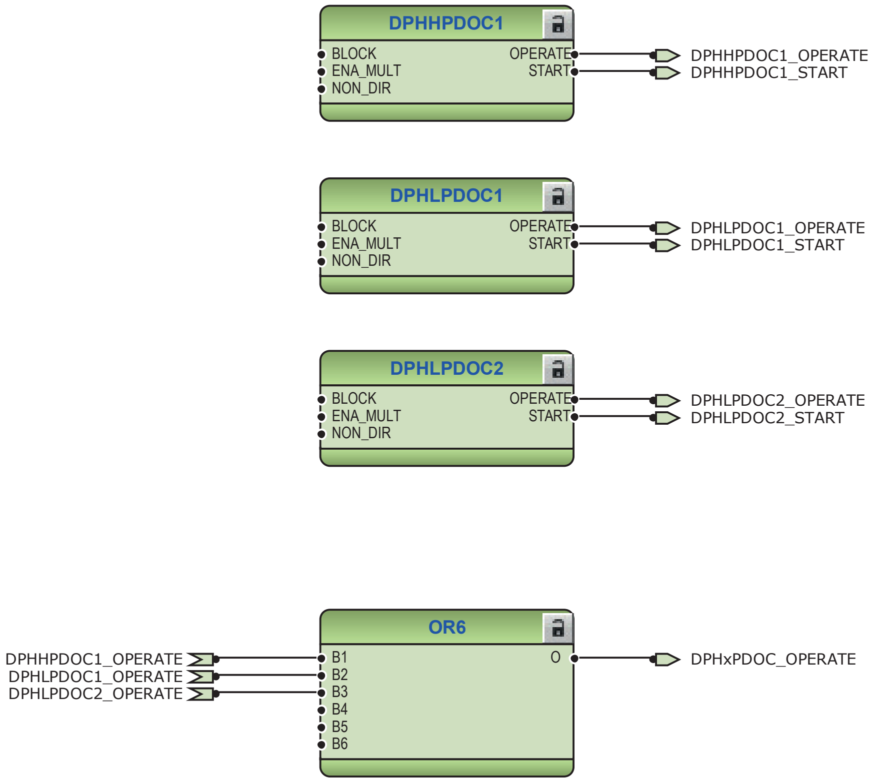


Figure 281: Directional overcurrent protection function

The upstream blocking from the start of the second low stage of three-phase directional overcurrent protection DPHLPDOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

Figure 282: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

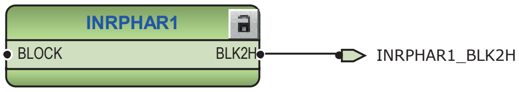


Figure 283: Inrush detector function

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 negative sequence overcurrent protections are blocked in case of detection in failure in secondary circuit of sensor.

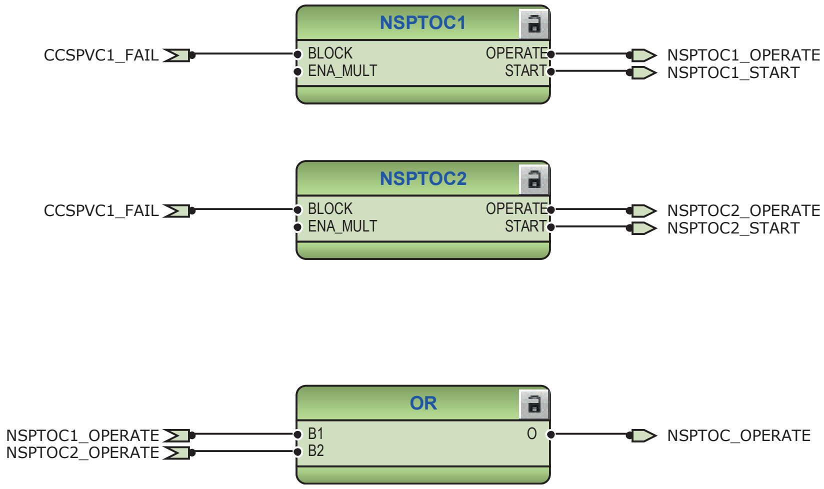


Figure 284: Negative-sequence overcurrent protection function

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 used together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE.

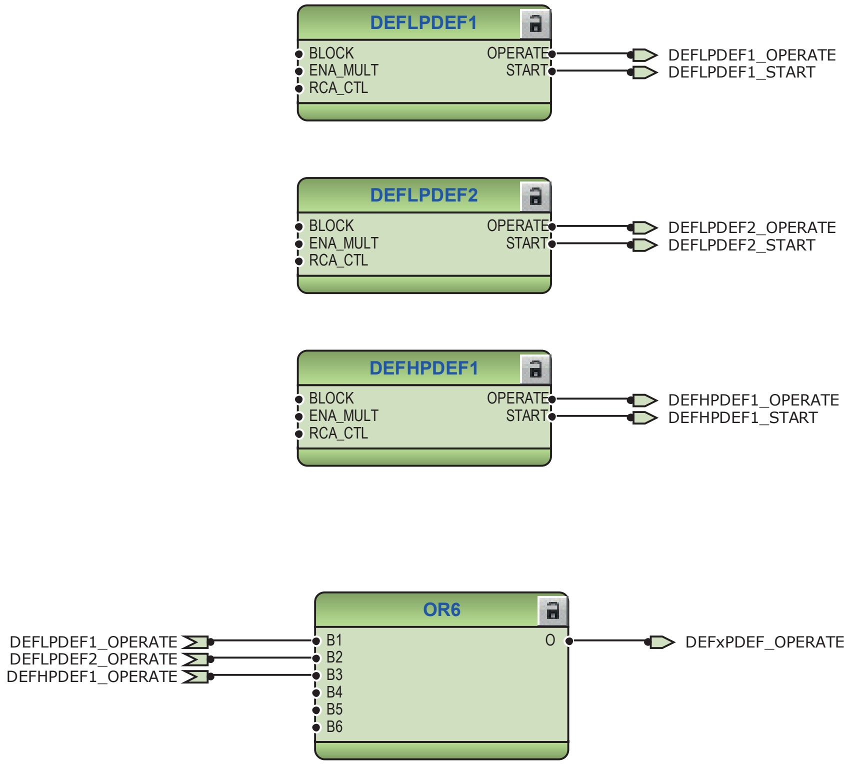


Figure 285: Directional earth-fault protection functions

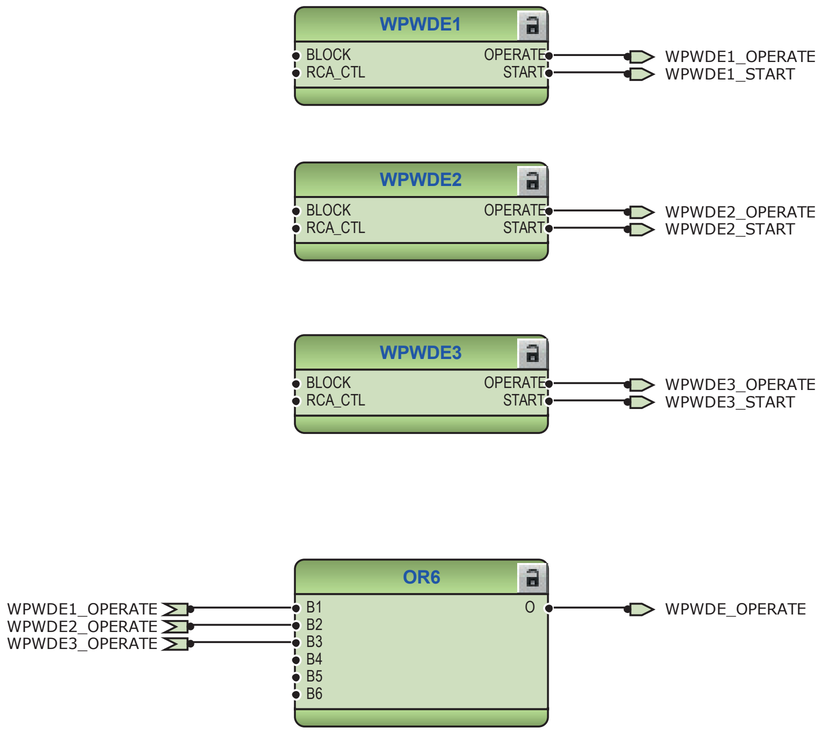


Figure 286: Wattmetric protection function

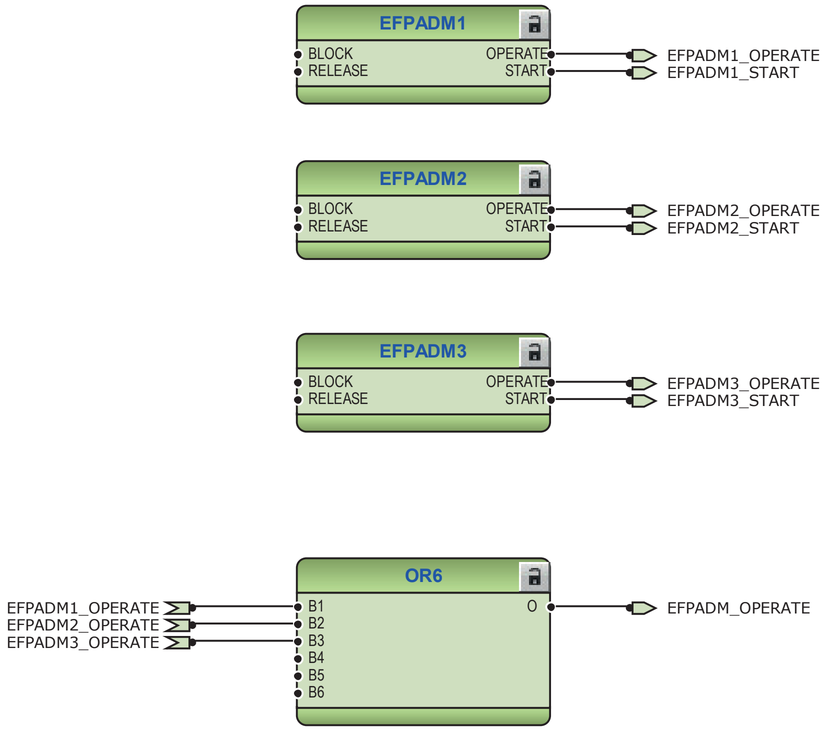


Figure 287: Admittance-based earth-fault protection function

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. Function is blocked in case of detection of a failure in secondary circuit of sensor.

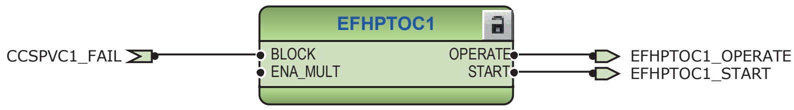


Figure 288: Earth-fault protection function

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 of a failure in secondary circuit of sensor.

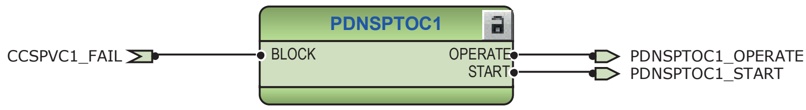


Figure 289: Phase discontinuity protection function

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

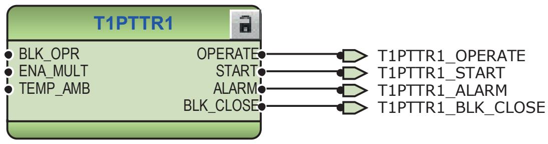


Figure 290: Thermal overcurrent protection function

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

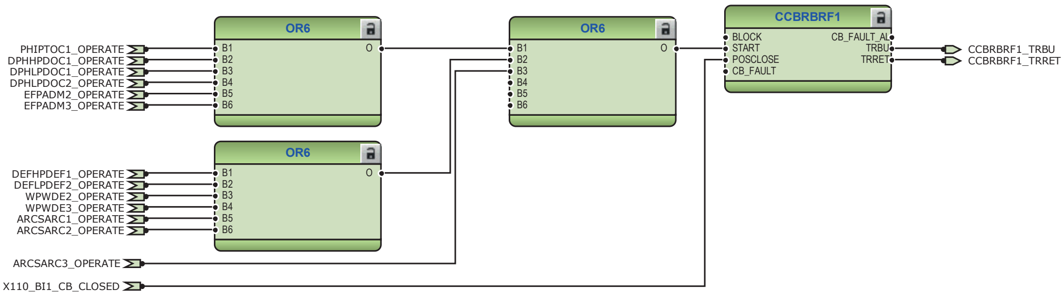


Figure 291: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

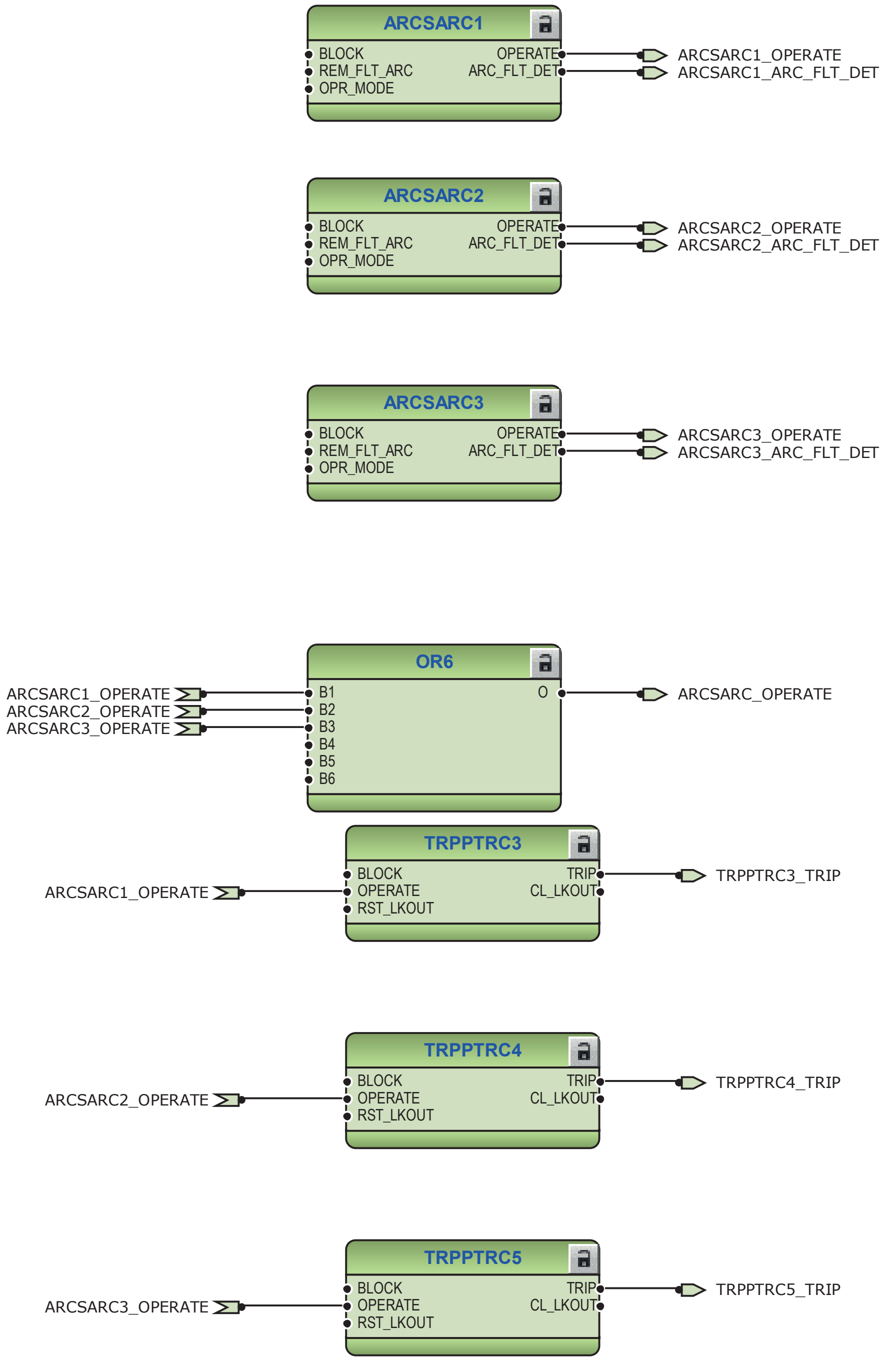


Figure 292: Arc protection with dedicated HSO

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 the close command is connected directly to binary output X100:PO1.

Set parameters for the DARREC1 function.

Check the initialization signals of DARREC1.

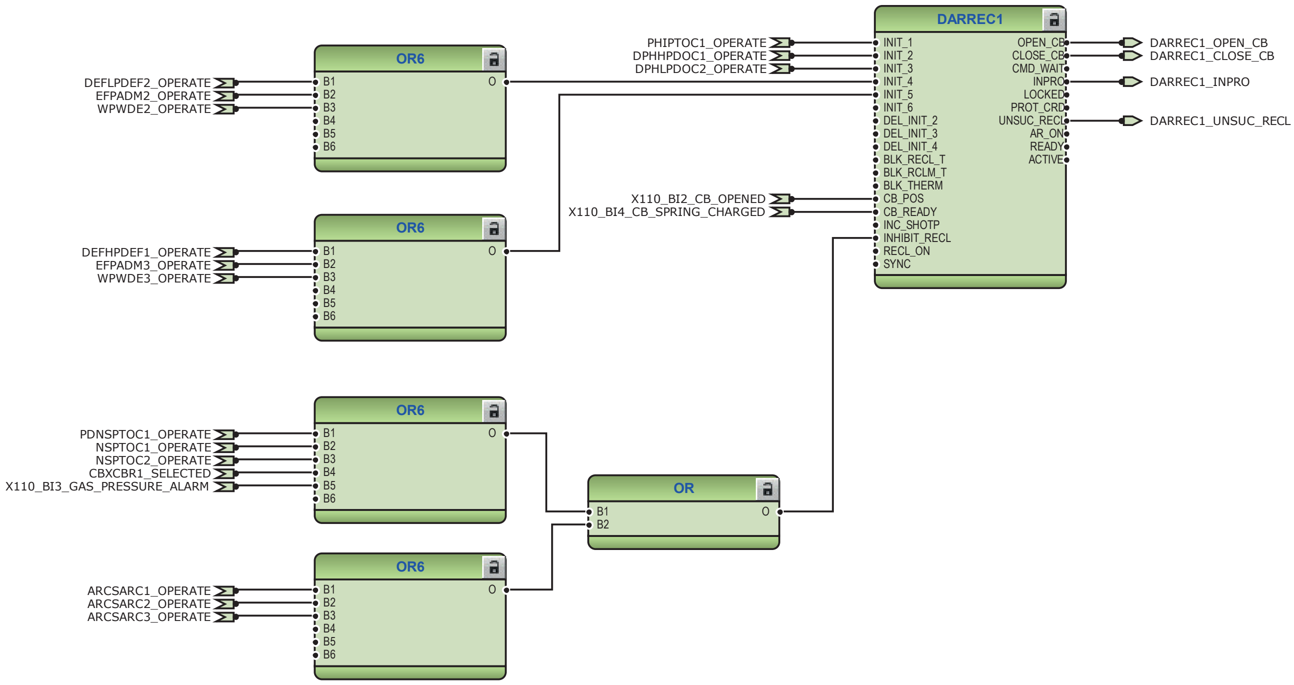


Figure 293: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV and negative-sequence overvoltage protection NSPTOV 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.

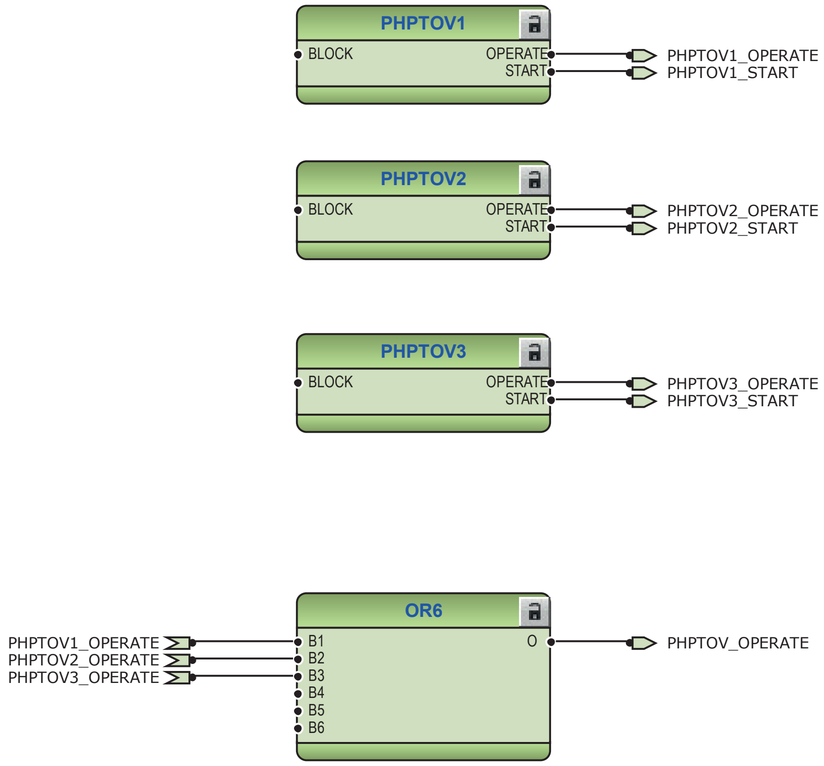


Figure 294: Overvoltage protection function

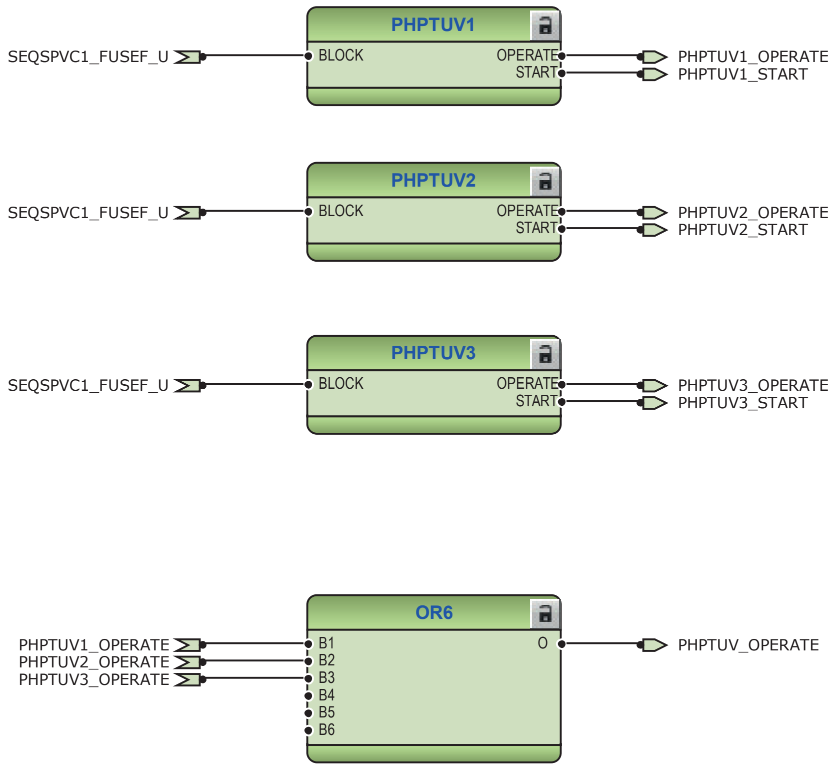


Figure 295: Undervoltage protection function

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.

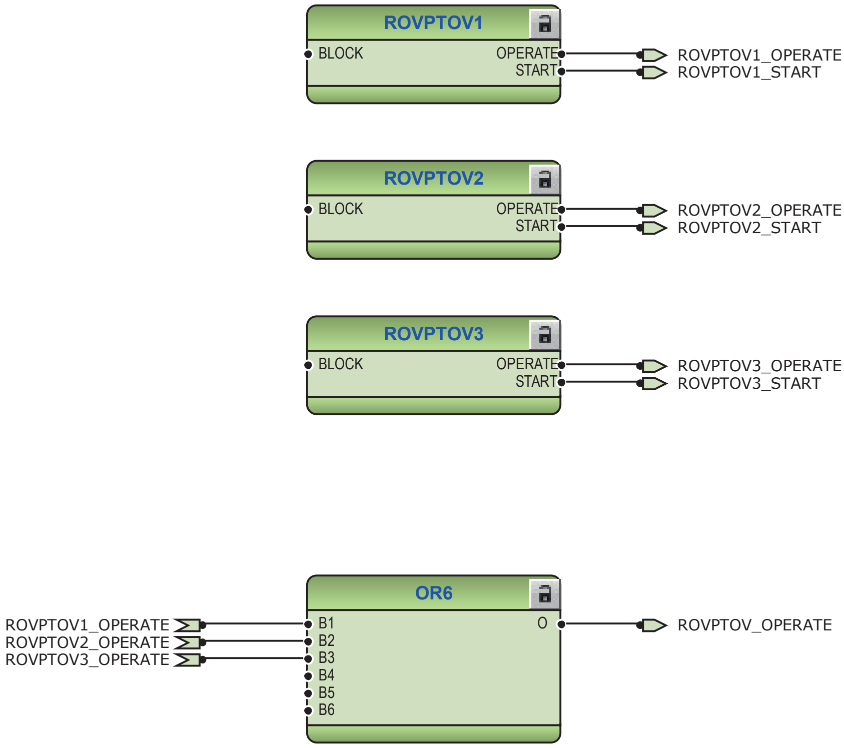


Figure 296: Residual overvoltage protection function

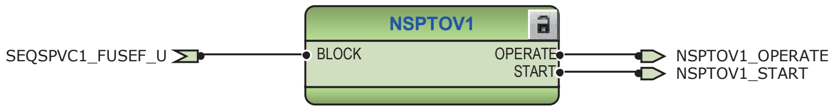


Figure 297: Negative sequence overvoltage protection function

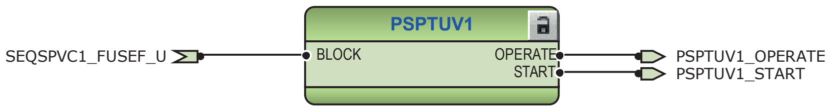


Figure 298: Positive sequence undervoltage protection function

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

If a new protection function block to the configuration is added, check the activation logic and also add the connections.

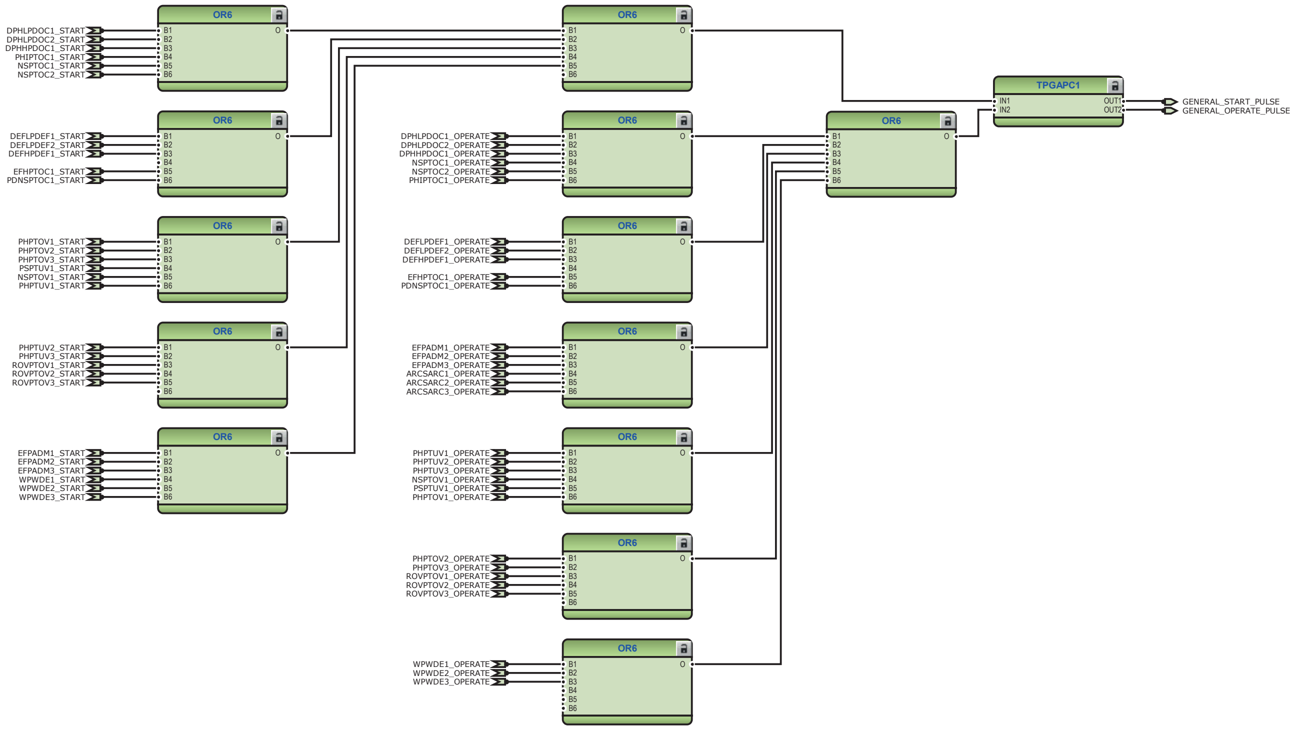


Figure 299: General start and operate signals

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 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

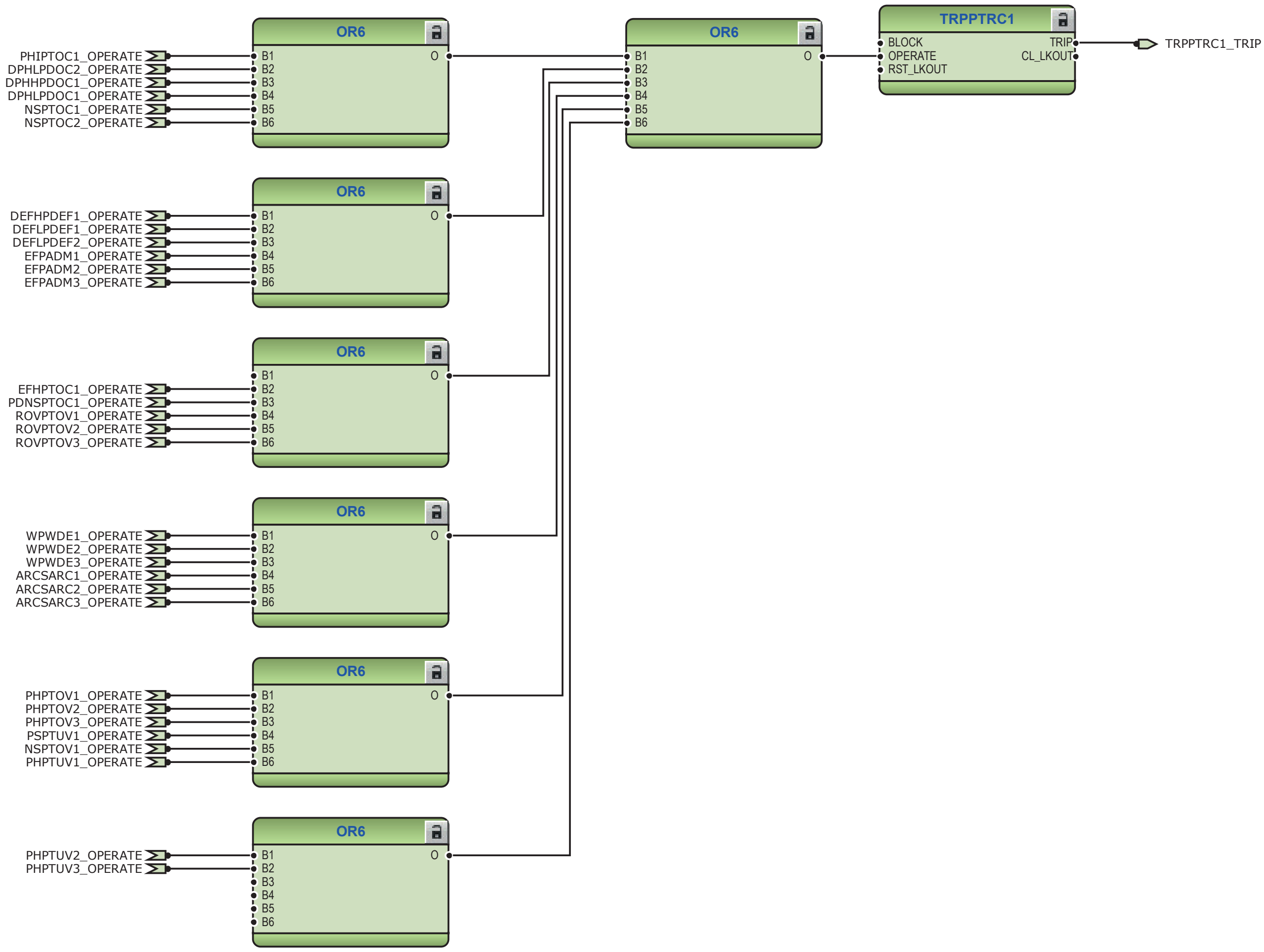


Figure 300: Trip logic TRPPTRC1

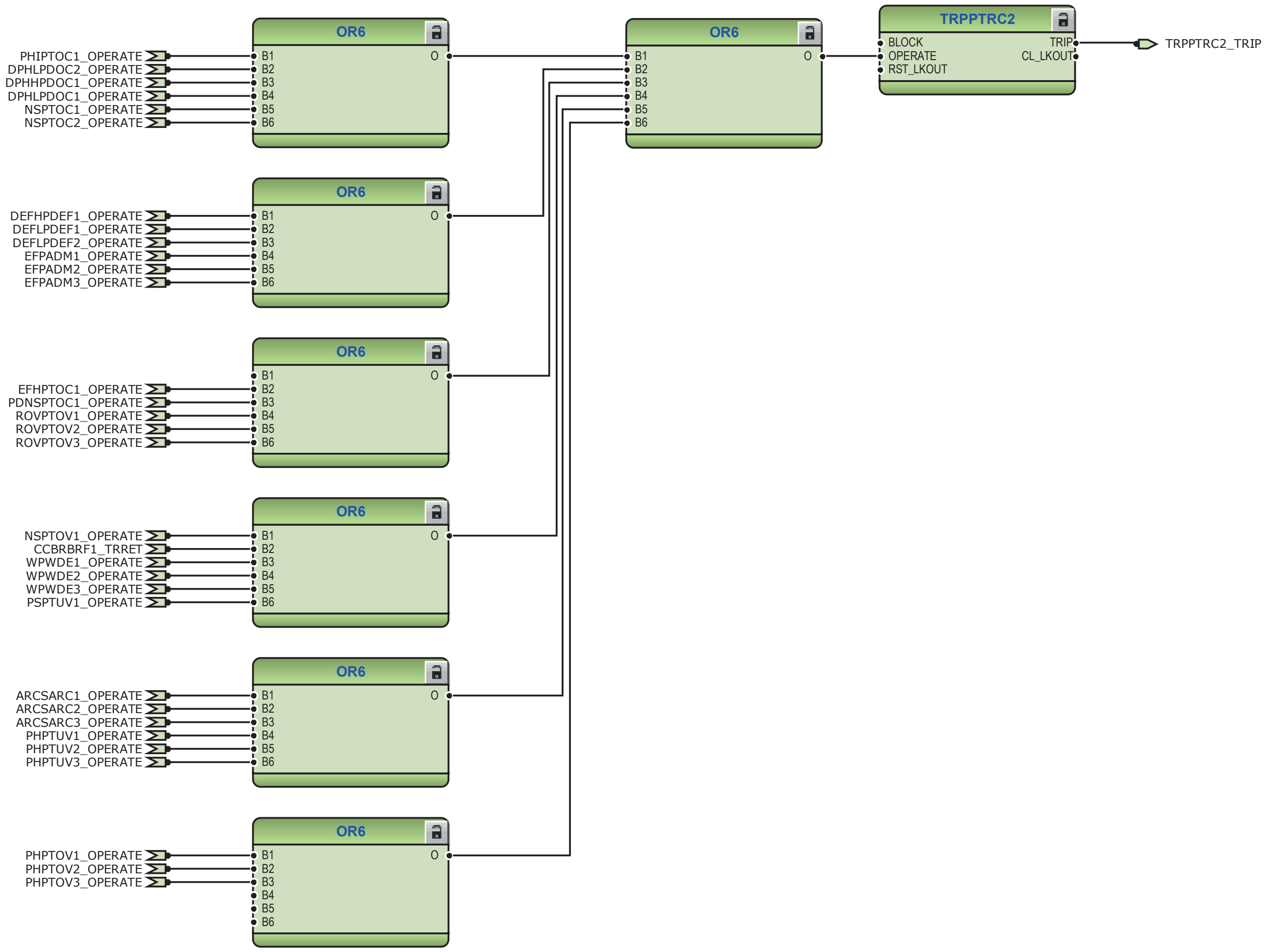


Figure 301: Trip logic TRPPTRC2

3.9.3.2 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.

The disturbance recorder main application sheet contains the disturbance recorder function block and the connections to variables.

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

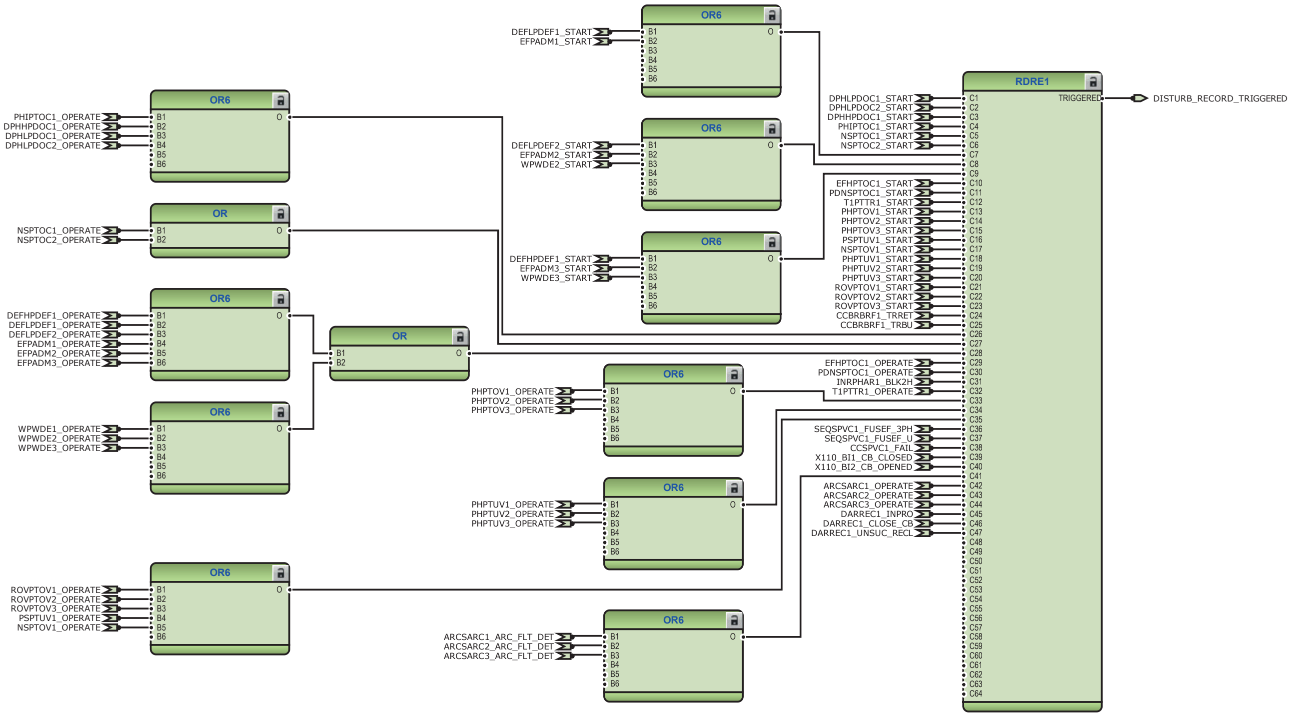


Figure 302: Disturbance recorder

3.9.3.3 Functional diagrams for condition monitoring

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

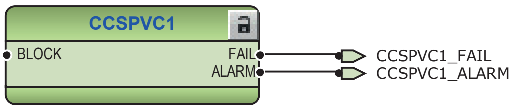


Figure 303: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits.

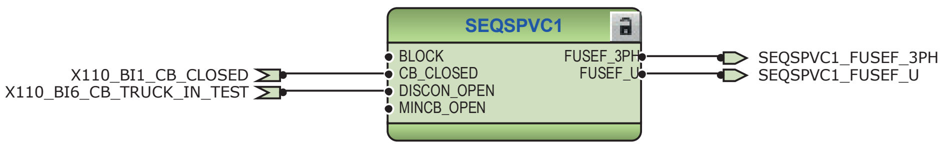


Figure 304: Fuse failure supervision function

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.

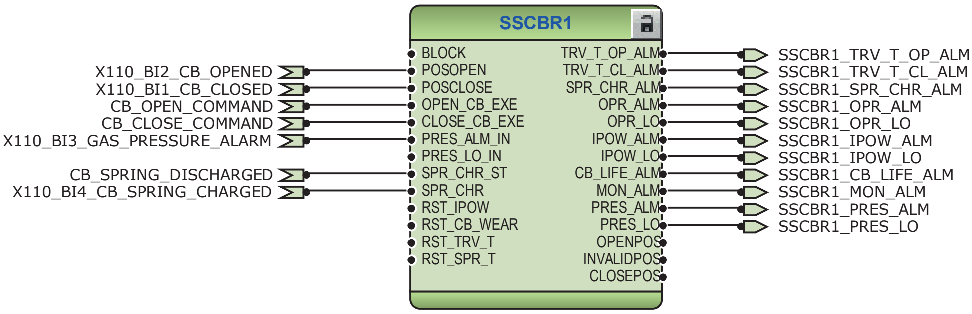


Figure 305: Circuit-breaker conditioning monitoring function

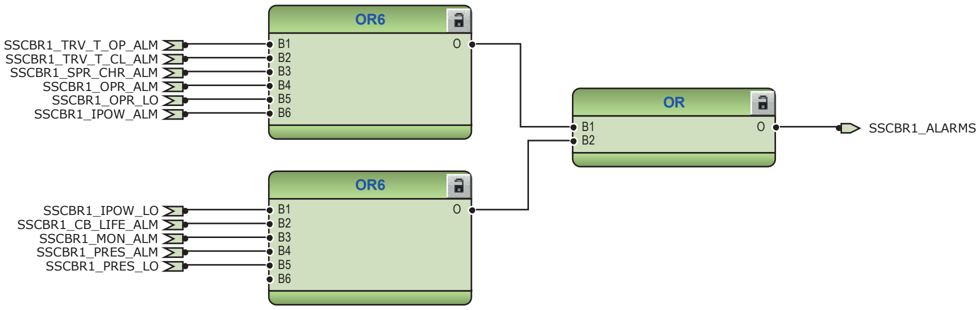


Figure 306: Logic for circuit breaker monitoring alarm

Figure 307: 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. 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.

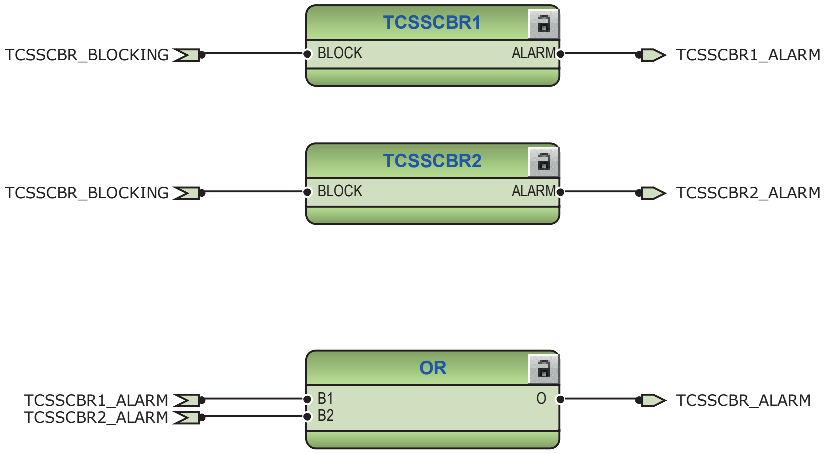


Figure 308: Trip circuit supervision function

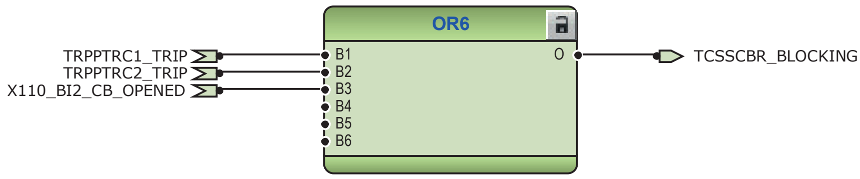


Figure 309: Logic for blocking of trip circuit supervision

3.9.3.4 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 a standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

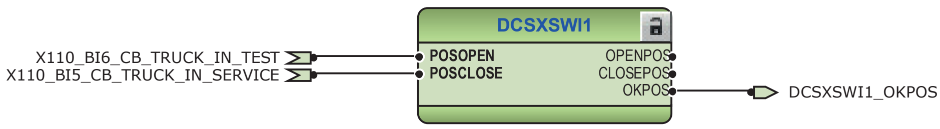


Figure 310: Disconnector control logic

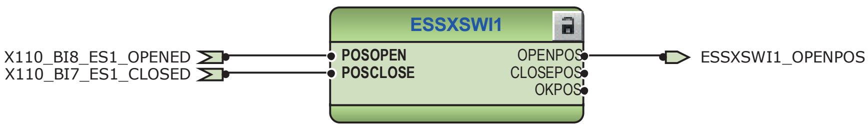


Figure 311: Earth switch control logic

The circuit breaker closing is enabled when the `ENA_CLOSE` input is activated. The input can be activated using the configuration logic, which is a combination of the disconnector or breaker truck and the earth-switch position status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status.

The `OKPOS` output from DCSXSWI defines whether the disconnector or breaker truck is definitely 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 circuit breaker is always enabled.

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

Connect the additional signals required for the application for closing and opening of circuit breaker.

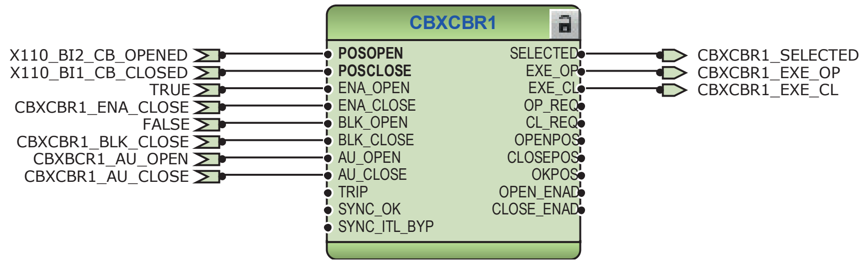


Figure 312: Circuit breaker 1 control logic

Figure 313: Signals for closing coil of circuit breaker 1

Figure 314: Signals for opening coil of circuit breaker 1

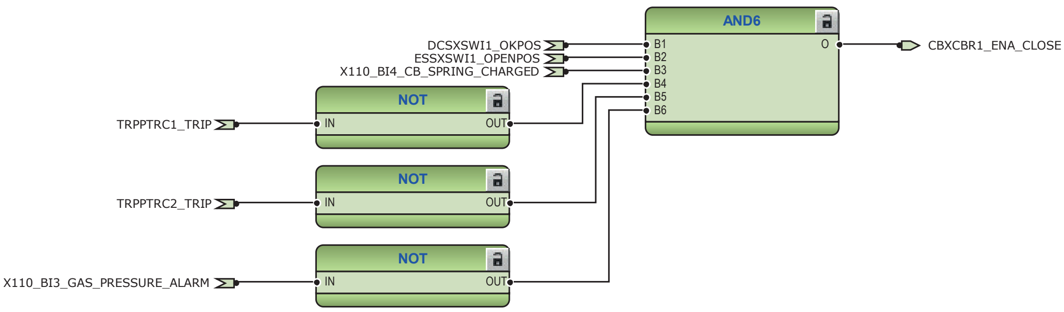


Figure 315: Circuit breaker 1 close enable logic

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

Figure 316: Circuit breaker 1 close blocking logic

The configuration includes the 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 additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration.

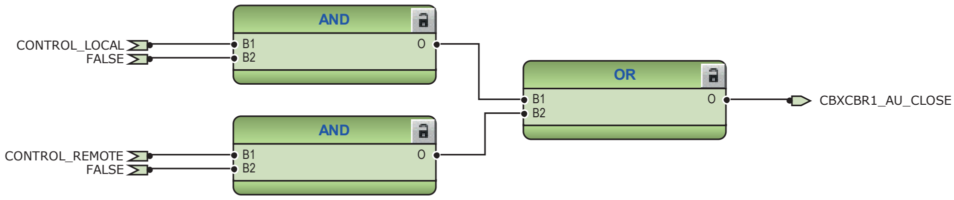


Figure 317: External closing command for circuit breaker 1

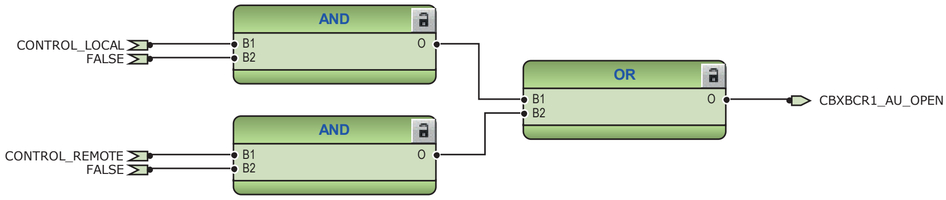


Figure 318: External opening command for circuit breaker 1

3.9.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The three-phase current input is connected to the X131, X132 and X133 card in the back panel for three phases. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current. Residual current input is connected to the X130 card in the back panel.

The three-phase bus side phase voltage inputs to the IED are measured by three-phase voltage measurement VMMXU1. The three-phase current input is connected to the X131, X132 and X133 card in the back panel for three phases. 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.

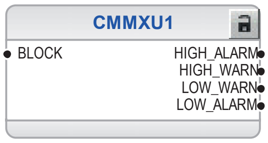


Figure 319: Current measurement: Three-phase current measurement

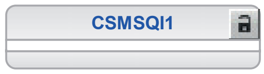


Figure 320: Current measurement: Sequence current measurement

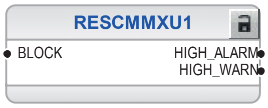


Figure 321: Current measurement: Residual current measurement

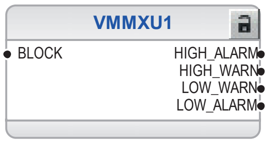


Figure 322: Voltage measurement: Three-phase voltage measurement

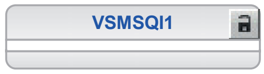


Figure 323: Voltage measurement: Sequence voltage measurement

Figure 324: Other measurement: Frequency measurement

Figure 325: Other measurement: Three-phase power and energy measurement

Figure 326: Other measurement: Data monitoring

Figure 327: Other measurement: Load profile record

3.9.3.6 Functional diagrams for I/O and alarm LEDs

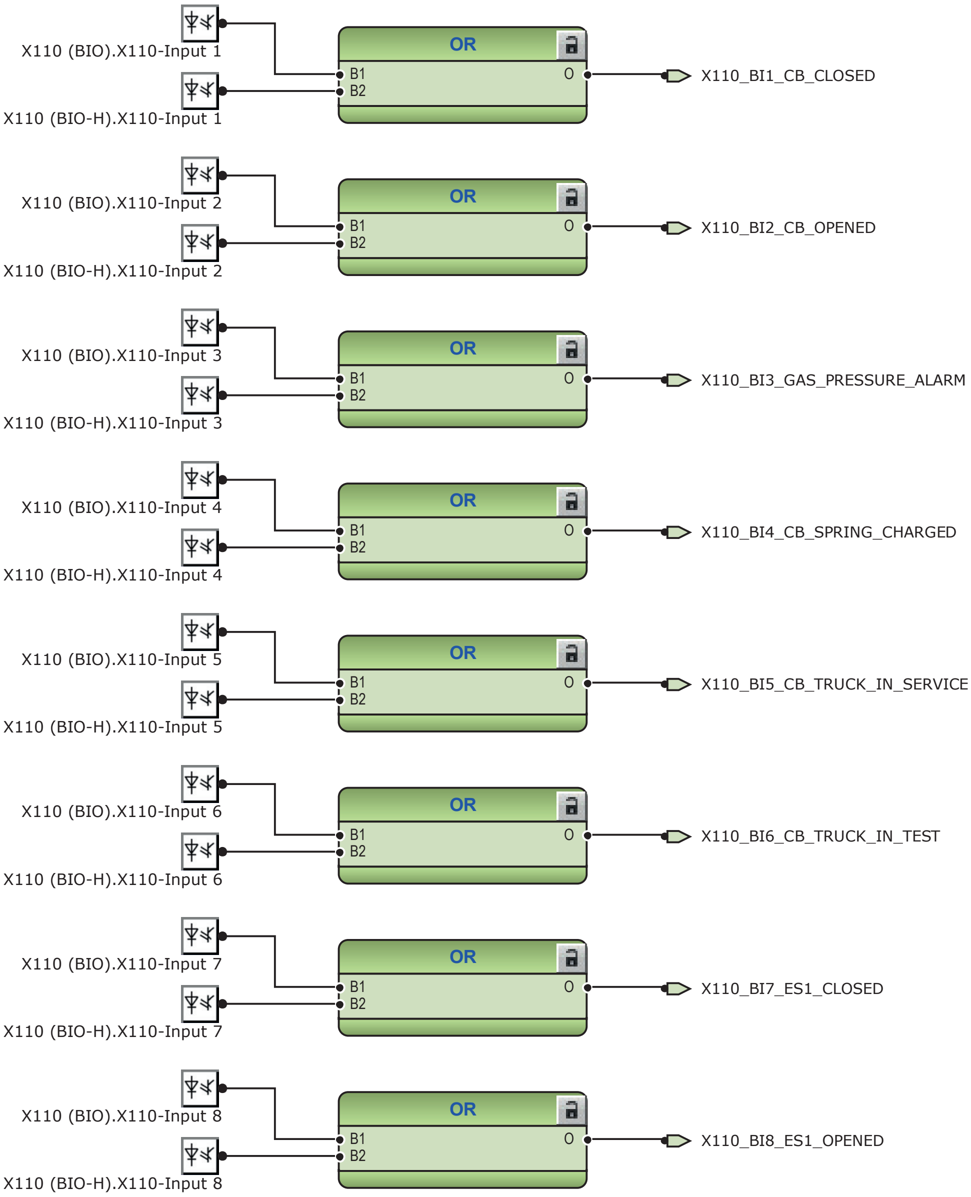


Figure 328: Default binary inputs - X110

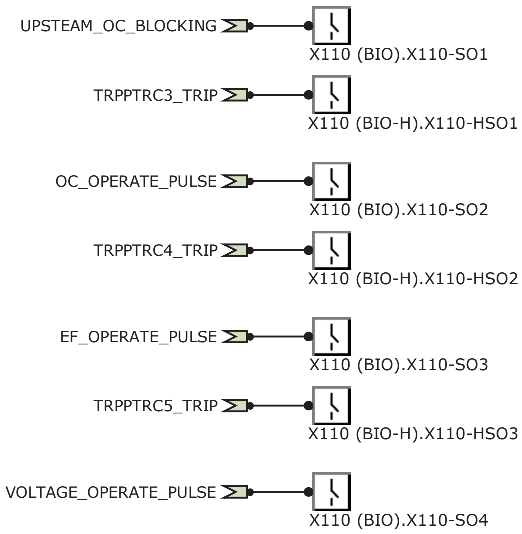


Figure 329: Default binary output - X110

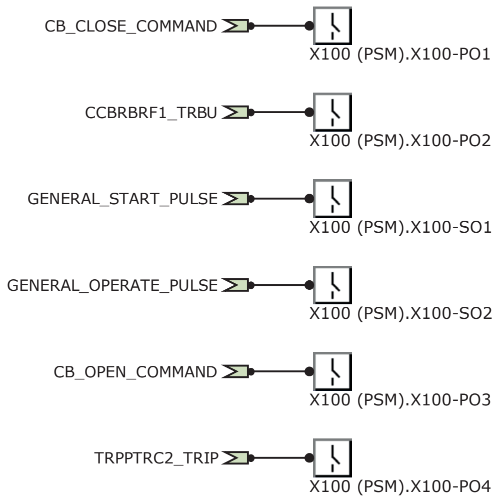
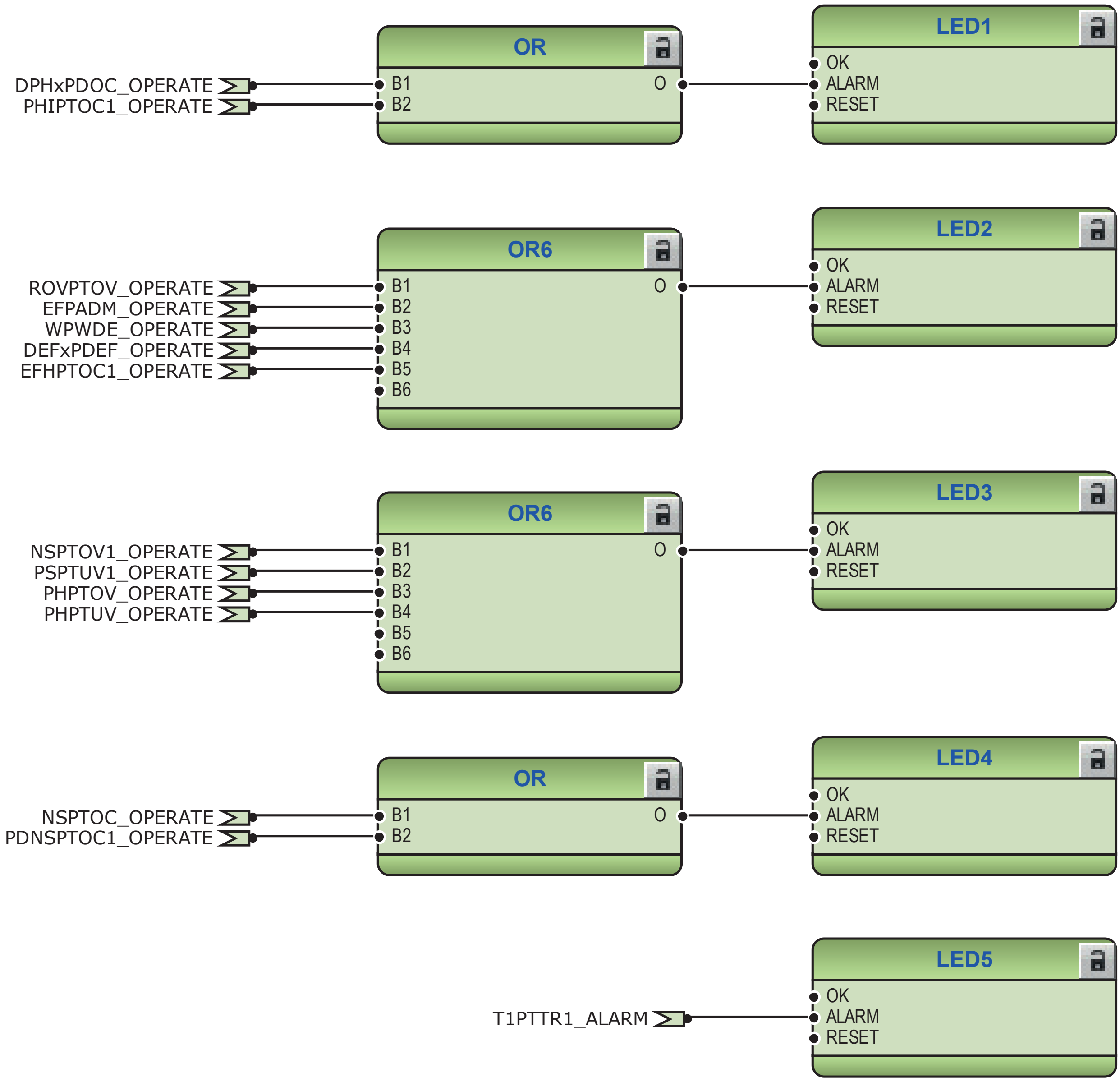


Figure 330: Default binary output - X100


OR
DPHxPDOC_OPERATE
PHIPTOC1_OPERATE
B1
B2
O
LED1
OK
ALARM
RESET
OR6
ROVPTOV_OPERATE
EFPADM_OPERATE
WPWDE_OPERATE
DEFxPDEF_OPERATE
EFHPTOC1_OPERATE
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
OR6
NSPTOV1_OPERATE
PSPTUV1_OPERATE
PHPTOV_OPERATE
PHPTUV_OPERATE
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
OR
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
B1
B2
O
LED4
OK
ALARM
RESET
T1PTTR1_ALARM
LED5
OK
ALARM
RESET

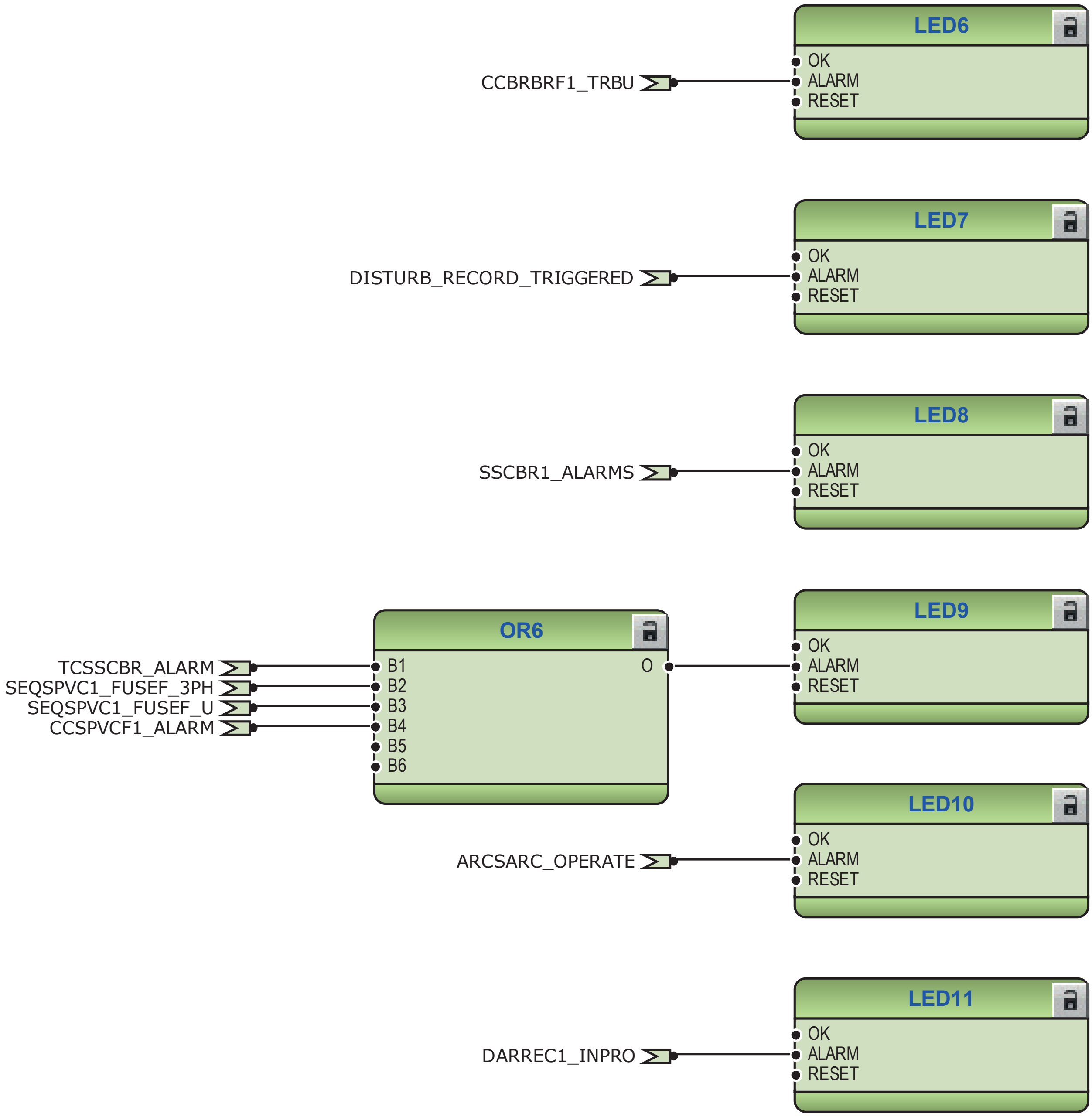


Figure 331: Default LED connection

3.9.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and voltage operate logic. The operate logics are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

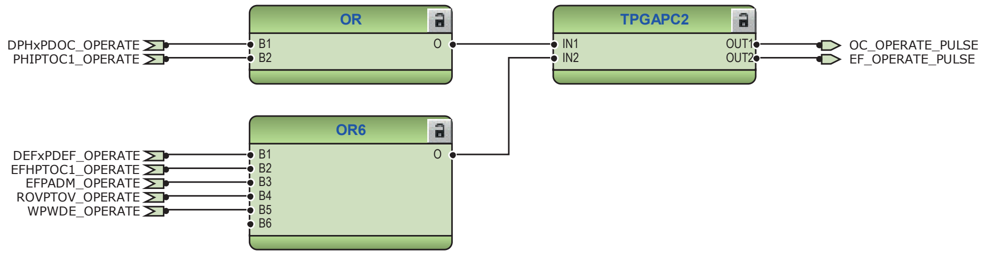


Figure 332: Timer logic for overcurrent and earth-fault operate pulse

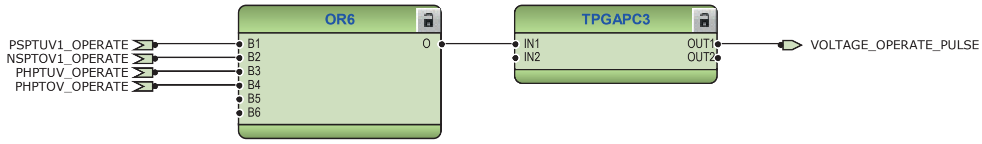


Figure 333: Timer logic for voltage operate pulse

3.9.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, high-impedance fault detection PHIZ, runtime counter for machines and devices MDSOPT and 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.

3.10 Standard configuration H

3.10.1 Applications

The standard configuration for non-directional overcurrent and non-directional earth-fault protection with phase voltage-based measurements, undervoltage and overvoltage protection, frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in directly or resistance-earthed distribution networks.

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.

3.10.2 Functions

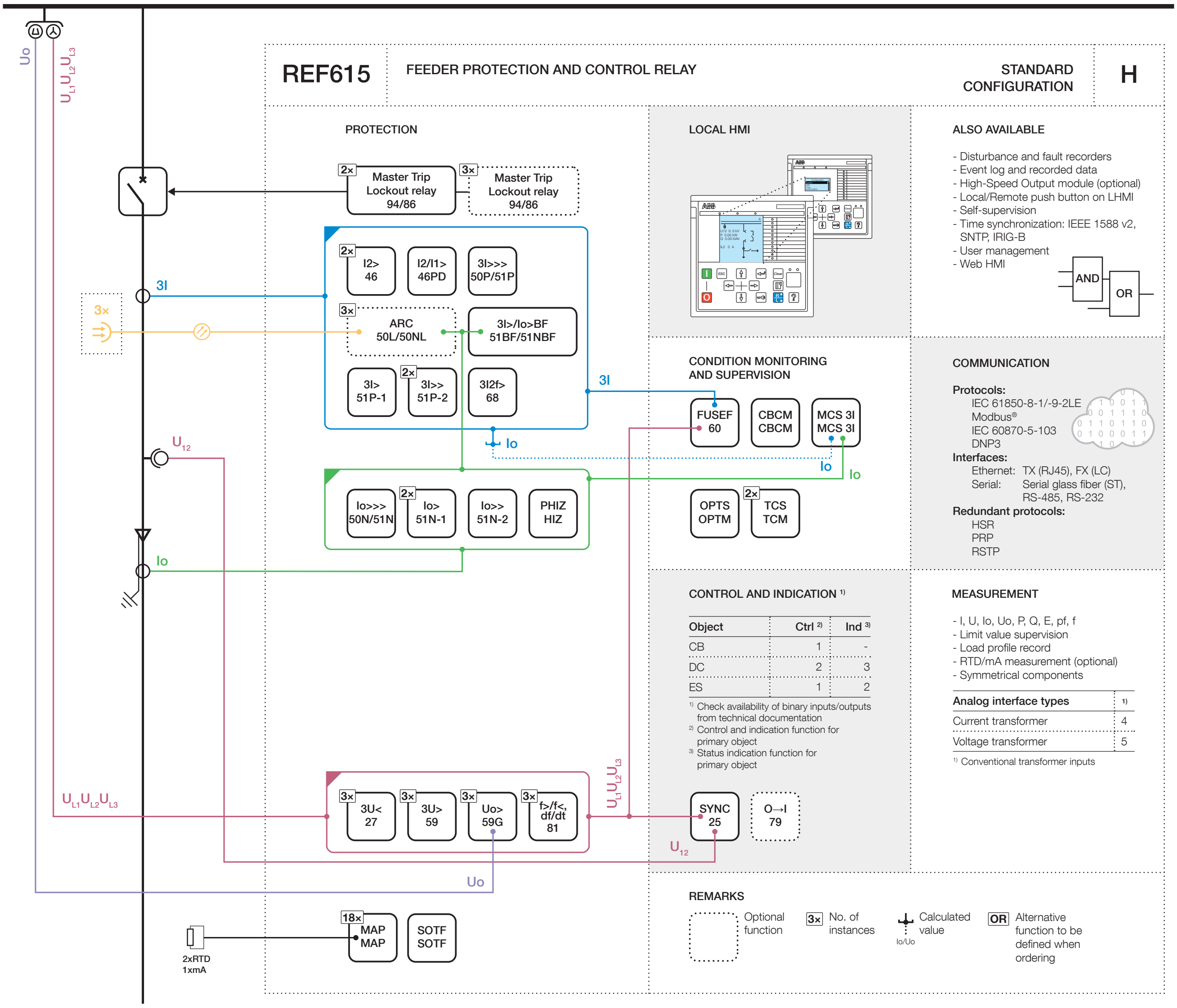


Figure 334: Functionality overview for standard configuration H

3.10.2.1 Default I/O connections

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

Table 46: Default connections for binary inputs

Binary input	Description
X110-BI1	Busbar VT secondary MCB open
X110-BI2	Line VT secondary MCB open
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Lock-out reset

Table 47: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-SO4	Voltage protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 48: Default connections for LEDs

LED	Description
1	Overcurrent protection operated
2	Earth-fault protection operated

Table continues on the next page

LED	Description
3	Combined protection operated indication
4	Synchronism or energizing check OK
5	Frequency protection
6	Circuit breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.10.2.2 Default disturbance recorder settings

Table 49: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	U1B
10	–
11	–
12	–

Table 50: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	EFLPTOC1 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	EFHPTOC1 - start	Positive or Rising
10	EFIPTOC1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
11	PDNSPTOC1 - start	Positive or Rising
12	PHPTOV1 - start	Positive or Rising
13	PHPTOV2 - start	Positive or Rising
14	PHPTOV3 - start	Positive or Rising
15	PHPTUV1 - start	Positive or Rising
16	PHPTUV2 - start	Positive or Rising
17	PHPTUV3 - start	Positive or Rising
18	ROVPTOV1 - start	Positive or Rising
19	ROVPTOV2 - start	Positive or Rising
20	ROVPTOV3 - start	Positive or Rising
21	FRPFRQ1 - start	Positive or Rising
22	FRPFRQ2 - start	Positive or Rising
23	FRPFRQ3 - start	Positive or Rising
24	CCBRBRF1 - trret	Level trigger off
25	CCBRBRF1 - trbu	Level trigger off
26	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
27	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
28	EFLPTOC1 - operate	Level trigger off
	EFLPTOC2 - operate	
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
29	EFHPTOC1 - operate	Level trigger off
30	PDNSPTOC1 - operate	Level trigger off
31	INRPHAR1 - blk2h	Level trigger off
32	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
	PHPTOV3 - operate	
33	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
	PHPTUV3 - operate	
34	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
35	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
36	SEQSPVC1 - fusef3ph	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
37	SEQSPVC1 - fusefu	Level trigger off
38	CCSPVC1 - fail	Level trigger off
39	X120BI1 - ext OC blocking	Level trigger off
40	X120BI2 - CB closed	Level trigger off
41	X120BI3 - CB opened	Level trigger off
42	SECRSYN1 - sync inpro	Level trigger off
43	SECRSYN1 - sync ok	Level trigger off
44	SECRSYN1 - cl fail al	Level trigger off
45	SECRSYN1 - cmd fail al	Level trigger off
46	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
47	ARCSARC1 - operate	Positive or Rising
48	ARCSARC2 - operate	Positive or Rising
49	ARCSARC3 - operate	Positive or Rising
50	DARREC1 - inpro	Level trigger off
51	DARREC1 - close CB	Level trigger off
52	DARREC1 - unsuc recl	Level trigger off

3.10.3 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.

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

3.10.3.1 Functional diagrams for protection

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

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.

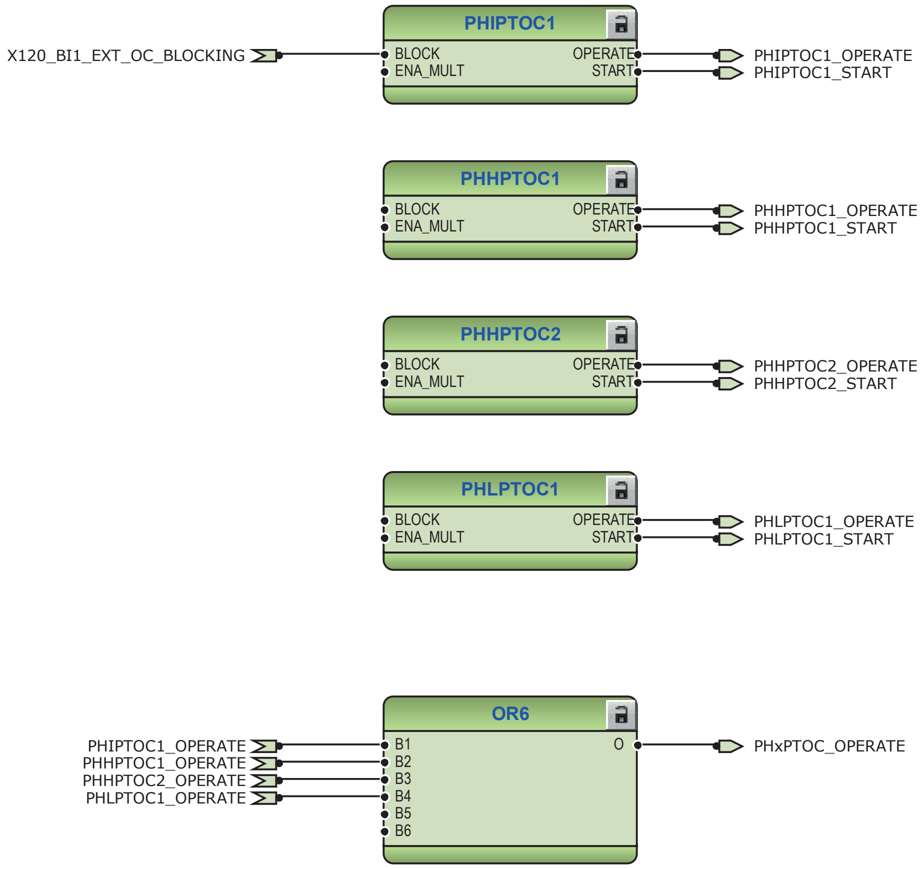


Figure 335: Overcurrent protection function

The upstream blocking from the start of the second high stage of three-phase non-directional overcurrent protection PHHPTOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

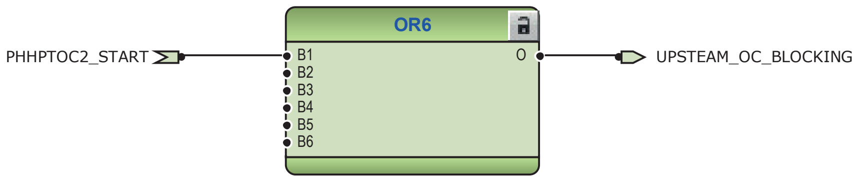


Figure 336: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

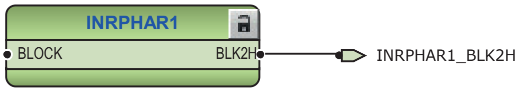


Figure 337: Inrush detector function

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 negative sequence overcurrent protections are blocked in case of detection of a failure in secondary circuit of current transformer.

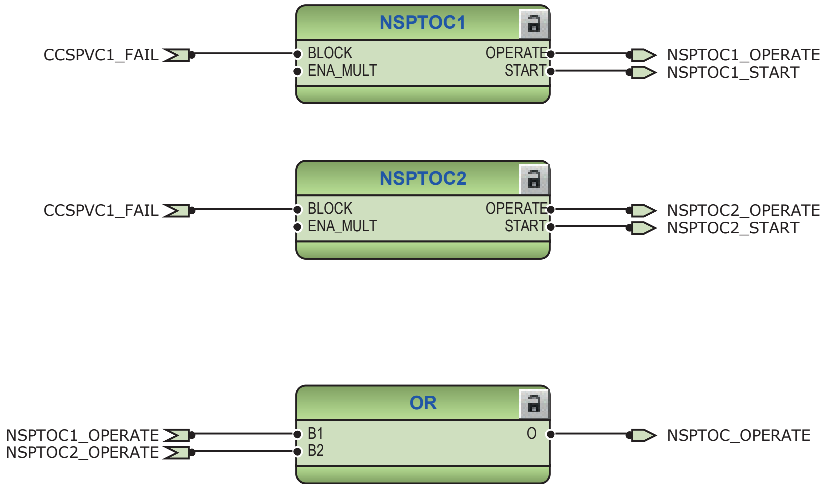


Figure 338: Negative sequence overcurrent protection function

Four stages are provided for non-directional earth-fault protection. One stage is dedicated to sensitive earth-fault protection.

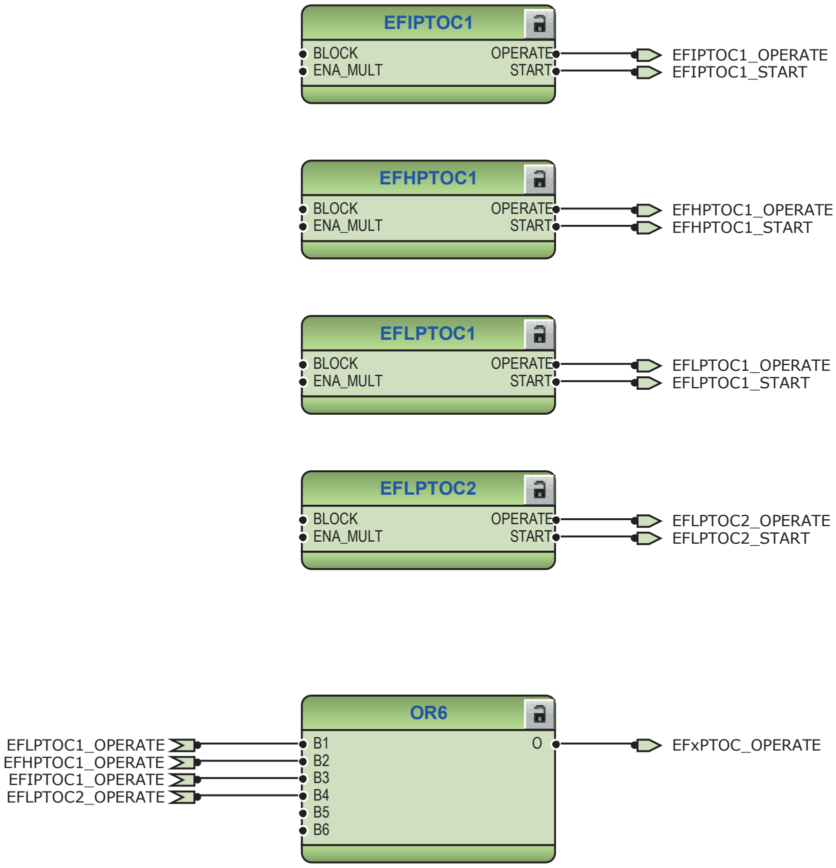


Figure 339: Earth-fault protection function

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 of a failure in secondary circuit of current transformer.

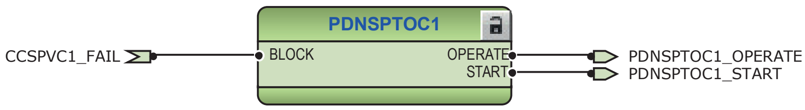


Figure 340: Phase discontinuity protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The 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.

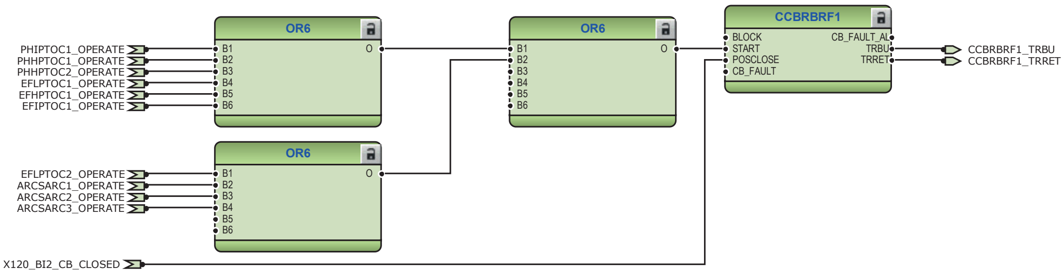


Figure 341: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3..5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

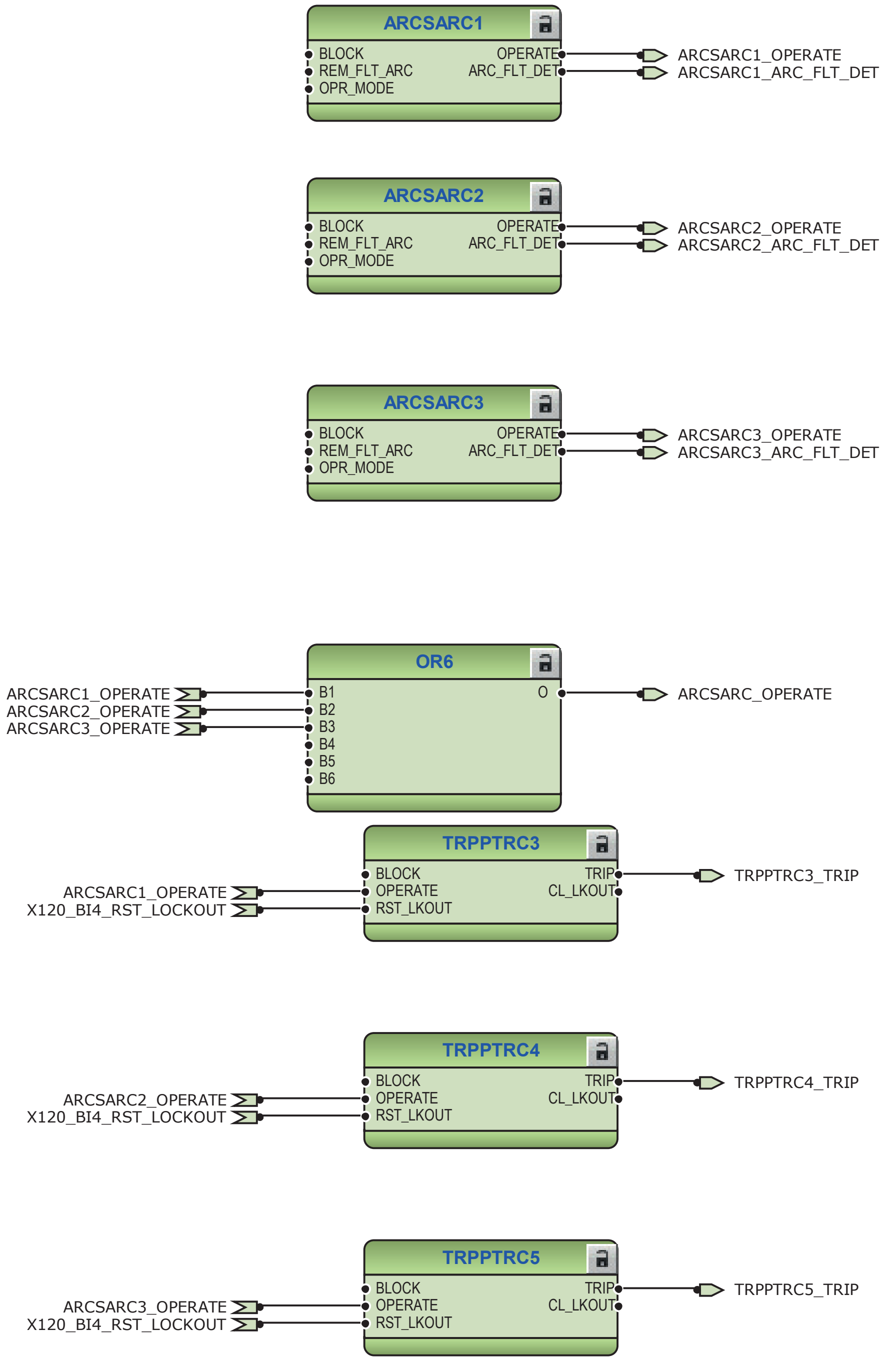


Figure 342: Arc protection with dedicated HSO

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 using 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.

Set the parameters for DARREC1 properly.

Check the initialization signals of DARREC1.

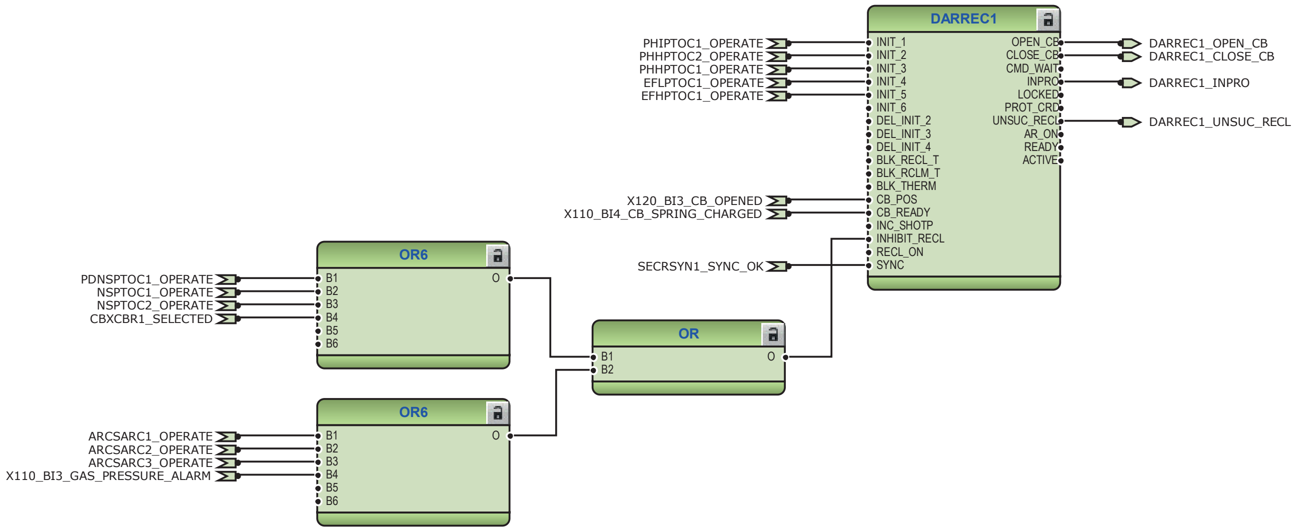


Figure 343: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

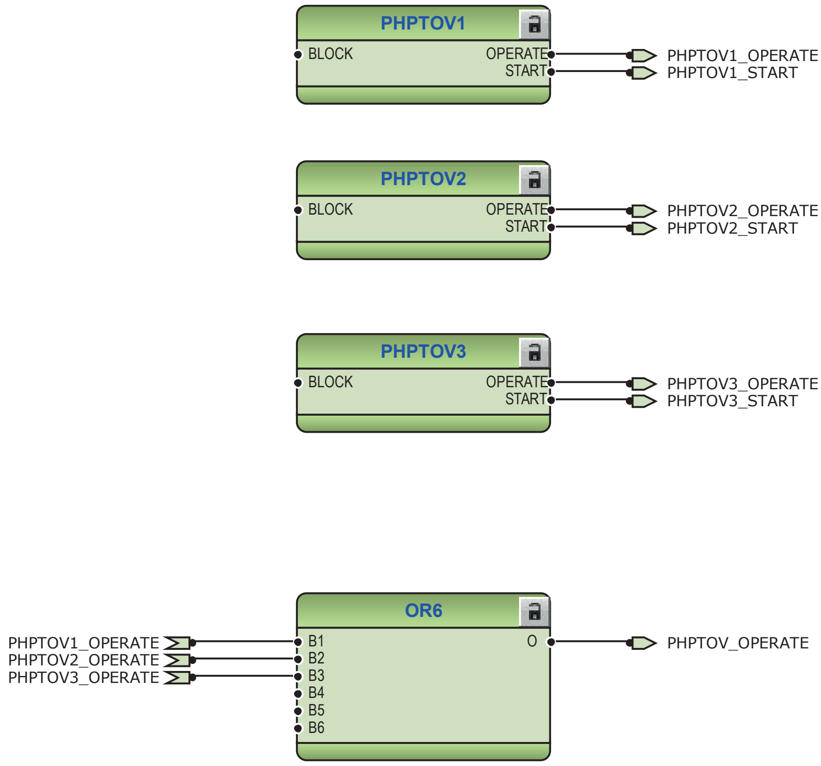


Figure 344: Overvoltage protection function

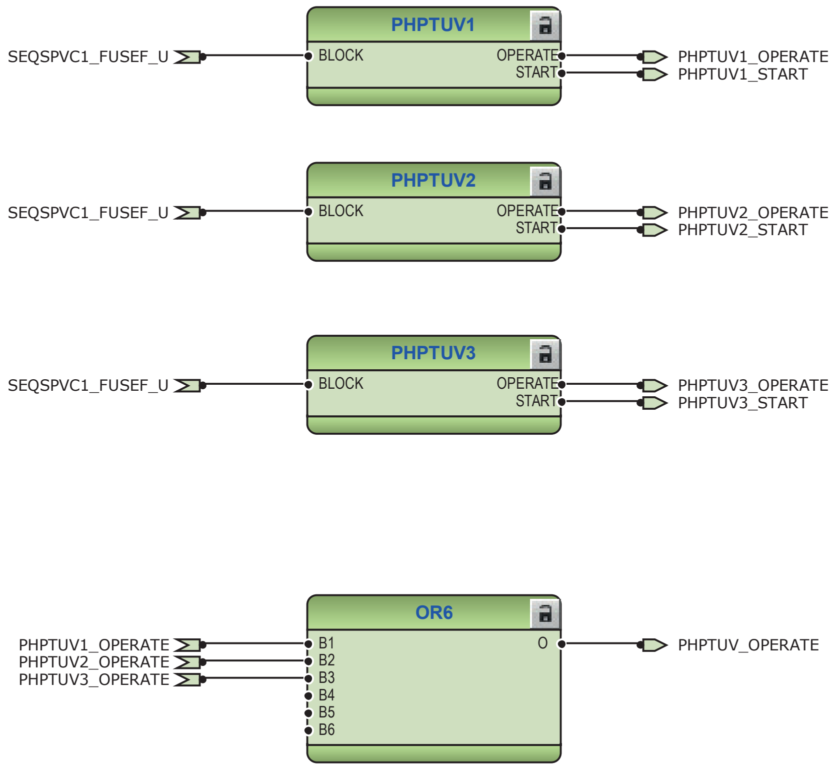


Figure 345: Undervoltage protection function

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 non-selective backup protection for the earth-fault functionality.

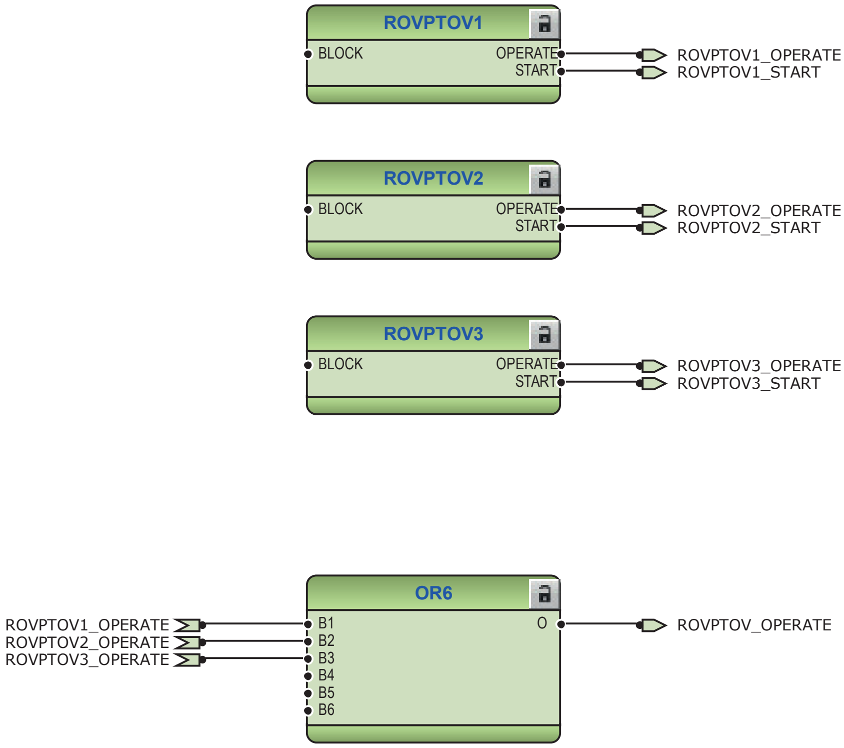


Figure 346: Residual overvoltage protection function

The selectable underfrequency or overfrequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system.

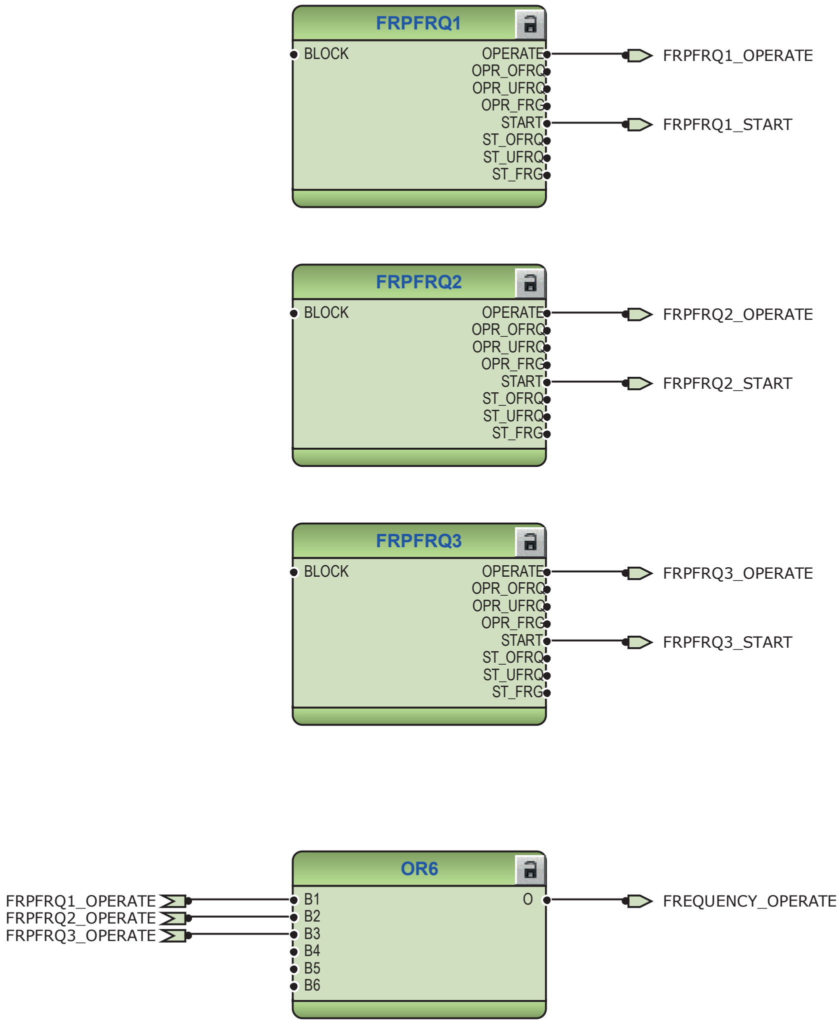


Figure 347: Frequency protection function

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

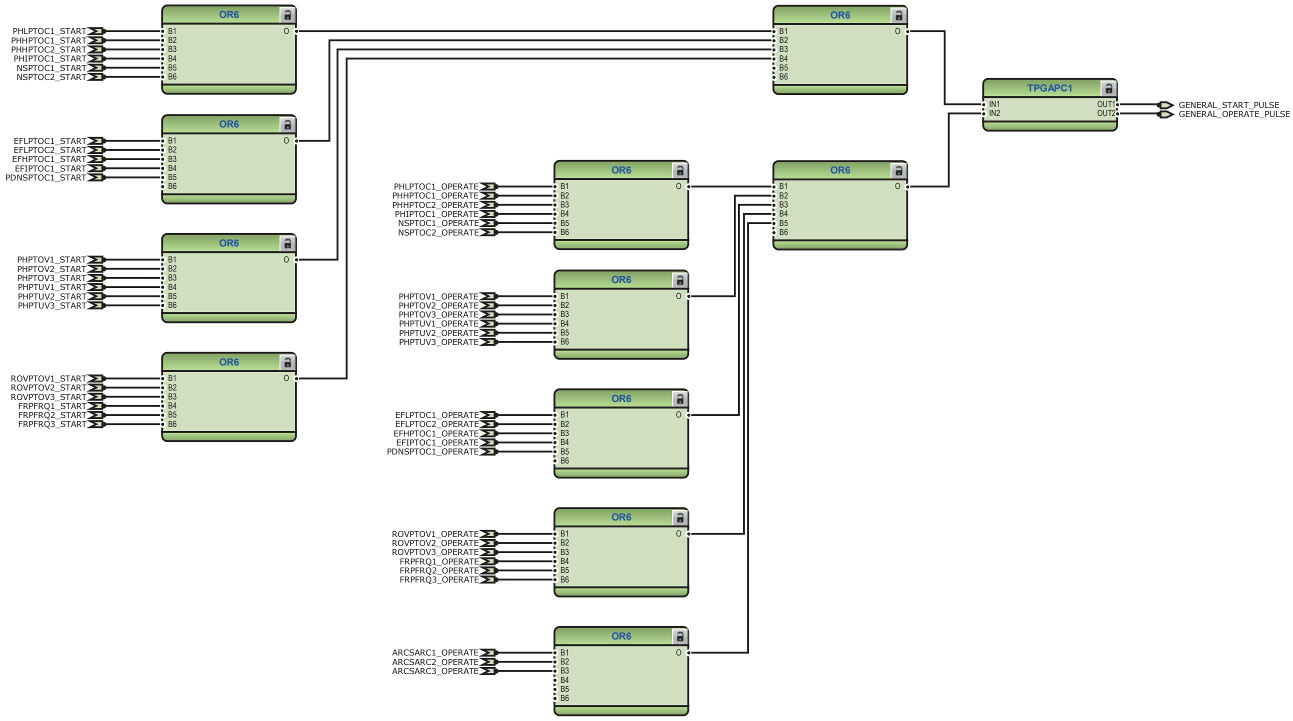


Figure 348: General start and operate signals

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 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

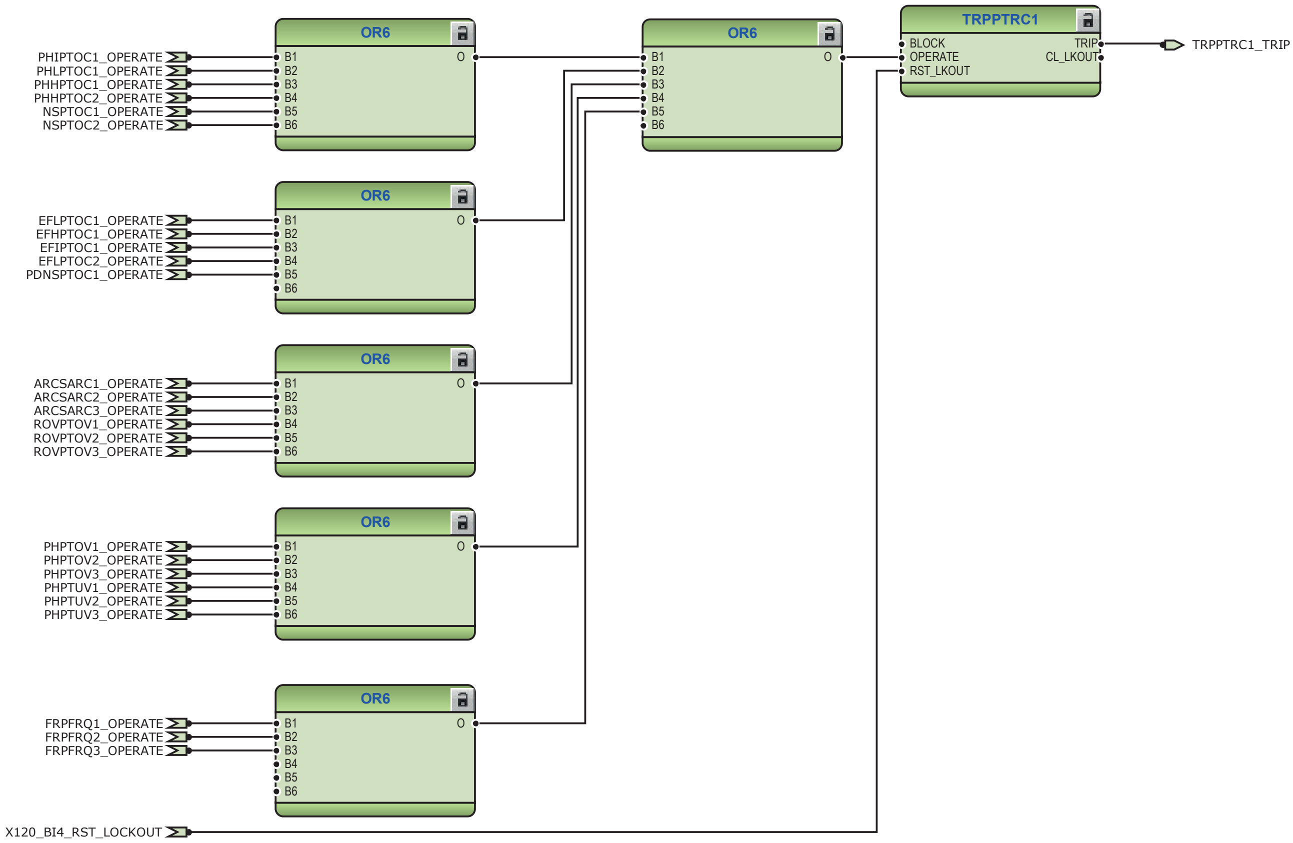


Figure 349: Trip logic TRPPTRC1

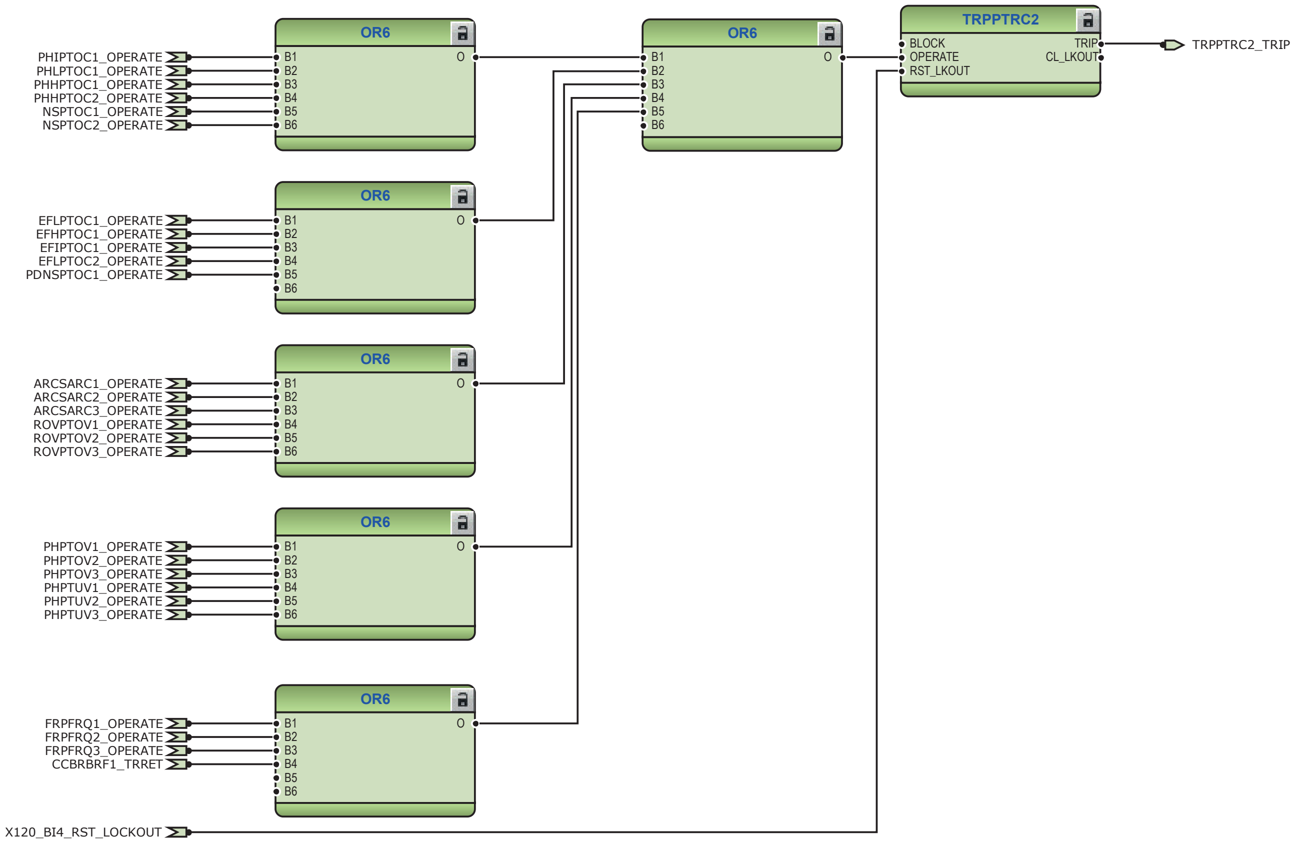


Figure 350: Trip logic TRPPTRC1

3.10.3.2 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.

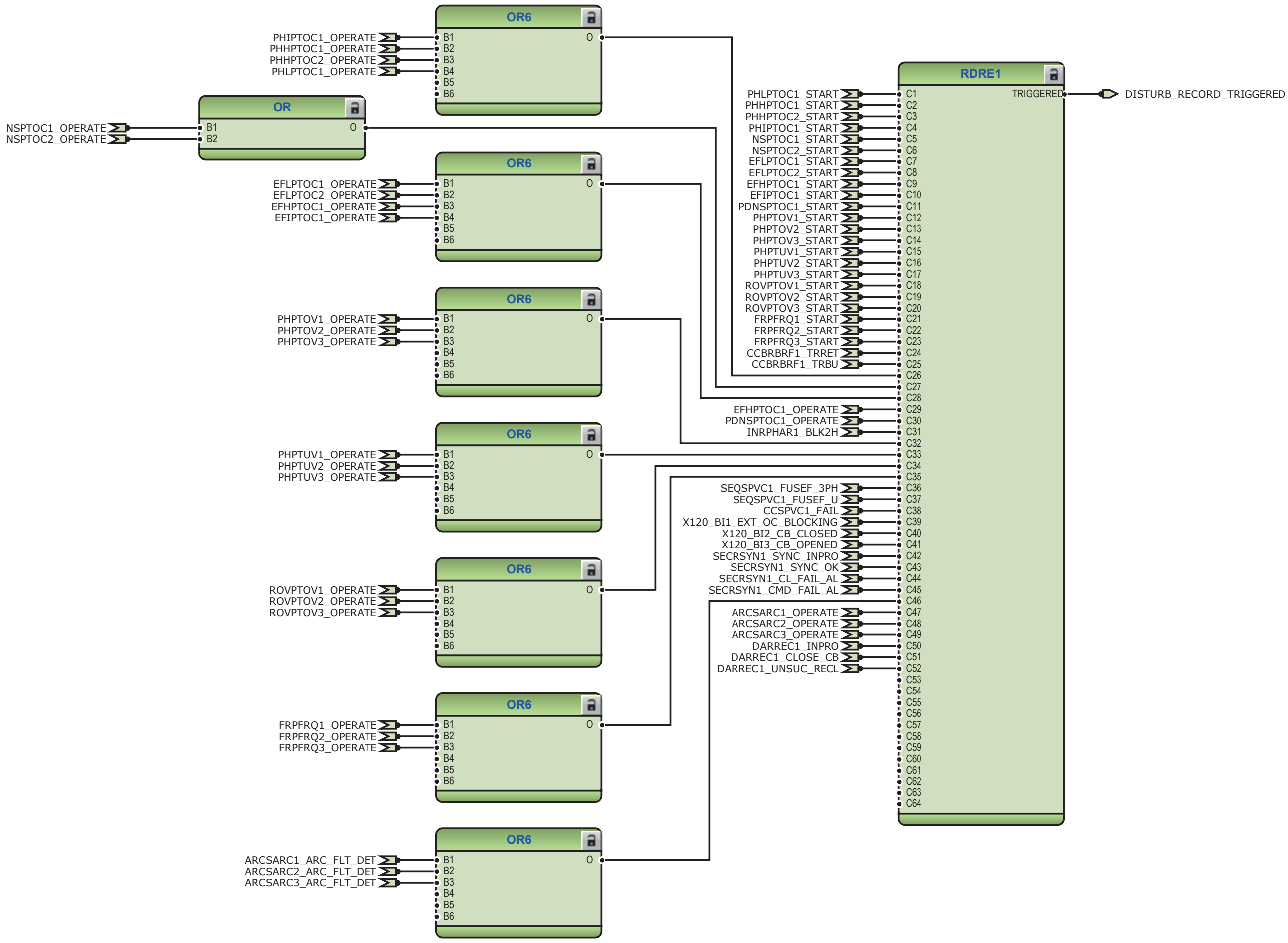


Figure 351: Disturbance recorder

3.10.3.3 Functional diagrams for condition monitoring

Failures in the current measuring circuits are detected by CCSPVC1. 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.

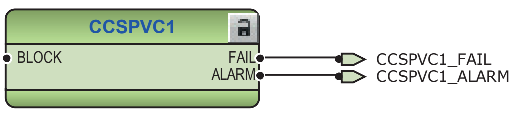


Figure 352: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

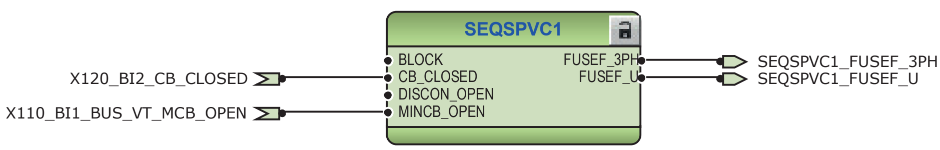


Figure 353: Fuse failure supervision function

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.

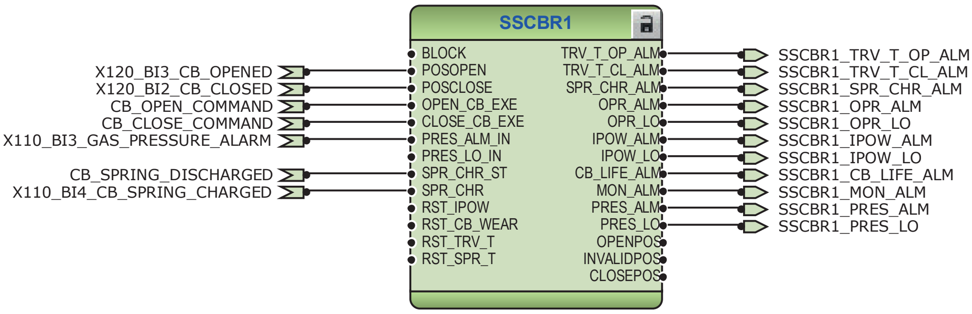


Figure 354: Circuit-breaker conditioning monitoring function

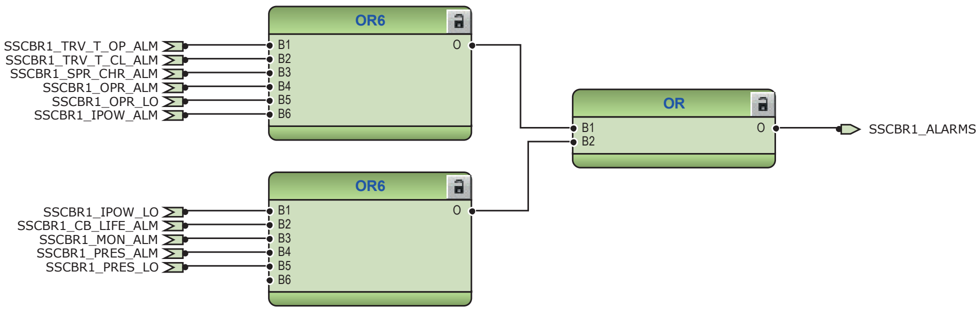


Figure 355: Logic for circuit-breaker monitoring alarm

Figure 356: 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. 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.

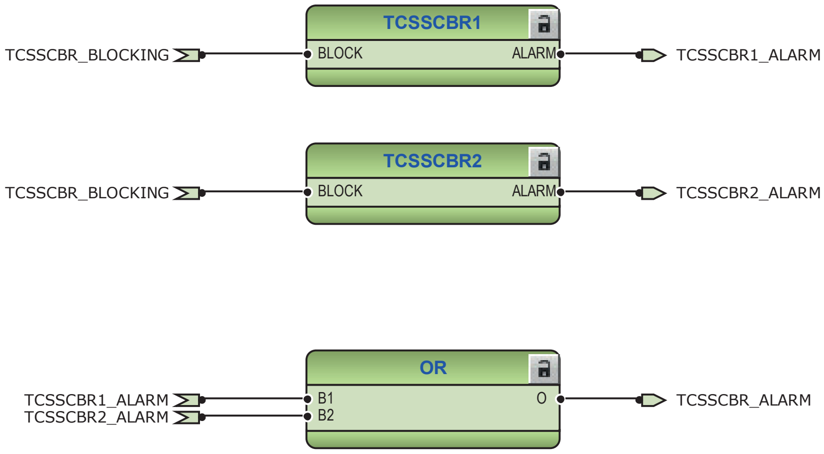


Figure 357: Trip circuit supervision function

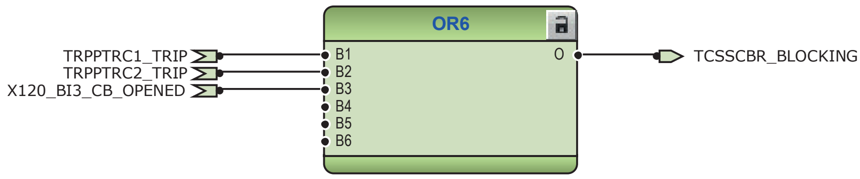


Figure 358: Logic for blocking of trip circuit supervision

3.10.3.4 Functional diagrams for control and interlocking

The main purpose of the synchronism and energizing check SECRSYN is to provide control over the closing of the circuit breakers in power networks to prevent the closing, if the conditions for synchronism are not detected. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN measures the bus and line voltages and compares them to the set conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for allowing closing or closing the circuit breaker. The `SYNC_OK` output signal of SECRSYN is connected to `ENA_CLOSE` input of CBXCBR through control logic. The function is block in case of line side or bus side MCB is open.

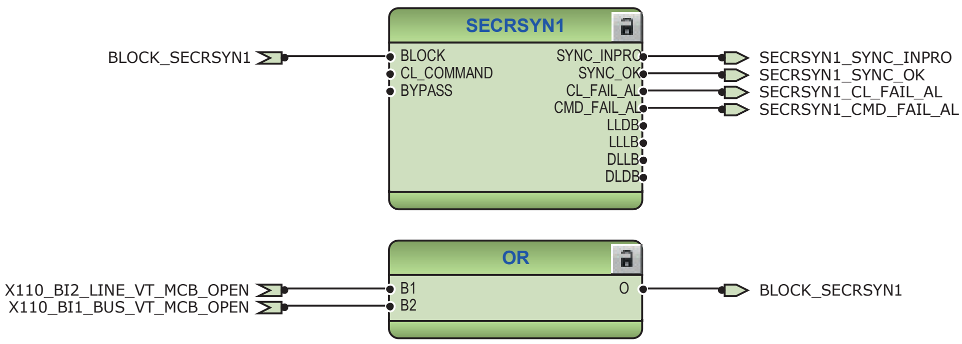


Figure 359: Synchrocheck function

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.

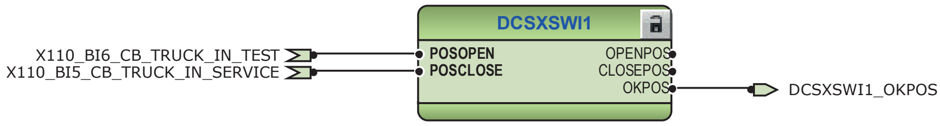


Figure 360: Disconnector control logic

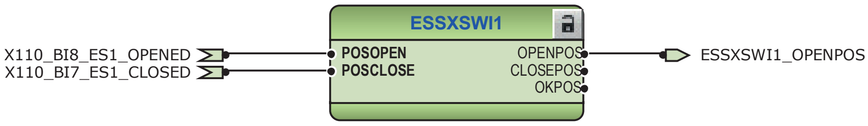


Figure 361: Earth switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm, circuit-breaker spring charging and synchronizing ok status.

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

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

Connect the additional signals required for the application for closing and opening of circuit breaker.

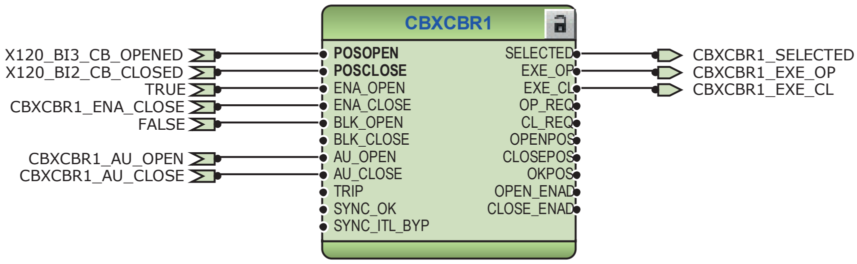


Figure 362: Circuit breaker 1 control logic

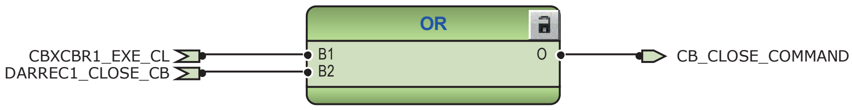


Figure 363: Signals for closing coil of circuit breaker 1

Figure 364: Signals for opening coil of circuit breaker 1

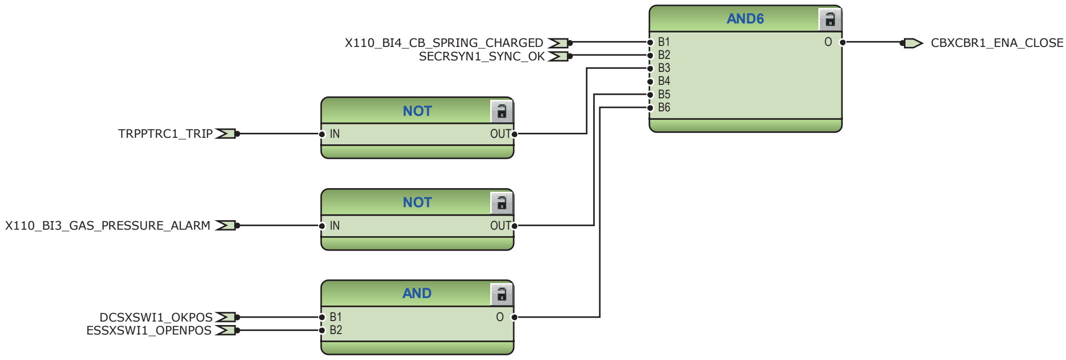


Figure 365: Circuit breaker 1 close enable logic

The configuration includes the 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 additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration.

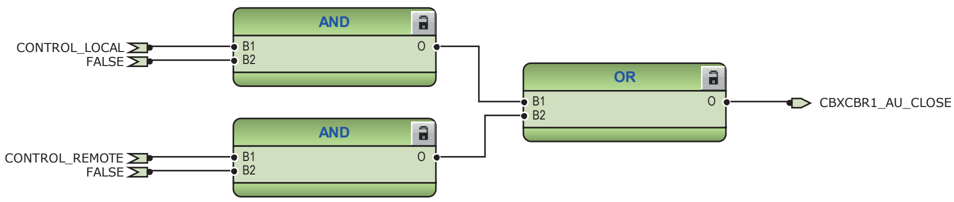


Figure 366: External closing command for circuit breaker 1

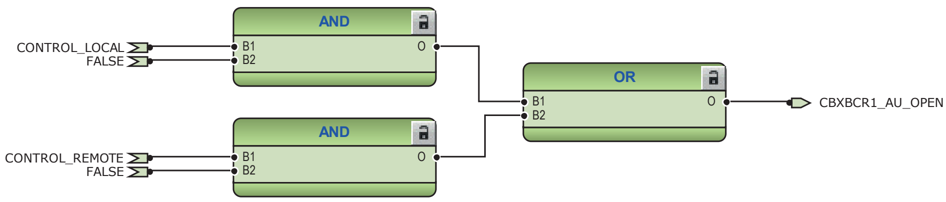


Figure 367: External opening command for circuit breaker 1

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

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

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

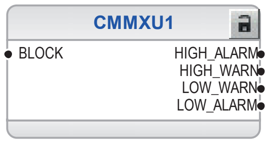


Figure 368: Current measurement: Three-phase current measurement

Figure 369: Current measurement: Sequence current measurement

Figure 370: Current measurement: Residual current measurement

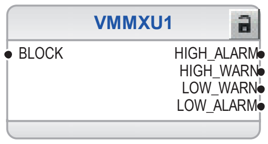


Figure 371: Voltage measurement: Three-phase voltage measurement

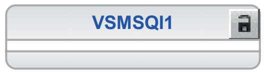


Figure 372: Voltage measurement: Sequence voltage measurement

Figure 373: Voltage measurement: Residual voltage measurement

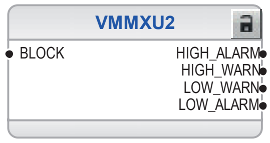


Figure 374: Voltage measurement: Three-phase voltage measurement

Figure 375: Other measurement: Frequency measurement

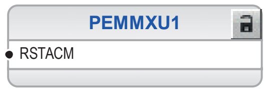


Figure 376: Other measurement: Three phase power and energy measurement

Figure 377: Other measurement: Data monitoring

Figure 378: Other measurement: Load profile record

3.10.3.6 Functional diagrams for I/O and alarm LEDs

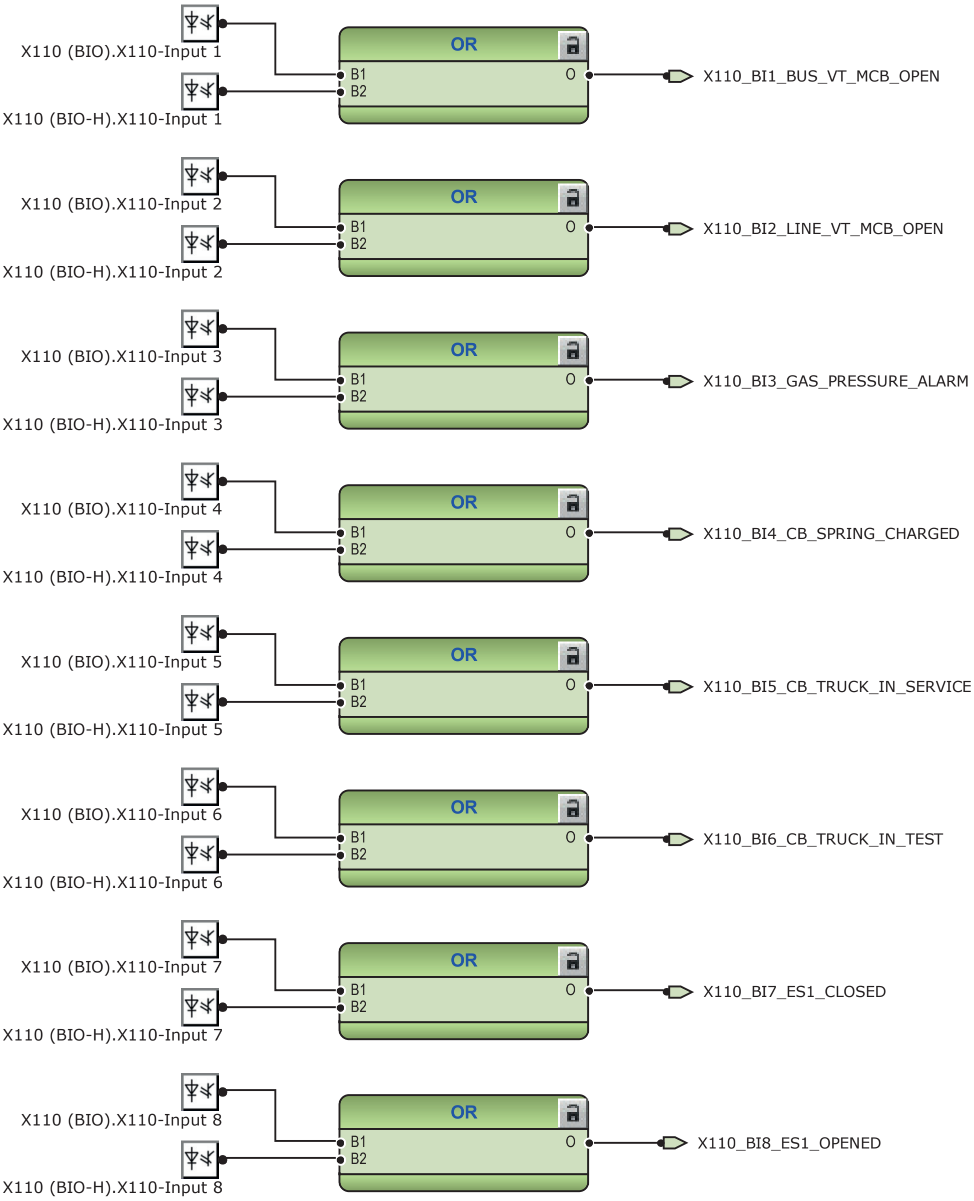


Figure 379: Default binary inputs - X110

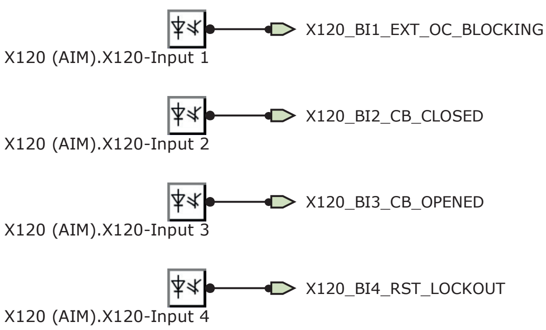


Figure 380: Default binary inputs - X120

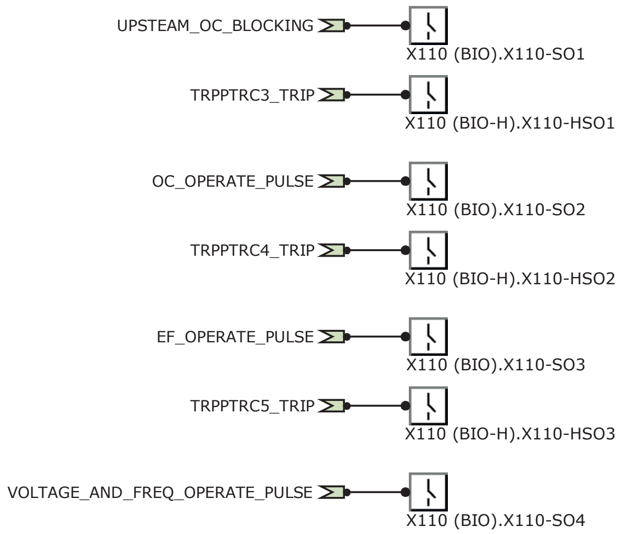


Figure 381: Default binary outputs - X110

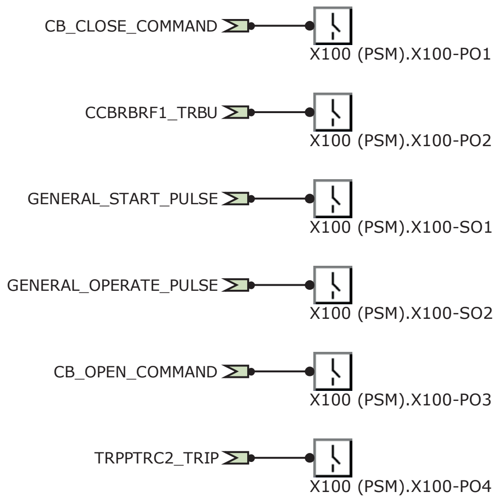
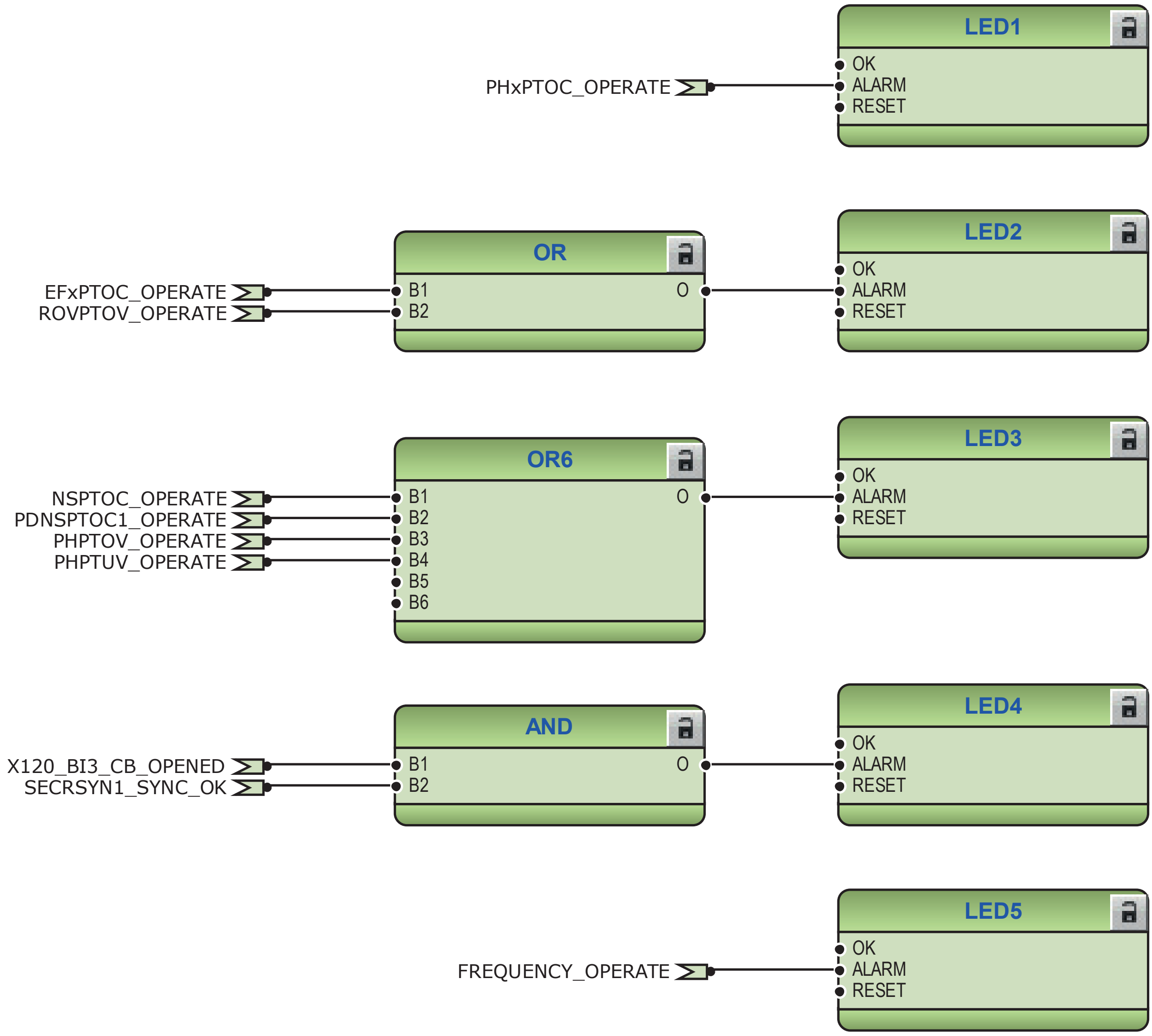


Figure 382: Default binary outputs - X100


LED1
PHxPTOC_OPERATE
OK
ALARM
RESET
OR
EFxPTOC_OPERATE
ROVPTOV_OPERATE
B1
B2
O
LED2
OK
ALARM
RESET
OR6
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
PHPTOV_OPERATE
PHPTUV_OPERATE
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
AND
X120_BI3_CB_OPENED
SECRSYN1_SYNC_OK
B1
B2
O
LED4
OK
ALARM
RESET
LED5
FREQUENCY_OPERATE
OK
ALARM
RESET

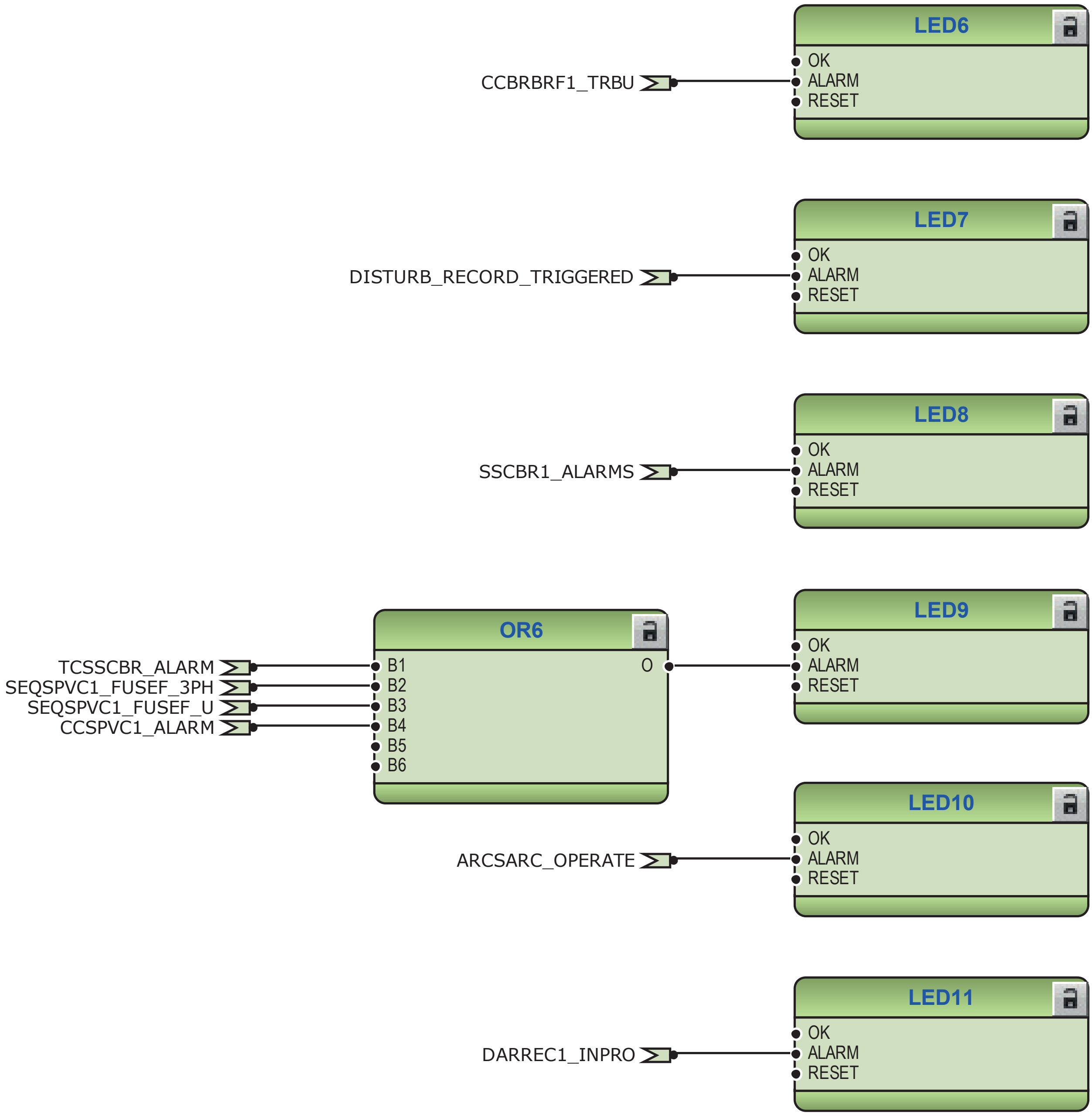


Figure 383: Default LED connection

3.10.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and combined voltage and frequency operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

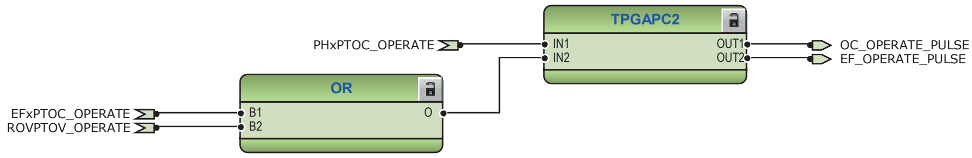


Figure 384: Timer logic for overcurrent and earth-fault operate pulse

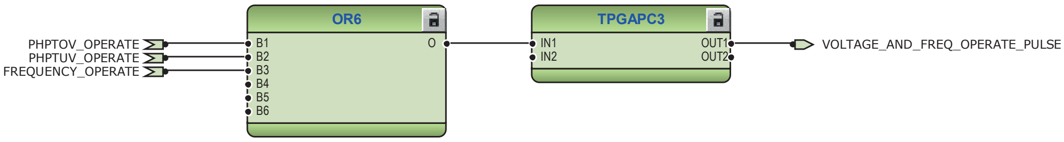


Figure 385: Timer logic for voltage and frequency operate pulse

3.10.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, high-impedance fault detection PHIZ, runtime counter for machines and devices MDSOPT and 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.

3.11 Standard configuration J

3.11.1 Applications

The standard configuration for directional overcurrent and directional earth-fault protection with phase voltage-based measurements, undervoltage and overvoltage protection, frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in isolated or resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance, wattmetric or harmonic-based 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.

3.11.2 Functions

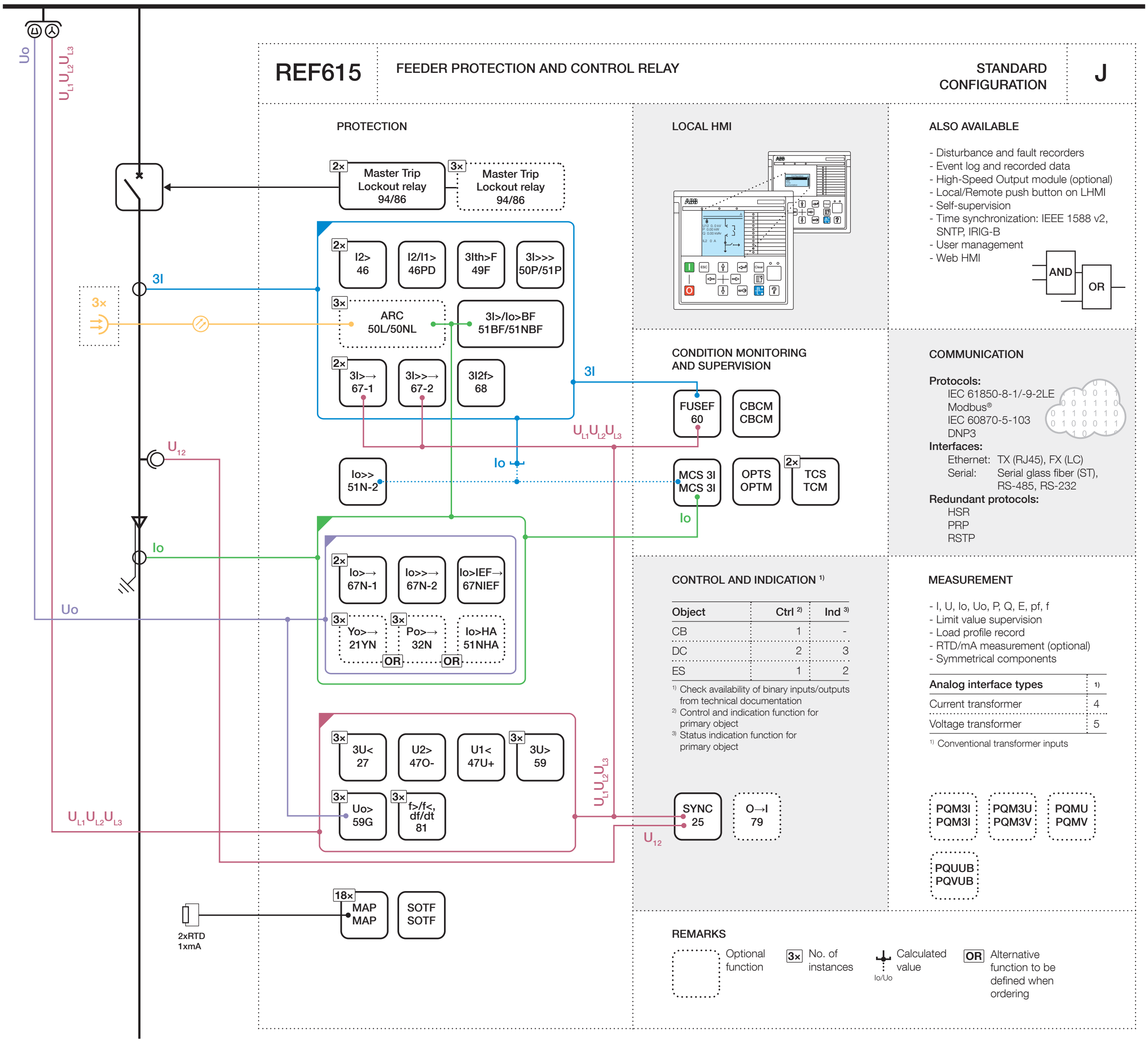


Figure 386: Functionality overview for standard configuration J

3.11.2.1 Default I/O connections

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

Table 51: Default connections for binary inputs

Binary input	Description
X110-BI1	Busbar VT secondary MCB open
X110-BI2	Line VT secondary MCB open
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Lock-out reset

Table 52: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-SO4	Voltage protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 53: Default connections for LEDs

LED	Description
1	Overcurrent protection operate
2	Earth-fault protection operate

Table continues on the next page

LED	Description
3	Combined protection operated indication
4	Synchronism or energizing check OK
5	Thermal overload alarm
6	Circuit breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring
9	Circuit supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.11.2.2 Default disturbance recorder settings

Table 54: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	U1B
10	–
11	–
12	–

Table 55: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	DPHLPDOC1 - start	Positive or Rising
2	DPHLPDOC2 - start	Positive or Rising
3	DPHHPDOC1 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
8	DEFLPDEF2 - start	Positive or Rising
9	DEFHPDEF1 - start	Positive or Rising
10	INTRPTEF1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	PHPTOV1 - start	Positive or Rising
15	PHPTOV2 - start	Positive or Rising
16	PHPTOV3 - start	Positive or Rising
17	PSPTUV1 - start	Positive or Rising
18	NSPTOV1 - start	Positive or Rising
19	PHPTUV1 - start	Positive or Rising
20	PHPTUV2 - start	Positive or Rising
21	PHPTUV3 - start	Positive or Rising
22	ROVPTOV1 - start	Positive or Rising
23	ROVPTOV2 - start	Positive or Rising
24	ROVPTOV3 - start	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHIPTOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
28	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
29	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
30	INTRPTEF1 - operate	Level trigger off
31	EFHPTOC1 - operate	Level trigger off
32	PDNSPTOC1 - operate	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off
34	T1PTTR1 - operate	Level trigger off
35	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
	PHPTOV3 - operate	
36	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
	PHPTUV3 - operate	
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
	PSPTUV1 - operate	
	NSPTOV1 - operate	

Table continues on the next page

Channel	ID text	Level trigger mode
38	SEQSPVC1 - fusef3ph	Level trigger off
39	SEQSPVC1 - fusefu	Level trigger off
40	CCSPVC1 - fail	Level trigger off
41	X120 BI1 - ext OC blocking	Level trigger off
42	X120 BI2 - CB closed	Level trigger off
43	X120 BI3 - CB opened	Level trigger off
44	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
45	DARREC1 - close CB	Level trigger off
	DARREC1 - unsuc recl	
46	ARCSARC1 - operate	Positive or Rising
47	ARCSARC2 - operate	Positive or Rising
48	ARCSARC3 - operate	Positive or Rising
49	DARREC1 - inpro	Level trigger off
50	FRPFRQ1 - start	Positive or Rising
51	FRPFRQ2 - start	Positive or Rising
52	FRPFRQ3 - start	Positive or Rising
53	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
54	SECRSYN1 - sync inpro	Level trigger off
55	SECRSYN1 - sync ok	Level trigger off
56	SECRSYN1 - cl fail al	Level trigger off
57	SECRSYN1 - cmd fail al	Level trigger off
58 - 64	-	-

3.11.3 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.

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

3.11.3.1 Functional diagrams for protection

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

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

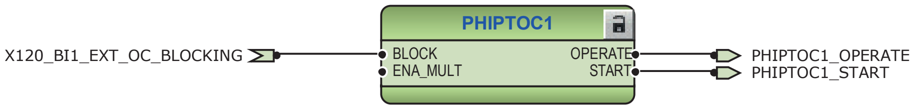


Figure 387: Overcurrent protection function

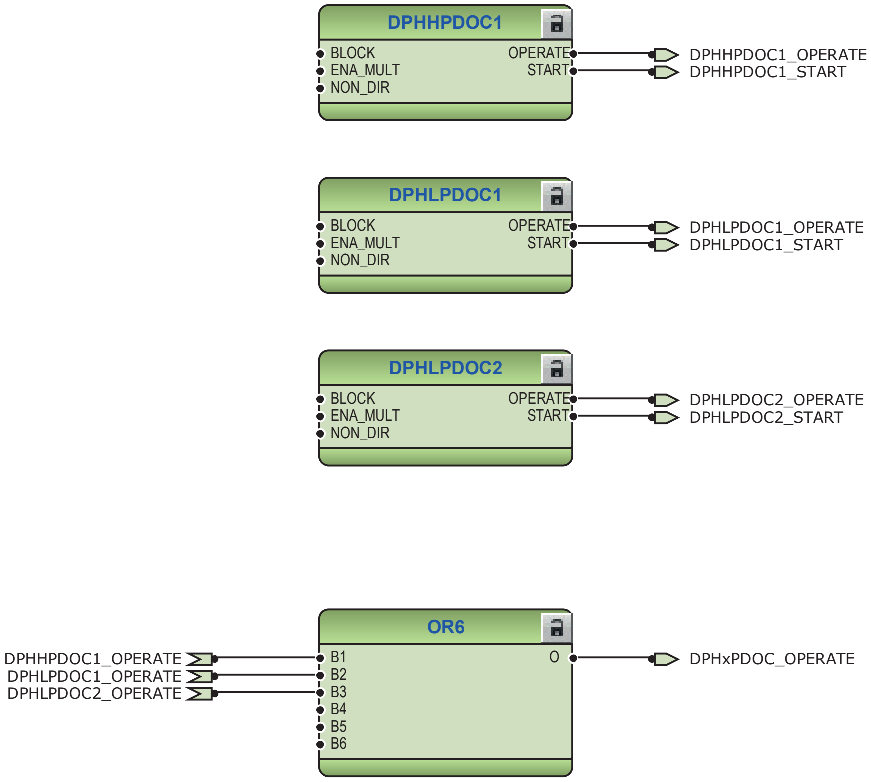


Figure 388: Directional overcurrent protection function

The upstream blocking from the start of the second low stage of three-phase directional overcurrent protection DPHLPDOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

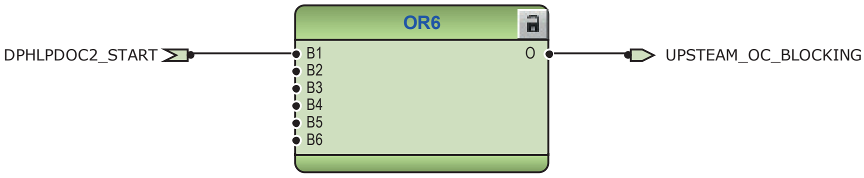


Figure 389: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

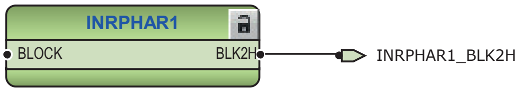


Figure 390: Inrush detector function

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.

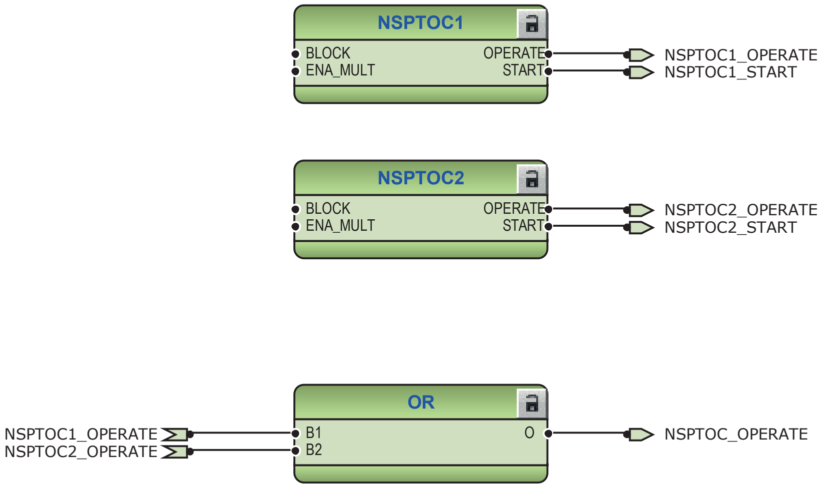


Figure 391: Negative-sequence overcurrent protection function

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 used 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.

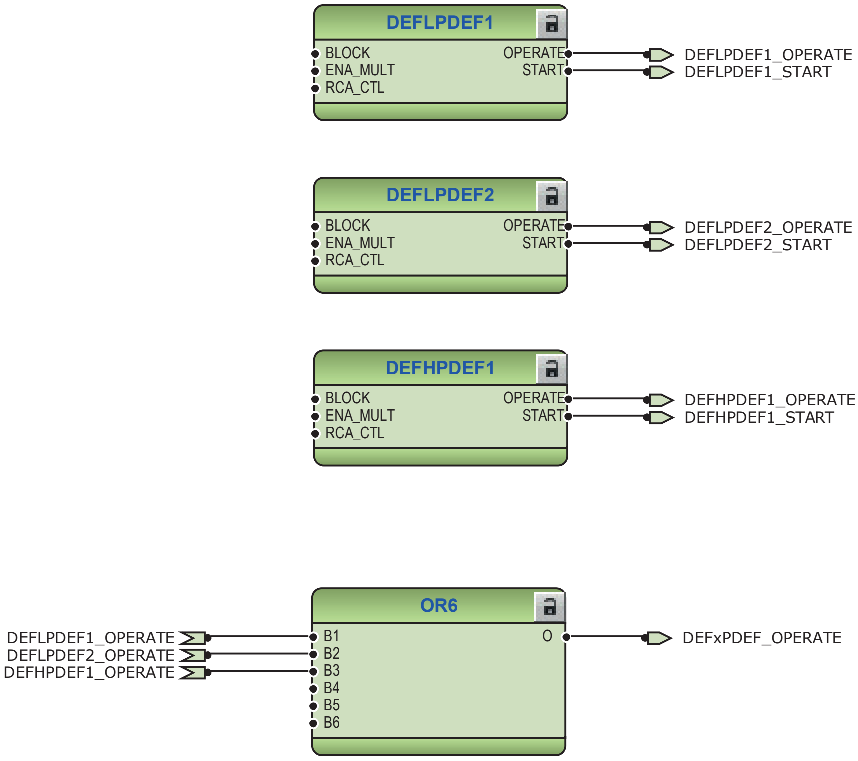


Figure 392: Directional earth-fault protection function

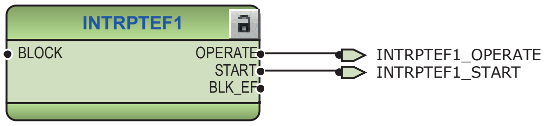


Figure 393: Transient or intermittent earth-fault protection function

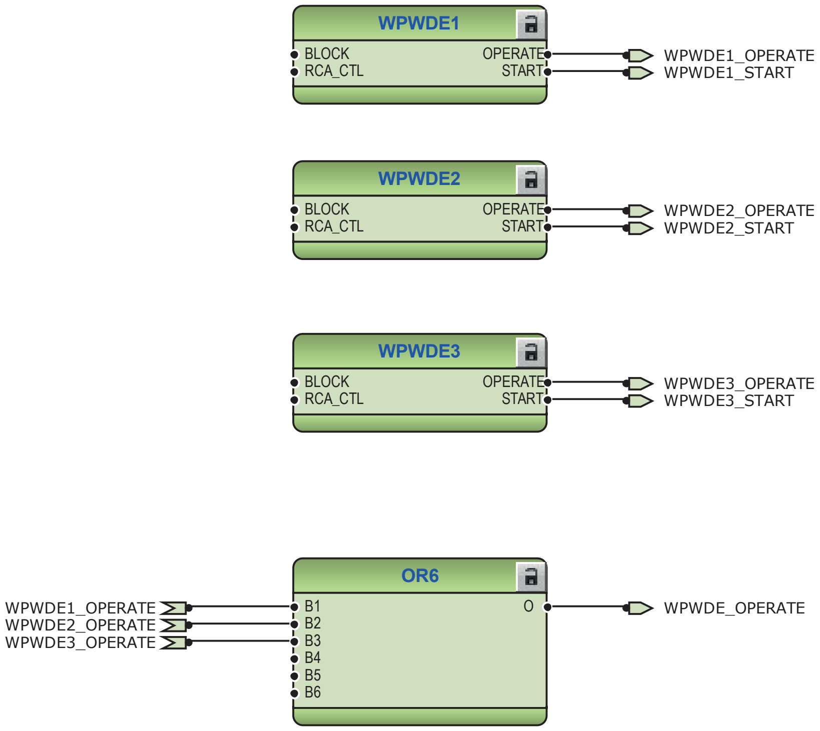


Figure 394: Wattmetric protection function

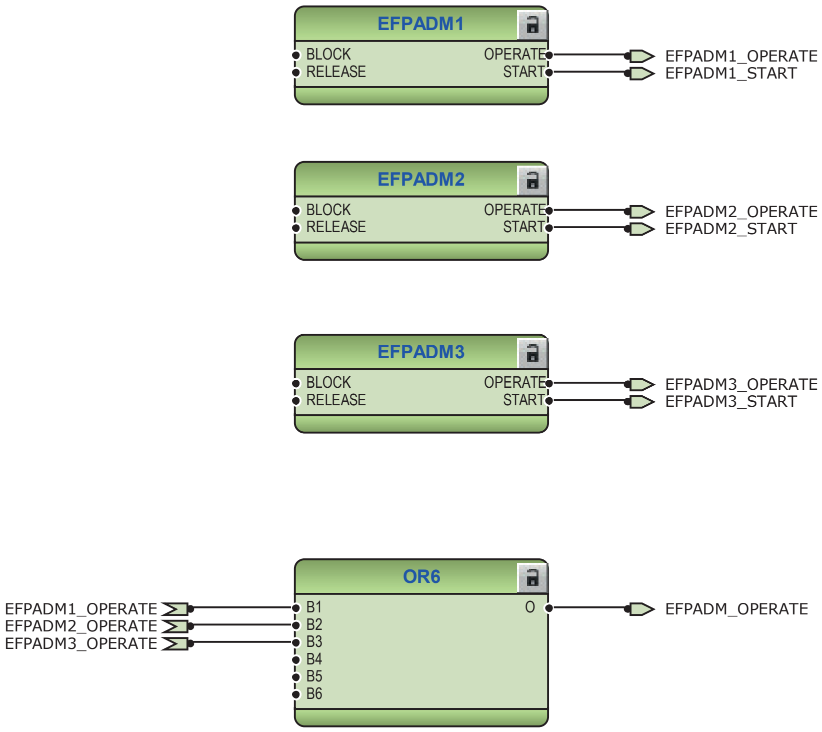


Figure 395: Admittance-based earth-fault protection function

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.

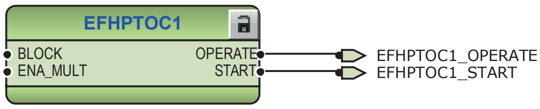


Figure 396: Earth-fault protection function

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

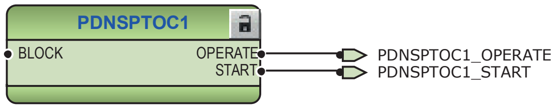


Figure 397: Phase discontinuity protection function

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

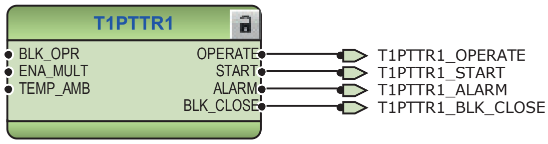


Figure 398: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by number of different protection functions available in the IED. The 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.

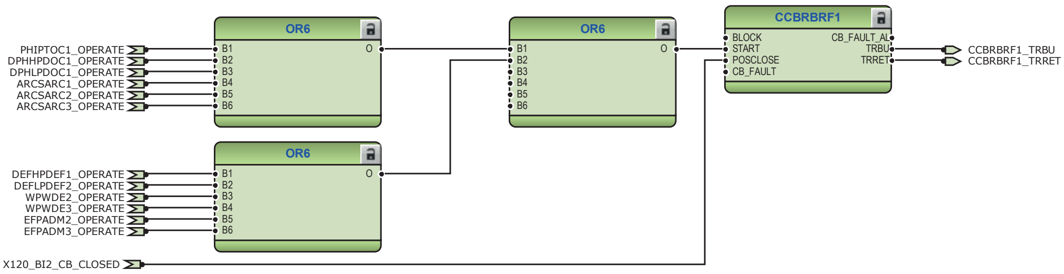


Figure 399: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to the dedicated trip logic TRPPTRC3..5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

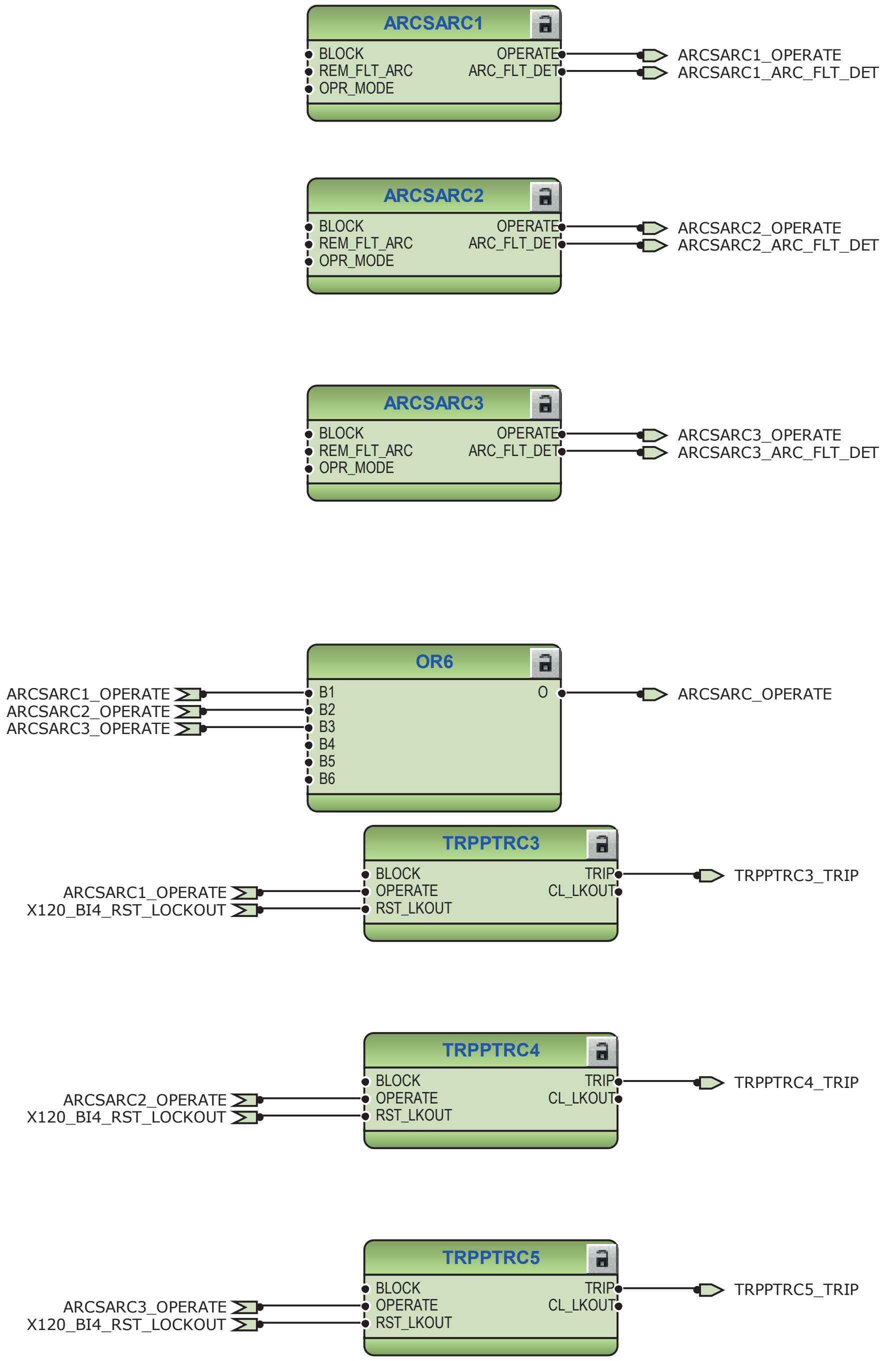


Figure 400: ARC protection with dedicated HSO

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 the close command is connected directly to binary output X100:PO1.

Set the parameters for DARREC1 properly.

Check the initialization signals of DARREC1.

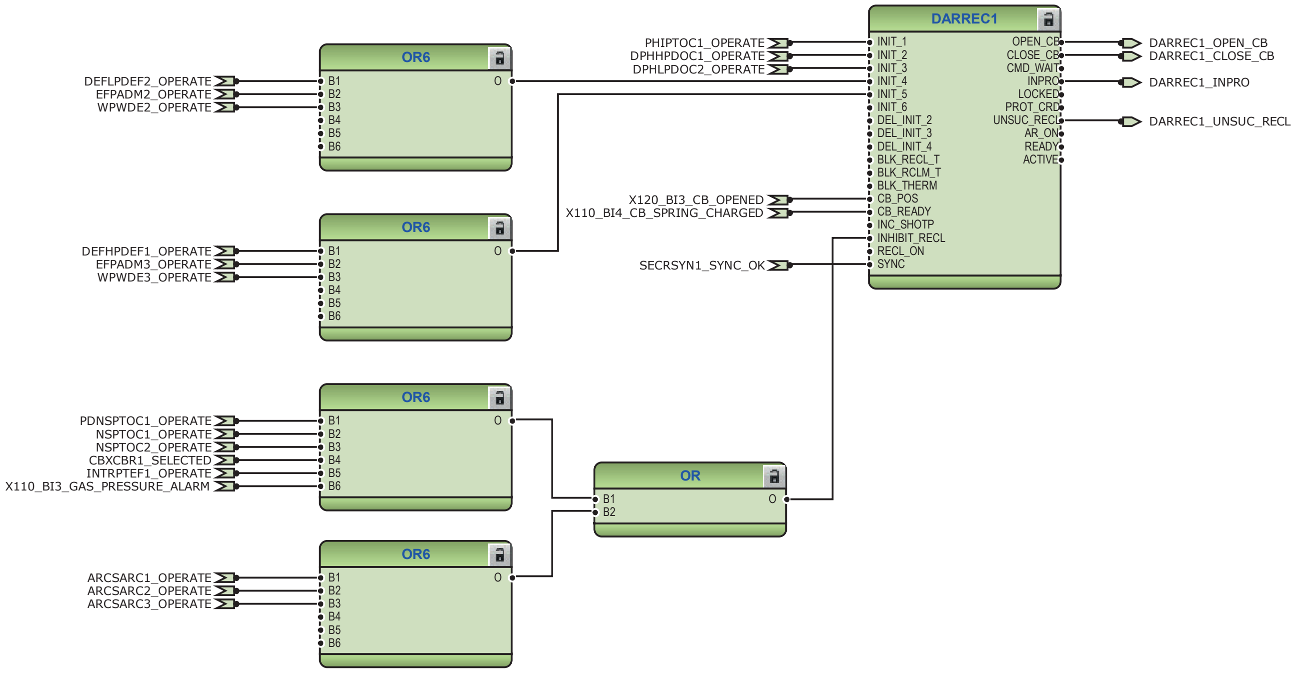


Figure 401: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV and negative-sequence overvoltage protection NSPTOV enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function. The activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

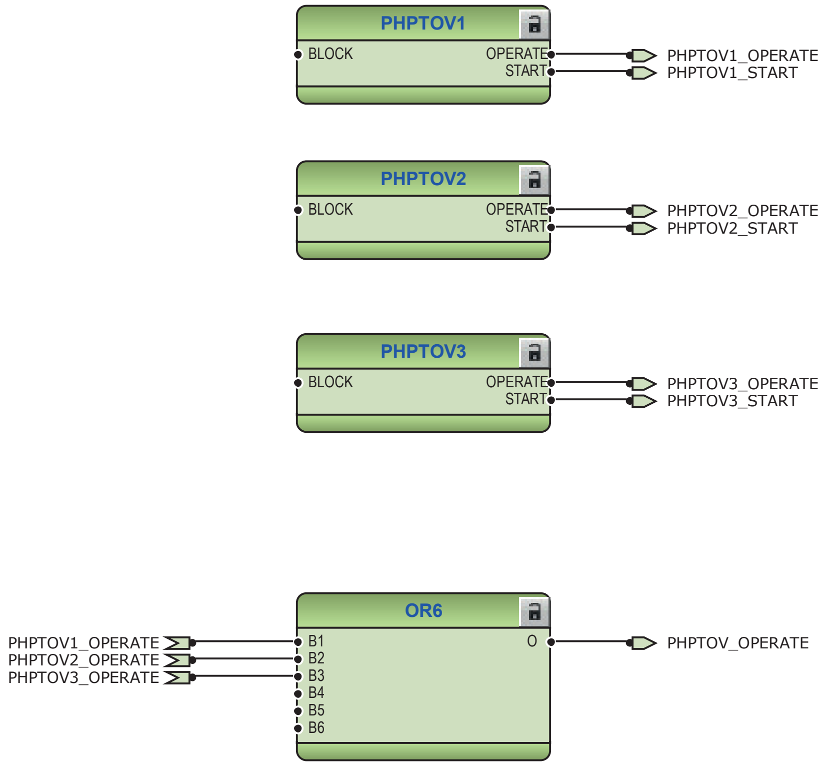


Figure 402: Overvoltage protection function

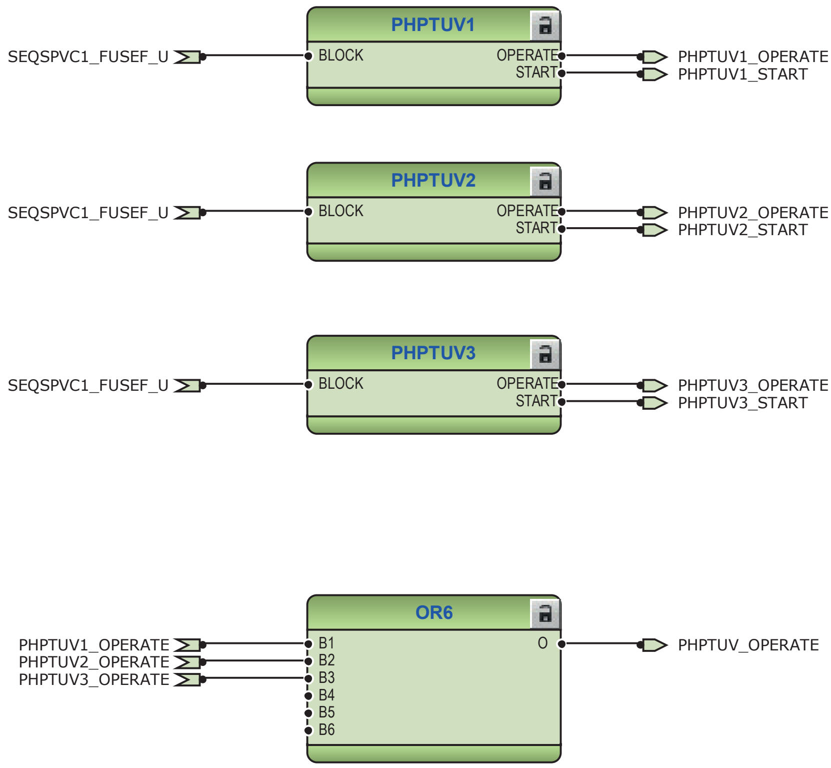


Figure 403: Undervoltage protection function

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.

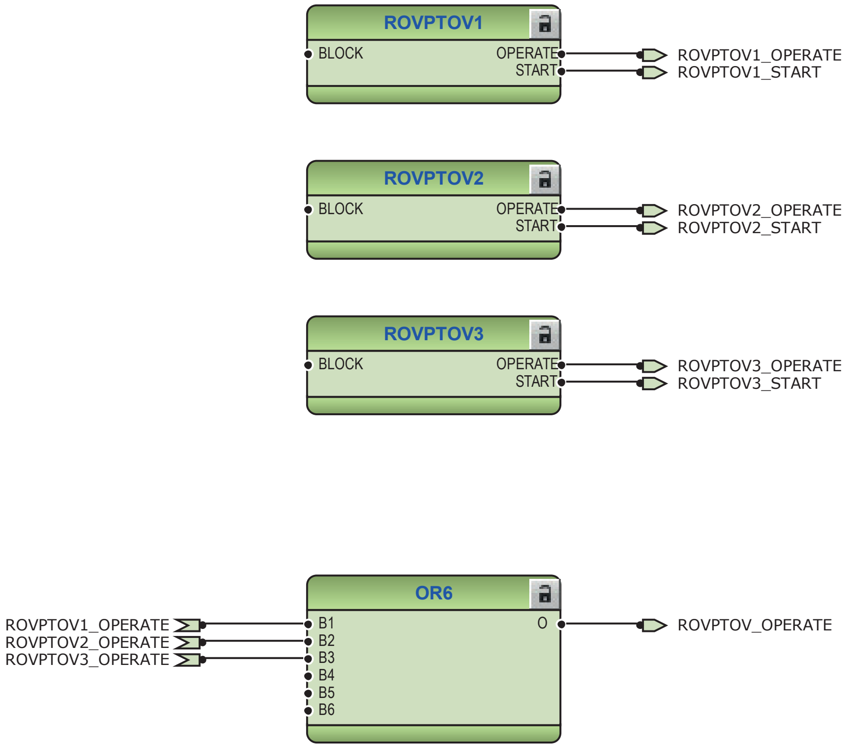


Figure 404: Residual overvoltage protection function

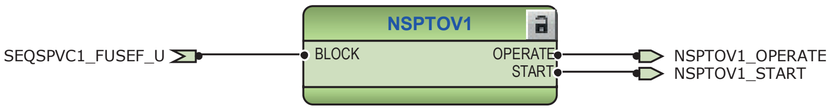


Figure 405: Negative-sequence overvoltage protection function

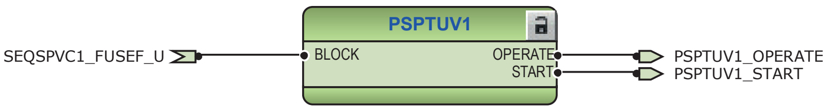


Figure 406: Positive-sequence undervoltage protection function

The selectable under-frequency or over-frequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system.

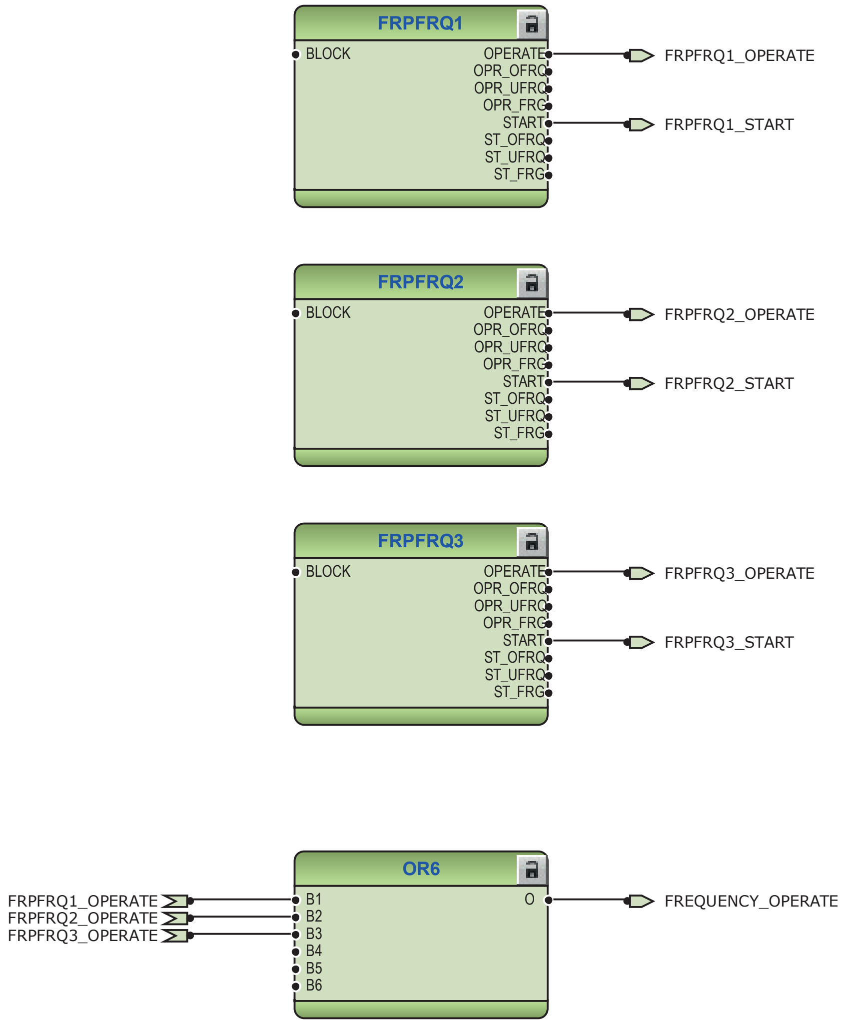


Figure 407: Frequency protection function

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

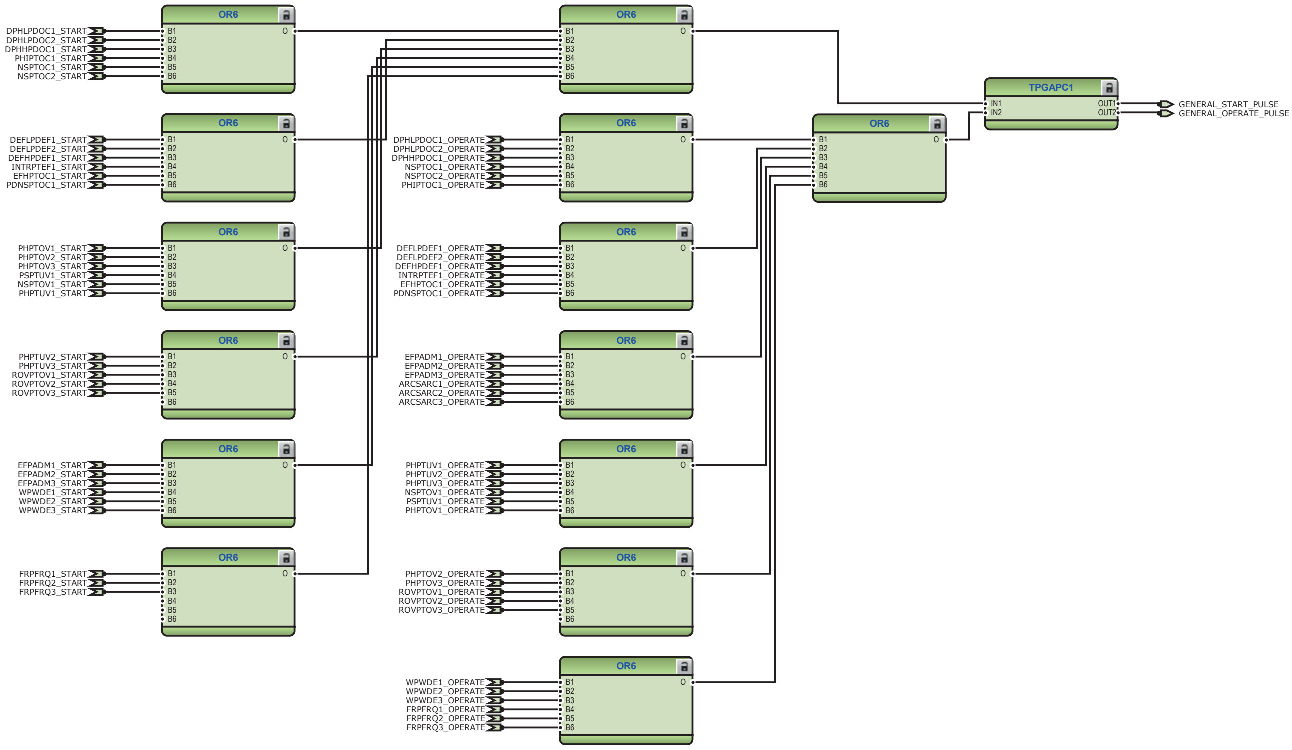


Figure 408: General start and operate signals

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 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

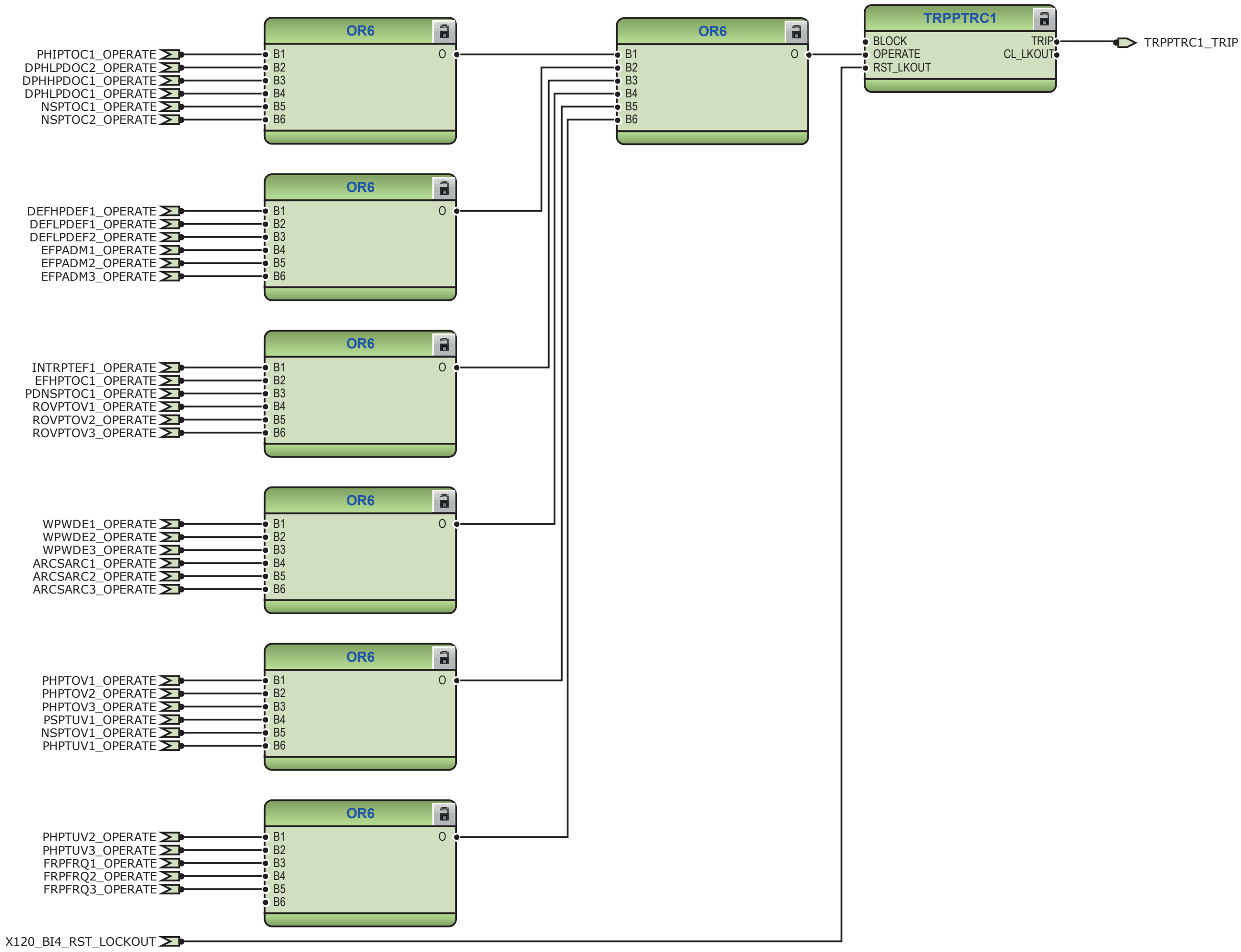


Figure 409: Trip logic TRPPTRC1

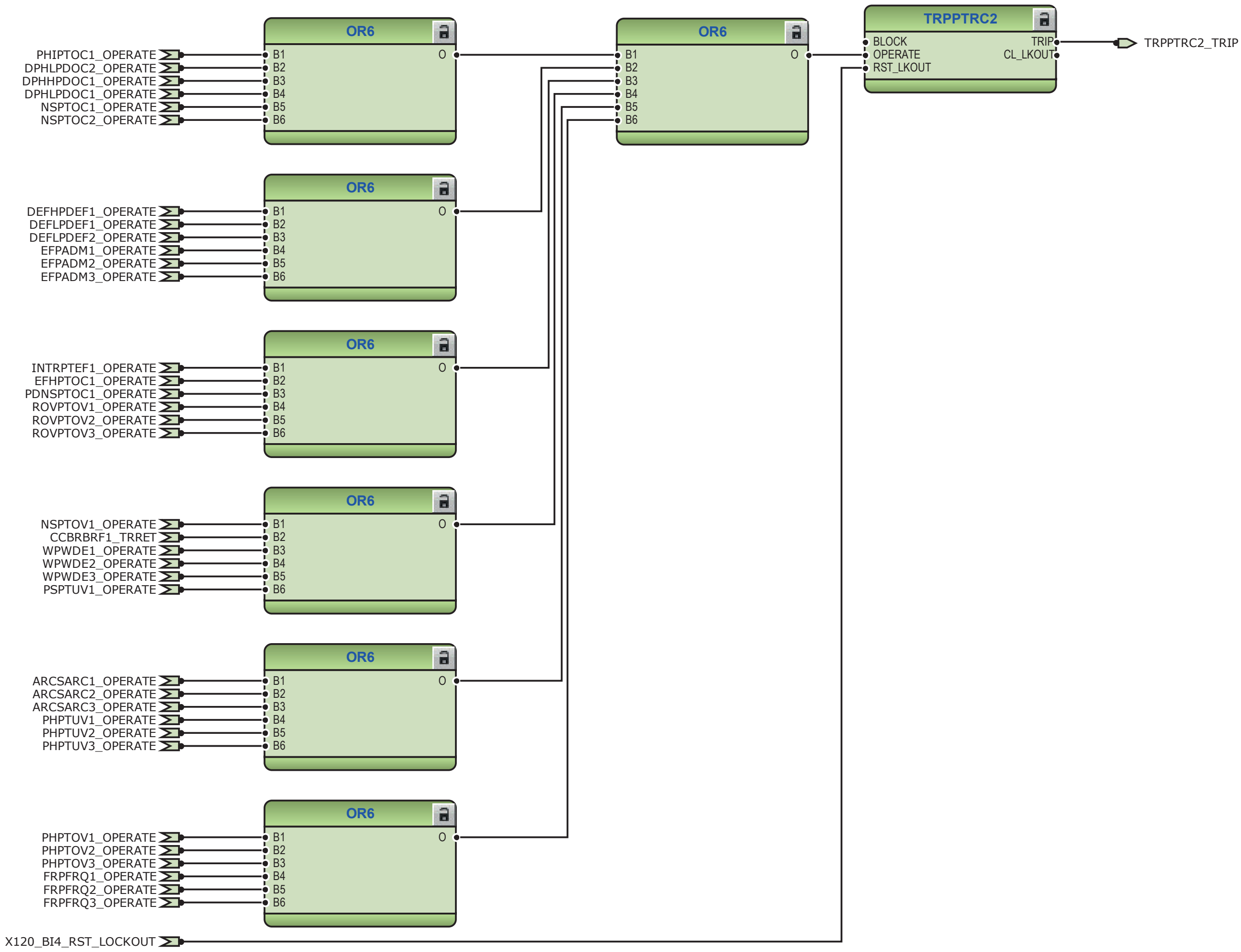


Figure 410: Trip logic TRPPTRC1

3.11.3.2 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 the different functions and the few binary inputs are also connected to the disturbance recorder.

The disturbance recorder main application sheet contains the disturbance recorder function block and the connections to variables.

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

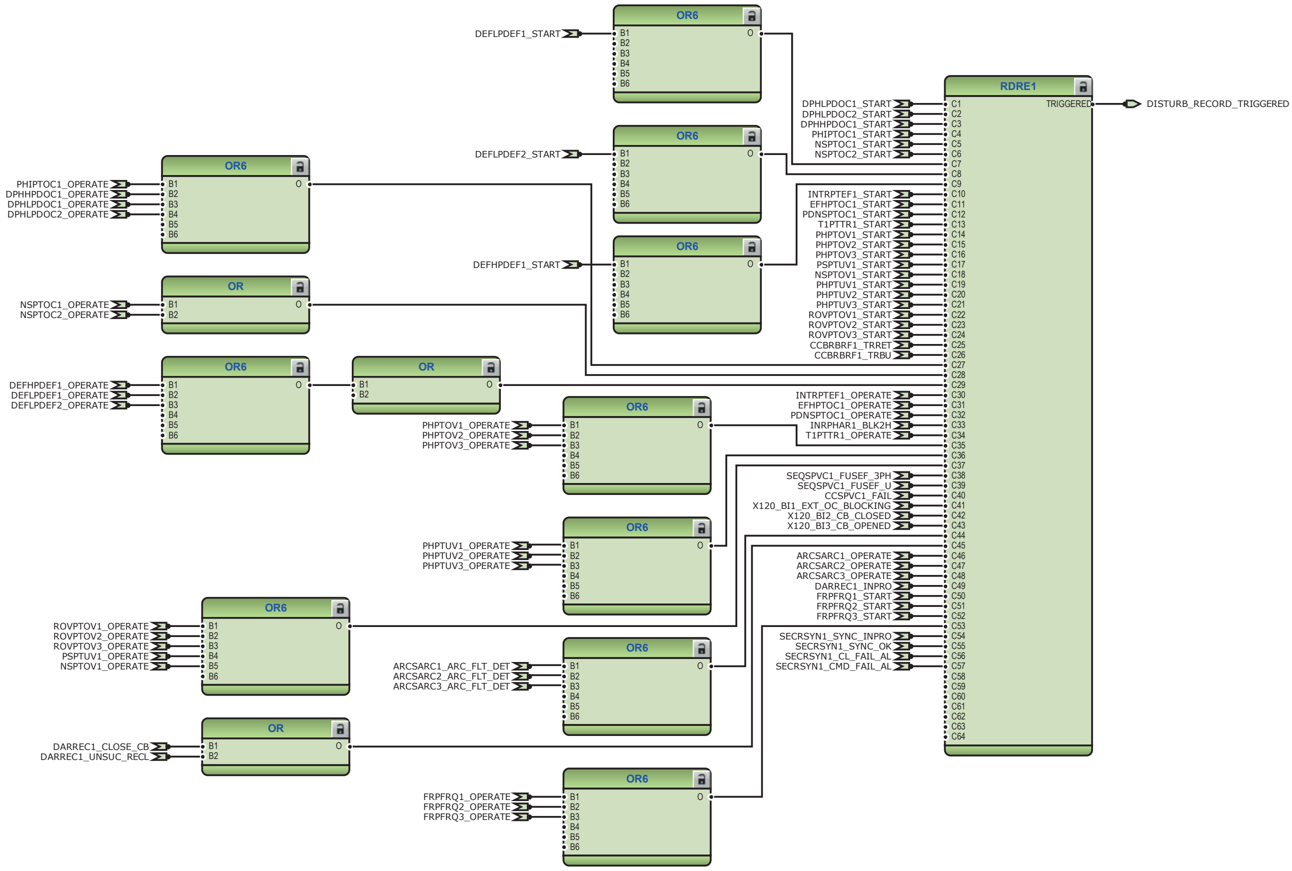


Figure 411: Disturbance recorder

3.11.3.3 Functional diagrams for condition monitoring

Failures in current measuring circuits are detected by CCSPVC1. When a failure is detected, it can be used to block the current protection functions that measure the calculated sequence component currents to avoid unnecessary operation. However, it is not connected in the configuration.

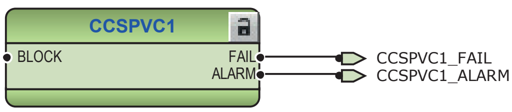


Figure 412: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

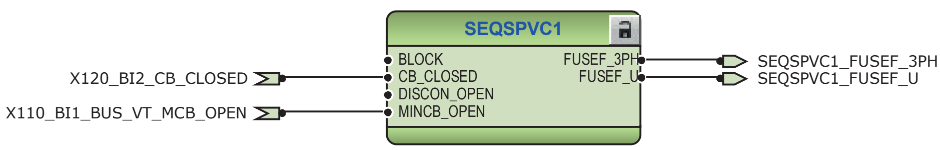


Figure 413: Fuse failure supervision function

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.

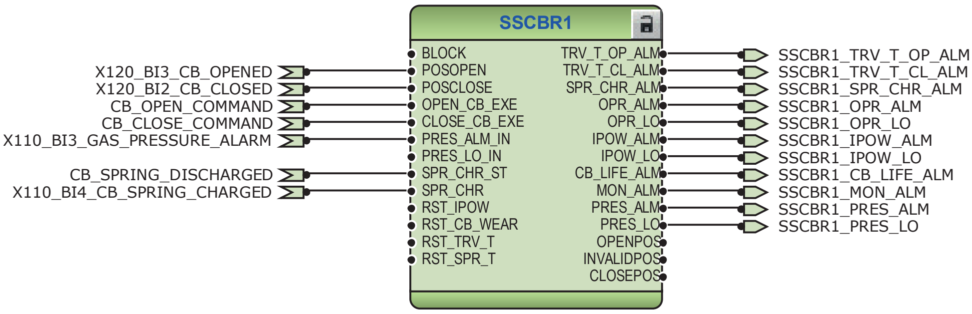


Figure 414: Circuit-breaker condition monitoring function

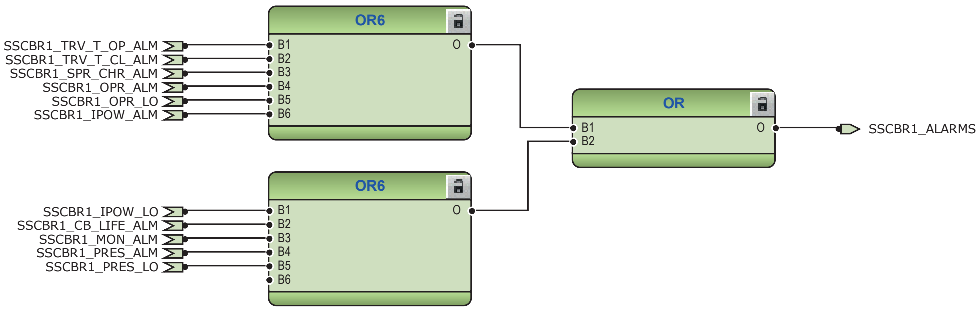


Figure 415: Logic for circuit-breaker monitoring alarm

Figure 416: 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.

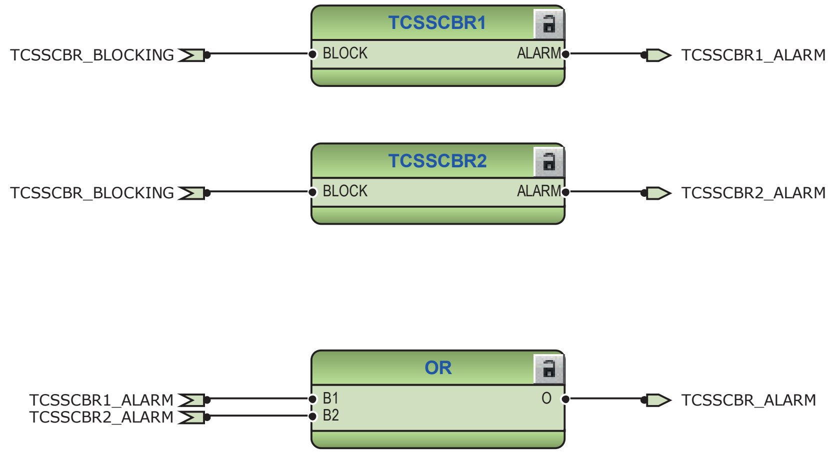


Figure 417: Trip circuit supervision function

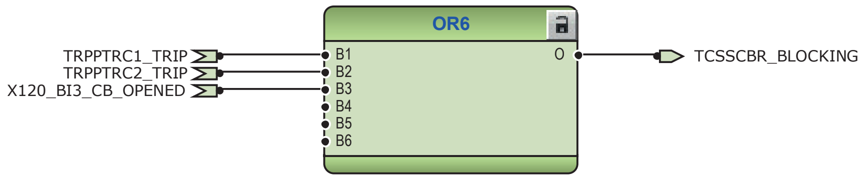


Figure 418: Logic for blocking trip circuit supervision

3.11.3.4 Functional diagrams for control and interlocking

The main purpose of the synchronism and energizing check SECRSYN is to provide control over the closing of the circuit breakers in power networks to prevent the closing, if conditions for synchronism are not detected. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN measures the bus and line voltages and compares them to set conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for allowing closing or closing the circuit breaker. The `SYNC_OK` output signal of SECRSYN is connected to `ENA_CLOSE` input of CBXCBR through control logic. The function is blocked in case if line side or bus side MCB is open.

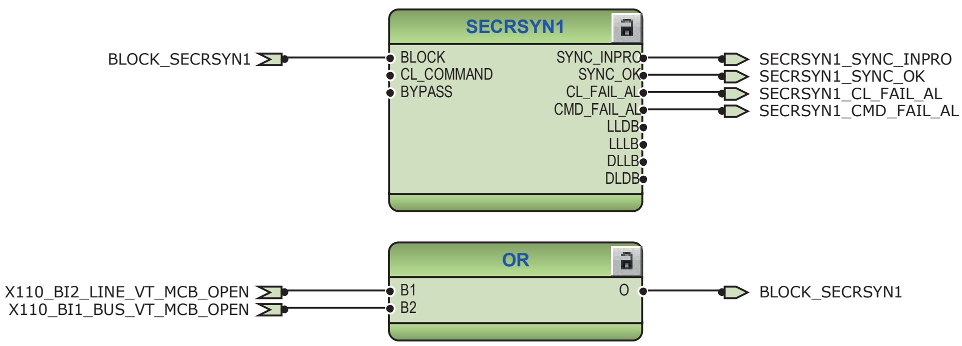


Figure 419: Synchrocheck function

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.

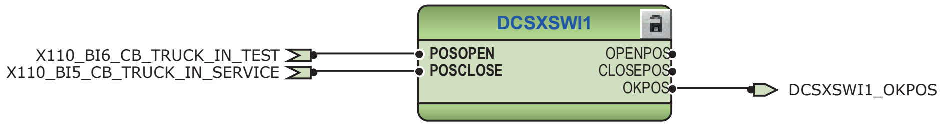


Figure 420: Disconnector control logic

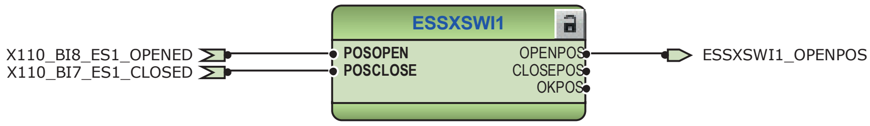


Figure 421: Earth switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm, circuit-breaker spring charging and synchronizing ok status.

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

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

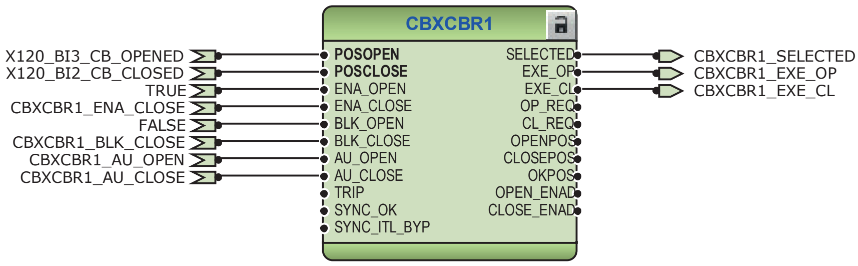


Figure 422: Circuit breaker 1 control logic

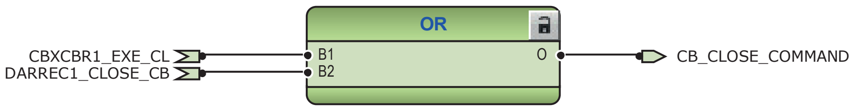


Figure 423: Signals for closing coil of circuit breaker 1

Figure 424: Signals for opening coil of circuit breaker 1

Connect the additional signals by the application for closing of circuit breaker.

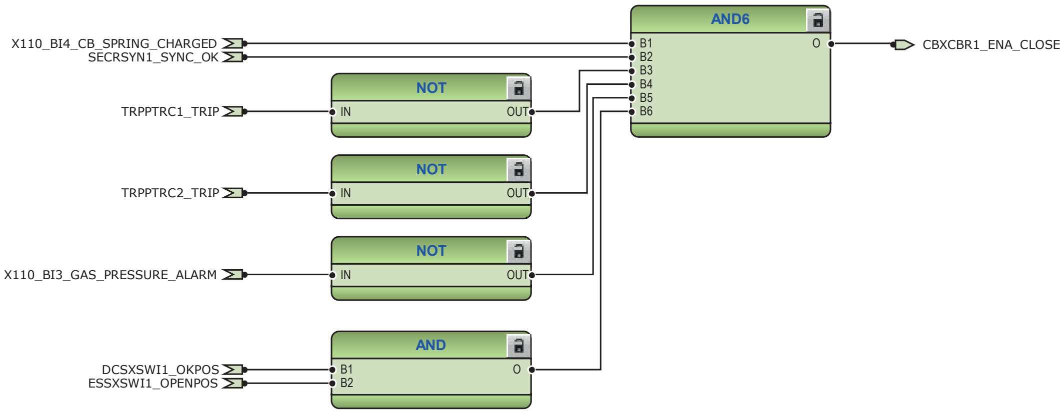


Figure 425: Circuit breaker 1 close enable logic

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

Figure 426: 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 additional signals for closing and opening of circuit breaker in local or remote mode, if applicable for the application.

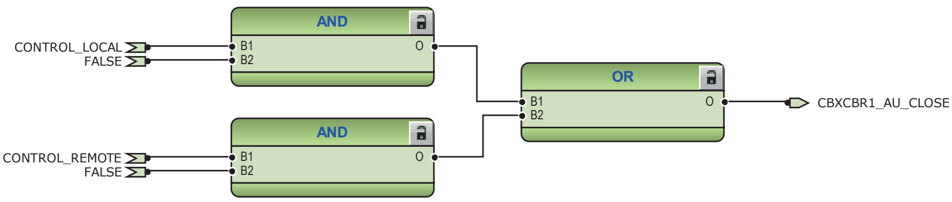


Figure 427: External closing command for circuit breaker 1

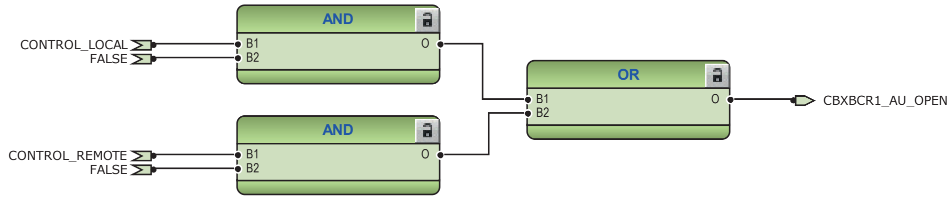


Figure 428: External opening command for circuit breaker 1

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

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

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

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 needed logic connections can be made by PCM600.

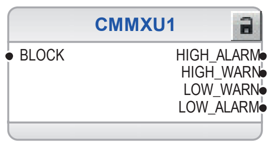


Figure 429: Current measurement: Three-phase current measurement

Figure 430: Current measurement: Sequence current measurement

Figure 431: Current measurement: Residual current measurement

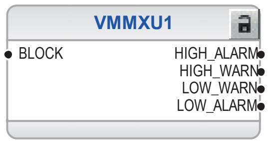


Figure 432: Voltage measurement: Three-phase voltage measurement

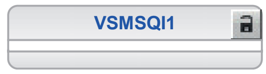


Figure 433: Voltage measurement: Sequence voltage measurement

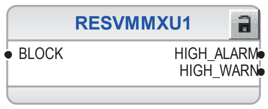


Figure 434: Voltage measurement: Residual voltage measurement

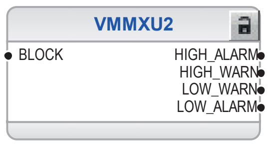


Figure 435: Voltage measurement: Three-phase voltage measurement

Figure 436: Other measurement: Frequency measurement

Figure 437: Other measurement: Three-phase power and energy measurement

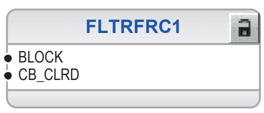


Figure 438: Other measurement: Data monitoring

Figure 439: Other measurement: Load profile record

3.11.3.6 Functional diagrams for I/O and alarm LEDs

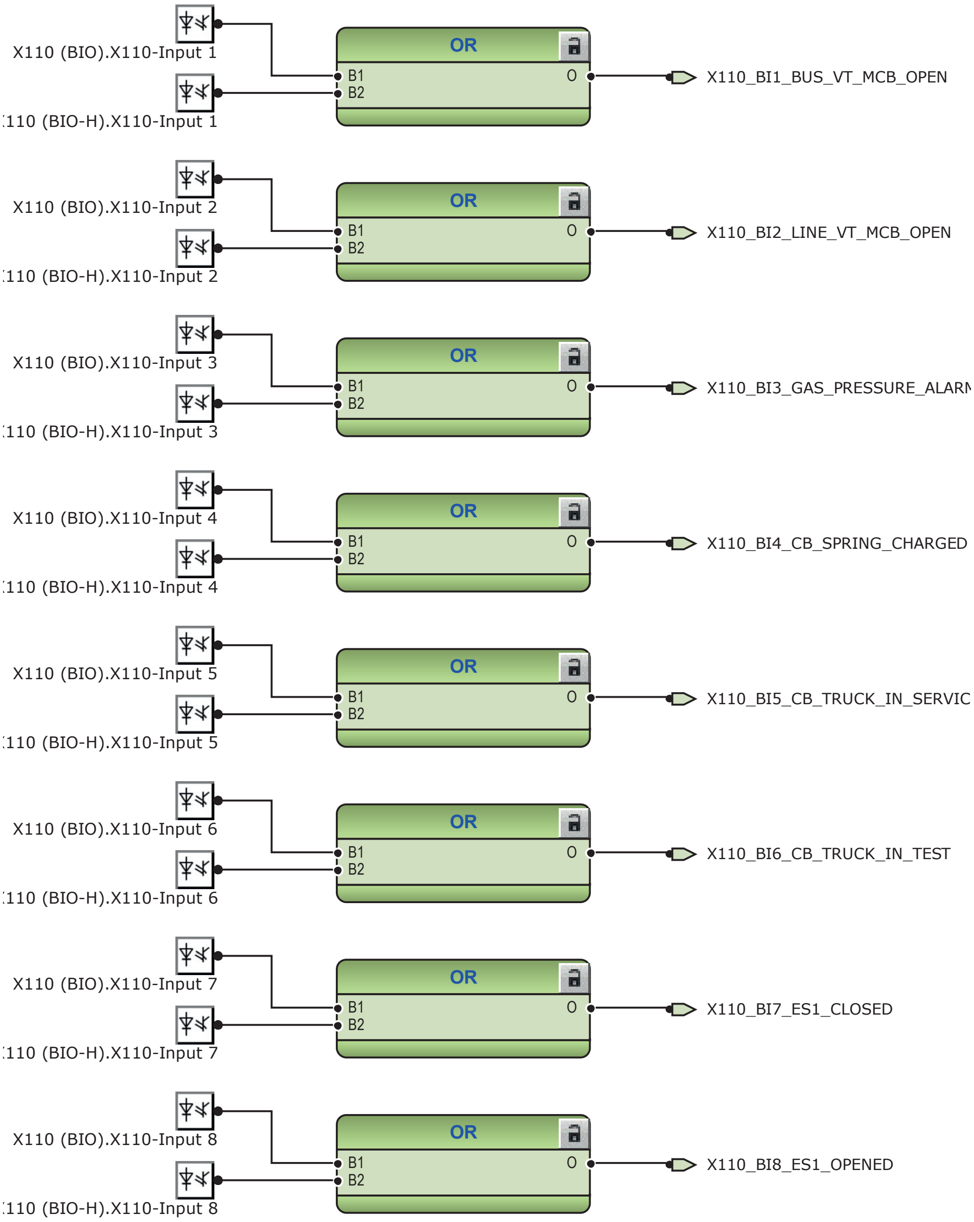


Figure 440: Default binary inputs - X110

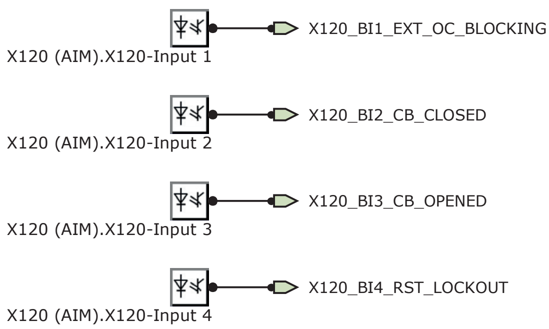


Figure 441: Default binary inputs - X120

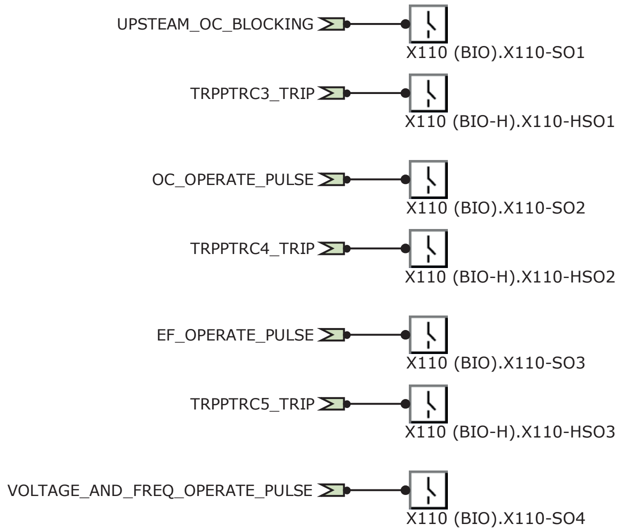


Figure 442: Default binary outputs - X110

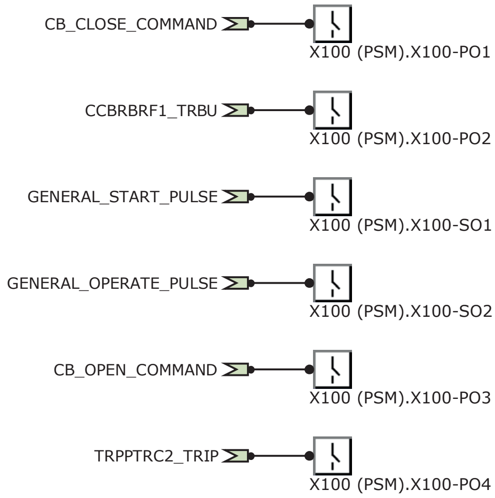
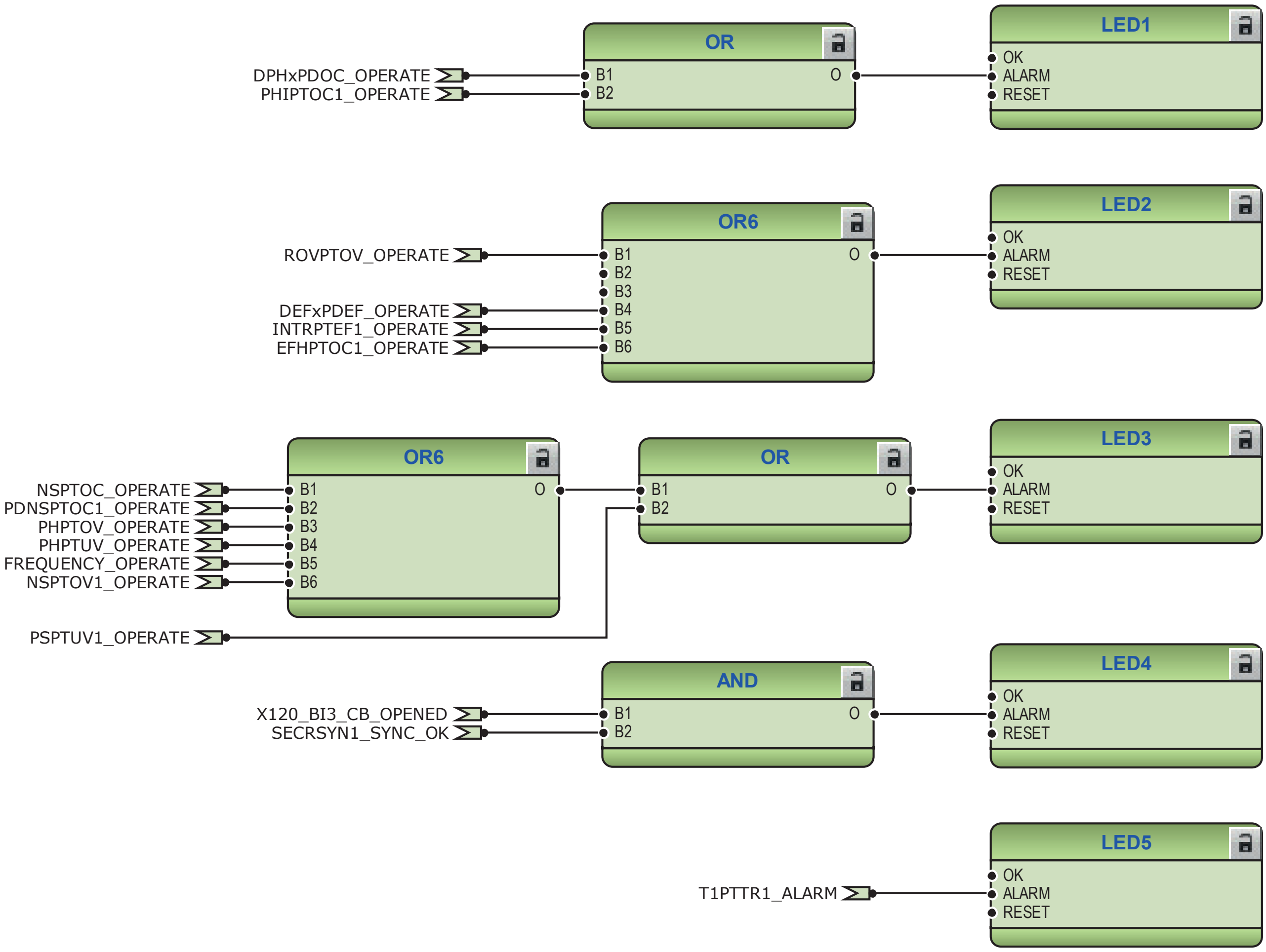


Figure 443: Default binary outputs - X100

The LED main application sheet contains programmable LED function blocks with initialization logic. If any LED function block is missing, insert it from the object library.


OR
DPHxPDOC_OPERATE
PHIPTOC1_OPERATE
B1
B2
O
LED1
OK
ALARM
RESET
OR6
ROVPTOV_OPERATE
DEFxPDEF_OPERATE
INTRPTEF1_OPERATE
EFHPTOC1_OPERATE
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
OR6
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
PHPTOV_OPERATE
PHPTUV_OPERATE
FREQUENCY_OPERATE
NSPTOV1_OPERATE
PSPTUV1_OPERATE
OR
LED3
OK
ALARM
RESET
AND
X120_BI3_CB_OPENED
SECRSYN1_SYNC_OK
LED4
OK
ALARM
RESET
LED5
T1PTTR1_ALARM
OK
ALARM
RESET

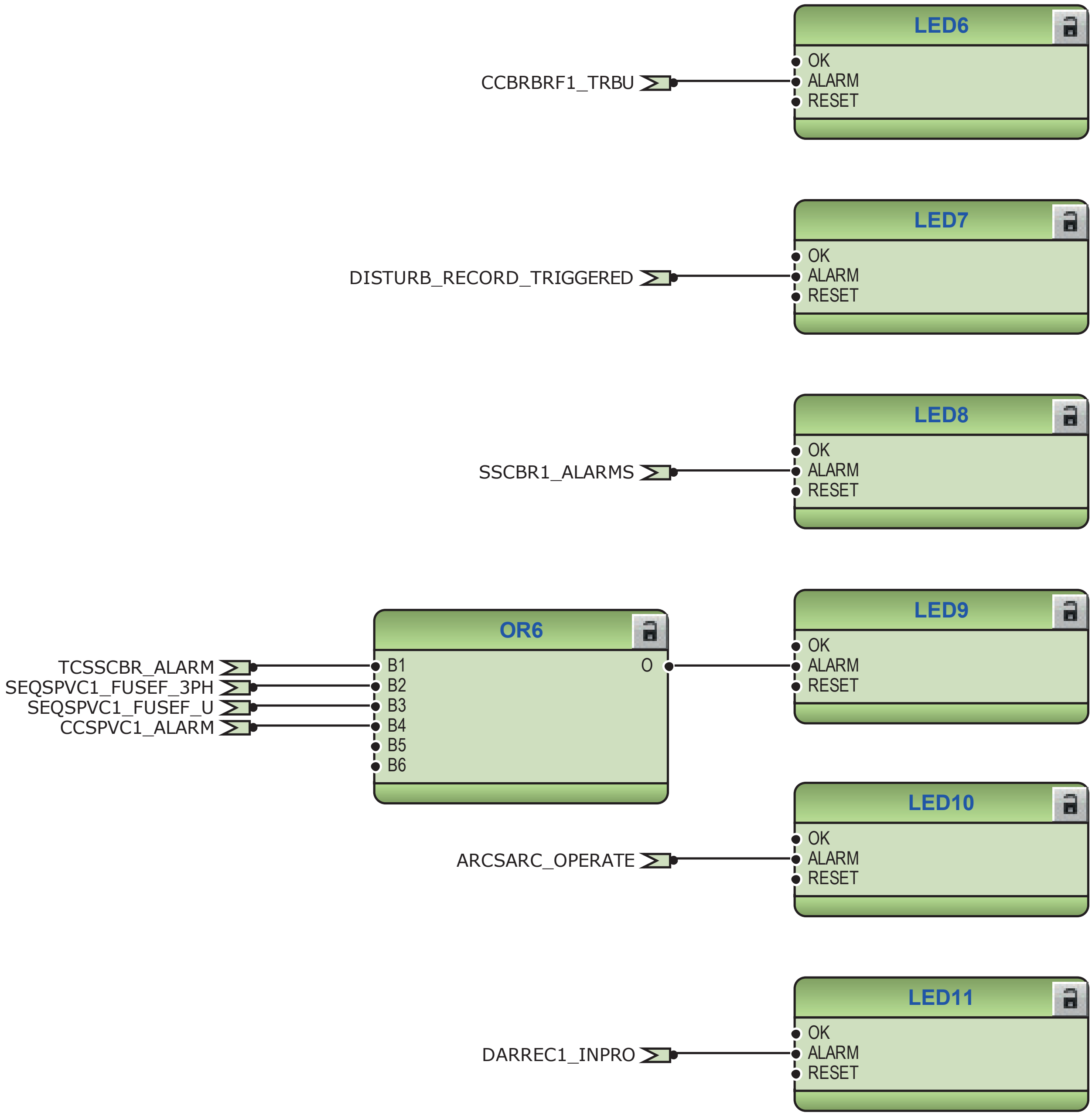


Figure 444: Default LED connections

3.11.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and combined voltage and frequency operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

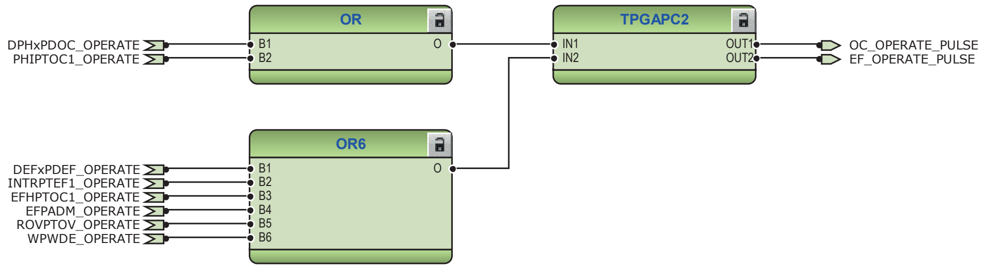


Figure 445: Timer logic for overcurrent and earth-fault operate pulse

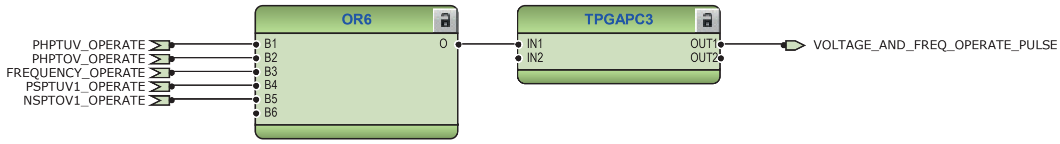


Figure 446: Timer logic for voltage and frequency operate pulse

3.11.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC, 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.

3.12 Standard configuration K

3.12.1 Applications

The standard configuration for directional overcurrent and directional earth-fault protection with phase voltage-based measurements, high-impendance restricted earth-fault protection, undervoltage and overvoltage protection, frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in isolated or resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance, wattmetric or harmonic-based 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.

3.12.2 Functions

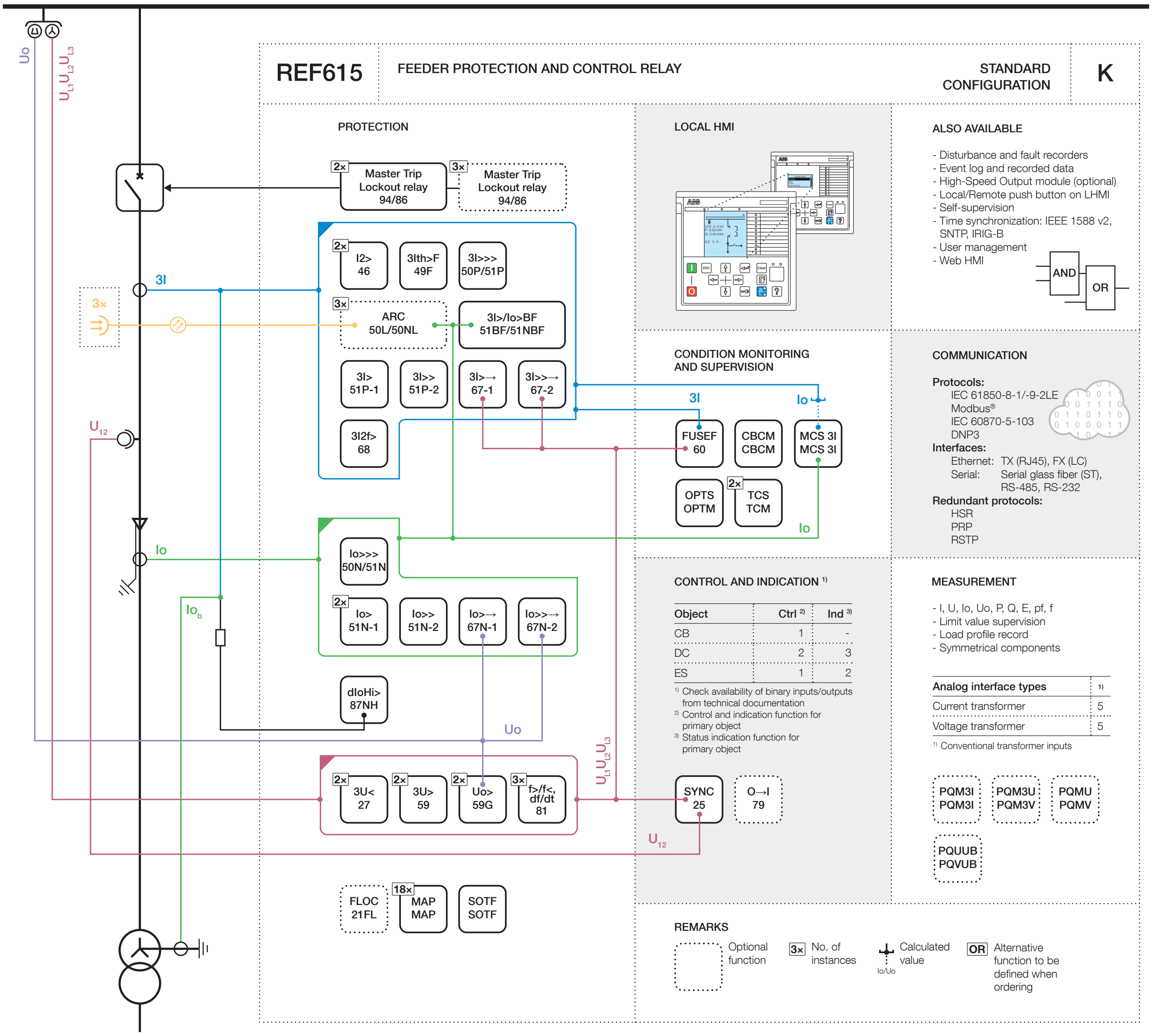


Figure 447: Functionality overview for standard configuration K

3.12.2.1 Default IO connections

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

Table 56: Default connections for binary inputs

Binary input	Description
X110-BI1	Busbar VT secondary MCB open
X110-BI2	Line VT secondary MCB open
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X130-BI1	Blocking of overcurrent instantaneous stage
X130-BI2	Circuit breaker closed position indication
X130-BI3	Circuit breaker open position indication
X130-BI4	Lock-out reset

Table 57: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2 or EFLPTOC2 operated
X110-SO1	–
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-SO4	Voltage or frequency protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 58: Default connections for LEDs

LED	Description
1	Overcurrent protection operate
2	Earth-fault protection operate

Table continues on the next page

LED	Description
3	Combined protection operation indication
4	Synchronism or energizing check Ok
5	Frequency protection operated
6	Circuit breaker failure protection operated
7	Disturbance recorder triggered
8	High impedance restricted earth-fault protection operated
9	Circuit breaker condition monitoring or supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.12.2.2 Default disturbance recorder settings

Table 59: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	IoB
6	Uo
7	U1
8	U2
9	U3
10	U1B
11	–
12	–

Table 60: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHIPTOC1 - start	Positive or Rising
4	DPHLPDOC1 - start	Positive or Rising
5	DPHHPDOC1 - start	Positive or Rising
6	NSPTOC1 - start	Positive or Rising
7	NSPTOC2 - start	Positive or Rising
8	EFLPTOC1 - start	Positive or Rising
9	EFLPTOC2 - start	Positive or Rising
10	EFHPTOC1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
11	EFIPTOC1 - start	Positive or Rising
12	DEFLPDEF1 - start	Positive or Rising
13	DEFHPDEF1 - start	Positive or Rising
14	T1PTTR1 - start	Positive or Rising
15	PHPTOV1 - start	Positive or Rising
16	PHPTOV2 - start	Positive or Rising
17	PHPTUV1 - start	Positive or Rising
18	PHPTUV2 - start	Positive or Rising
19	ROVPTOV1 - start	Positive or Rising
20	ROVPTOV2 - start	Positive or Rising
21	FRPFRQ1 - start	Positive or Rising
22	FRPFRQ2 - start	Positive or Rising
23	FRPFRQ3 - start	Positive or Rising
24	HREFPDIF1 - start	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
28	DPHLPDOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
29	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
30	EFLPTOC1 - operate	Level trigger off
	EFLPTOC2 - operate	
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
31	DEFLPDEF1 - operate	Level trigger off
	DEFHPDEF1 - operate	
32	T1PTTR1 - operate	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off
34	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
35	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
36	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
37	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
38	SEQSPVC1 - fusef3ph	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
39	SEQSPVC1 - fusefu	Level trigger off
40	CCSPVC1 - fail	Level trigger off
41	X130BI1 - ext OC blocking	Level trigger off
42	X130BI2 - CB closed	Level trigger off
43	X130BI3 - CB opened	Level trigger off
44	SECRSYN1 - sync inpro	Level trigger off
45	SECRSYN1 - sync ok	Level trigger off
46	SECRSYN1 - cl fail al	Level trigger off
47	SECRSYN1 - cmd fail al	Level trigger off
48	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
49	ARCSARC1 - operate	Positive or Rising
50	ARCSARC2 - operate	Positive or Rising
51	ARCSARC3 - operate	Positive or Rising
52	DARREC1 - inpro	Level trigger off
53	DARREC1 - close CB	Level trigger off
54	DARREC1 - unsuc recl	Level trigger off

3.12.3 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.

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

3.12.3.1 Functional diagrams for protection

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

Five overcurrent stages are offered for overcurrent and short-circuit protection. Two of them include directional functionality DPHxPDOC. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1 can be blocked by energizing the binary input X130: BI1.

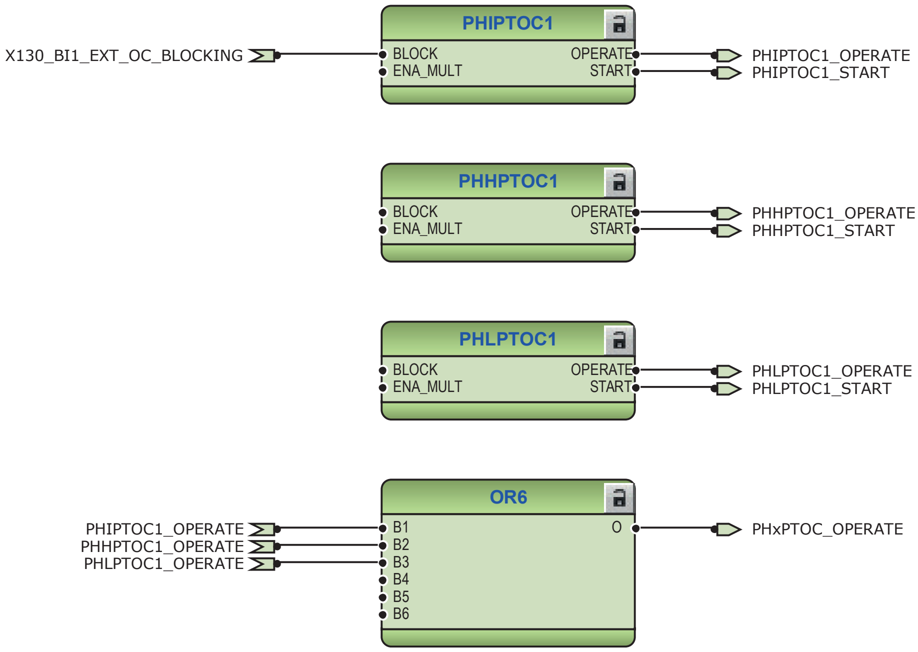


Figure 448: Overcurrent protection function

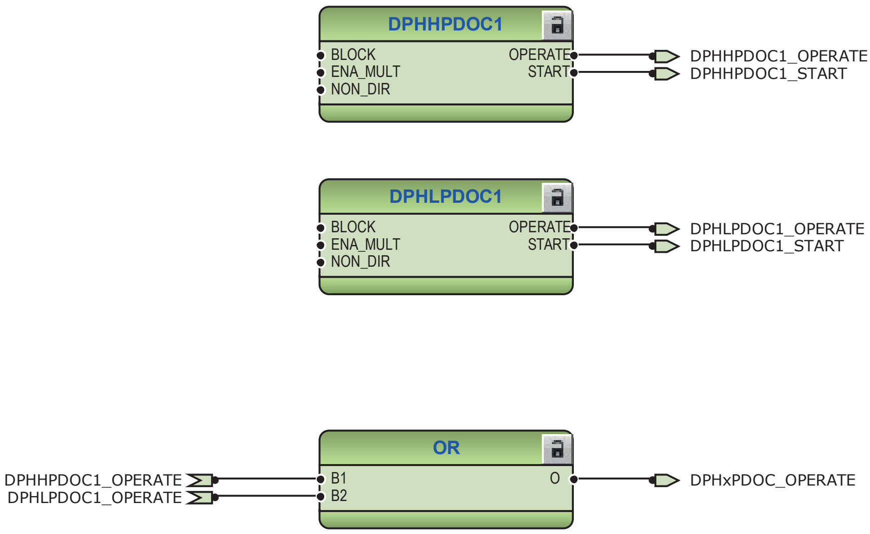


Figure 449: Directional overcurrent protection function

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

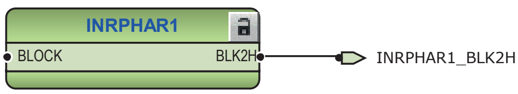


Figure 450: Inrush detector function

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 protections are blocked in case of detection in failure in secondary circuit of current transformer.

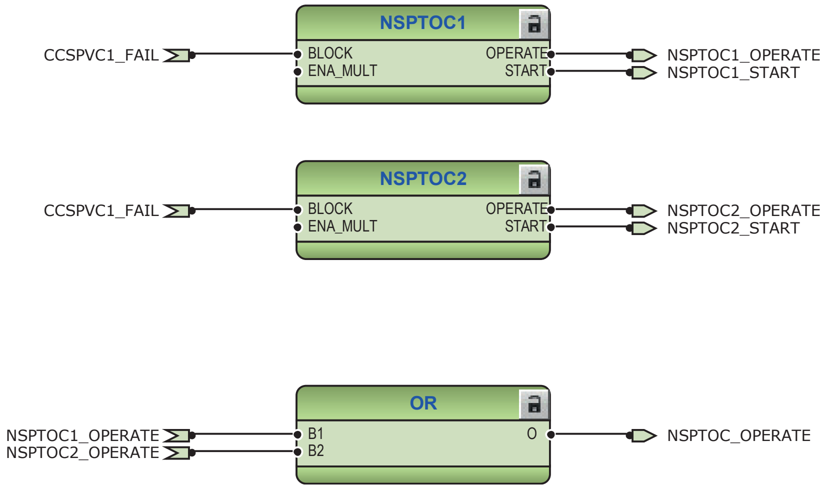


Figure 451: Negative-sequence overcurrent protection function

Six stages are provided for earth-fault protection. Two stages are dedicated for directional earth-fault protection. Apart from these earth-fault protection functions, configuration also includes a dedicated high impedance restricted earth-fault protection function.

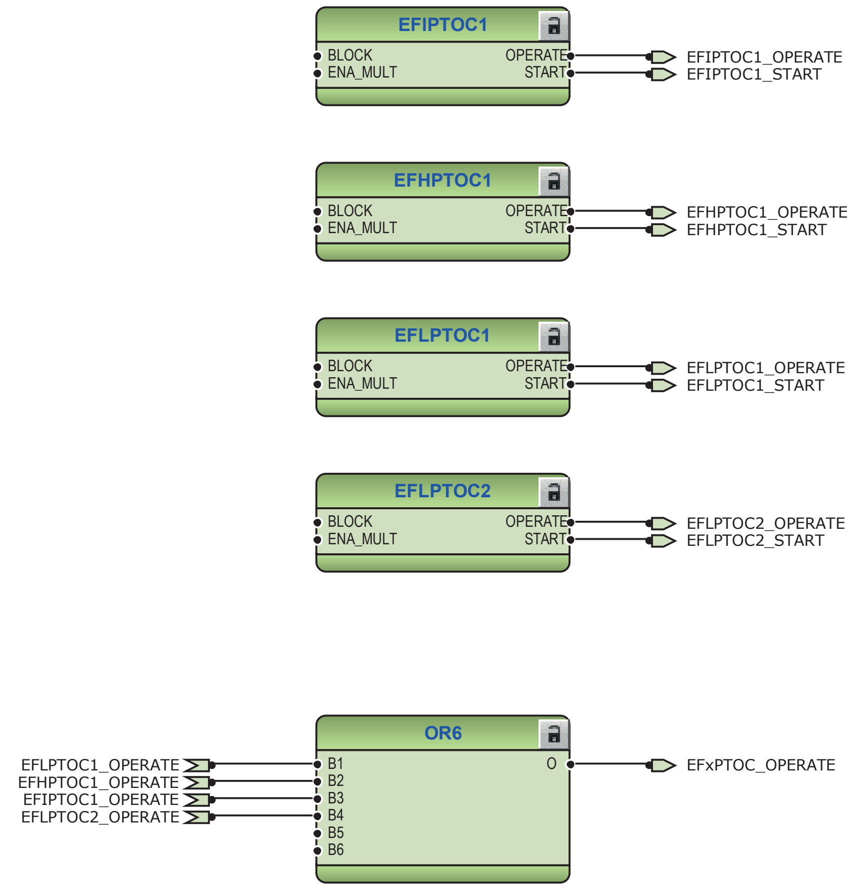


Figure 452: Earth-fault protection function

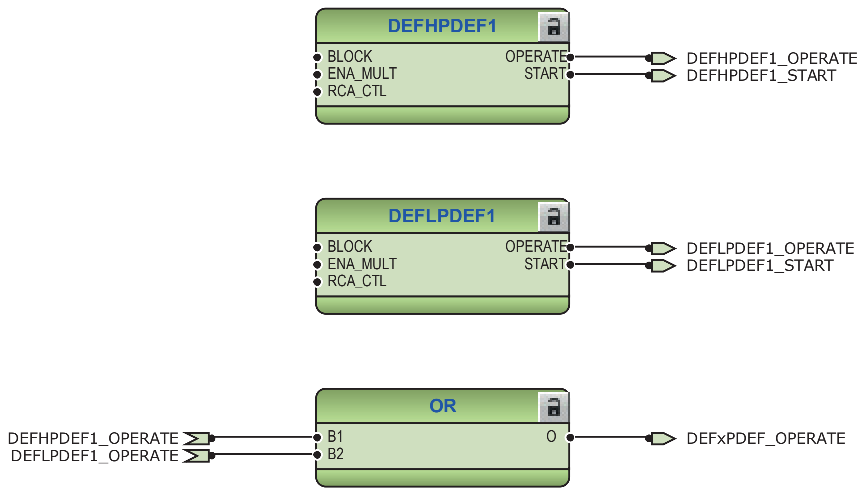


Figure 453: Directional overcurrent protection function

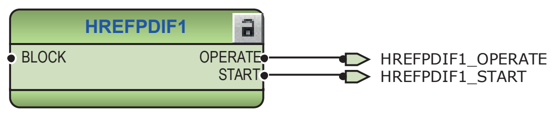


Figure 454: High impedance restricted earth-fault protection function

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

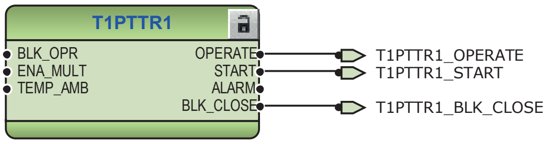


Figure 455: Thermal overcurrent protection function

Fault locator SCEFRFLO1 provides impedance-based fault location. Function is triggered by operation of non-directional overcurrent and earth-fault protection function. However the outputs of fault locator are not connected to any logic and those needs to be connected as per application need.

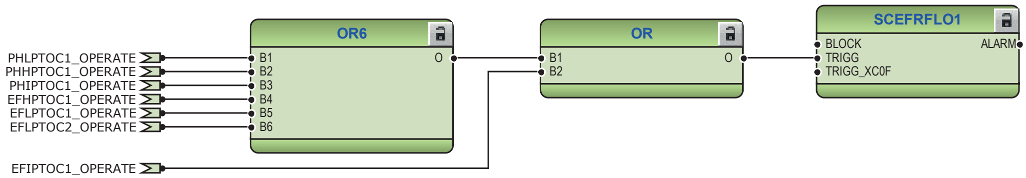


Figure 456: Fault locator function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The 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.

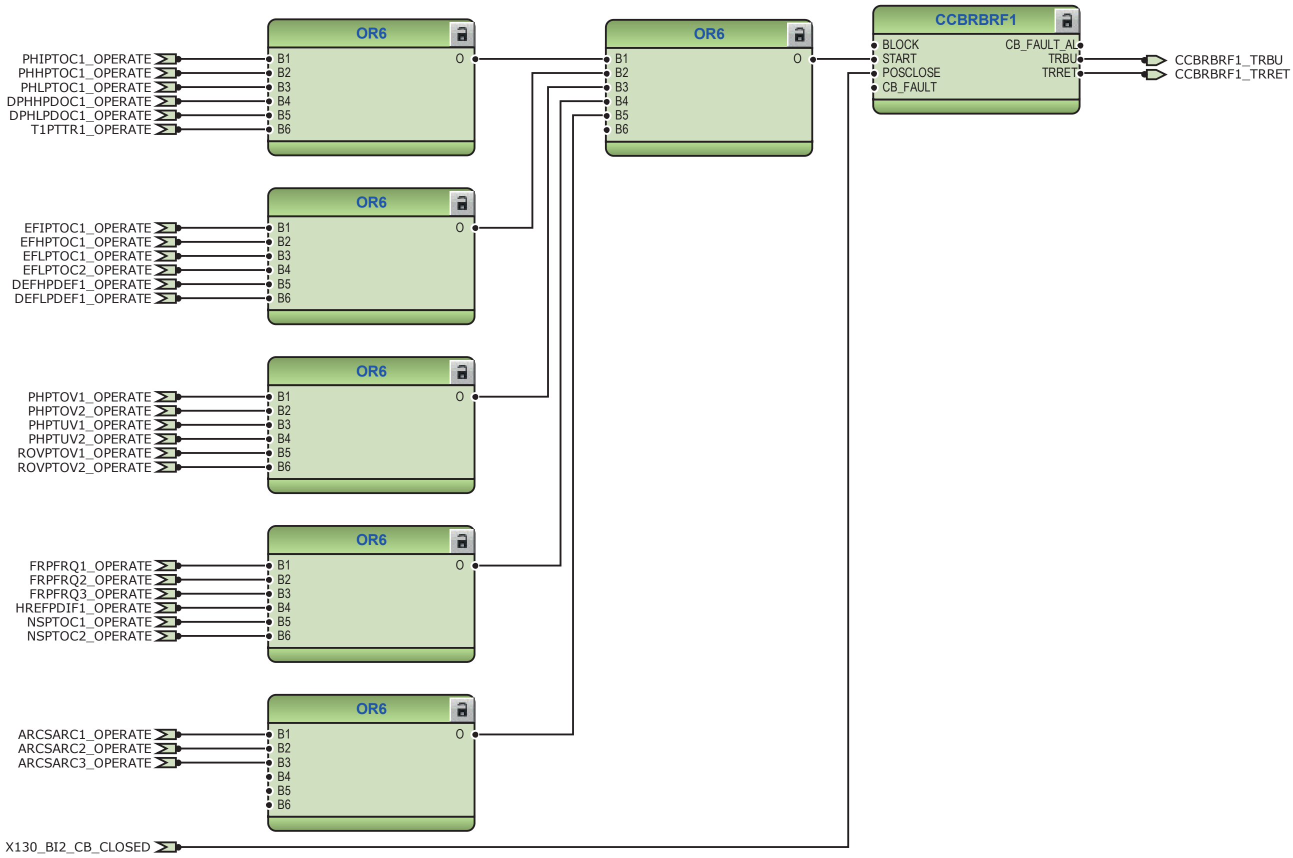


Figure 457: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

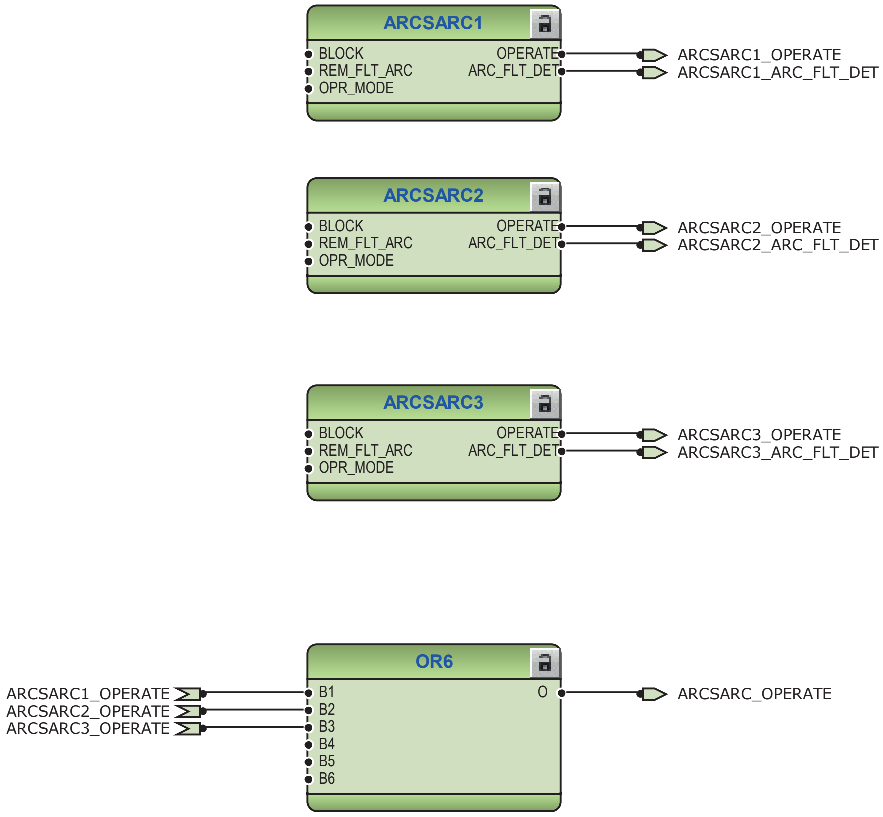


Figure 458: Arc protection function

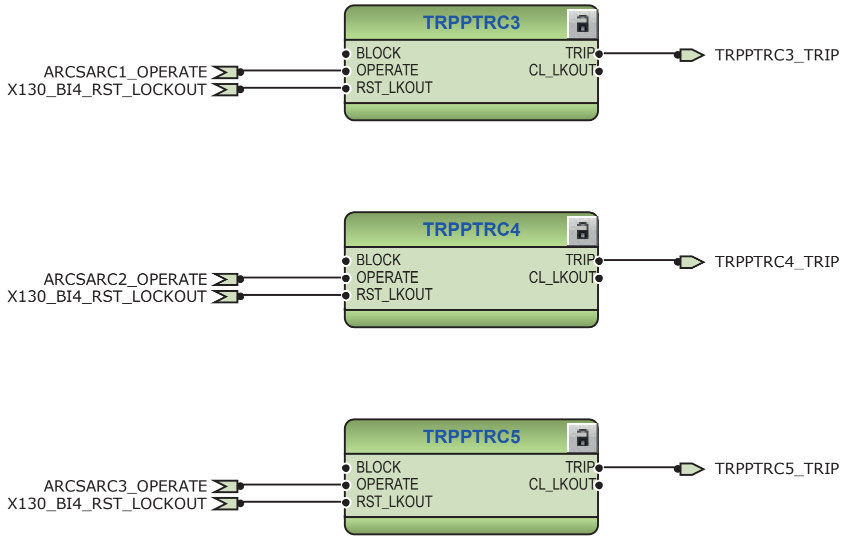


Figure 459: Arc protection with dedicated HSO

The optional autoreclosing function is configured to be initiated by operate signals from a number of protection stages through the `INIT_1...4` inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclosing function can be inhibited with the I `NHIBIT_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 autoreclosure 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.

Set the parameters for DARREC1 properly.

Check the initialization signals of the DARREC1.

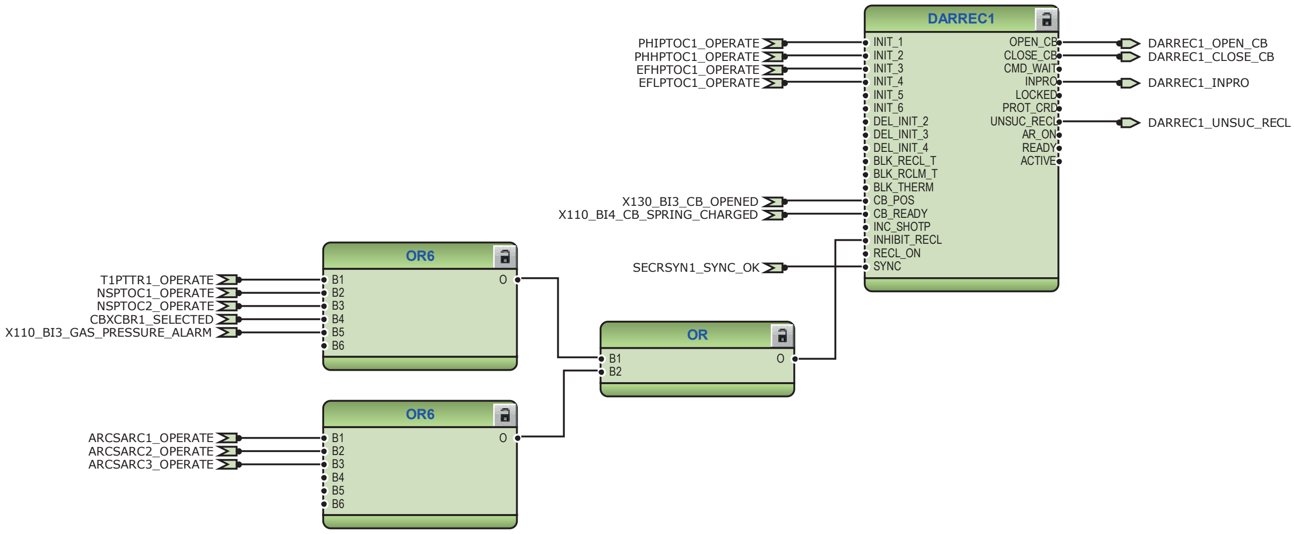


Figure 460: Autoreclosing function

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

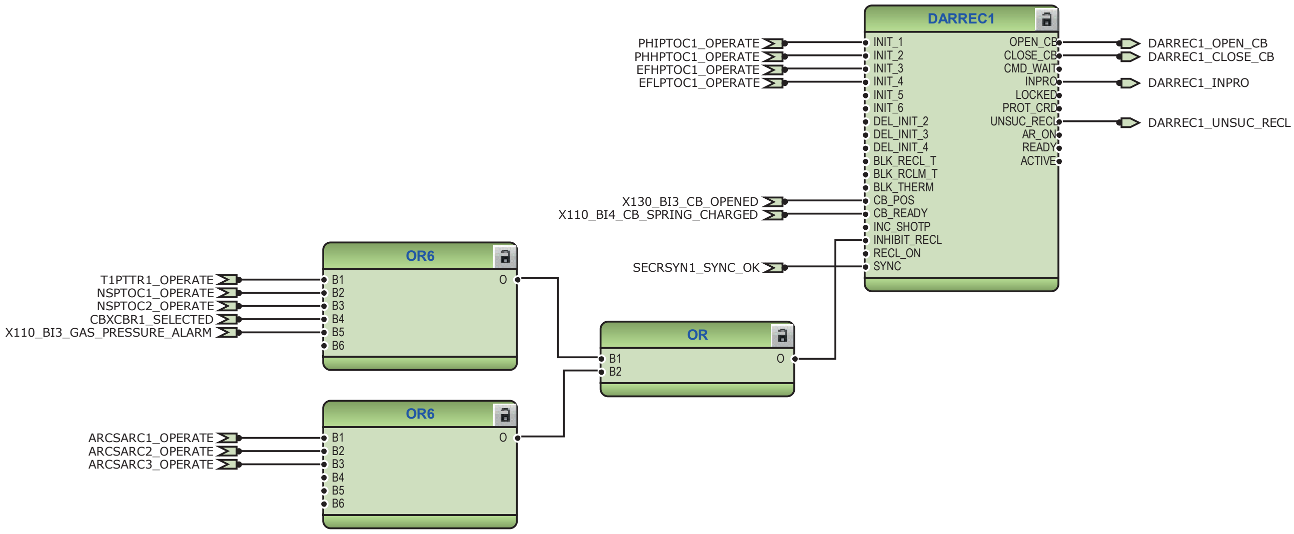


Figure 461: Overvoltage protection function

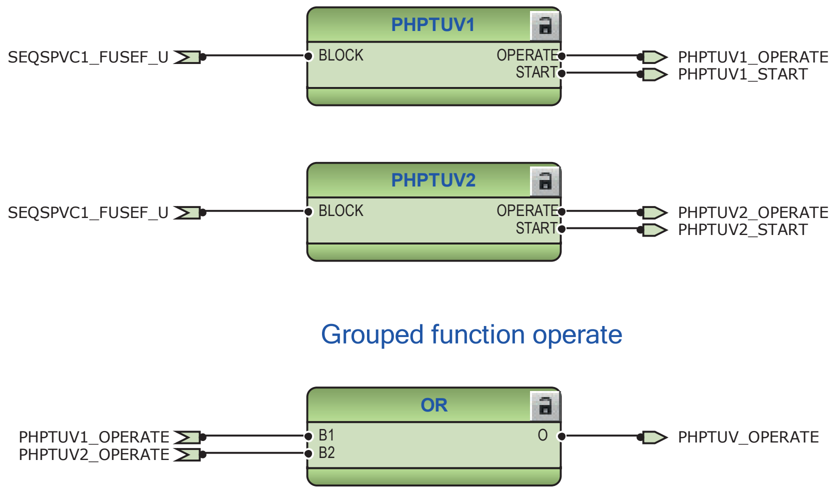


Figure 462: Undervoltage protection function

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 earth-fault functionality.

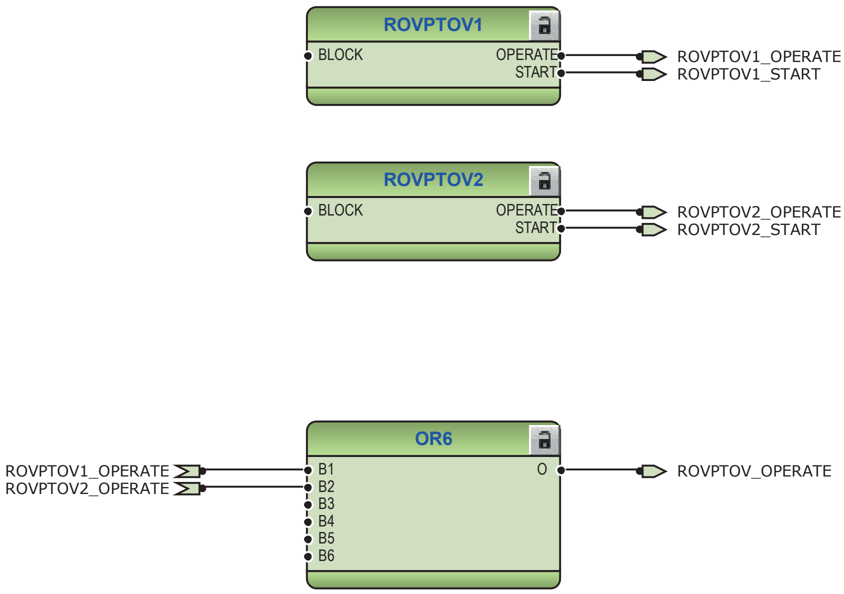


Figure 463: Residual voltage protection function

The selectable underfrequency or overfrequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system.

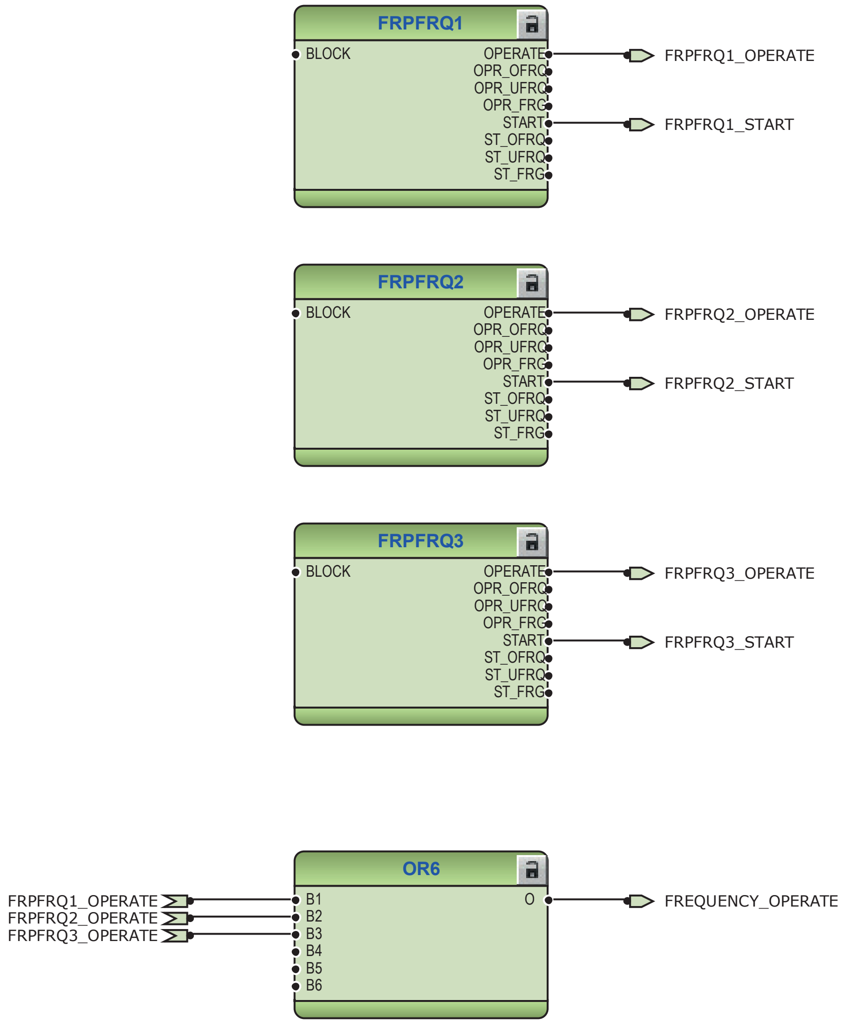


Figure 464: Frequency protection function

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

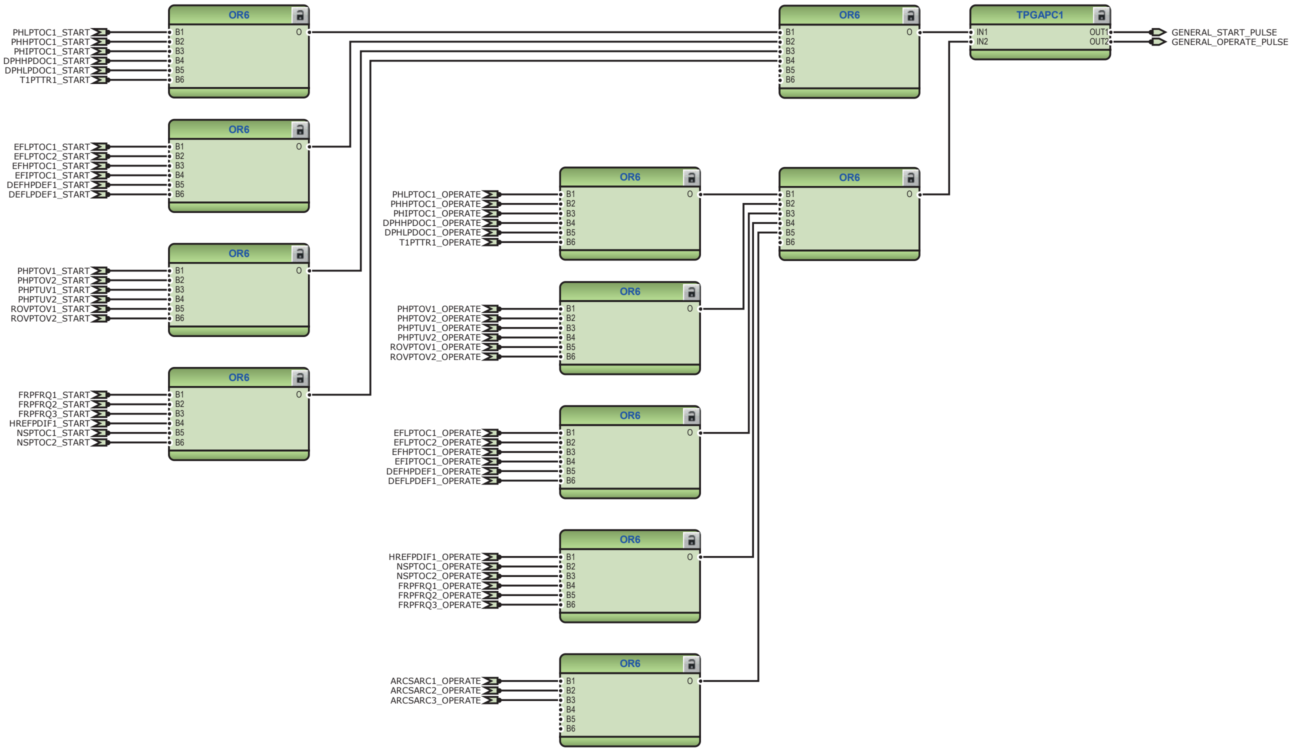


Figure 465: General start and operate signals

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 X130:BI4 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

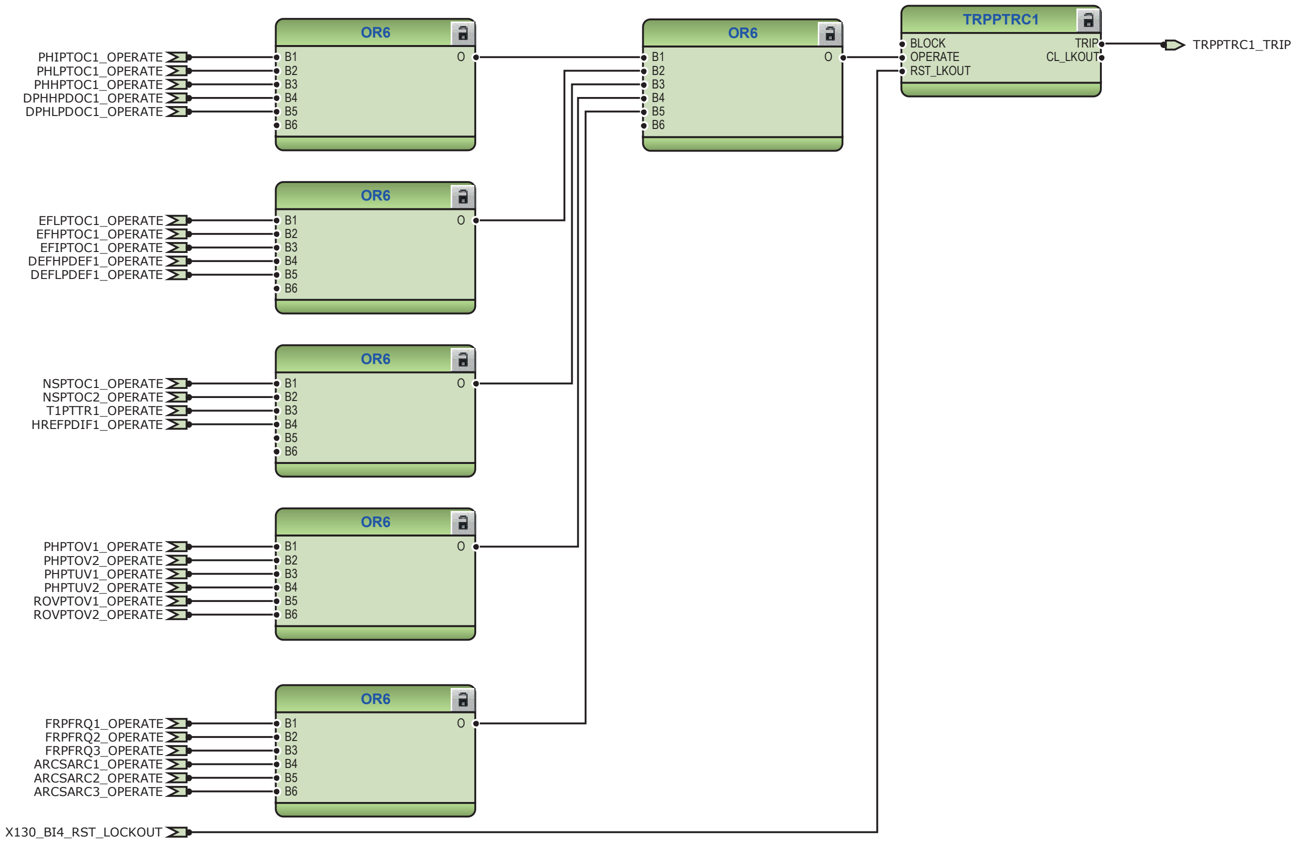


Figure 466: Trip logic TRPPTRC1

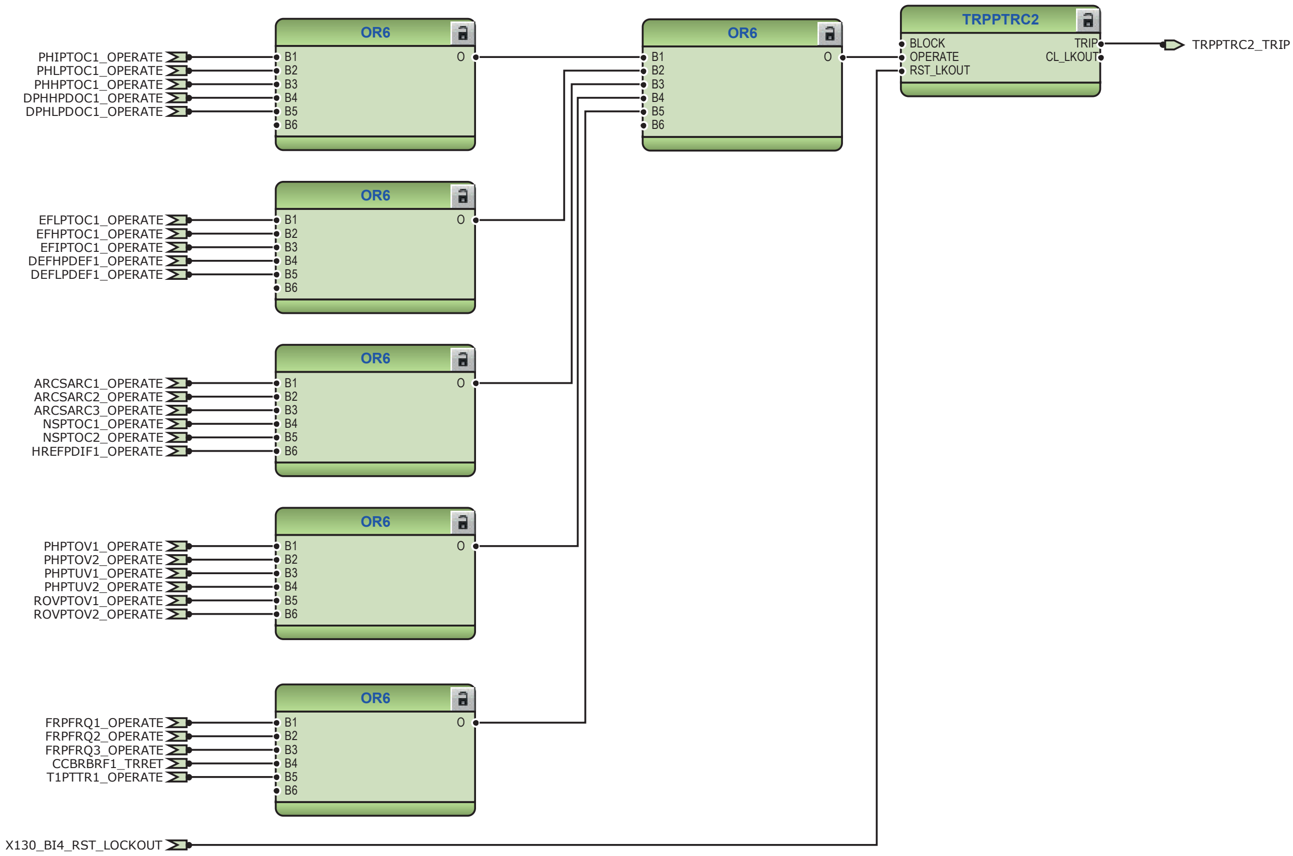


Figure 467: Trip logic TRPPTRC2

3.12.3.2 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.

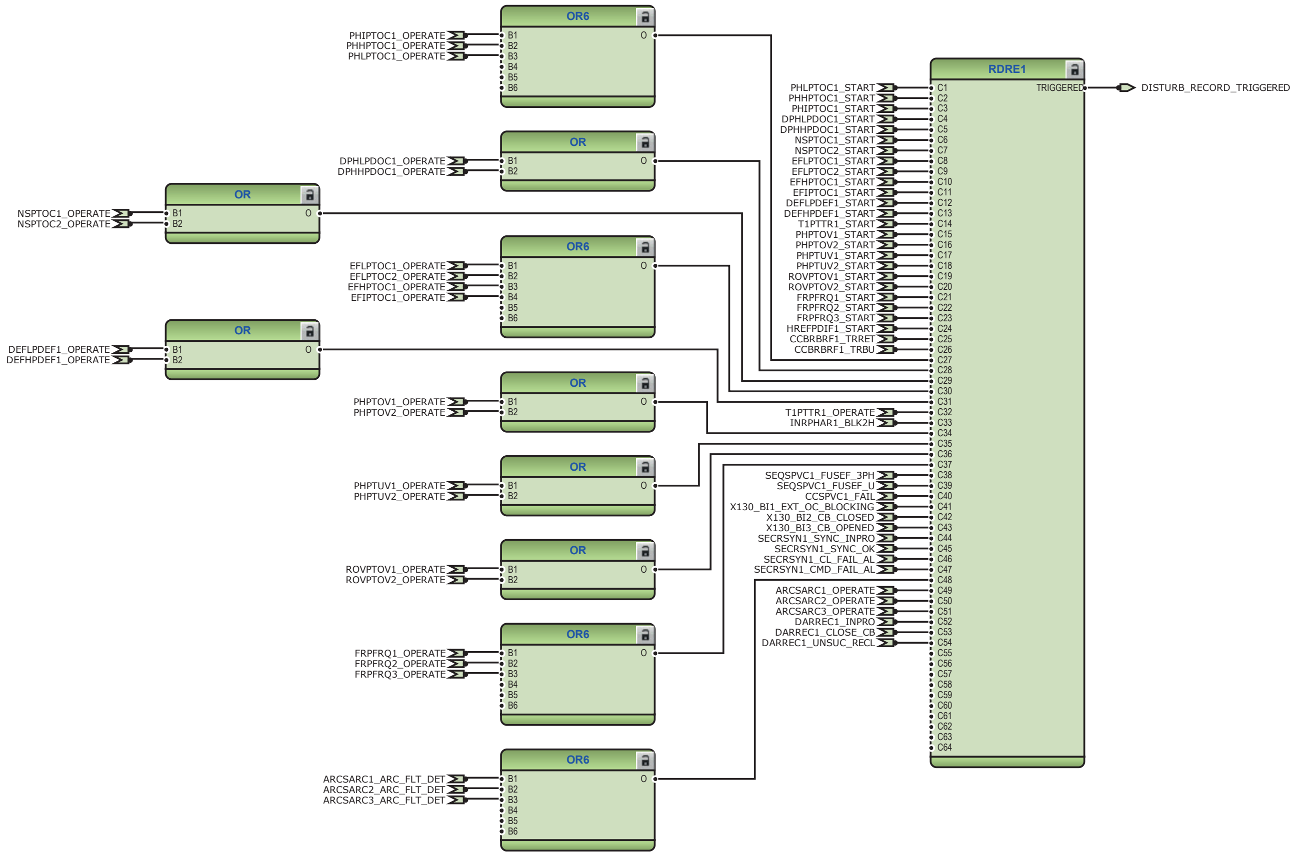


Figure 468: Disturbance recorder

3.12.3.3 Functional diagrams for condition monitoring

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

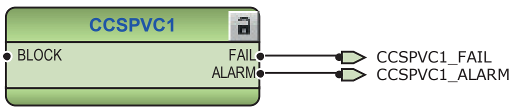


Figure 469: Current circuit supervision function

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

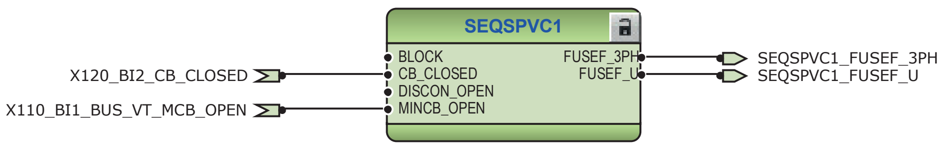


Figure 470: Fuse failure supervision function

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.

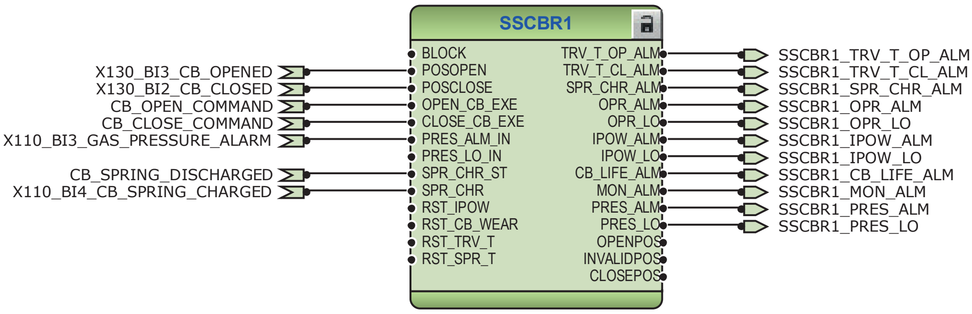


Figure 471: Circuit-breaker condition monitoring function

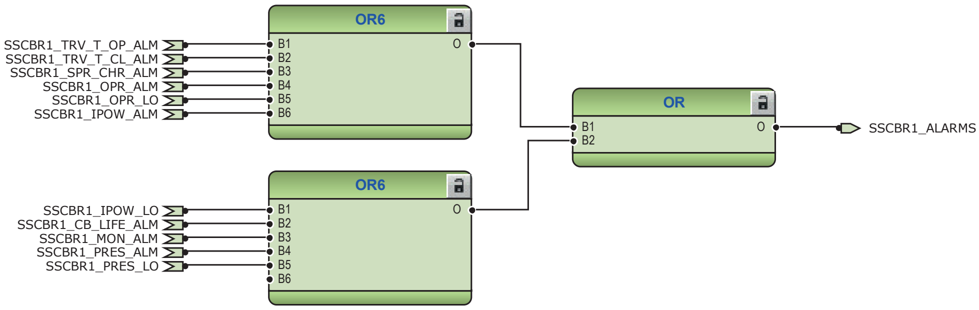


Figure 472: Logic for circuit-breaker monitoring alarm

Figure 473: 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. 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.

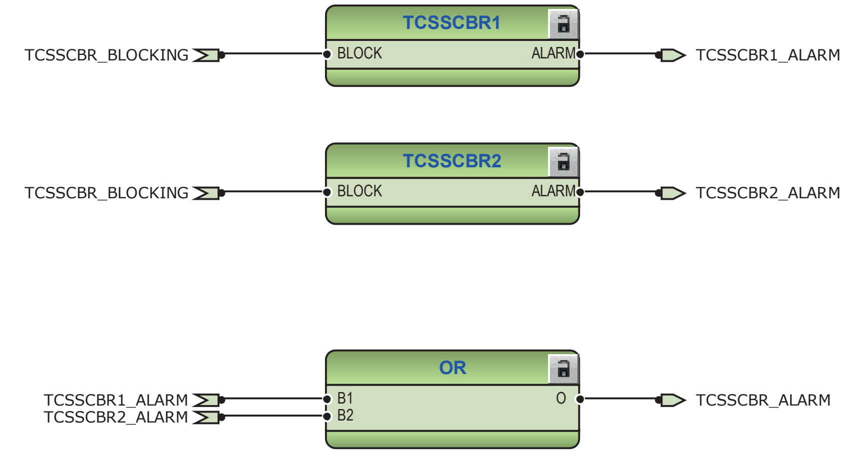


Figure 474: Trip circuit supervision function

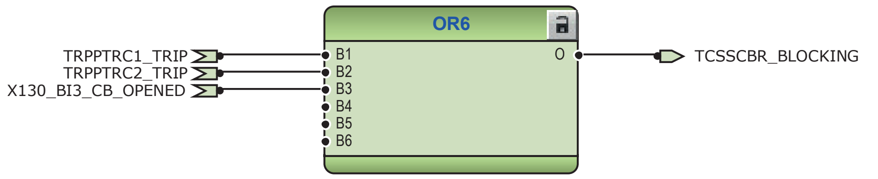


Figure 475: Logic for blocking trip circuit supervision

3.12.3.4 Functional diagrams for control and interlocking

The main purpose of the synchronism and energizing check SECRSYN is to provide control over the closing of the circuit breakers in power networks to prevent the closing if conditions for synchronism are not detected. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN measures the bus and line voltages and compares them to set conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for allowing closing or closing the circuit breaker. The `SYNC_OK` output signal of SECRSYN is connected to `ENA_CLOSE` input of CBXCBR through control logic. The function is blocked in case of line side or bus side MCB is open.

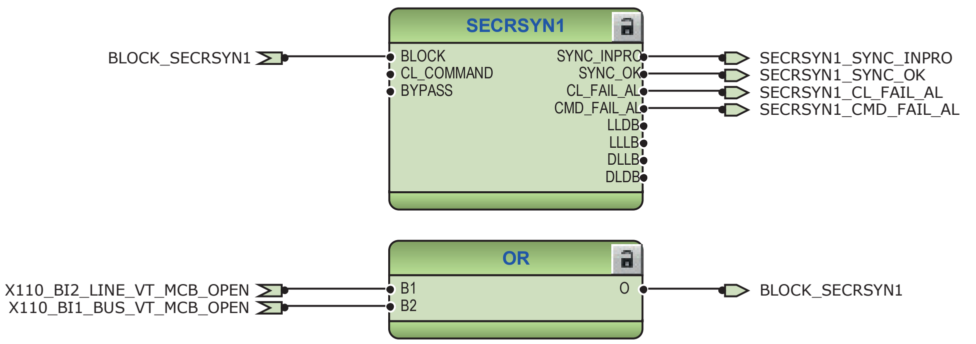


Figure 476: Synchrocheck function

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.

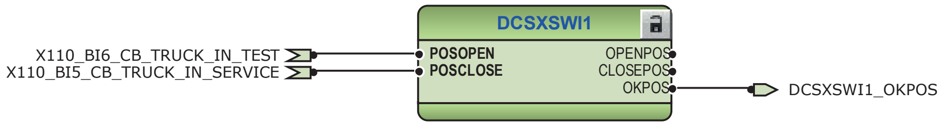


Figure 477: Disconnector control logic

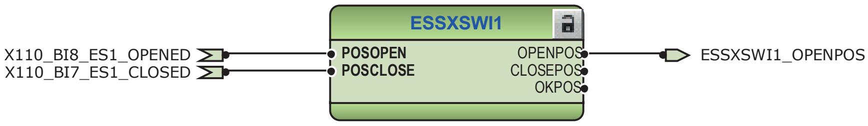


Figure 478: Earthing switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm, circuit-breaker spring charging and synchronizing ok status.

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely 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 circuit breaker is always enabled.

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

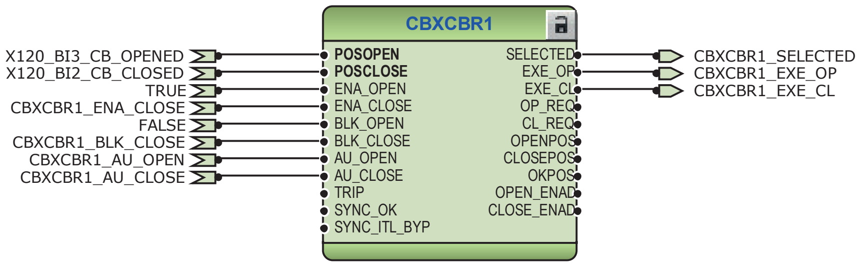


Figure 479: Circuit breaker control logic: Circuit breaker 1

Connect the addition signals required by the application for closing and opening coil of circuit breaker.

Figure 480: Circuit breaker control logic: Signals for closing coil of circuit breaker 1

Figure 481: Circuit breaker control logic: Signals for opening coil of circuit breaker 1

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

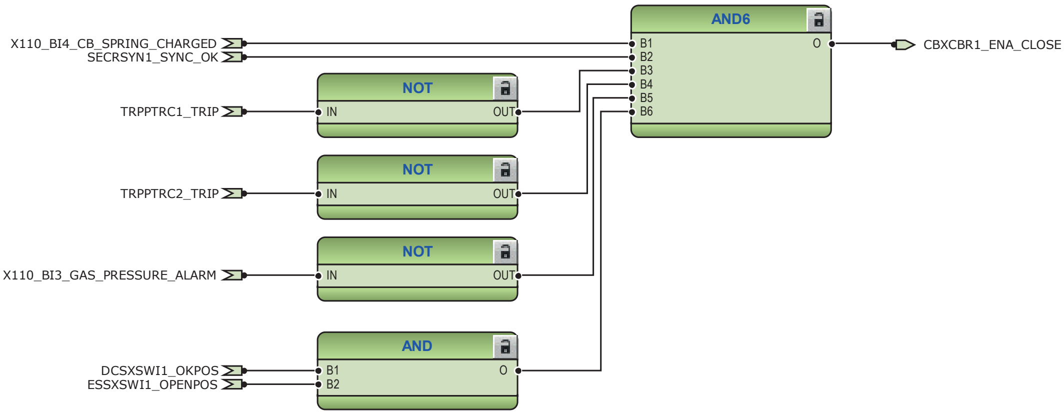


Figure 482: Circuit breaker 1 close enable logic

Figure 483: Circuit breaker 1 close blocking logic

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

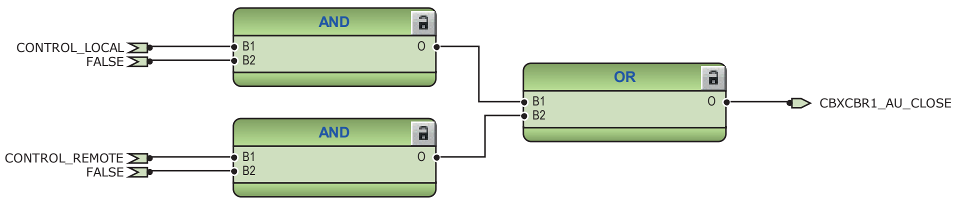


Figure 484: External closing command for circuit breaker

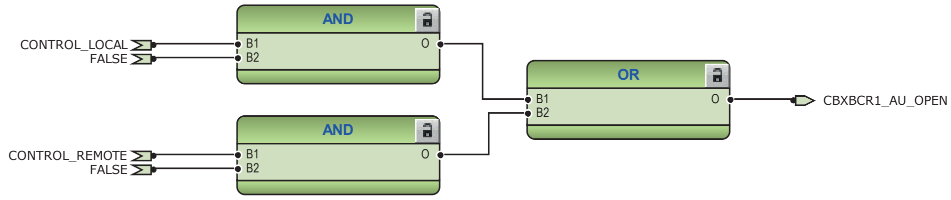


Figure 485: External opening command for circuit breaker

3.12.3.5 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 current input to high impedance restricted earth fault protection function is measured by RESCMMXU2.

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

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

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

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. The required logic connections can be made depending on the application using PCM600.

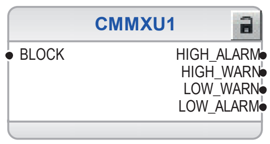


Figure 486: Current measurement: Three-phase current measurement

Figure 487: Current measurement: Sequence current measurement

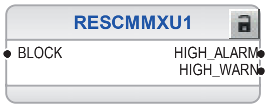


Figure 488: Current measurement: Residual current measurement

Figure 489: Current measurement: Residual current measurement

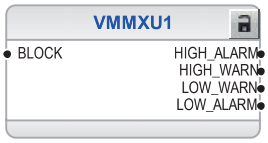


Figure 490: Voltage measurement: Three-phase voltage measurement

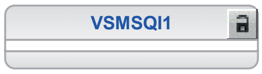


Figure 491: Voltage measurement: Sequence voltage measurement

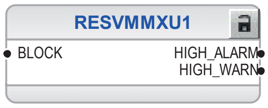


Figure 492: Voltage measurement: Residual voltage measurement

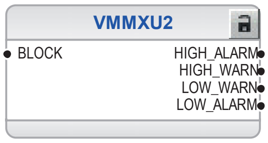


Figure 493: Voltage measurement: Three-phase voltage measurement

Figure 494: Other measurement: Frequency measurement

Figure 495: Other measurement: Three phase power and energy measurement

Figure 496: Other measurement: Data monitoring

Figure 497: Other measurement: Load profile record

3.12.3.6 Functional diagrams for I/O and alarm LEDs

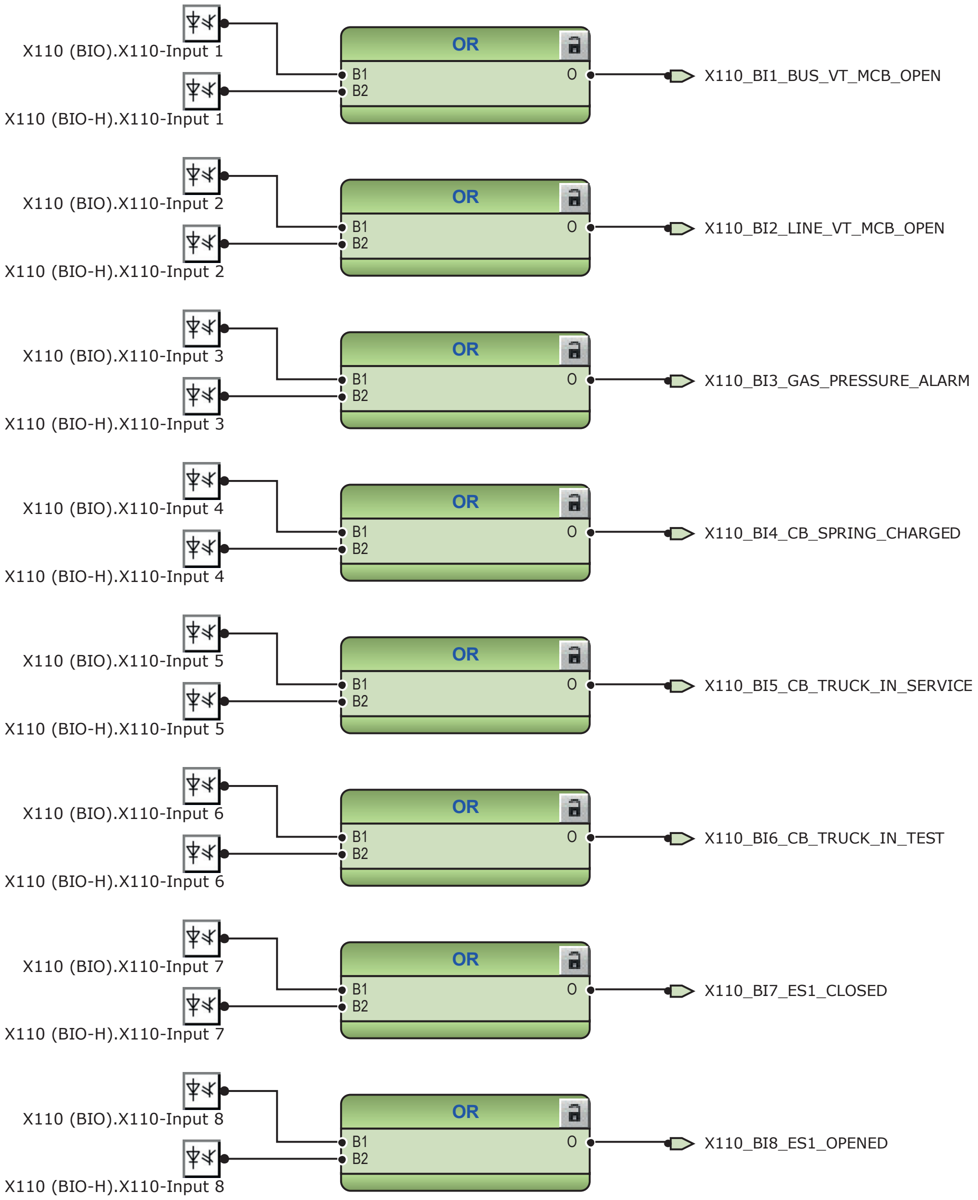


Figure 498: Binary input - X110 terminal block

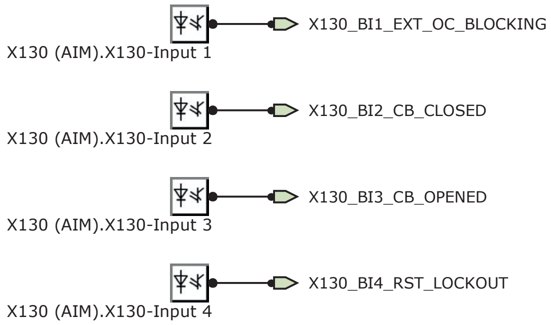


Figure 499: Binary input - X130 terminal block

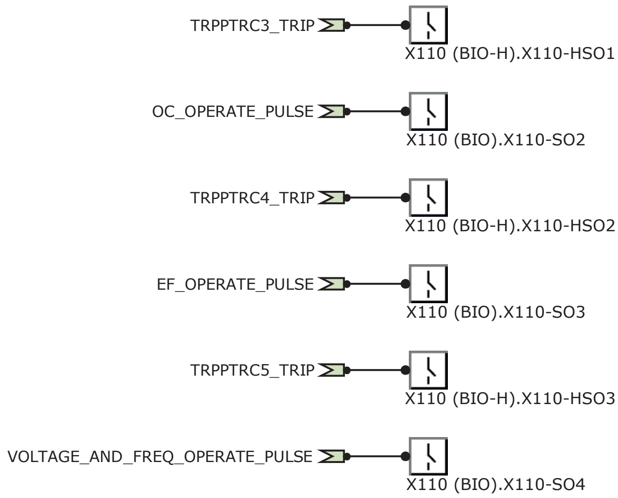


Figure 500: Binary output - X110 terminal block

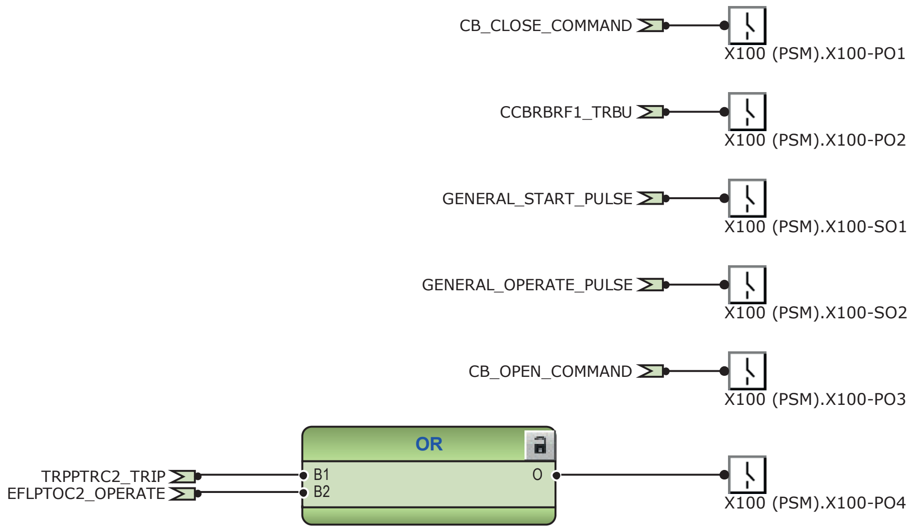
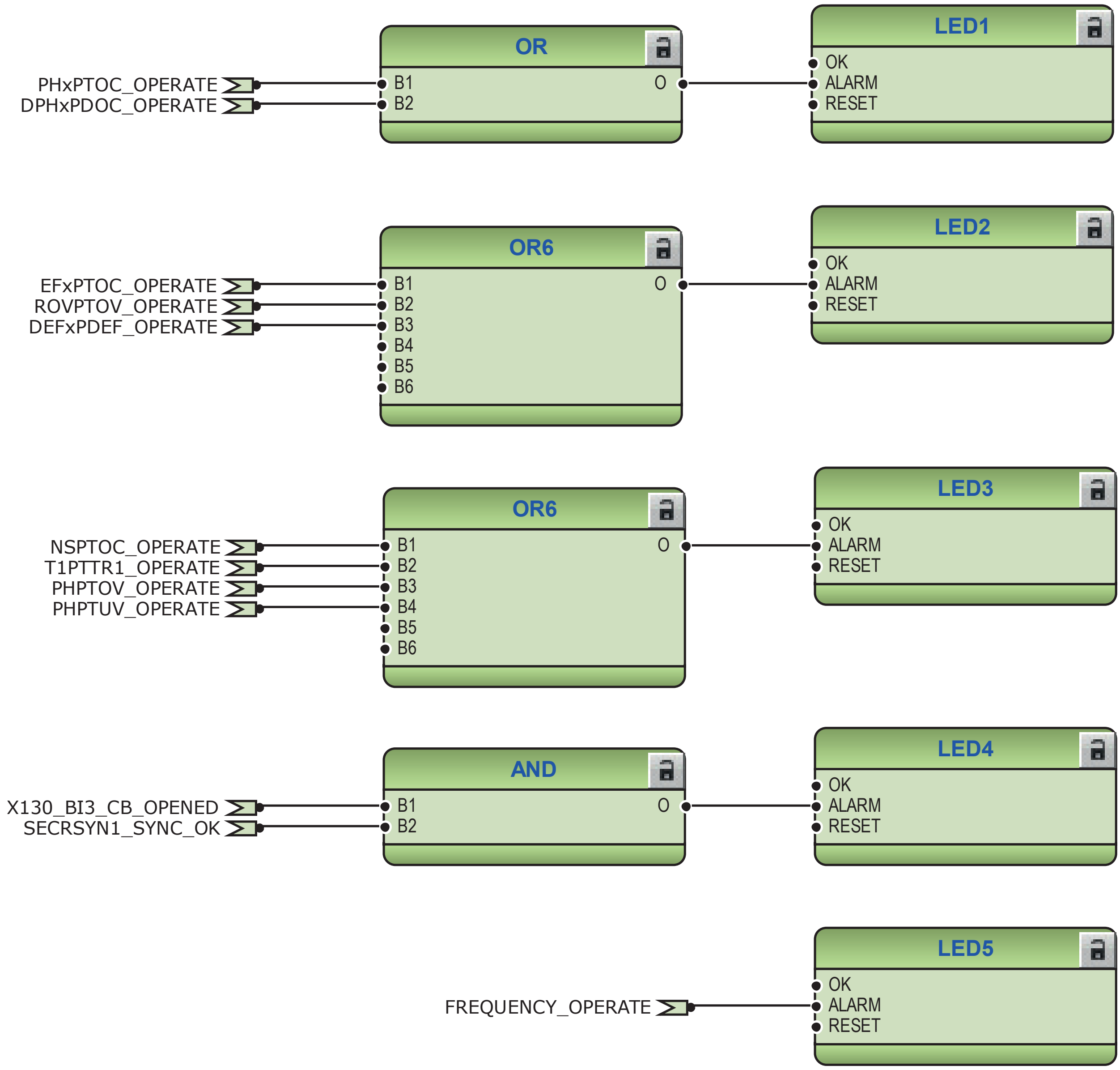


Figure 501: Binary output - X100 terminal block


OR
PHxPTOC_OPERATE
DPHxPDOC_OPERATE
B1
B2
O
LED1
OK
ALARM
RESET
OR6
EFxPTOC_OPERATE
ROVPTOV_OPERATE
DEFxPDEF_OPERATE
B1
B2
B3
B4
B5
B6
O
LED2
OK
ALARM
RESET
OR6
NSPTOC_OPERATE
T1PTTR1_OPERATE
PHPTOV_OPERATE
PHPTUV_OPERATE
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
AND
X130_BI3_CB_OPENED
SECRSYN1_SYNC_OK
B1
B2
O
LED4
OK
ALARM
RESET
FREQUENCY_OPERATE
LED5
OK
ALARM
RESET

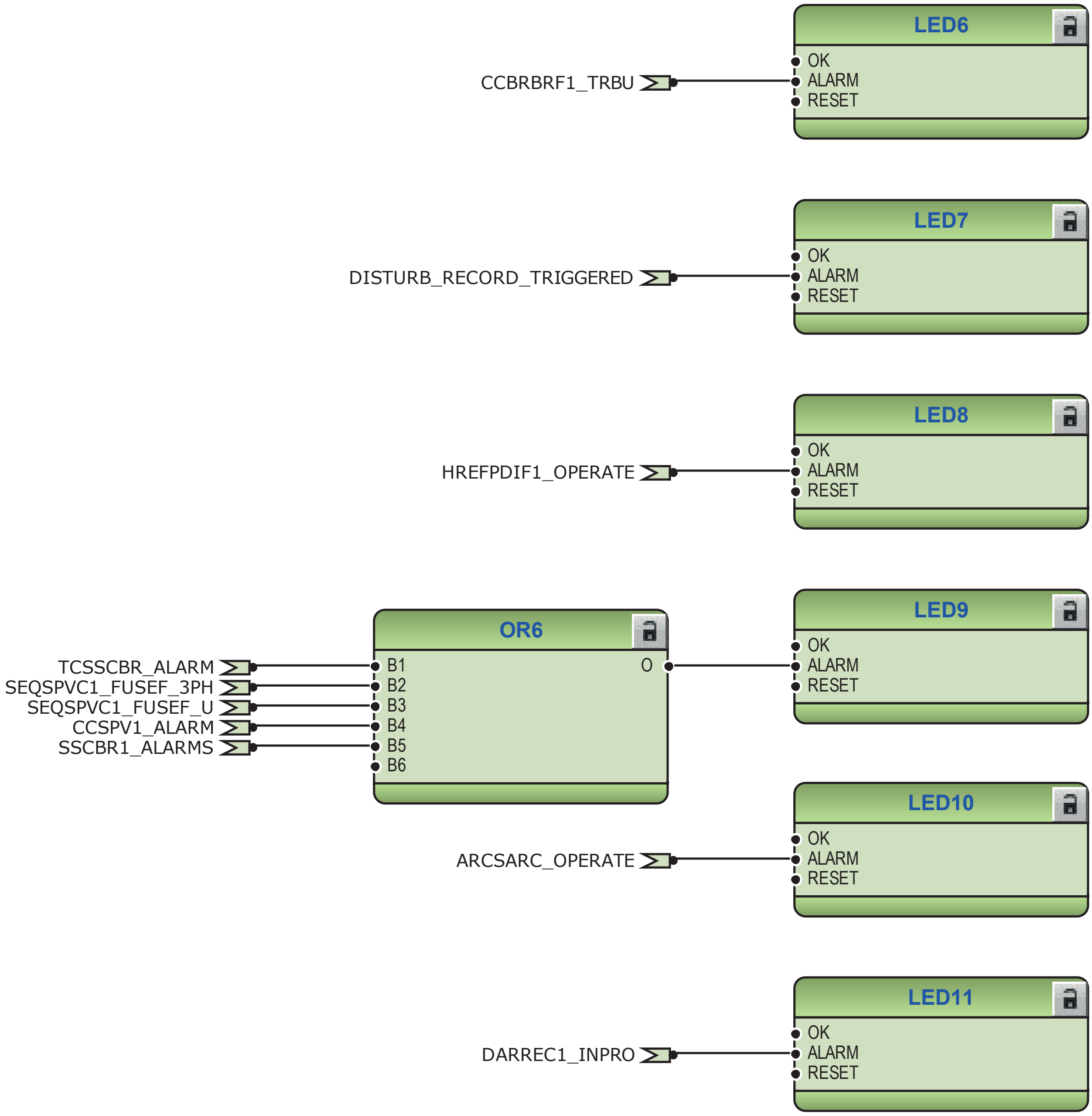


Figure 502: Default LED connection

3.12.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and combined voltage and frequency operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

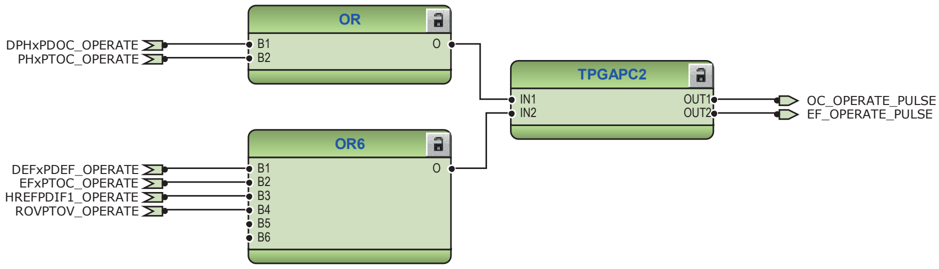


Figure 503: Timer logic for overcurrent and earth-fault operate pulse

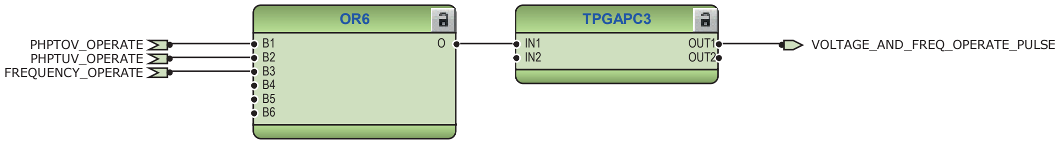


Figure 504: Timer logic for voltage and frequency operate pulse

3.12.3.8 Other functions

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

3.13 Standard configuration L

3.13.1 Applications

The standard configuration for directional overcurrent and directional earth-fault protection with phase voltage-based measurements, undervoltage and overvoltage protection, frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in isolated or resonant-earthed distribution networks. The configuration also includes additional options for selecting earth-fault protection based on admittance, wattmetric or harmonic-based 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.

Standard configuration L provides the highest functionality level of REF615 standard configurations supporting sensor inputs. Standard configuration L is delivered preconfigured with directional overcurrent protection but it also supports non-directional overcurrent protection as well as directional overpower. Depending on the specific feeder application, the appropriate functionality can be selected and an own configuration created with the Application Configuration tool in PCM600. Standard configuration L is not designed for using all the available functionality content in one IED at the same time. To ensure the performance of the IED, the user specific configuration load is verified with the Application Configuration tool of PCM600.

3.13.2 Functions

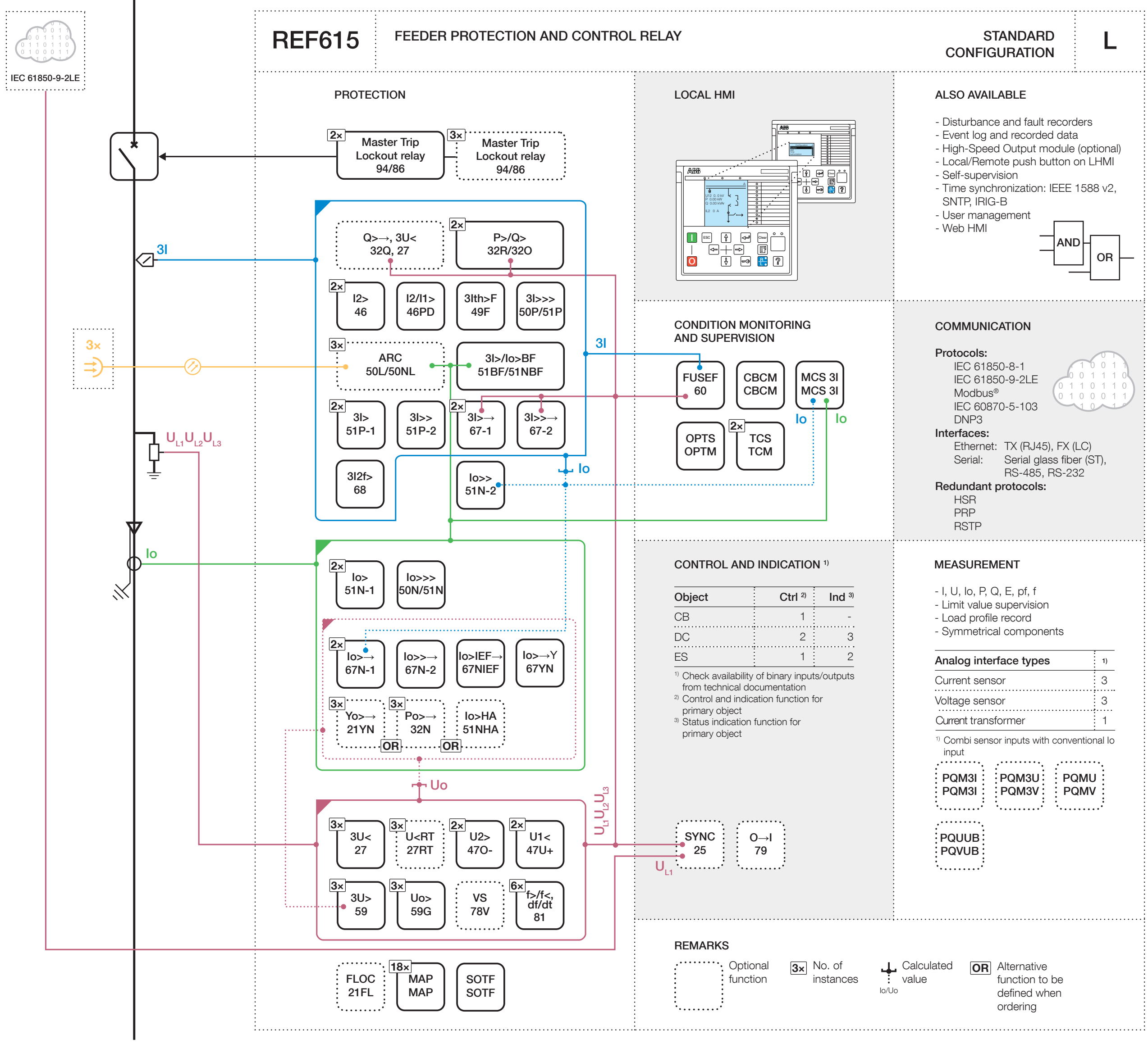


Figure 505: Functionality overview for standard configuration L

3.13.2.1 Default I/O connections

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

Table 61: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker plug not inserted
X110-BI2	Circuit breaker spring discharged
X110-BI3	Circuit breaker open indication
X110-BI4	Circuit breaker closed indication
X110-BI5	Circuit breaker truck out (test position) indication
X110-BI6	Circuit breaker truck in (service position) indication
X110-BI7	Earthing switch open indication
X110-BI8	Earthing switch closed indication

Table 62: Default connections for binary outputs

Binary output	Description
X100-PO1	Release for circuit breaker closing
X100-PO2	Circuit breaker close command
X100-SO1	Release for circuit breaker tuck
X100-SO2	Release for earthing switch
X100-PO3	Circuit breaker open command
X100-PO4	Breaker failure backup trip to upstream breaker
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 63: Default connections for LEDs

LED	Description
1	Circuit breaker close enabled
2	Short circuit protection operated
3	Earth-fault protection operated
4	Current unbalance protection operated
5	NPS or PPS voltage protection operated
6	Overvoltage or residual overvoltage protection operated
7	Thermal overload alarm
8	Undervoltage or frequency protection operated
9	Supervision alarm
10	Circuit breaker condition monitoring alarm
11	–

3.13.2.2 Default disturbance recorder settings

Table 64: Default disturbance recorder analog channels

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

Table 65: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	DPHLPDOC1 - start	Positive or Rising
2	DPHLPDOC2 - start	Positive or Rising
3	DPHHPDOC1 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
	EFPADM1 - start	
	WPWDE1 - start	
8	DEFLPDEF2 - start	Positive or Rising
	EFPADM2 - start	
	WPWDE2 - start	
9	EFPADM3 - start	Positive or Rising
	WPWDE3 - start	
10	INTRPTEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	PDNSPTOC1 - start	Positive or Rising
13	T1PTTR1 - start	Positive or Rising
14	PHPTOV1 - start	Positive or Rising
15	PHPTOV2 - start	Positive or Rising
16	PHPTOV3 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
17	PSPTUV1 - start	Positive or Rising
18	NSPTOV1 - start	Positive or Rising
19	PHPTUV1 - start	Positive or Rising
20	PHPTUV2 - start	Positive or Rising
21	PHPTUV3 - start	Positive or Rising
22	ROVPTOV1 - start	Positive or Rising
23	ROVPTOV2 - start	Positive or Rising
24	ROVPTOV3 - start	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHIPTOC1 - operate	Level trigger off
	DPHHPDOC1 - operate	
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
28	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
29	DEFHPDEF1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	EFPADM1 - operate	
	EFPADM2 - operate	
	EFPADM3 - operate	
	WPWDE1 - operate	
	WPWDE2 - operate	
	WPWDE3 - operate	
30	INTRPTEF1 - operate	Level trigger off
31	EFHPTOC1 - operate	Level trigger off
32	PDNSPTOC1 - operate	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off
34	T1PTTR1 - operate	Level trigger off
	ROVPTOV2 - operate	
	ROVPTOV3 - operate	
	PSPTUV1 - operate	
	NSPTOV2 - operate	
38	SEQSPVC - fusef3ph	Level trigger off
39	SEQSPVC1 - fusefu	Level trigger off
40	CCSPVC1 - fail	Level trigger off
35	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
	PHPTOV3 - operate	
36	PHPTUV1 - operate	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
	PHPTUV2 - operate	
	PHPTUV3 - operate	
37	ROVPTOV1 - operate	Level trigger off
41	X110BI4 - CB closed	Level trigger off
42	X110BI3 - CB opened	Level trigger off
43	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
44	DARREC1 - close CB	Level trigger off
	DARREC1 - unsuc recl	
45	ARCSARC1 - operate	Level trigger off
46	ARCSARC2 - operate	Positive or Rising
47	ARCSARC3 - operate	Positive or Rising
48	DARREC1 - inpro	Positive or Rising
49	FRPFRQ1 - start	Level trigger off
50	FRPFRQ2 - start	Positive or Rising
51	FRPFRQ3 - start	Positive or Rising
52	FRPFRQ - operate	Positive or Rising
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	

3.13.3 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.

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

3.13.3.1 Functional diagrams for protection

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

Four overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC.

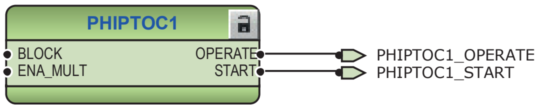


Figure 506: Overcurrent protection function

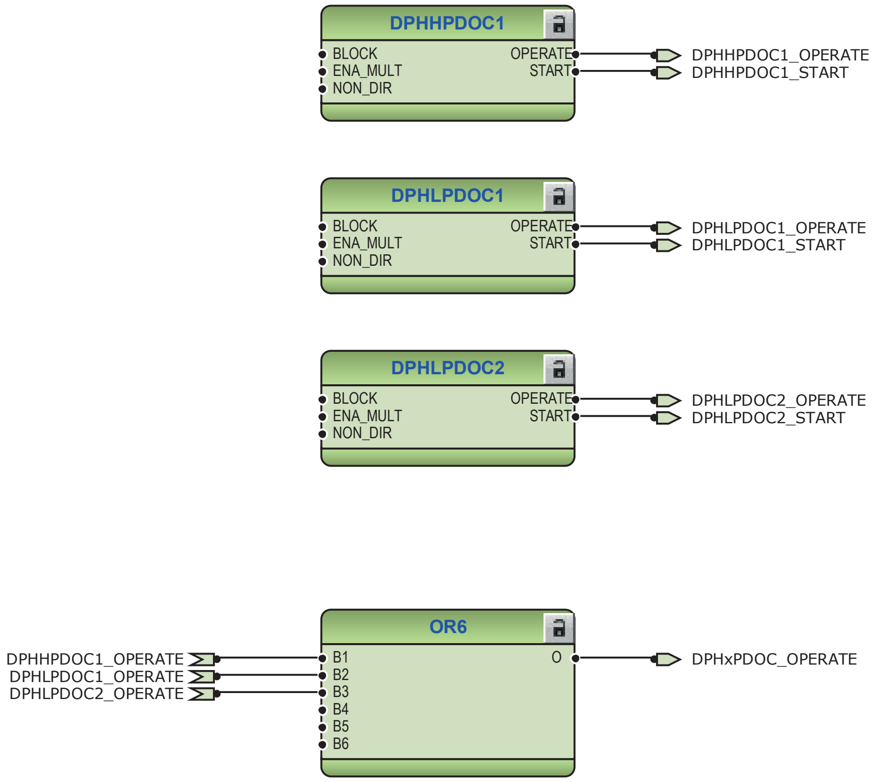


Figure 507: Directional overcurrent protection functions

The upstream blocking from the start of the second low stage of three-phase directional overcurrent protection DPHLPDOC2 is connected to the binary output. This signal is not connected in the configuration. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

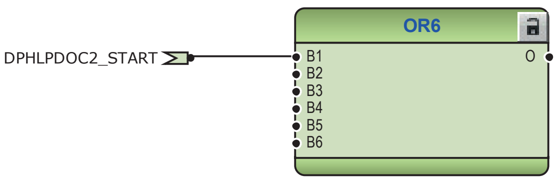


Figure 508: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

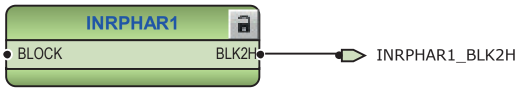


Figure 509: Inrush detector function

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.

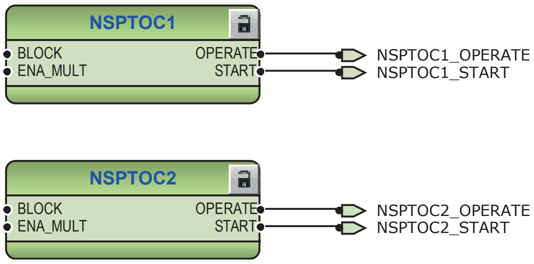


Figure 510: Negative-sequence overcurrent protection function

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 used together with admittance-based earth-fault protection EFPADM or wattmetric-based earth-fault protection WPWDE or harmonics-based earth-fault protection HAEFPTOC. A dedicated protection stage INTRPTEF is used either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

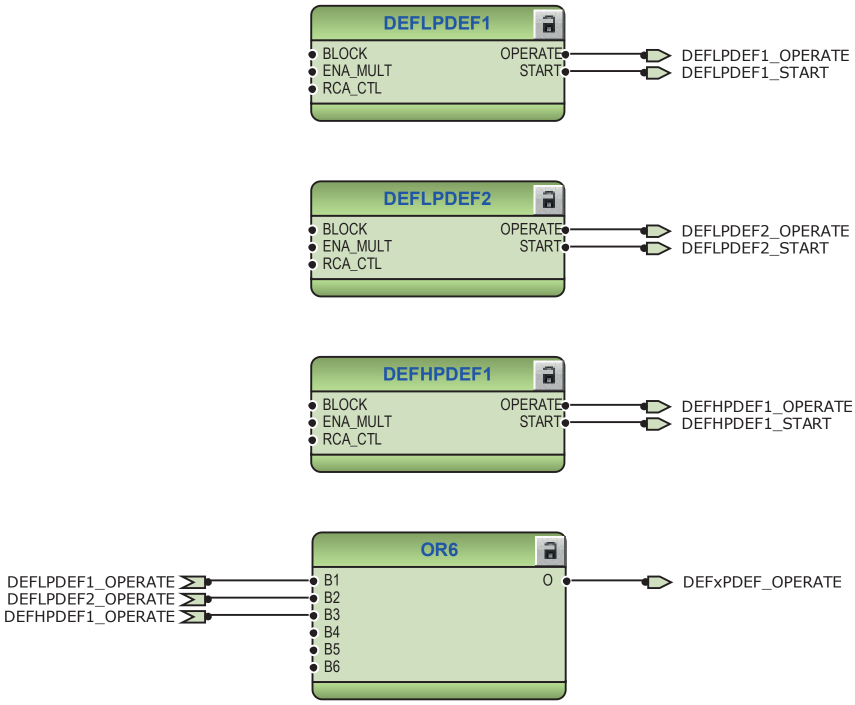


Figure 511: Directional earth-fault protection functions

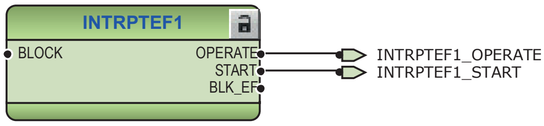


Figure 512: Transient or intermittent earth-fault protection function

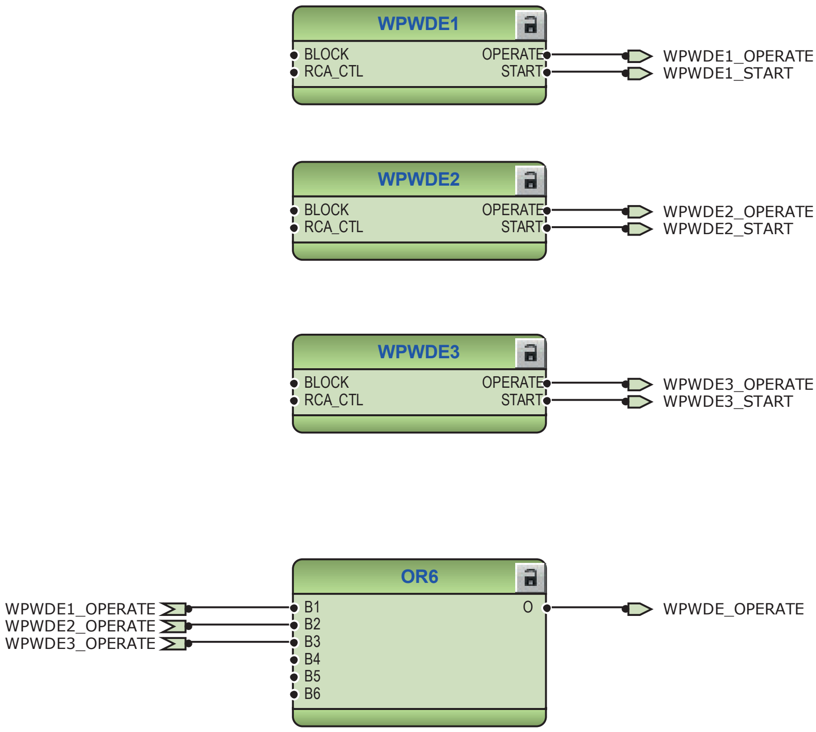


Figure 513: Wattmetric protection function

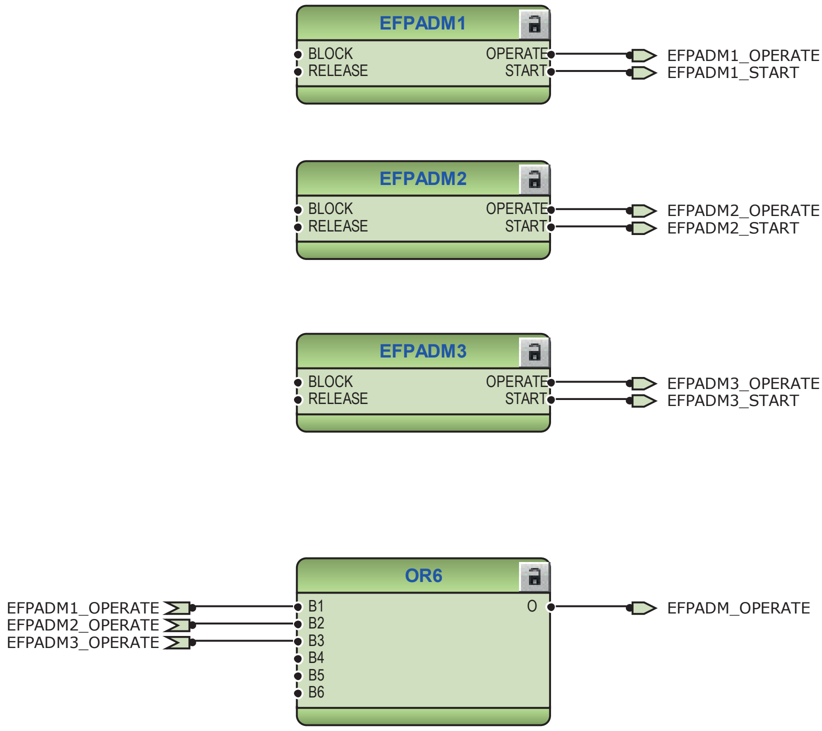


Figure 514: Admittance-based earth-fault protection function

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

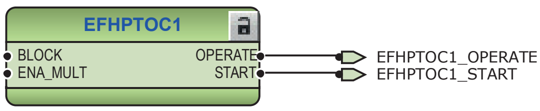


Figure 515: Earth-fault protection function

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

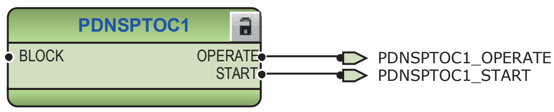


Figure 516: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

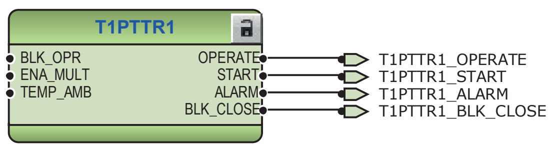


Figure 517: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by a number of different protection functions available in the IED. The 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.

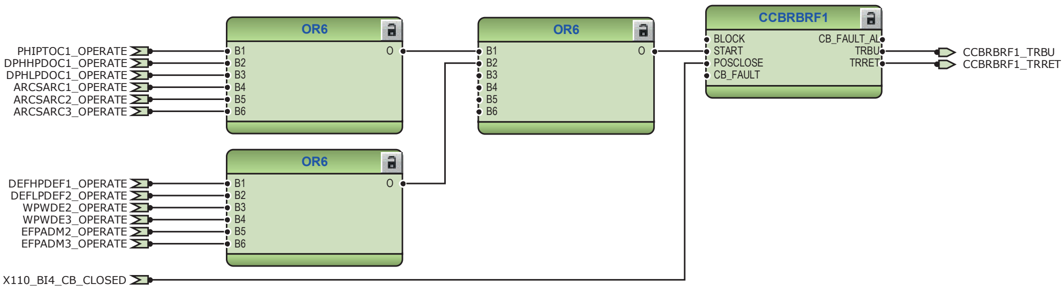


Figure 518: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

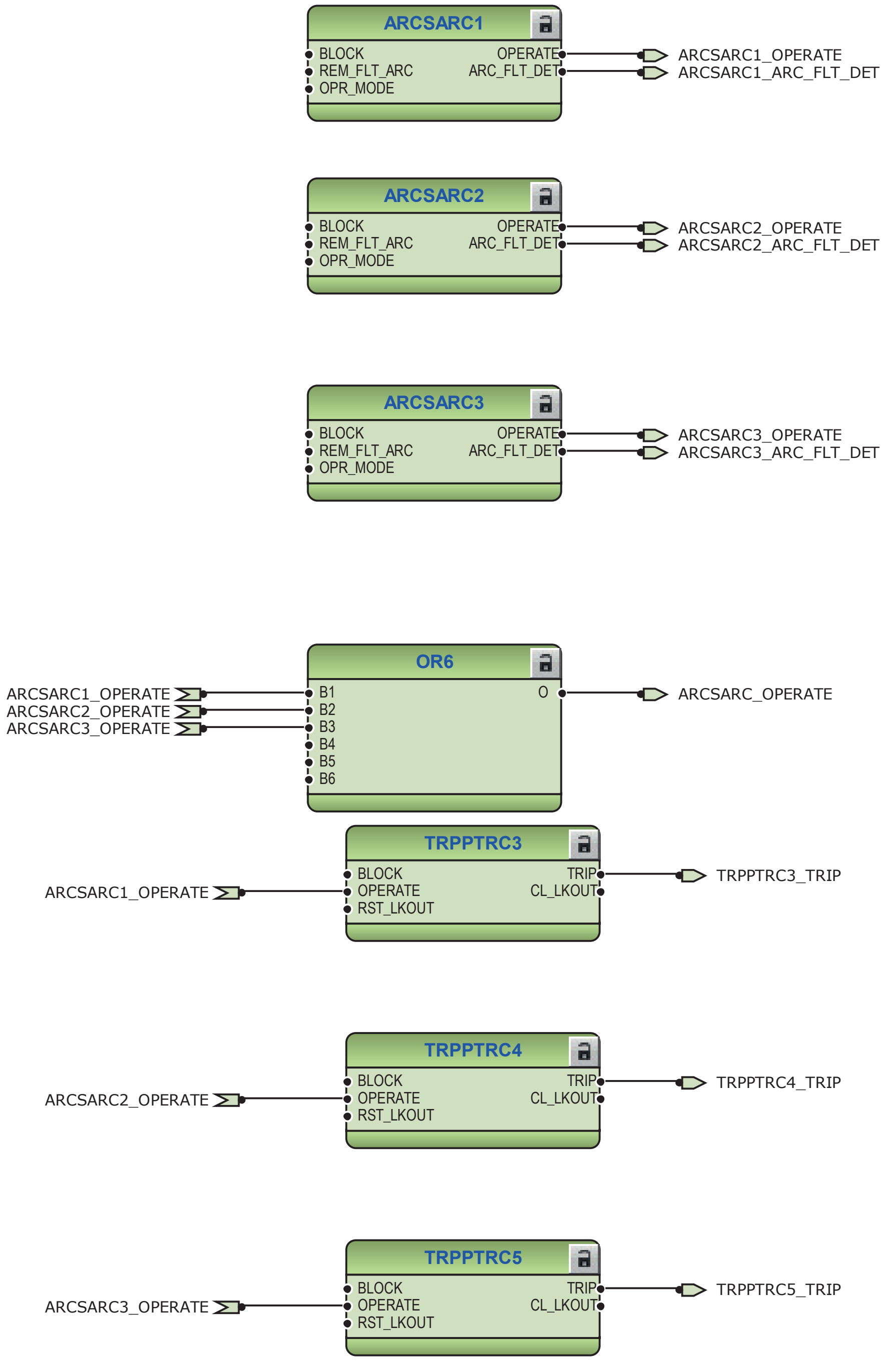


Figure 519: Arc protection with dedicated HSO

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 the close command is connected directly to the binary output X100:PO2.

Set the parameters for DARREC1 properly.

Check the initialization signals of the DARREC1.

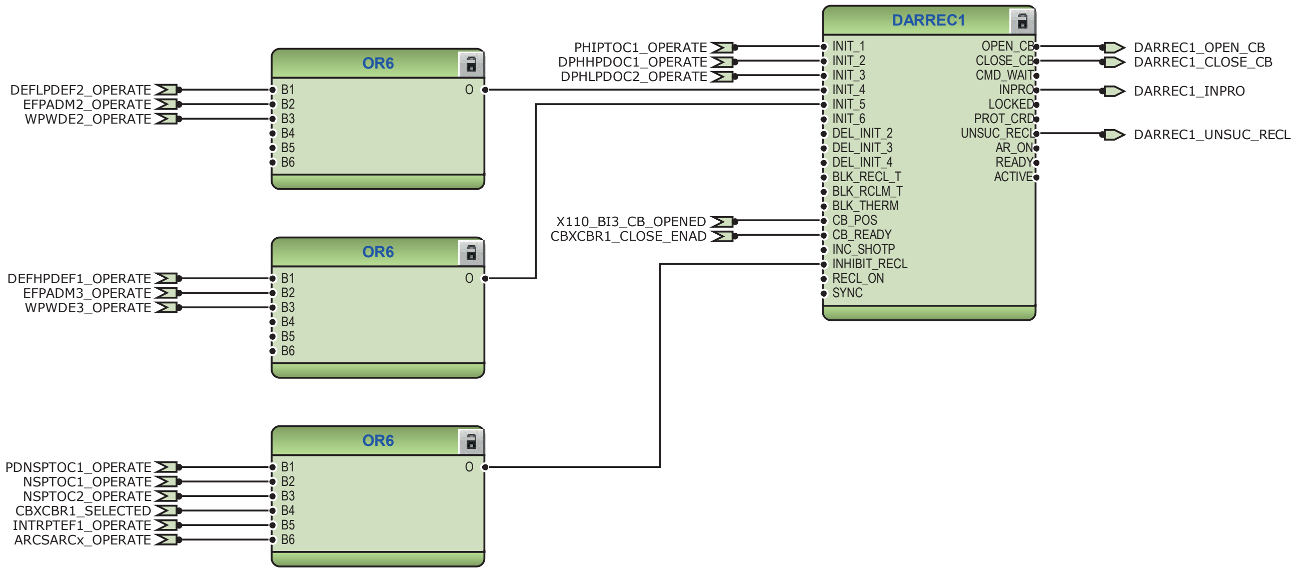


Figure 520: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV and negative-sequence overvoltage protection NSPTOV enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function. The activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

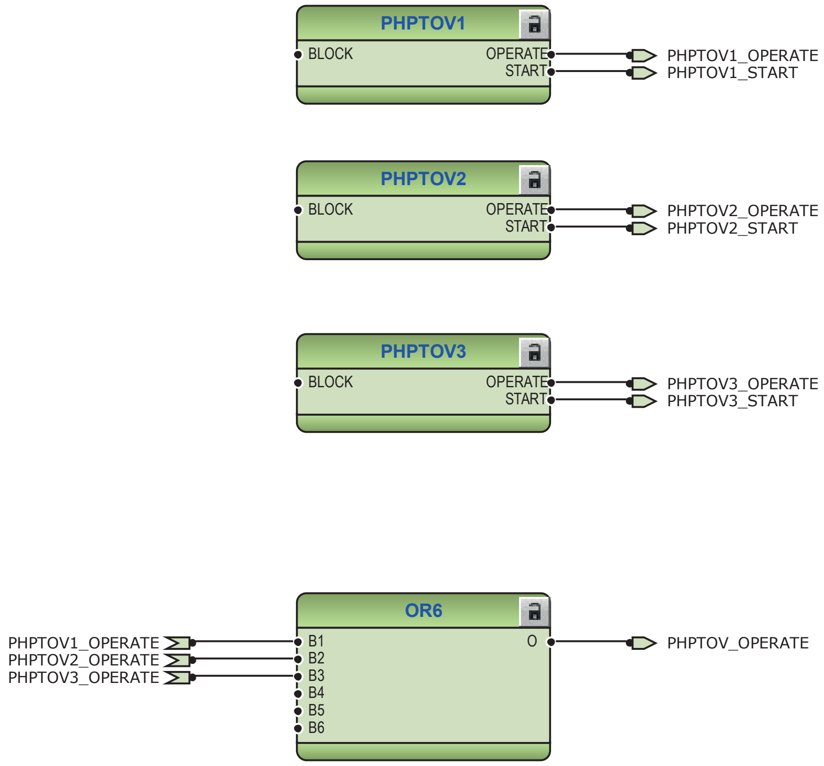


Figure 521: Overvoltage protection function

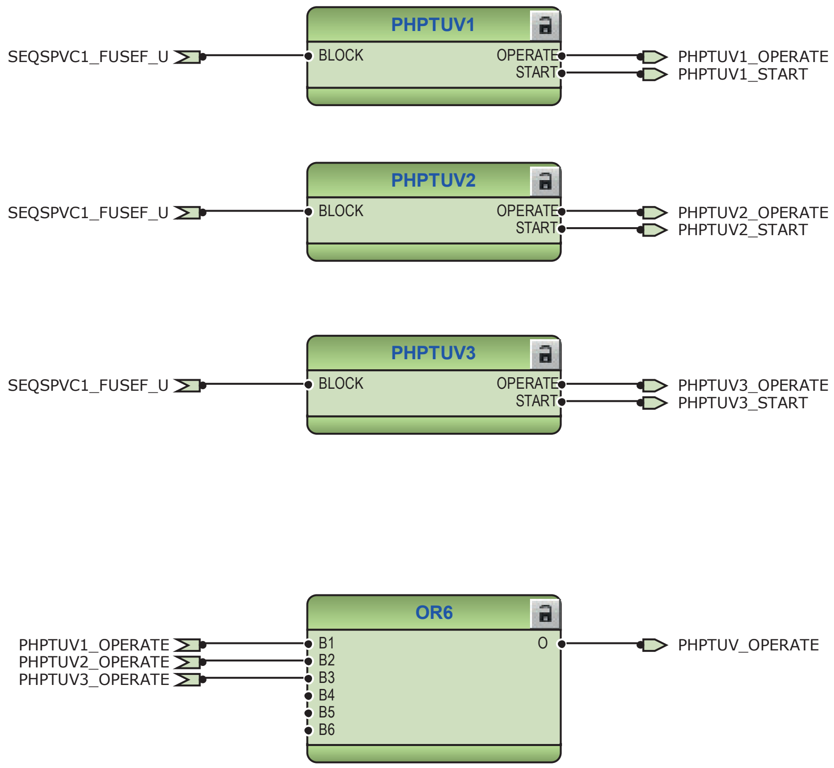


Figure 522: Undervoltage protection function

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.

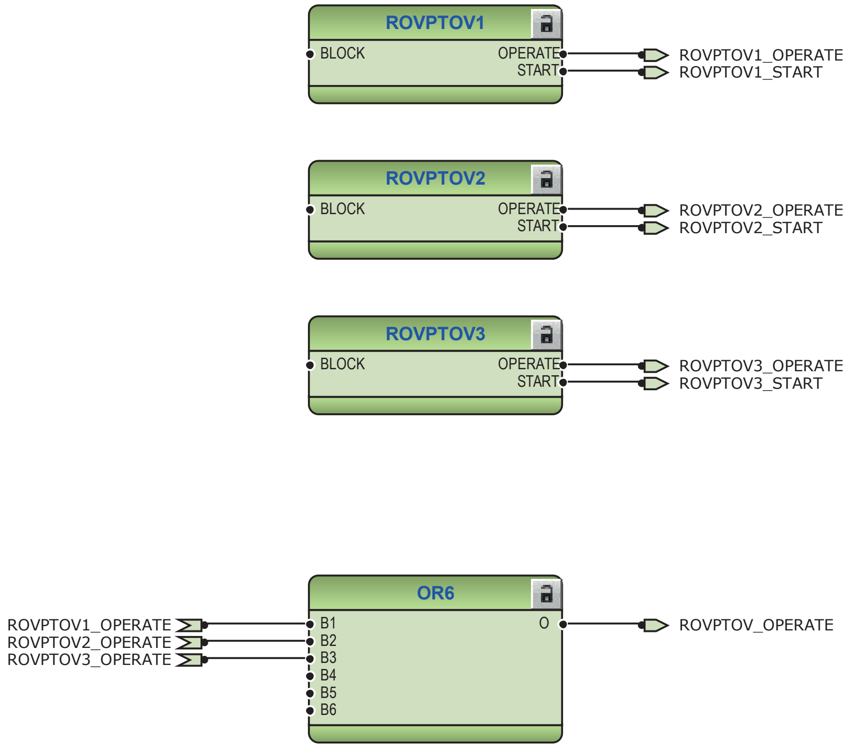


Figure 523: Residual voltage protection function

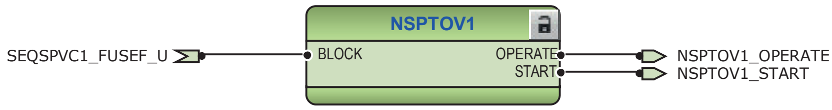


Figure 524: Negative sequence overvoltage protection function

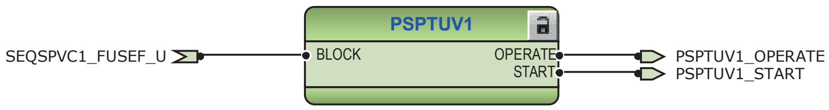


Figure 525: Positive sequence undervoltage protection function

The selectable underfrequency or overfrequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system.

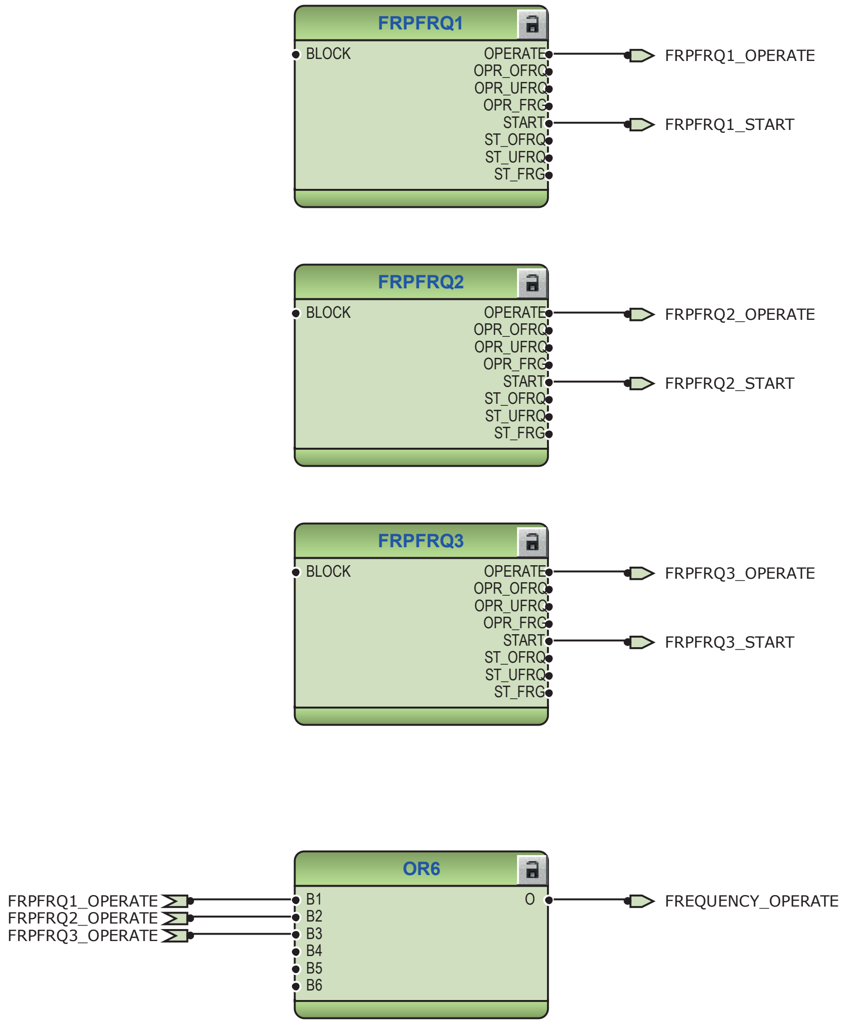


Figure 526: Frequency protection function

General start and operate signals from all functions are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC can be connected to binary outputs. However, these are not connected in the configuration.

If a new protection function block is added to the configuration, check the activation logic and add connections.

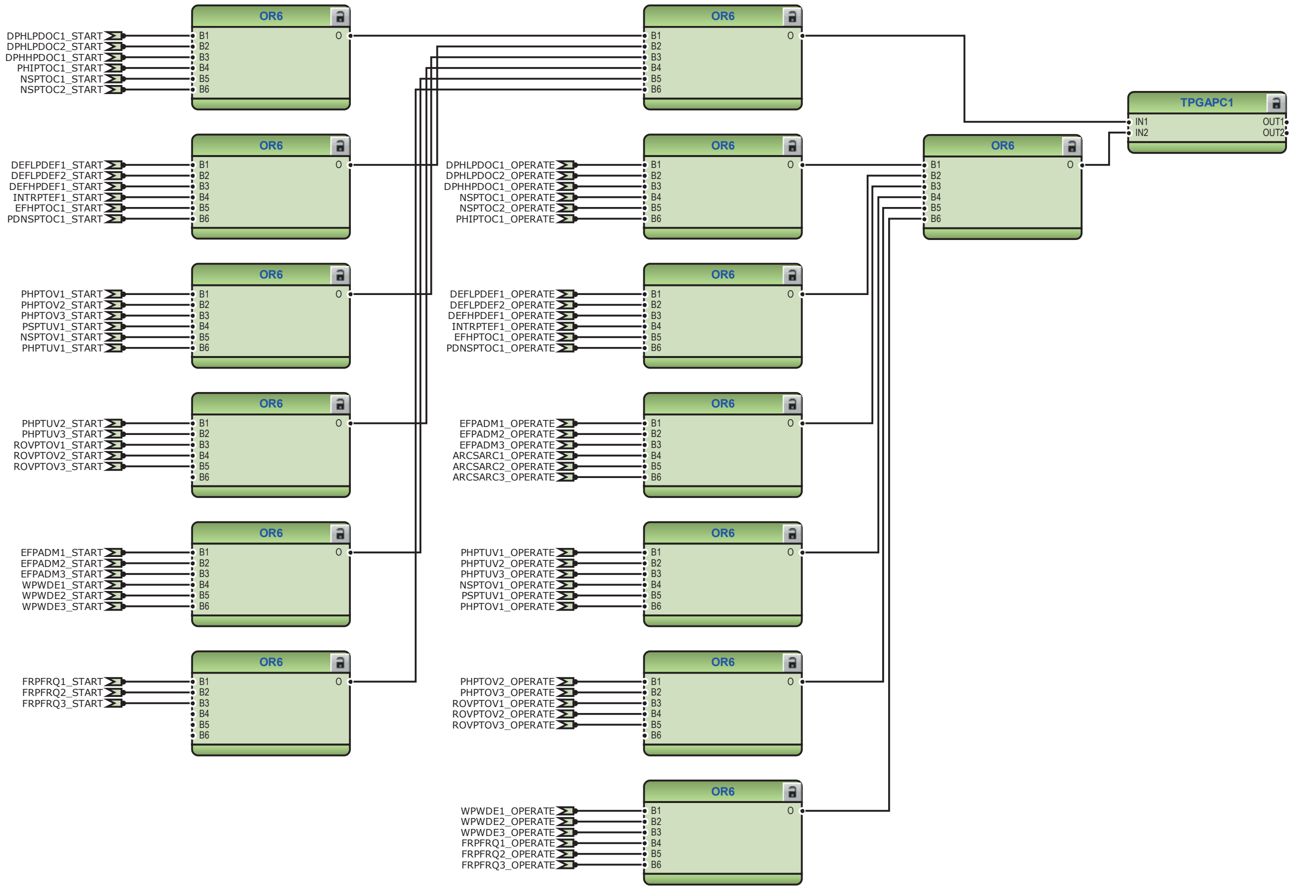


Figure 527: General start and operate signals

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, the binary input has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3..4 are also available if the IED is ordered with high speed binary outputs options.

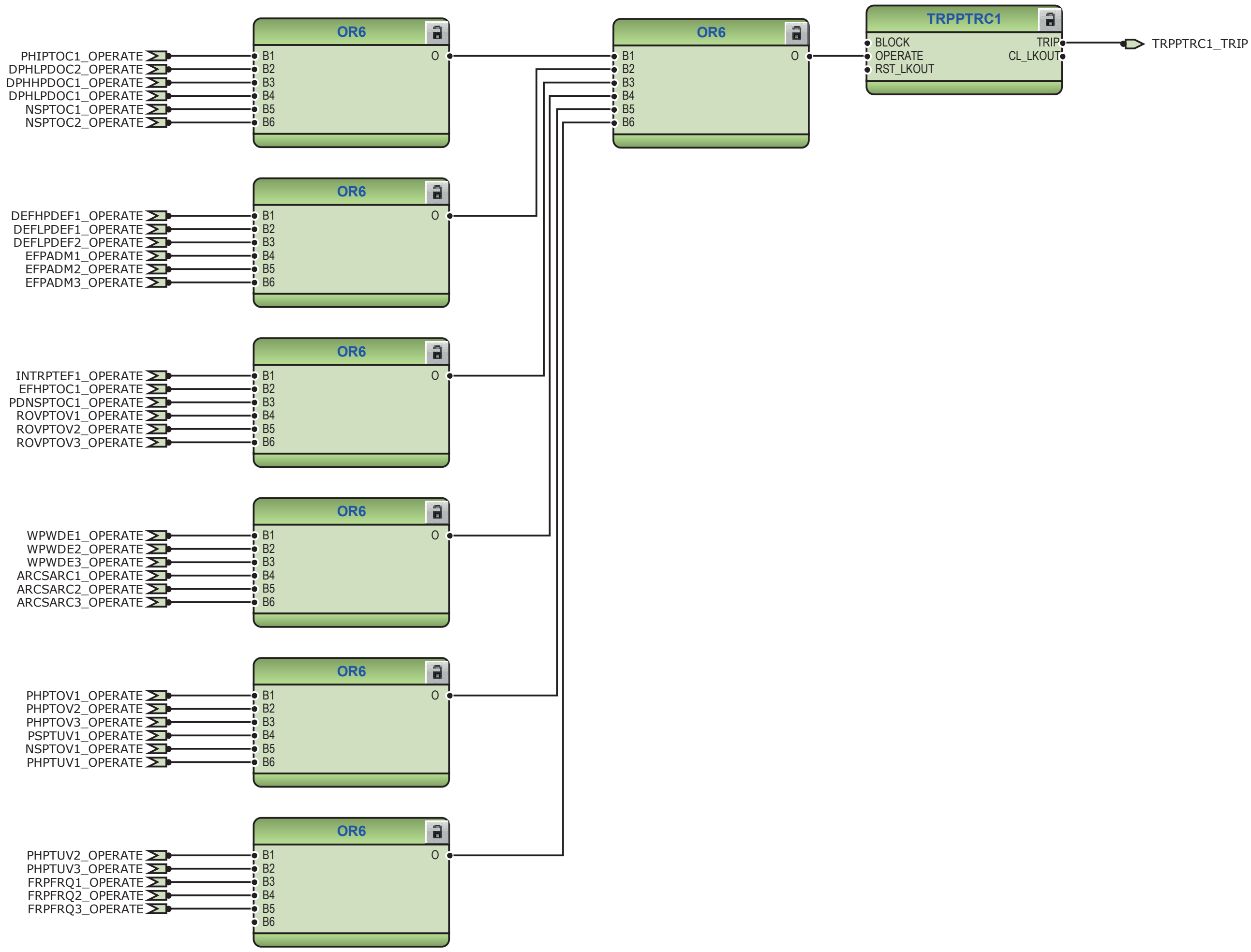


Figure 528: Trip logic TRPPTRC1

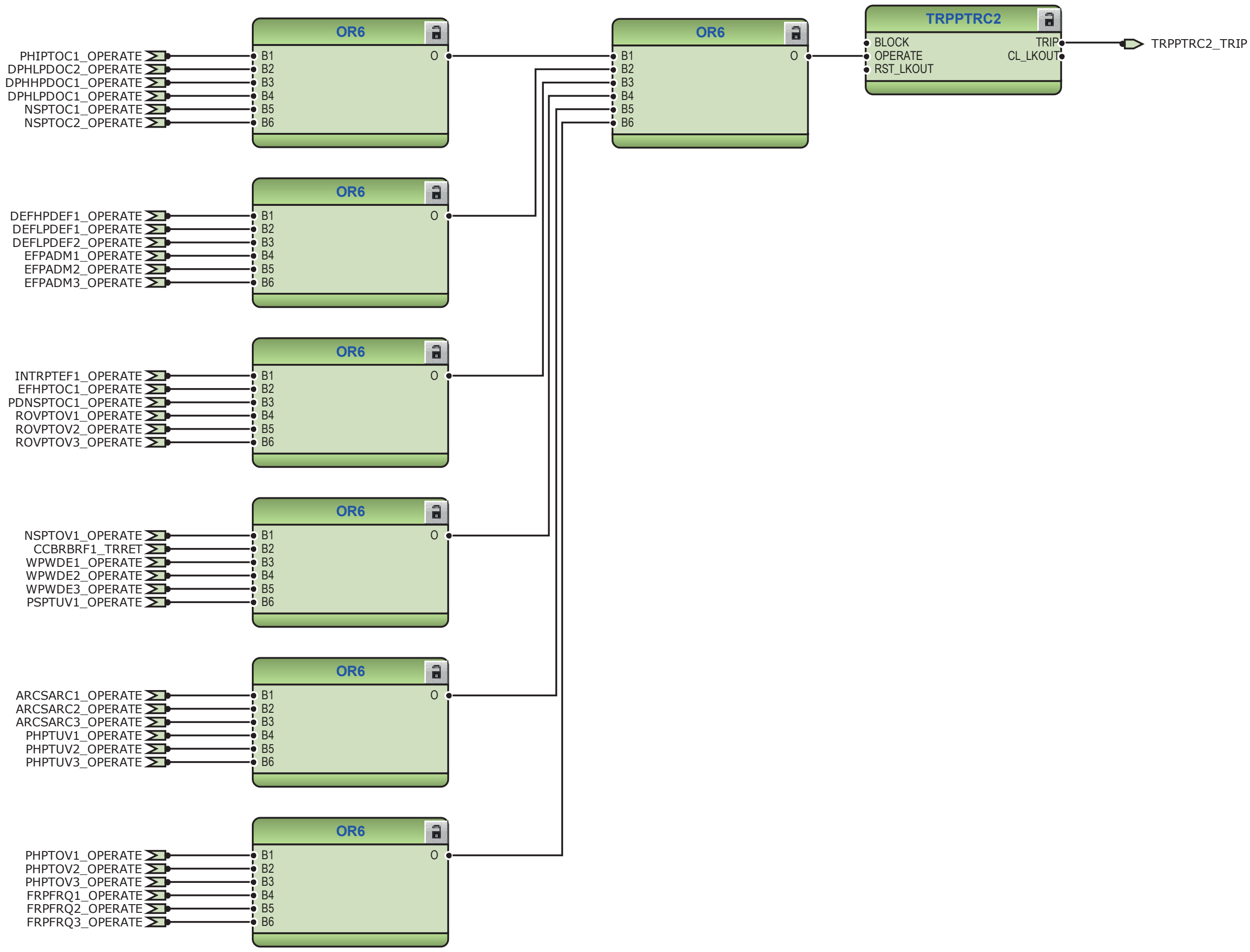


Figure 529: Trip logic TRPPTRC2

3.13.3.2 Functional diagrams for disturbance recorder

The START and 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 few binary inputs are also connected to the disturbance recorder.

The disturbance recorder main application sheet contains disturbance recorder function block and the connections to the variables.

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

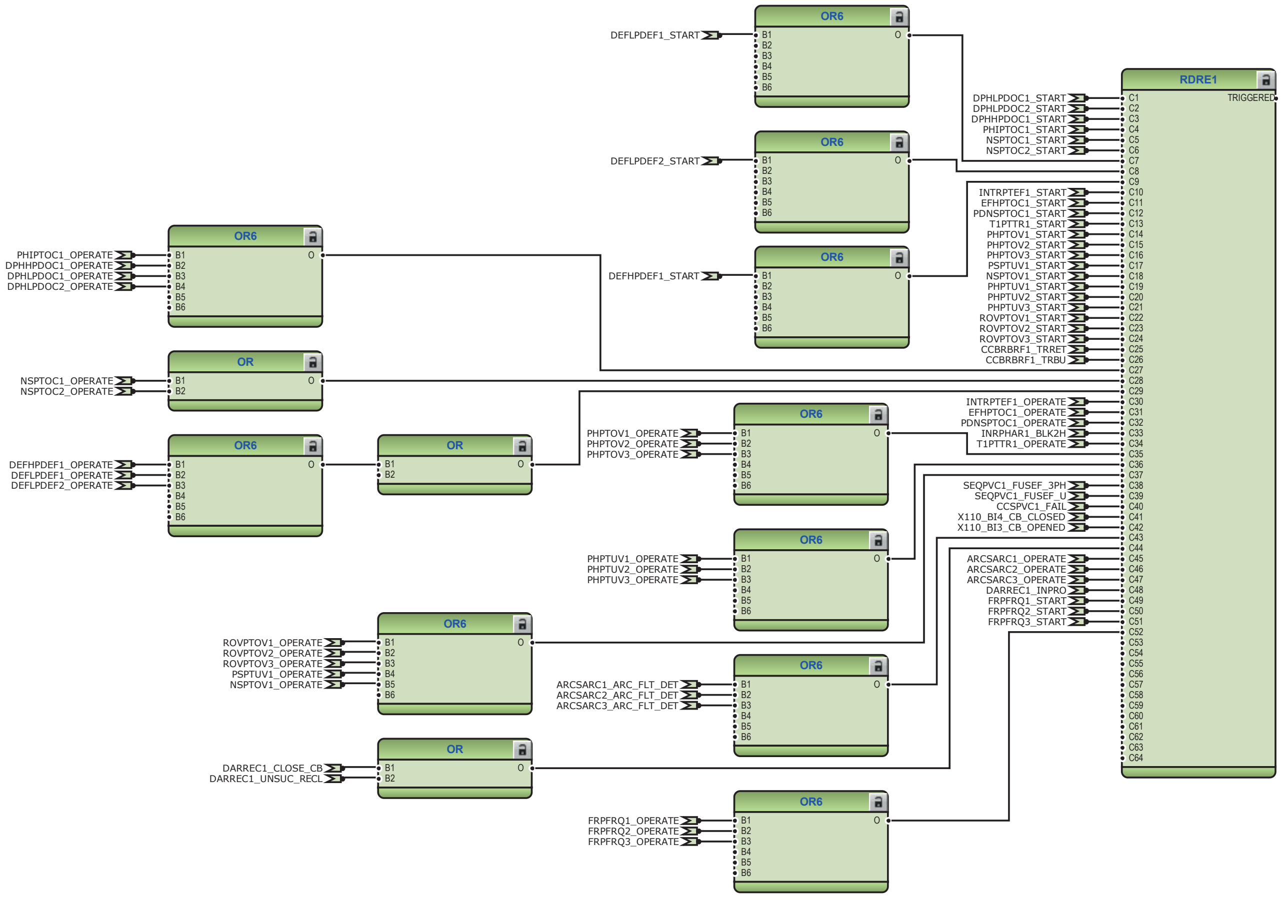


Figure 530: Disturbance recorder

3.13.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects the failure 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 to avoid unnecessary operation. However, it is not connected in the configuration.

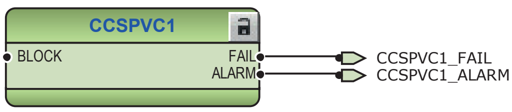


Figure 531: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

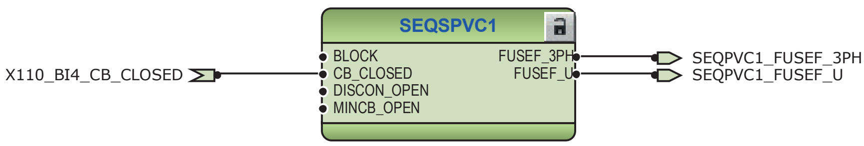


Figure 532: Fuse failure supervision function

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.

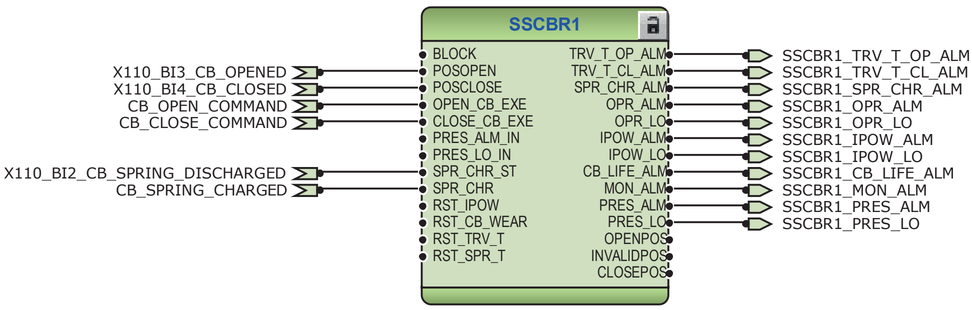


Figure 533: Circuit-breaker condition monitoring function

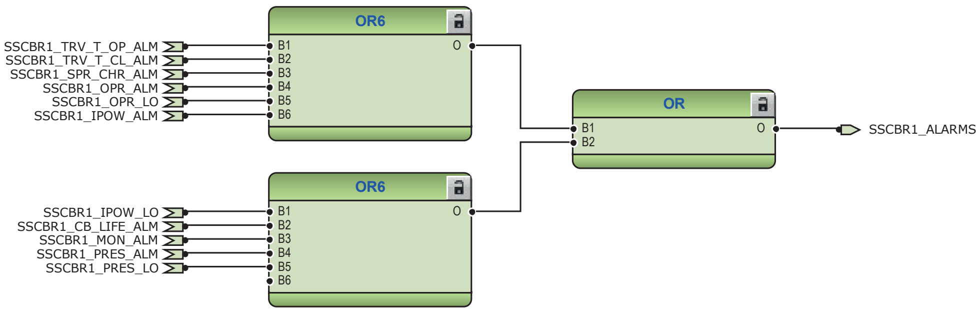


Figure 534: Logic for circuit-breaker monitoring alarm

Figure 535: Logic for start of circuit-breaker spring charged

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 binary input X110:BI1 indicating IED plug out.

It is assumed that there is an 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.

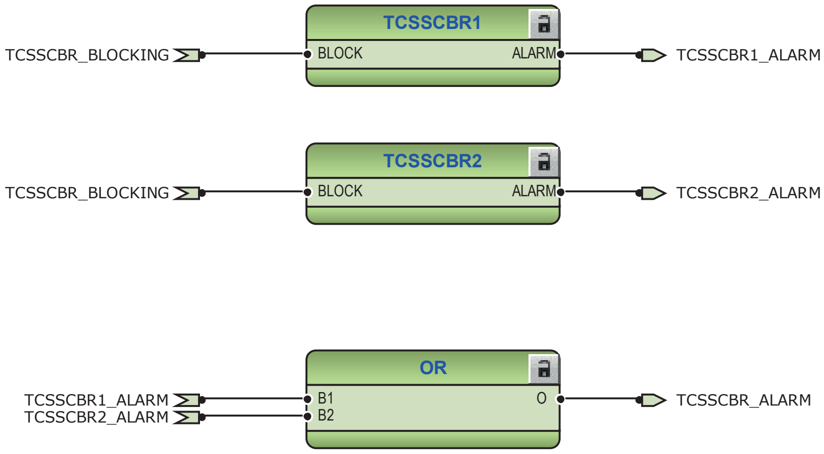


Figure 536: Trip circuit supervision function

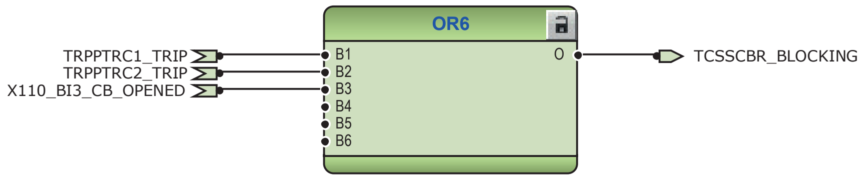


Figure 537: Logic for blocking trip circuit supervision

3.13.3.4 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 are connected to DCSXSWI1 and ESSXSI1.

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

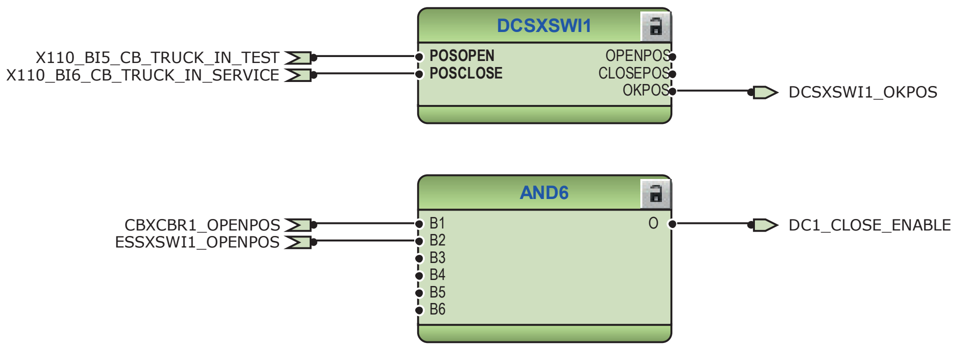


Figure 538: Disconnector interlocking logic

Connect the additional signals for the application for closing of earthing switch.

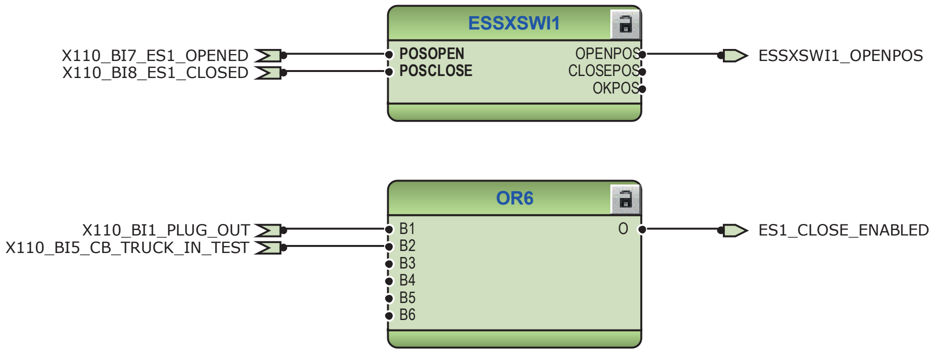


Figure 539: Earthing switch close enable logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit-breaker spring charging status.

The OKPOS output from DCSXSWI defines whether disconnector or 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 circuit breaker is always enabled.

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

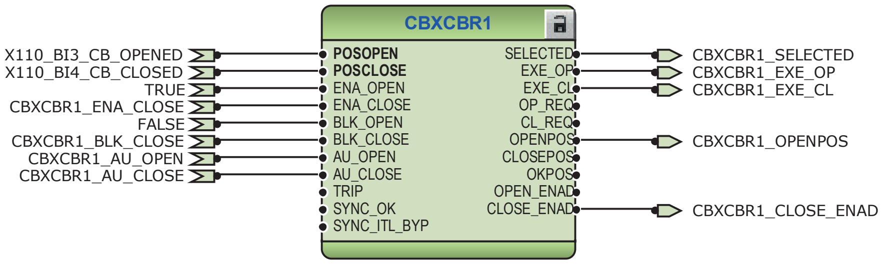


Figure 540: Circuit breaker control logic: Circuit breaker 1

Connect the additional signals required for the application for closing and opening of circuit breaker.

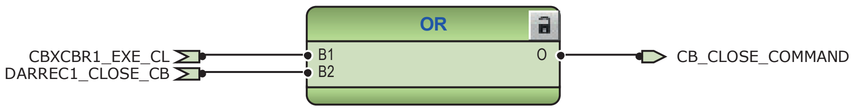


Figure 541: Circuit breaker control logic: Signal for closing coil of circuit breaker 1

Figure 542: Circuit breaker control logic: Signal for opening coil of circuit breaker 1

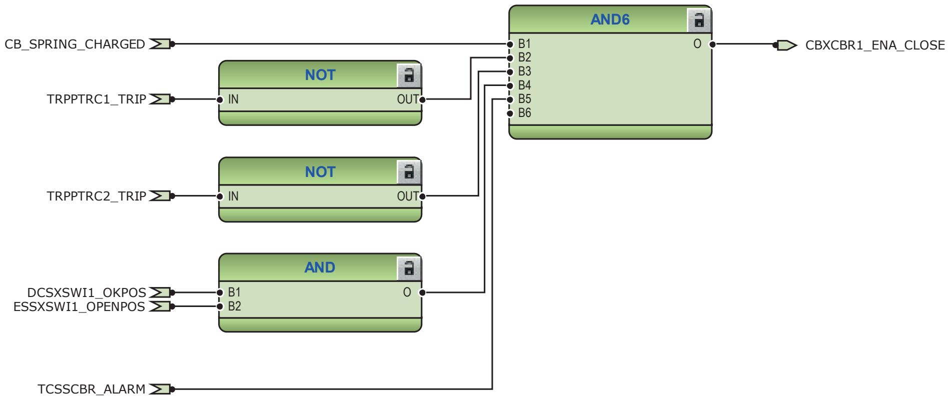


Figure 543: Circuit breaker close enable logic

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

Figure 544: Circuit breaker 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 signal for closing and opening of circuit breaker in local or remote mode if applicable for the configuration.

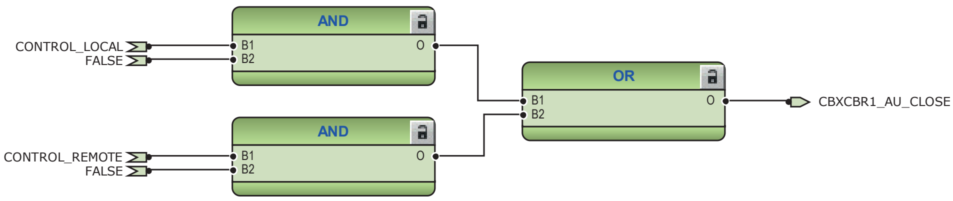


Figure 545: External closing command for circuit breaker

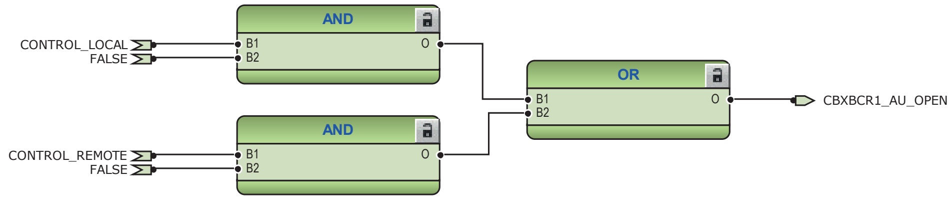


Figure 546: External opening command for circuit breaker

3.13.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The three phase current input is connected to the X131, X132 and X133 card in the back panel for three phases. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current. Residual current input is connected to the X130 card in the back panel.

The three-phase bus side phase voltage inputs to the IED are measured by three-phase voltage measurement VMMXU1. The three-phase current input is connected to the X131, X132 and X133 card in the back panel for three-phases. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESCMMXU1 measures the voltage 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.

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

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. The required logic connections can be made depending on the application by PCM600.

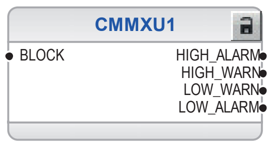


Figure 547: Current measurement: Three-phase current measurement

Figure 548: Current measurement: Sequence current measurement

Figure 549: Current measurement: Residual current measurement

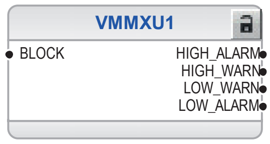


Figure 550: Voltage measurement: Three-phase voltage measurement

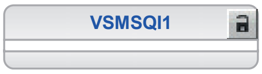


Figure 551: Voltage measurement: Sequence voltage measurement

Figure 552: Other measurement: Frequency measurement

Figure 553: Other measurement: Three-phase power and energy measurement

Figure 554: Other measurement: Data monitoring

Figure 555: Other measurement: Load profile record

3.13.3.6 Functional diagrams for I/O and alarm LEDs

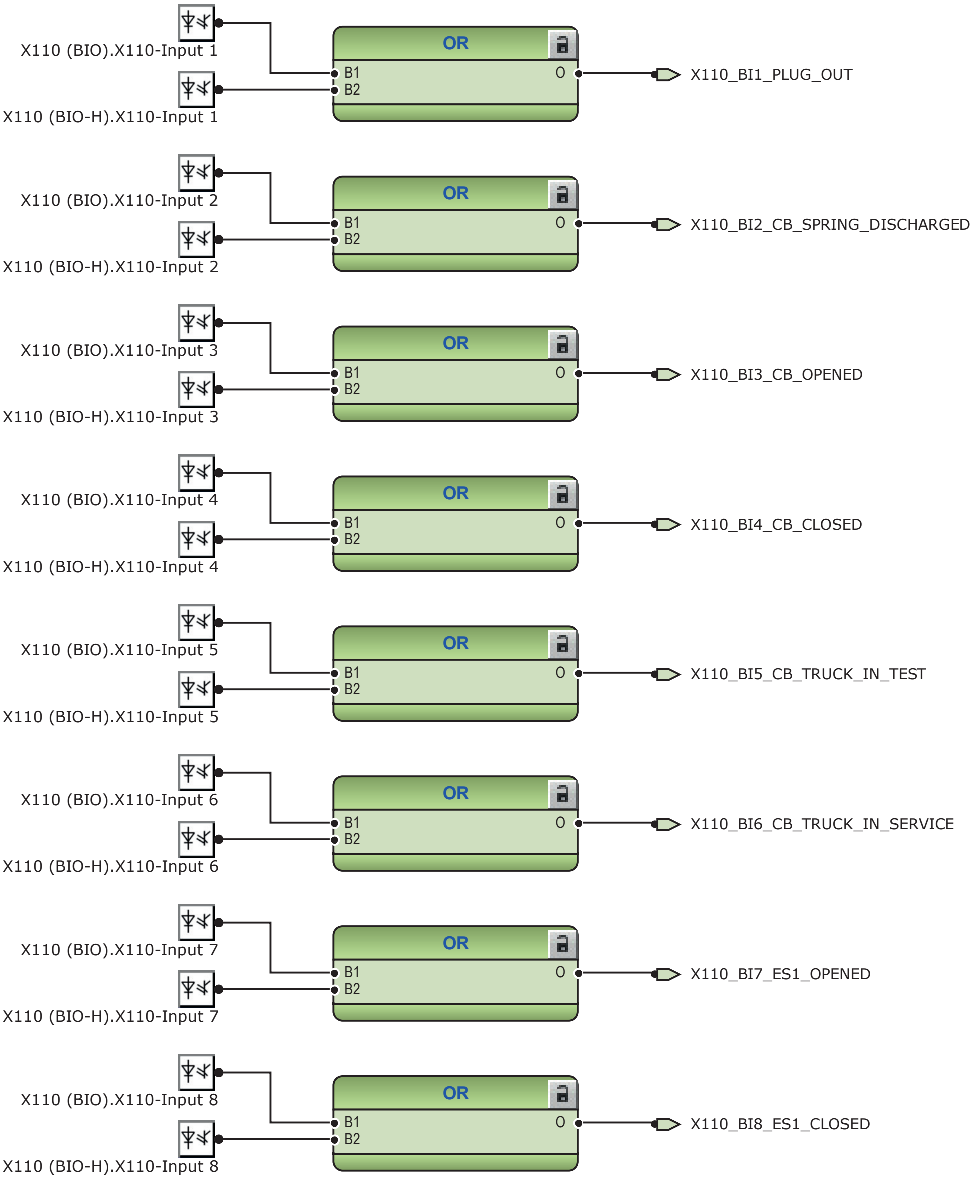


Figure 556: Default binary inputs - X110 terminal block

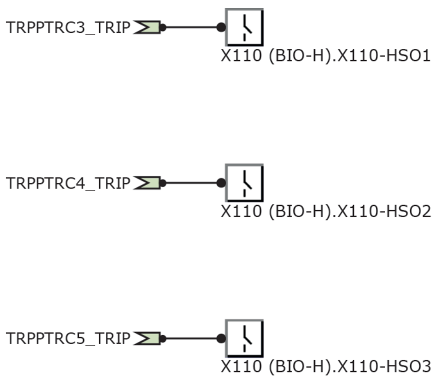


Figure 557: Default binary outputs - X110 terminal block

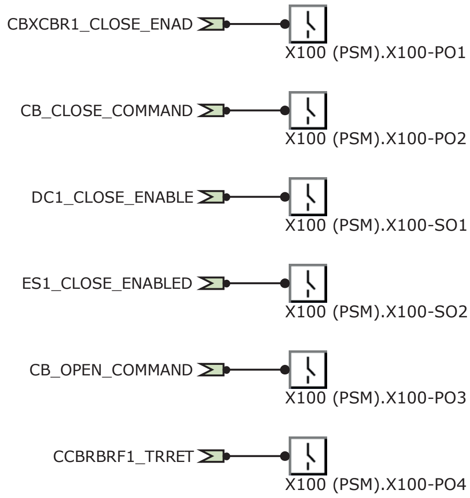
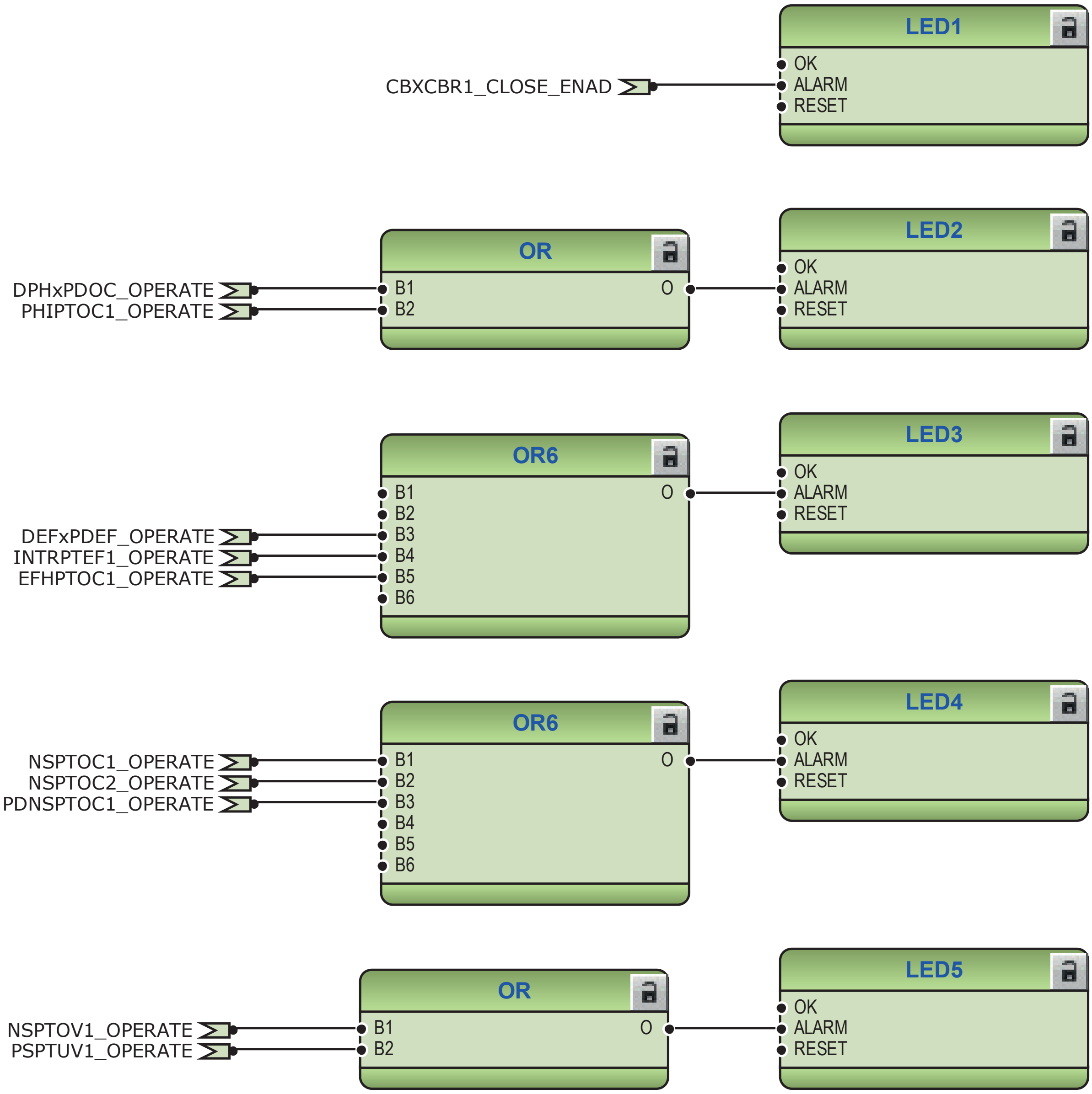


Figure 558: Default binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
CBXCBR1_CLOSE_ENAD
OR
B1
B2
O
LED2
OK
ALARM
RESET
DPHxPDOC_OPERATE
PHIPTOC1_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED3
OK
ALARM
RESET
DEFxPDEF_OPERATE
INTRPTEF1_OPERATE
EFHPTOC1_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED4
OK
ALARM
RESET
NSPTOC1_OPERATE
NSPTOC2_OPERATE
PDNSPTOC1_OPERATE
OR
B1
B2
O
LED5
OK
ALARM
RESET
NSPTOV1_OPERATE
PSPTUV1_OPERATE

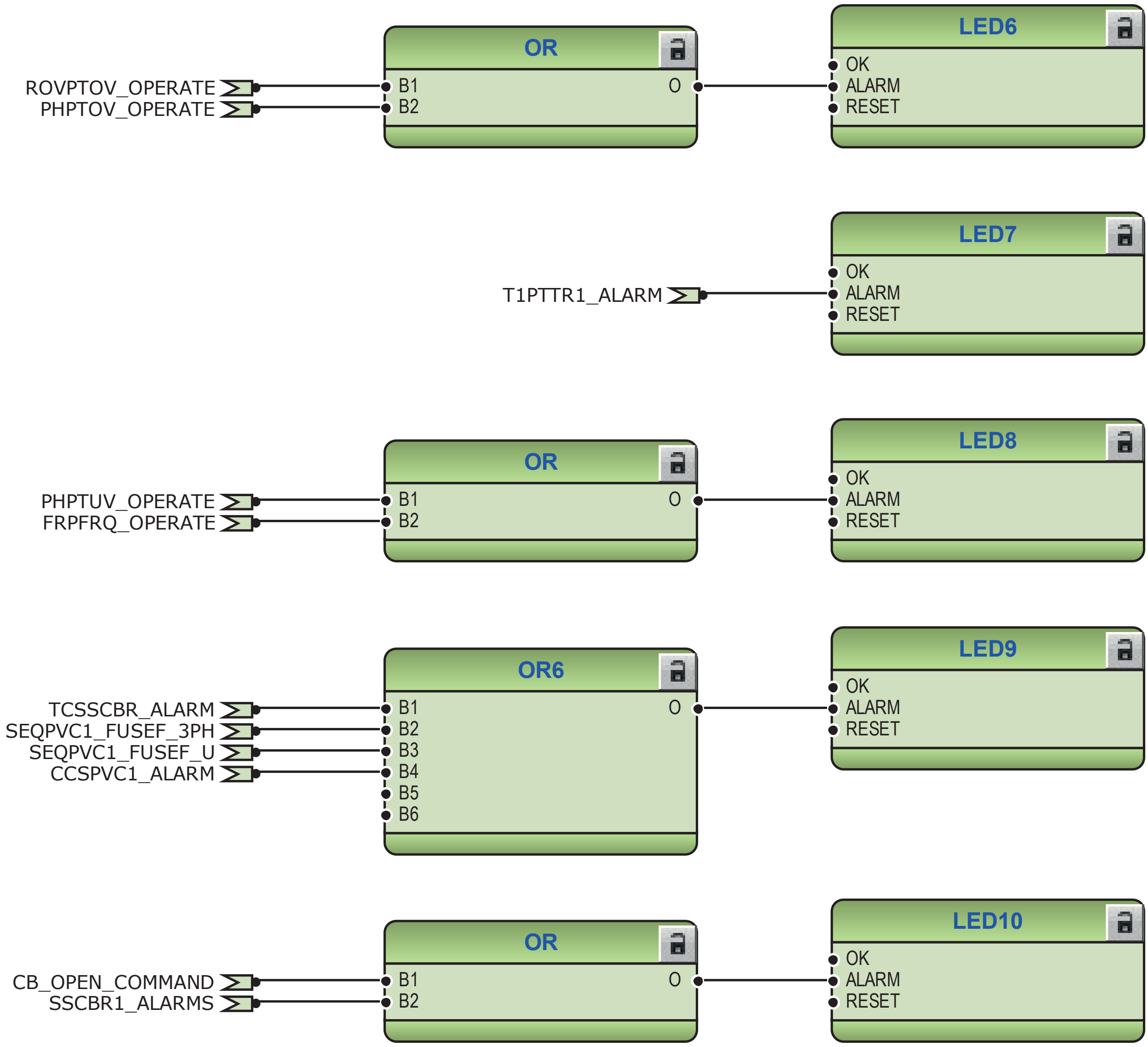


Figure 559: Default LED connections

3.13.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate and combined voltage & frequency operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

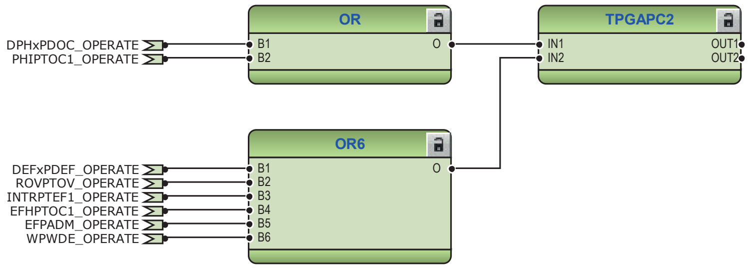


Figure 560: Timer logic for overcurrent and earth-fault operate pulse

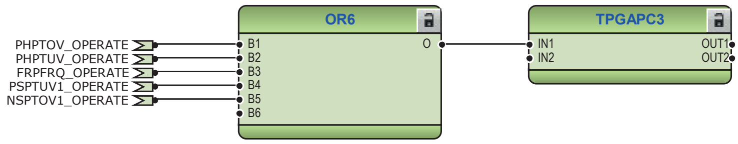


Figure 561: Timer logic for voltage and frequency operate pulse

3.13.3.8 Other functions

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

3.14 Standard configuration N

3.14.1 Applications

The standard configuration N provides the highest functionality level of all the REF615 standard configurations. Standard configuration N is delivered as pre-configured with the same configuration as standard configuration D. Standard configuration N provides the possibility to standardize on one type of REF615. Depending on the specific feeder application, the appropriate functionality can be selected and an own configuration created with the Application Configuration tool in PCM600. Standard configuration N is not designed to utilize at once all the available functionality content in one IED. To ensure the performance of the IED, the user specific configuration load needs to be verified with the Application Configuration tool in PCM600.

3.14.2 Functions

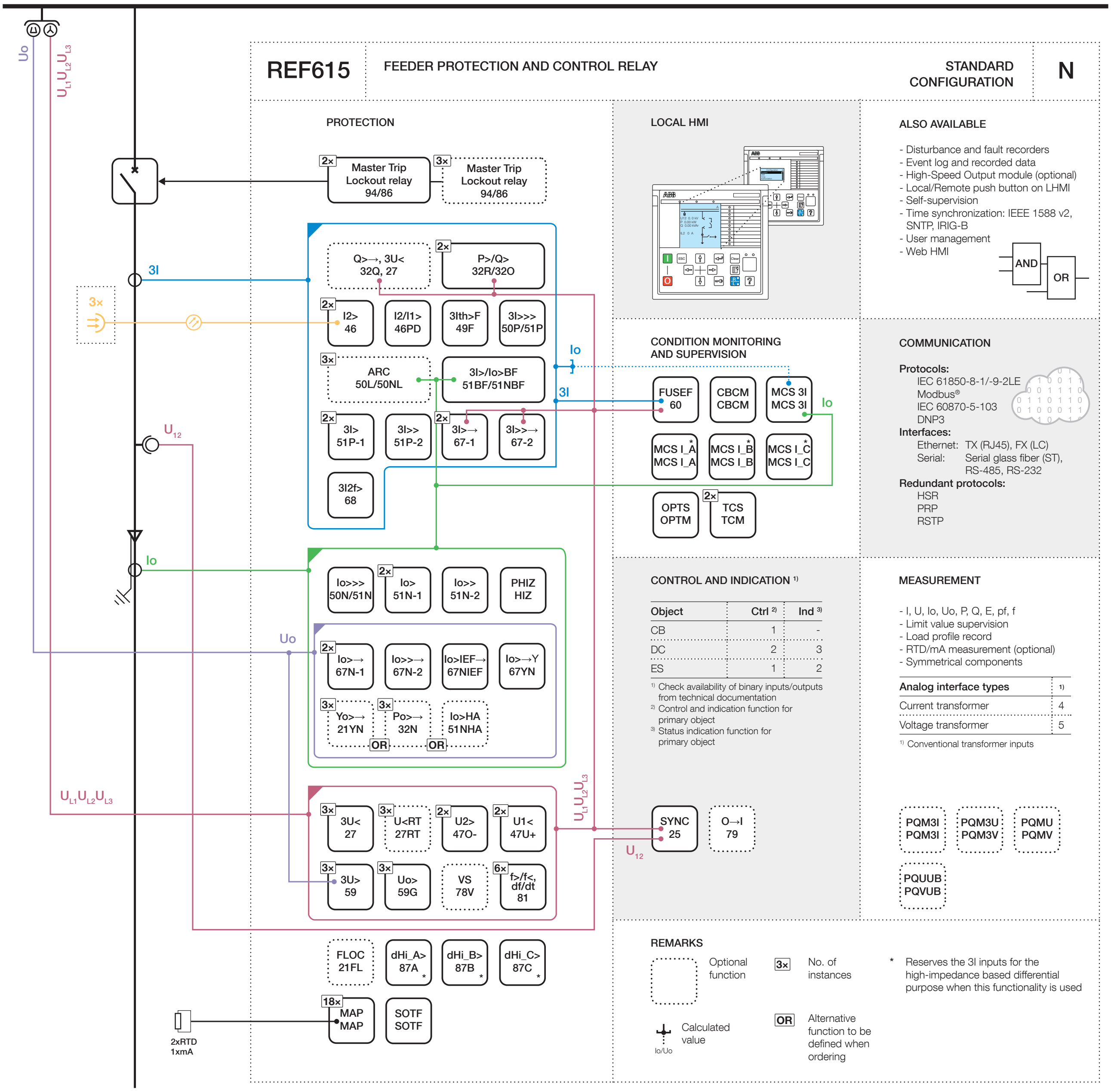


Figure 562: Functionality overview for standard configuration N

3.14.2.1 Default I/O connections

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

Table 66: Default connections for binary inputs

Binary input	Description
X110-BI2	Autoreclose external start command
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	Circuit breaker truck in (service position) indication
X110-BI6	Circuit breaker truck out (test position) indication
X110-BI7	Earthing switch closed indication
X110-BI8	Earthing switch open indication
X120-BI1	Blocking of overcurrent instantaneous stage
X120-BI2	Circuit breaker closed indication
X120-BI3	Circuit breaker open indication
X120-BI4	Reset of master trip lockout

Table 67: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Circuit breaker failure protection trip to upstream breaker
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Open circuit breaker/trip coil 2
X100-SO1	General start indication
X100-SO2	General operate indication
X110-SO1	Upstream overcurrent blocking
X110-SO2	Overcurrent operate alarm
X110-SO3	Earth-fault operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 68: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Non-directional earth-fault operate
3	Sensitive earth-fault operate
4	Negative sequence overcurrent or phase discontinuity

Table continues on the next page

LED	Description
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Trip circuit supervision alarm
10	Arc protection operate
11	Autoreclose in progress

3.14.2.2 Default disturbance recorder settings

Table 69: Default disturbance recorder analog channels

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

Table 70: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC2 - start	Positive or Rising
4	PHIPTOC1 - start	Positive or Rising
5	NSPTOC1 - start	Positive or Rising
6	NSPTOC2 - start	Positive or Rising
7	EFLPTOC1 - start	Positive or Rising
8	EFHPTOC1 - start	Positive or Rising
9	EFIPTOC1 - start	Positive or Rising
10	EFLPTOC2 - start	Positive or Rising
11	–	–
12	PDNSPTOC1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
13	T1PTTR1 - start	Positive or Rising
14	CCBRBRF1 - trret	Level trigger off
15	CCBRBRF1 - trbu	Level trigger off
16	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC2 - operate	
	PHLPTOC1 - operate	
17	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
18	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
19	X110BI2 - ext start AutoReclose	Level trigger off
20	EFLPTOC2 - operate	Level trigger off
21	PDNSPTOC1 - operate	Level trigger off
22	INRPHAR1 - blk2h	Level trigger off
23	T1PTTR1 - operate	Level trigger off
24	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
25	ARCSARC1 - operate	Positive or Rising
26	ARCSARC2 - operate	Positive or Rising
27	ARCSARC3 - operate	Positive or Rising
28	DARREC1 - inpro	Level trigger off
29	DARREC1 - close CB	Level trigger off
30	DARREC1 - unsuc recl	Level trigger off
31	X120BI1 - ext OC blocking	Level trigger off
32	X120BI2 - CB closed	Level trigger off
33	X120BI3 - CB opened	Level trigger off

3.14.3 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.

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

3.14.3.1 Functional diagrams for protection

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

Four non-directional overcurrent stage and three 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.

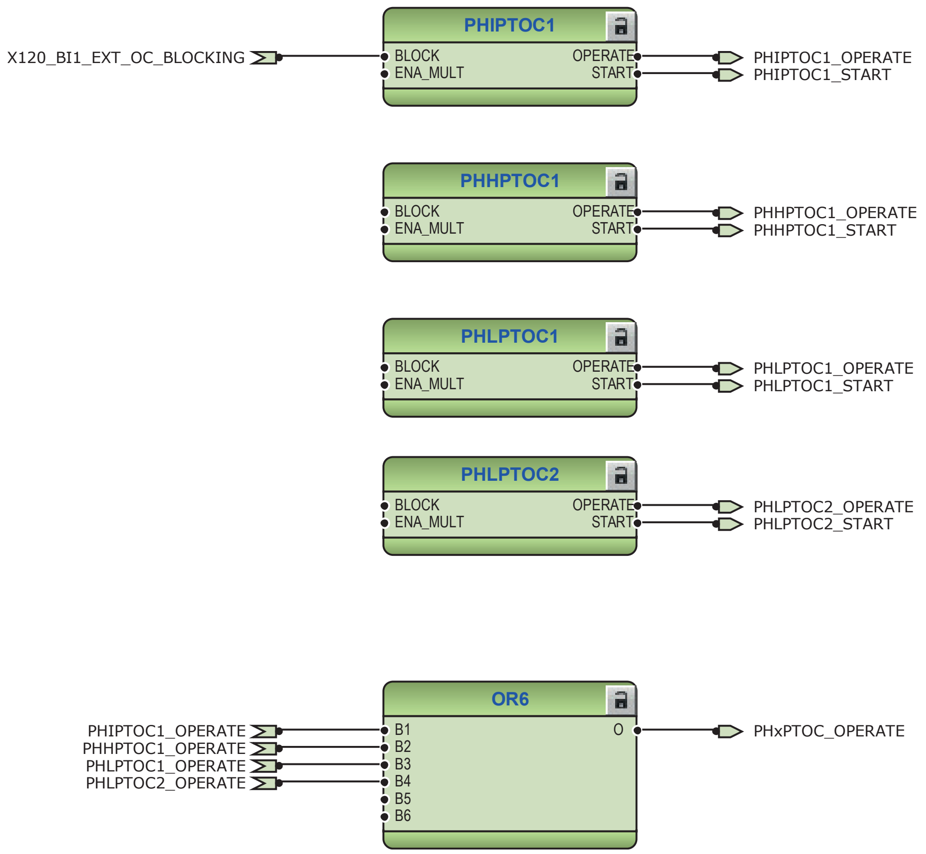


Figure 563: Overcurrent protection functions

The upstream blocking from the start of the second low stage of three-phase non-directional overcurrent protection PHLPTOC2 is connected to the binary output X110:SO1. This output can be used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

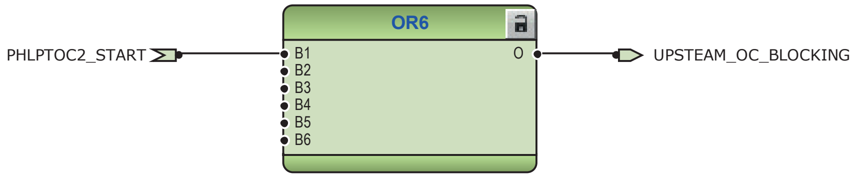


Figure 564: Upstream blocking logic

The output `BLK2H` of three-phase inrush detector INRPHAR1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or earth-fault function blocks.

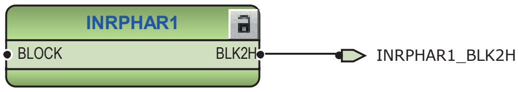


Figure 565: Inrush detector function

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.

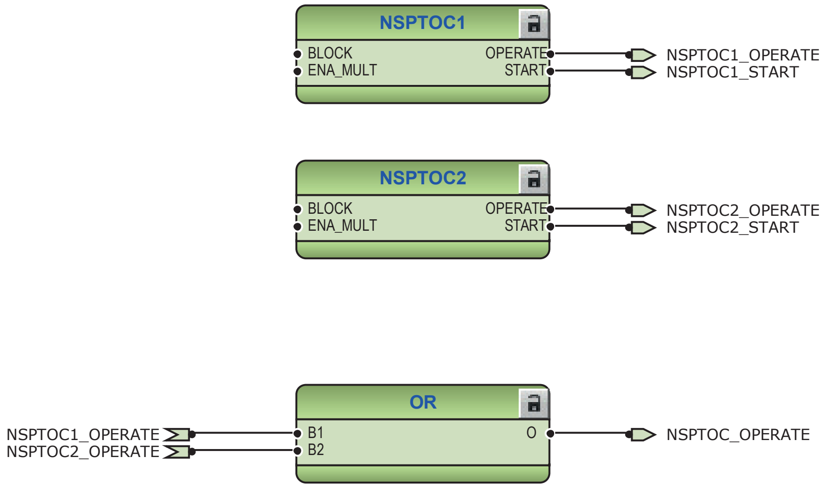


Figure 566: Negative sequence overcurrent protection function

Four non-directional earth-fault stages and three directional earth-fault stages are offered earth-fault protection. However in the configuration three non-directional earth fault stages are considered. One stage is dedicated to sensitive earth-fault protection EFLPTOC2. 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 used together with admittance-based earth-fault protection EFPADM, wattmetric-based earth-fault protection WPWDE or harmonics-based earth-fault protection HAEFPTOC. A dedicated protection stage INTRPTEF is used either for transient based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

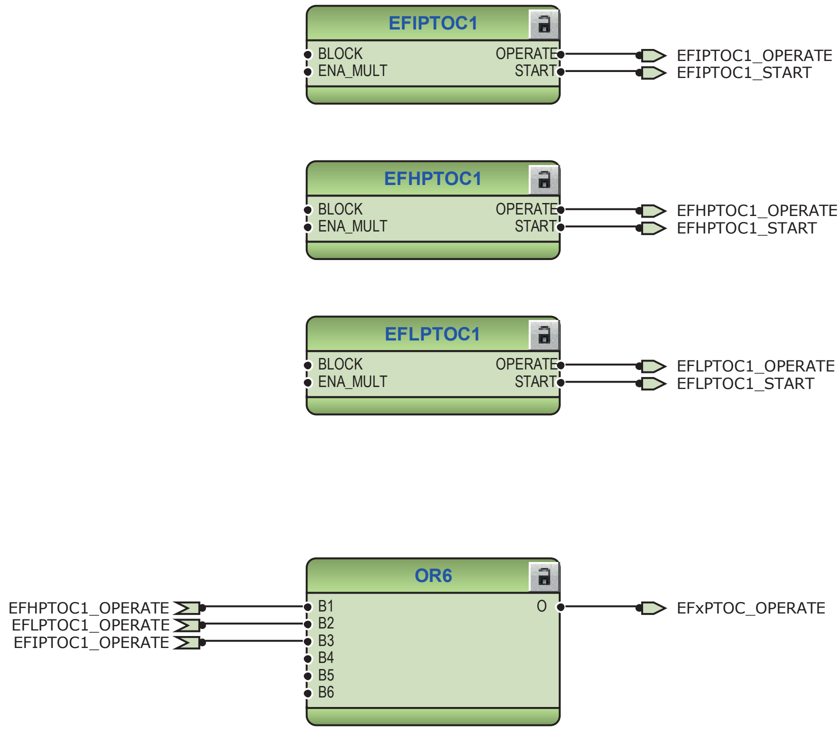


Figure 567: Earth-fault protection functions

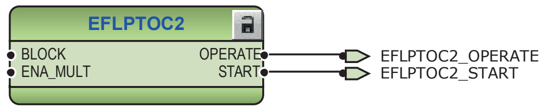


Figure 568: Sensitive earth-fault protection function

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

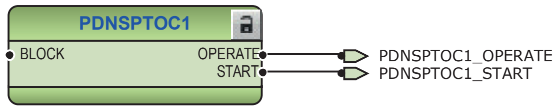


Figure 569: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function can be used to block the closing operation of circuit breaker.

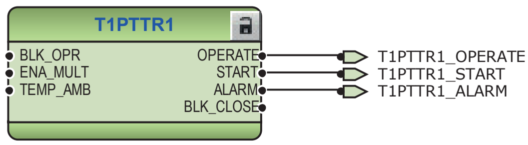


Figure 570: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by number of different protection functions available in the IED. The 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.

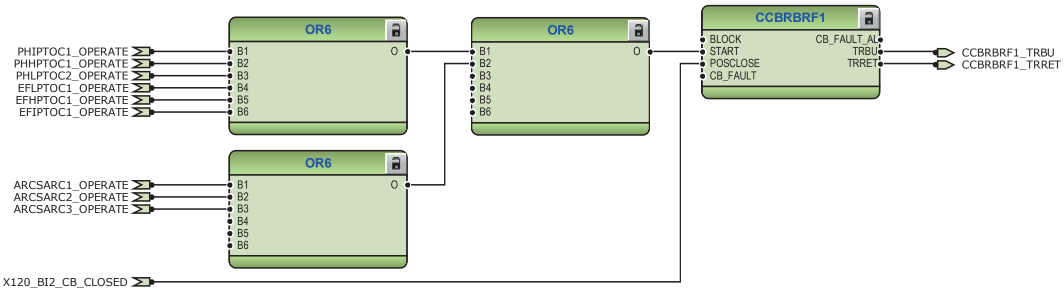


Figure 571: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The outputs of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

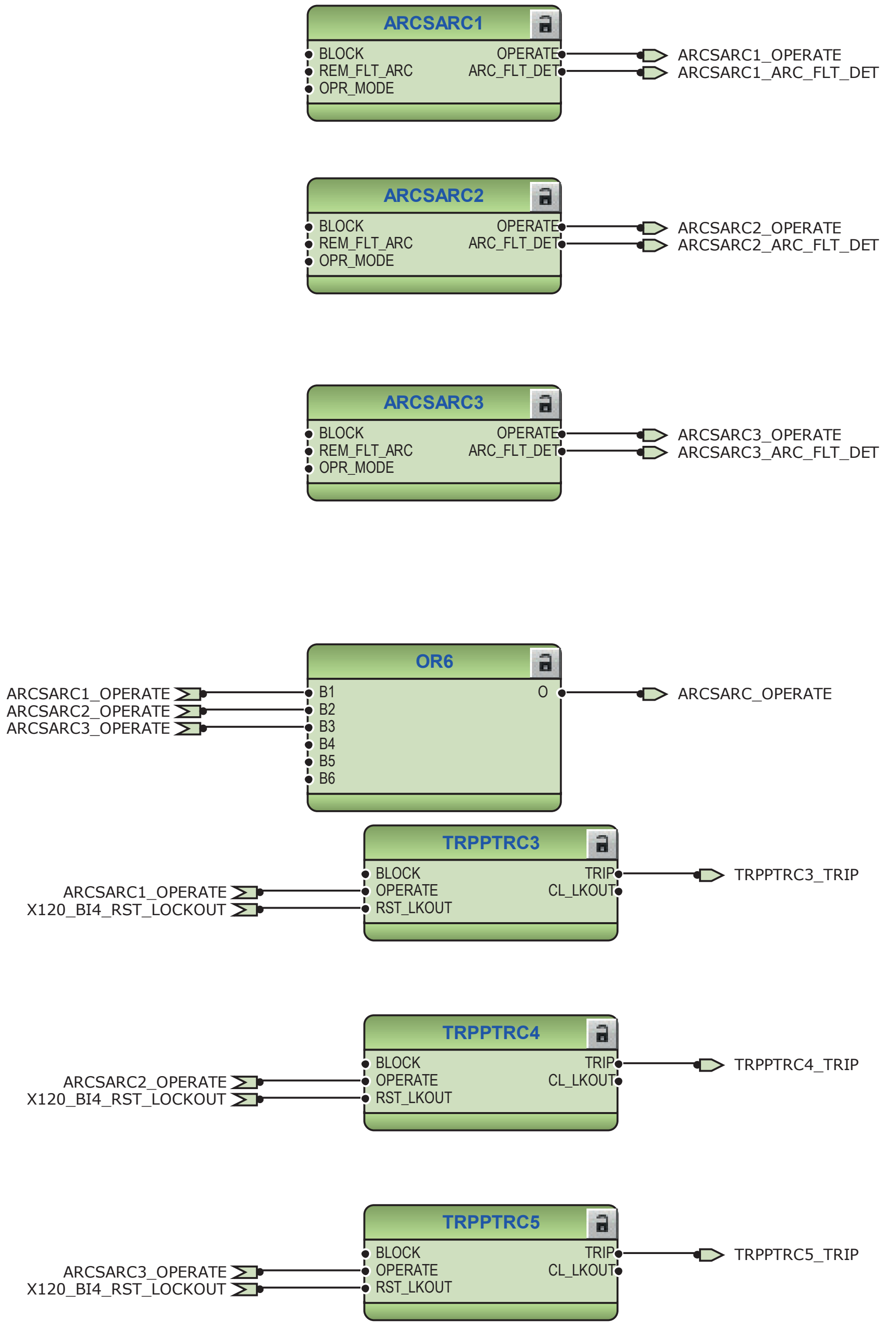


Figure 572: Arc protection with dedicated HSO

The optional autoreclosing function is configured to be initiated by operate signals from a number of protection stages through the `INIT_1...5` inputs. The `INIT_6` input in the autoreclosing function block is controlled by a binary input X110: BI2 enabling the use of the external autoreclosing start command. 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 the close command is connected directly to the binary output X100:PO1.

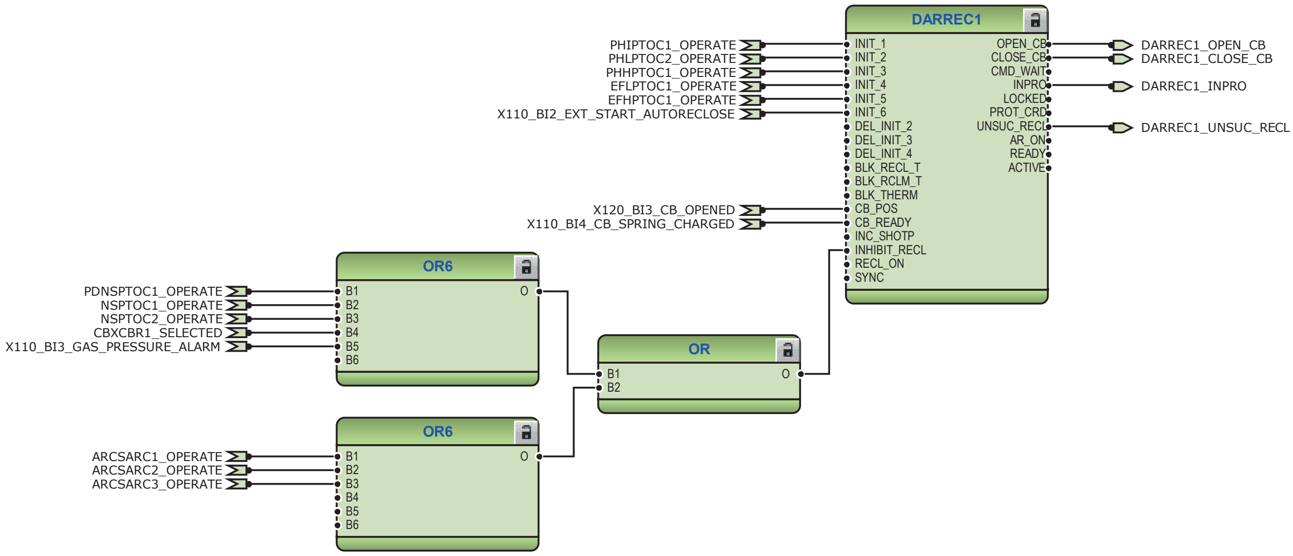


Figure 573: Autoreclosing function

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 is connected to binary outputs

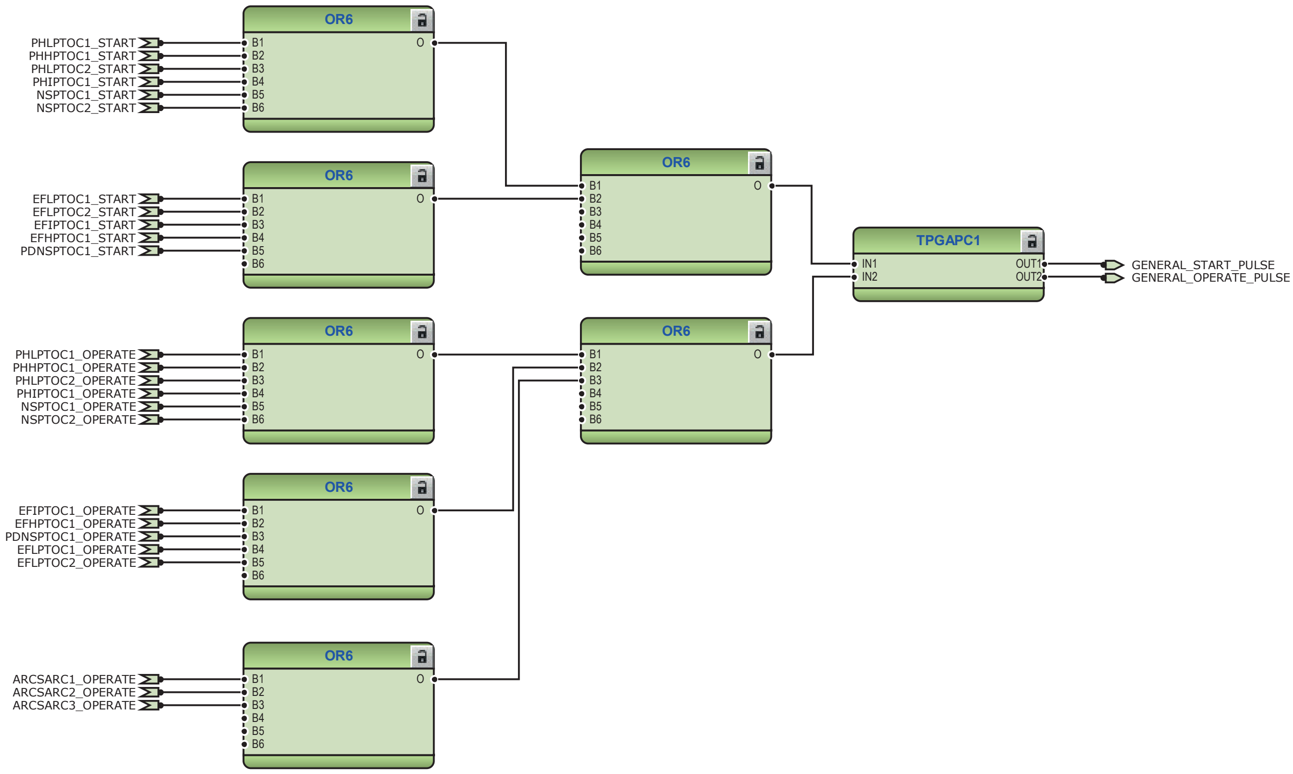


Figure 574: General start and operate signals

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 has been assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

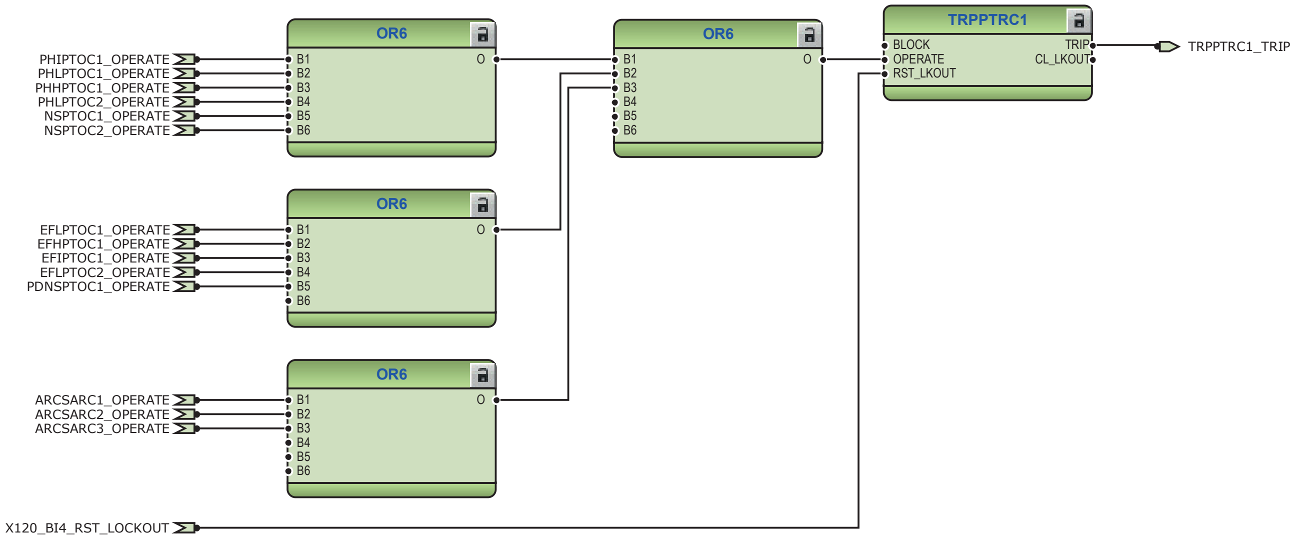


Figure 575: Trip logic TRPPTRC1

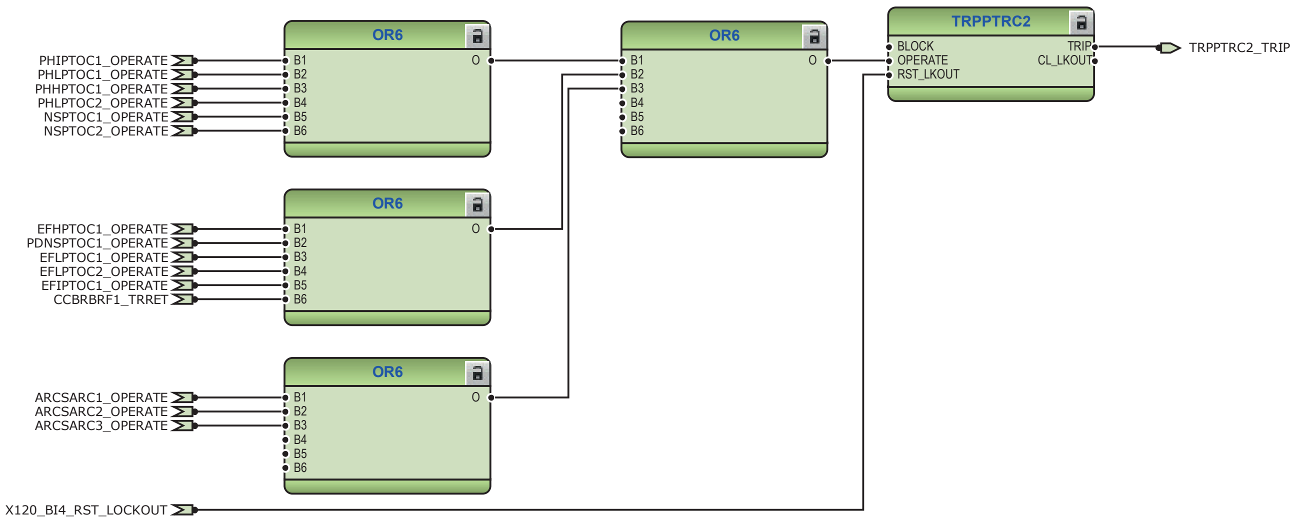


Figure 576: Trip logic TRPPTRC2

3.14.3.2 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 few binary inputs are also connected to the disturbance recorder.

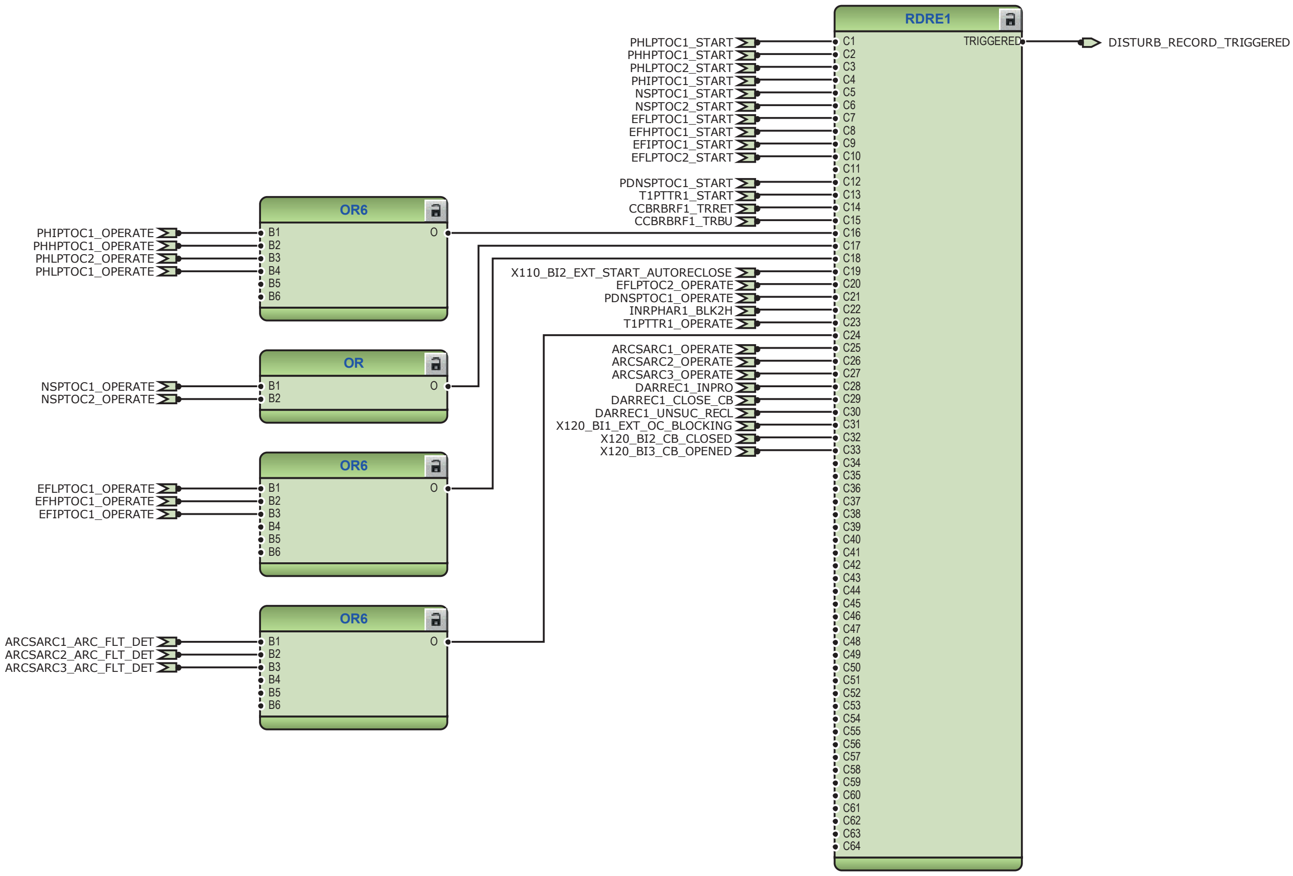


Figure 577: Disturbance recorder

3.14.3.3 Functional diagrams for condition monitoring

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.

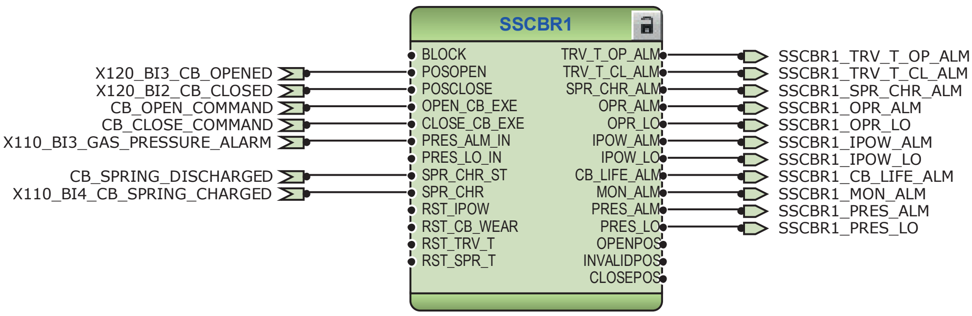


Figure 578: Circuit-breaker condition monitoring function

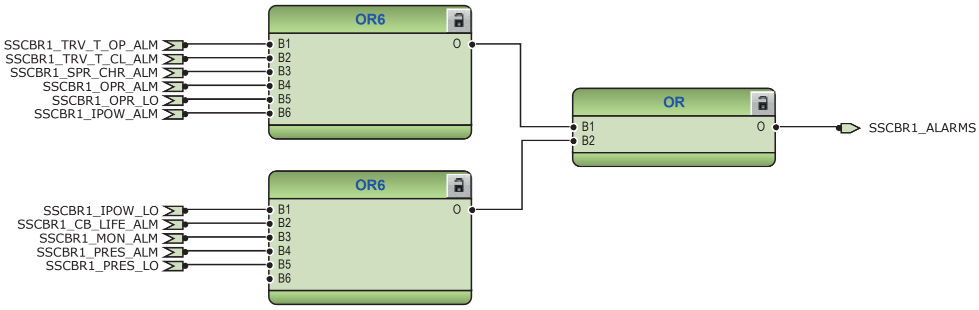


Figure 579: Logic for circuit-breaker monitoring alarm

Figure 580: 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. 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 TCSSCBR properly.

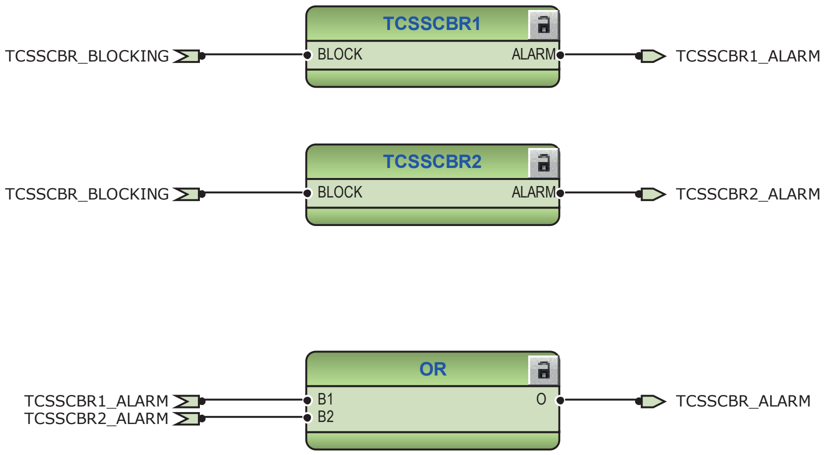


Figure 581: Trip circuit supervision function

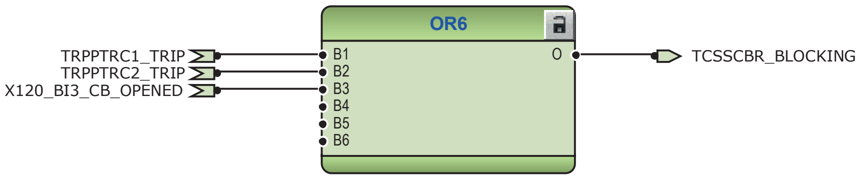


Figure 582: Logic for blocking of trip circuit supervision function

3.14.3.4 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 are connected to DCSXSWI1 and ESSXSI1.

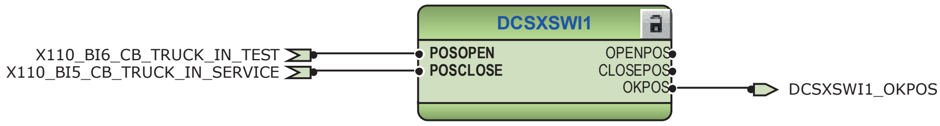


Figure 583: Disconnector control logic

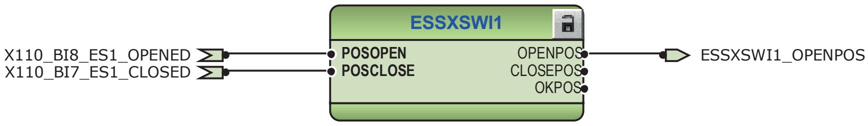


Figure 584: Earthing-switch control logic

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 breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit-breaker spring charging status.

The OKPOS output from DCSXSWI defines whether the disconnector or 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 circuit breaker is always enabled.

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

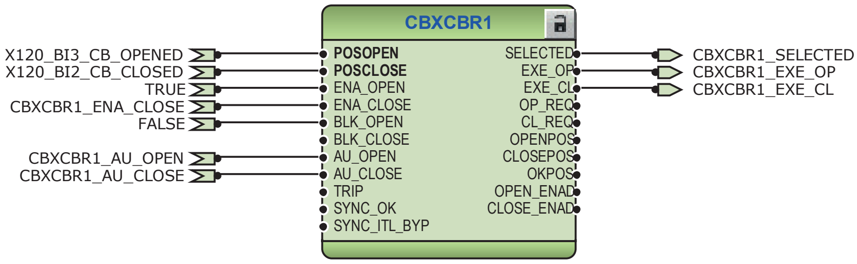


Figure 585: Circuit breaker control logic: Circuit breaker 1

Connect the addition signals required for the application for closing and opening of circuit breaker.

Figure 586: Circuit breaker control logic: Signals for closing coil of circuit breaker

Figure 587: Circuit breaker control logic: Signals for opening coil of circuit breaker

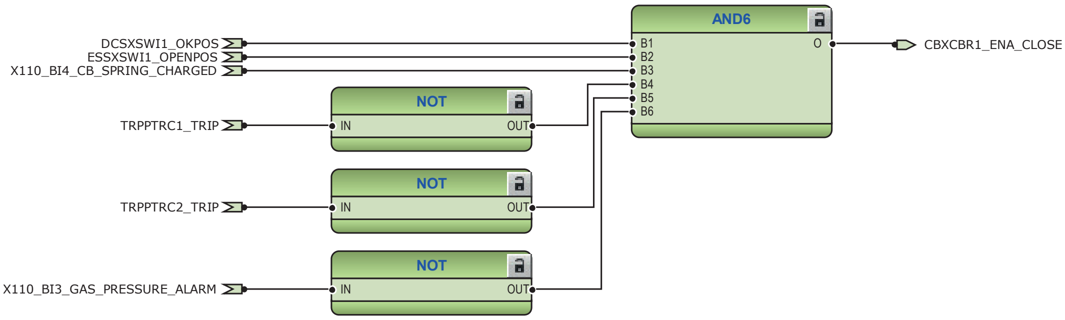


Figure 588: Circuit breaker close enable logic

The configuration includes the 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 signal for closing and opening of circuit breaker in local or remote mode if applicable for the configuration.

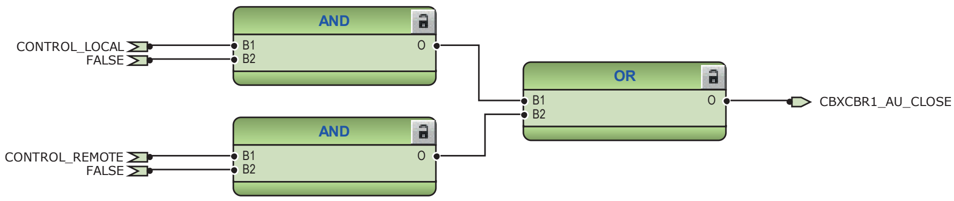


Figure 589: External closing command for circuit breaker 1

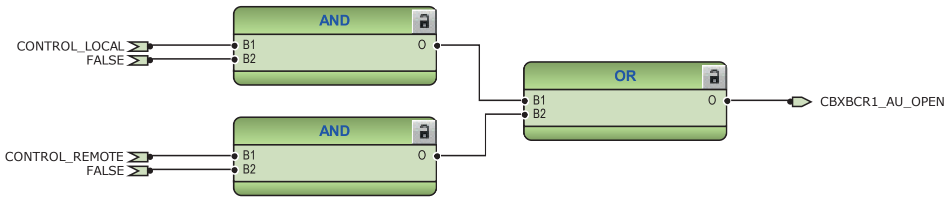


Figure 590: External opening command for circuit breaker 1

3.14.3.5 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 gives the ability to observe the loading history of the corresponding feeder.

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. The required logic connections can be made depending on the application by PCM600.

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

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 are available.

However, these voltage, frequency and power measurement functions need to be added in application configurations.

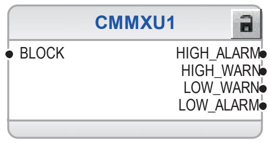


Figure 591: Current measurement: Three-phase current measurement

Figure 592: Current measurement: Sequence current measurement

Figure 593: Current measurement: Residual current measurement

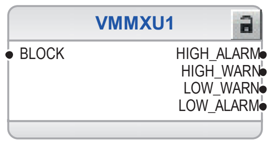


Figure 594: Voltage measurement: Three-phase voltage measurement

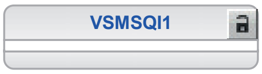


Figure 595: Residual measurement: Residual voltage measurement

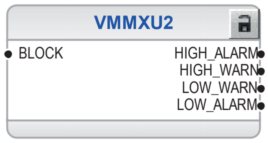


Figure 596: Voltage measurement: Three-phase voltage measurement

Figure 597: Other measurement: Frequency measurement

Figure 598: Other measurement: Three-phase power and energy measurement

Figure 599: Other measurement: Data monitoring

Figure 600: Other measurement: Load profile record

3.14.3.6 Functional diagrams for I/O and alarm LEDs

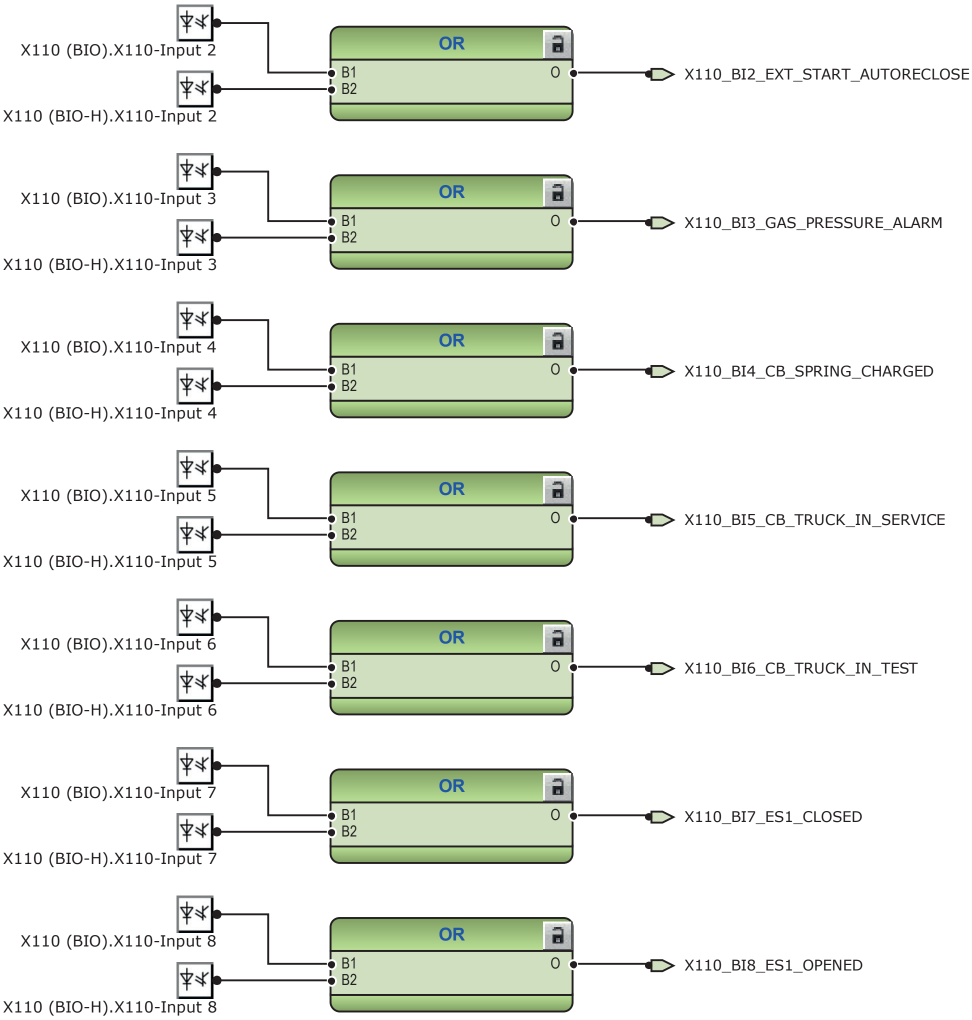


Figure 601: Binary inputs - X110 terminal block

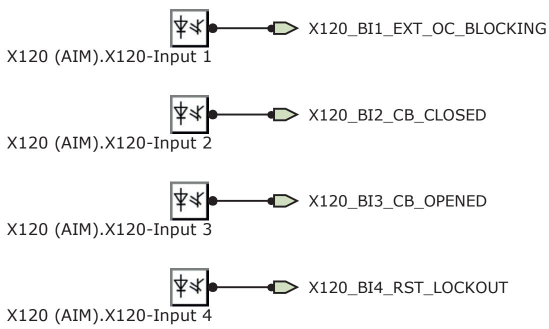


Figure 602: Binary inputs - X120 terminal block

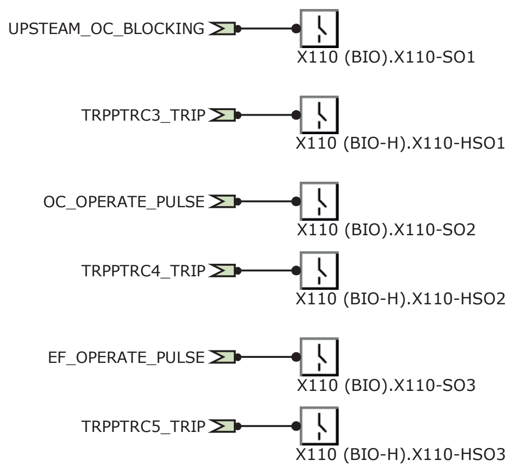


Figure 603: Binary outputs - X110 terminal block

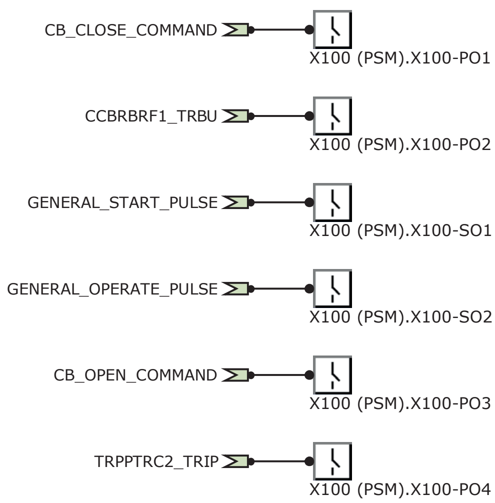
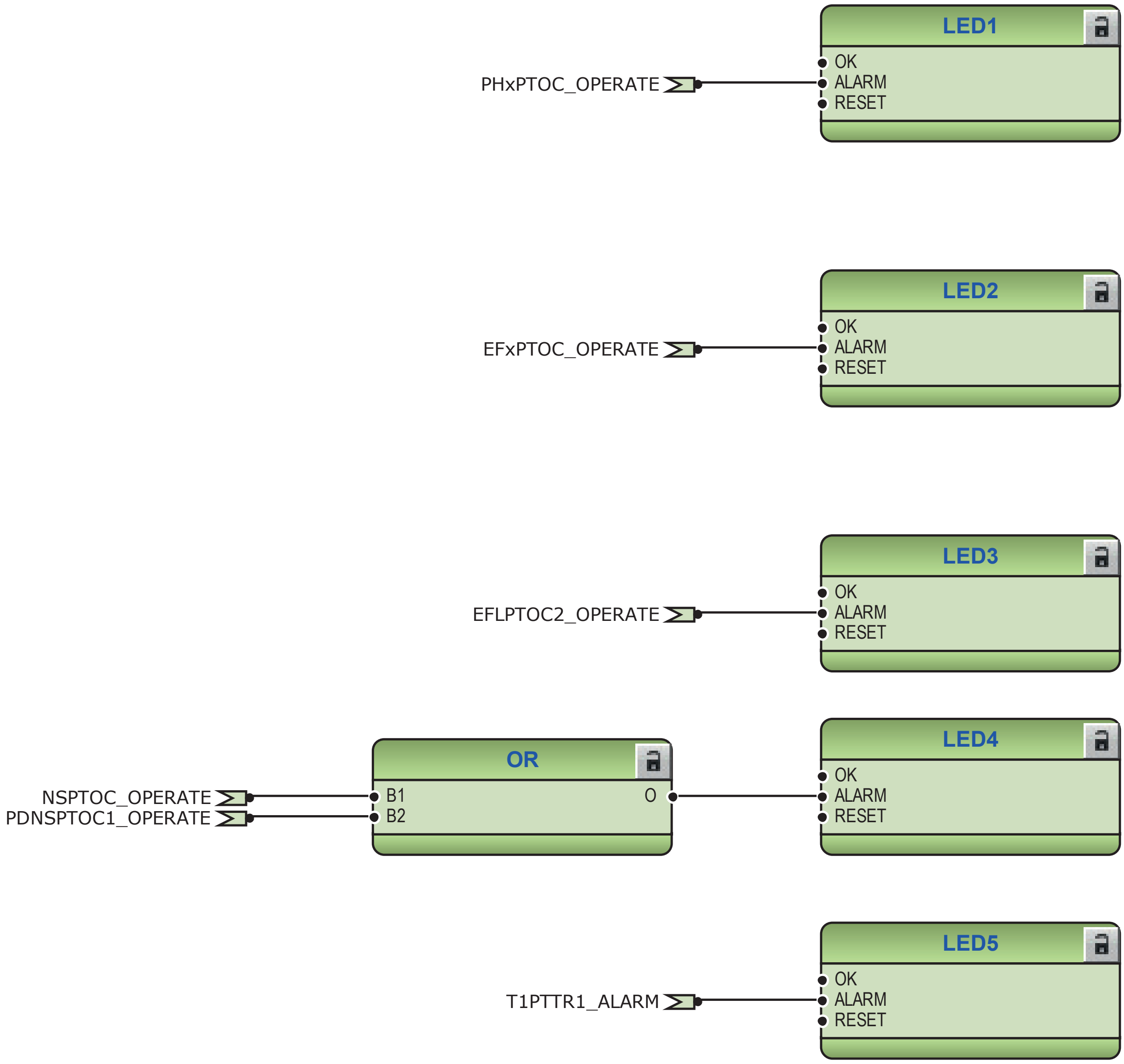


Figure 604: Binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
PHxPTOC_OPERATE
LED2
OK
ALARM
RESET
EFxPTOC_OPERATE
LED3
OK
ALARM
RESET
EFLPTOC2_OPERATE
OR
B1
B2
O
NSPTOC_OPERATE
PDNSPTOC1_OPERATE
LED4
OK
ALARM
RESET
LED5
OK
ALARM
RESET
T1PTTR1_ALARM

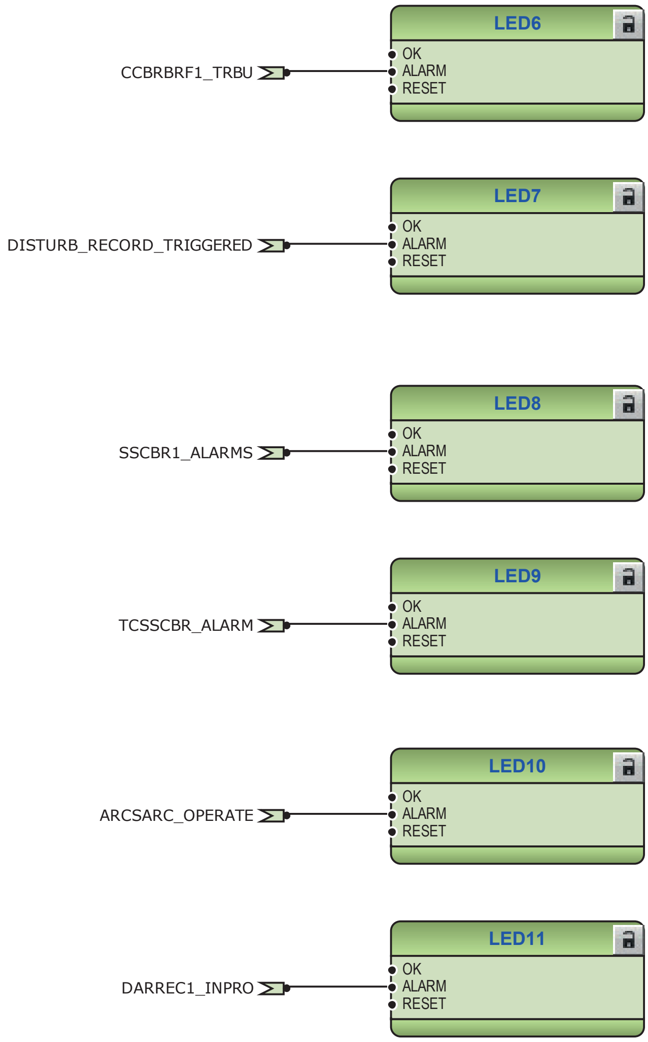


Figure 605: Default LED connection

3.14.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate and earth-fault operate logic. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

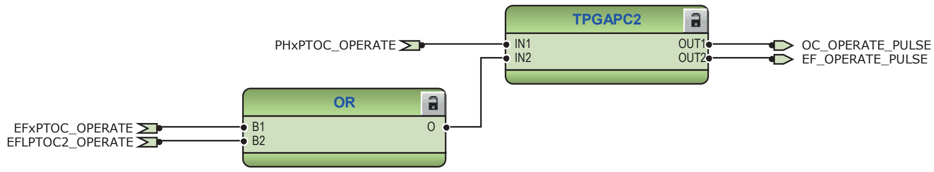


Figure 606: Timer logic for overcurrent and earth-fault operate pulse

3.14.3.8 Other functions

The configuration includes few instances of residual overvoltage protection, phase overvoltage and undervoltage protection, positive-sequence undervoltage protection, negative-sequence overvoltage protection, frequency protection, multipurpose protection MAPGAPC, high-impedance fault detection 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.

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 71: 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 $< 0.7 \times (I_{kmin} / I_{1n})$

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

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

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The 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.

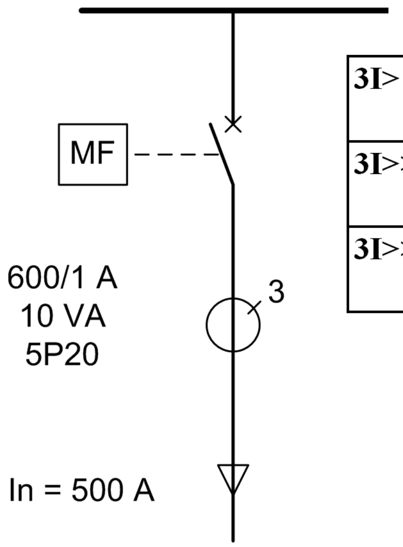
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen 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 607: 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 607*). 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 607*.

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 72: Phase current inputs included in configurations A, B, C, D, E, F, H, J, K and N

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

5.1.1.2 Residual current

Table 73: Residual current input included in configurations A, B, C, D, E, F, H, J and N

Terminal	Description
X120:13-14	Io

Table 74: Residual current input included in configuration K

Terminal	Description
X120:5-6	IoB[4]
X120:13-14	Io

Table 75: Residual current input included in configuration G

Terminal	Description
X130:1-2	Io

[4] Used only for HREFPDIF1

5.1.1.3 Phase voltages

Table 76: Phase voltage inputs included in configurations E, F, H, J, K and N

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

Table 77: Reference voltage input for SECRSYN1 included in configurations H, J, K and N

Terminal	Description
X130:9-10	U12B

5.1.1.4 Residual voltage

Table 78: Additional residual voltage input included in configurations A and B

Terminal	Description
X120:5-6	Uo

Table 79: Additional residual voltage input included in configurations E, F, H, J, K and N

Terminal	Description
X130:17-18	Uo

5.1.1.5 Sensor inputs

Table 80: Combi sensor inputs included in configurations G and L

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 81: 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.

Binary inputs of slot X110 are available with configurations B, D, E, F, G, H, J, K, L and N.

Table 82: 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, +

Table 83: Binary input terminals X110:1-10 with BIO0007 module

Terminal	Description
X110:1 X110:5	BI1, + BI1, -
X110:2 X110:5	BI2, + BI2, -
X110:3 X110:5	BI3, + BI3, -
X110:4 X110:5	BI4, + BI4, -

Table continues on the next page

Terminal	Description
X110:6 X110:10	BI5, + BI5, -
X110:7 X110:10	BI6, + BI6, -
X110:8 X110:10	BI7, + BI7, -
X110:9 X110:10	BI8, + BI8, -

Binary inputs of slot X120 are available with configurations C, D, E, F, H, J and N.

Table 84: 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 configurations A and B.

Table 85: 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 B and D.

Table 86: 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, -

Table continues on the next page

Terminal	Description
X130:5 X130:6	BI4, - BI4, +
X130:7 X130:8	BI5, + BI5, -
X130:8 X130:9	BI6, - BI6, +

Binary inputs of slot X130 are available with configuration K and optionally available with configurations E, F, H, J and N.

Table 87: Binary input terminals X130:1-8 with AIM0006 module

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 Optional light sensor inputs

If the protection relay is provided with the optional communication module with light sensor inputs, the pre-manufactured lens-sensor fibers are connected to inputs X13, X14 and X15. See the connection diagrams. For further information, see arc protection.

The protection relay is provided with connection sockets X13, X14 and X15 only if the optional communication module with light sensor inputs has been installed. If the arc protection option is selected when ordering a protection relay, the light sensor inputs are included in the communication module.

Table 88: Light sensor input connectors

Terminal	Description
X13	Input Light sensor 1
X14	Input Light sensor 2
X15	Input Light sensor 3

5.1.5 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 the optional RTD0001 module in standard configurations A and B and with the AIM0003 module in standard configurations E, F, H, J and N.

Table 89: Optional RTD/mA inputs with RTD0001 module

Terminal	Description
X130:1 X130:2	mA1 (AI1), + mA1 (AI1), -
X130:3 X130:4	mA2 (AI2), + mA2 (AI2), -
X130:5 X130:6	RTD1 (AI3), + RTD1 (AI3), -
X130:7 X130:8	RTD2 (AI4), + RTD2 (AI4), -
X130:9 X130:10	RTD3 (AI5), + RTD3 (AI5), -
X130:11 X130:12	Common[5] Common[6]
X130:13 X130:14	RTD4 (AI6), + RTD4 (AI6), -
X130:15 X130:16	RTD5 (AI7), + RTD5 (AI7), -
X130:17 X130:18	RTD6 (AI8), + RTD6 (AI8), -

Table 90: Optional RTD/mA inputs with AIM0003 module

Terminal	Description
X130:1 X130:2	mA1 (AI1), + mA1 (AI1), -
X130:3	RTD1 (AI2), +
X130:4 X130:5	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.

5 Common ground for RTD channels 1-3
6 Common ground for RTD channels 4-6

Table 91: 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 92: Output contacts X100:10-14

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

Output contacts of slot X110 are available with configurations B, D, E, F, G, H, J, K, L and N.

Table 93: 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

Table continues on the next page

Terminal	Description
X110:21 X110:22	SO3, NO SO3, NC
X110:23 X110:24	SO4, common SO4, NO

Table 94: Optional high-speed output contacts X110:15-24 with BIO0007

Terminal	Description
X110:15 X110:16	HSO1, NO HSO1, NO
X110:19 X110:20	HSO2, NO HSO2, NO
X110:23 X110:24	HSO3, NO HSO3, NO

Output contacts of slot X130 are available in the optional BIO module (BIO0006).

Output contacts of slot X130 are optional for configurations B and D.

Table 95: Output contacts X130:10-18

Terminal	Description
X130:10 X130:11 X130:12	SO1, common SO1, NO SO1, NC
X130:13 X130:14 X130:15	SO2, common SO2, NO SO2, NC
X130:16 X130:17 X130:18	SO3, common SO3, NO 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 96: 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

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
AC	Alternating current
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
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
HW	Hardware
I/O	Input/output

IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
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
RCA	Also known as MTA or base angle. Characteristic angle.
REF615	Feeder protection and control relay
RIO600	Remote I/O unit
RJ-45	Galvanic connector type

Table continues on the next page

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
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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