RELION® 615 SERIES

Feeder Protection and Control
REF615 ANSI
Application Manual

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Section 1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

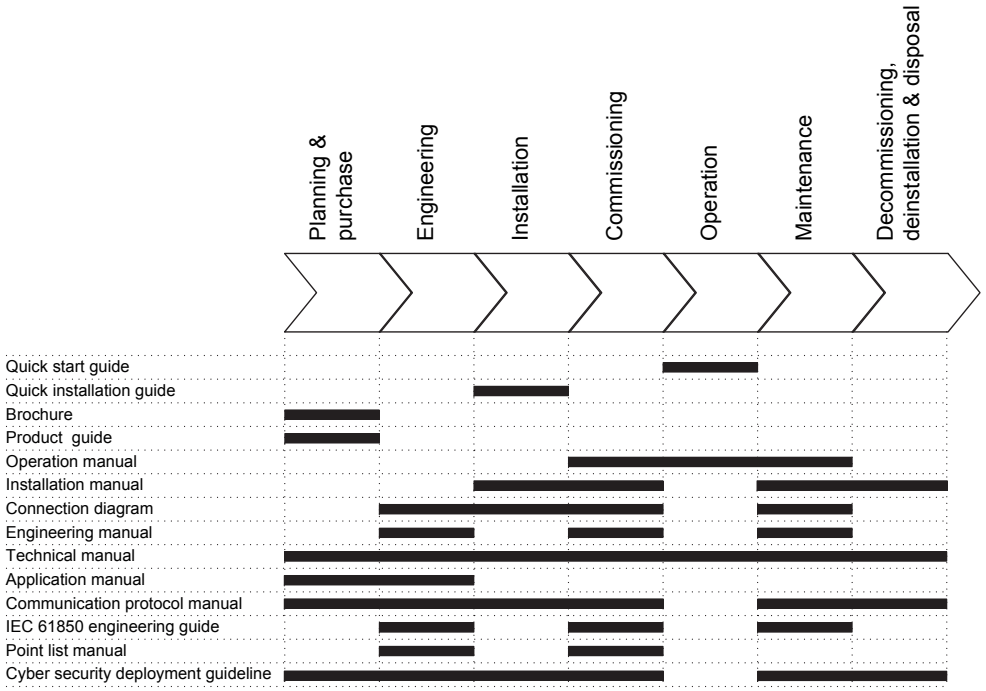

Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2018-02-26	5.0 FP1	First release
B/2019-05-08	5.0 FP1	Content updated
C/2019-06-07	5.0 FP1	Content updated

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

1.3.3 Related documentation

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

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

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

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1
	PHLPTOC2	3I> (2)	51P-2
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	50P-1
	PHHPTOC2	3I>> (2)	50P-2
Table continues on next page			

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P-3
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67/51P-1
	DPHLPDOC2	3I> -> (2)	67/51P-2
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67/50P-1
	DPHHPDOC2	3I>> -> (2)	67/50P-2
Non-directional ground-fault protection, low stage	EFLPTOC1	Io> (1)	51G
	EFLPTOC2	Io> (2)	51N-1
Non-directional ground-fault protection, high stage	EFHPTOC1	Io>> (1)	50G-1
	EFHPTOC2	Io>> (2)	50G-2
	EFHPTOC3	Io>> (3)	50N-1
	EFHPTOC4	Io>> (4)	50N-2
Non-directional ground-fault protection, instantaneous stage	EFIPTOC1	Io>>> (1)	50G-3
	EFIPTOC2	Io>>> (2)	50N-3
Directional ground-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67/51N-1
	DEFLPDEF2	Io> -> (2)	67/51N-2
Directional ground-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67/50N-1
	DEFHPDEF2	Io>> -> (2)	67/50N-2
Admittance-based ground-fault protection	EFPADM1	Yo> -> (1)	21YN-1
	EFPADM2	Yo> -> (2)	21YN-2
	EFPADM3	Yo> -> (3)	21YN-3
Wattmetric-based ground-fault protection	WPWDE1	Po> -> (1)	32N-1
	WPWDE2	Po> -> (2)	32N-2
	WPWDE3	Po> -> (3)	32N-3
Transient/intermittent ground-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF
Harmonics-based ground-fault protection	HAEFPTOC1	Io>HA (1)	51NHA
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46-1
	NSPTOC2	I2> (2)	46-2
Phase discontinuity protection	PDNSPTOC1	I2/I1> (1)	46PD
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G
	ROVPTOV2	Uo> (2)	59N-1
	ROVPTOV3	Uo> (3)	59N-2
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27-1
	PHPTUV2	3U< (2)	27-2
	PHPTUV3	3U< (3)	27-3

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
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)	47-1
	NSPTOV2	U2> (2)	47-2
Three-phase remnant undervoltage protection	MSVPR1	3U< (1)	27R-1
	MSVPR2	3U< (2)	27R-2
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81-1
	FRPFRQ2	f>/f<,df/dt (2)	81-2
	FRPFRQ3	f>/f<,df/dt (3)	81-3
	FRPFRQ4	f>/f<,df/dt (4)	81-4
	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 differential protection for phase A	HIAPDIF1	dHi_A>(1)	87A
High-impedance differential protection for phase B	HIBPDIF1	dHi_B>(1)	87B
High-impedance differential protection for phase C	HICPDIF1	dHi_C>(1)	87C
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	50BF-1
	CCBRBRF2	3I>/Io>BF (2)	50BF-2
Three-phase inrush detector	INRPHAR1	3I2f> (1)	INR-1
Switch onto fault	CBPSOF1	SOTF (1)	SOTF-1
Master trip	TRPPTRC1	Master Trip (1)	86/94-1
	TRPPTRC2	Master Trip (2)	86/94-2
	TRPPTRC3	Master Trip (3)	86/94-3
	TRPPTRC4	Master Trip (4)	86/94-4
	TRPPTRC5	Master Trip (5)	86/94-5
Arc protection	ARCSARC1	ARC (1)	AFD-1
	ARCSARC2	ARC (2)	AFD-2
	ARCSARC3	ARC (3)	AFD-3

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
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
Loss of phase	PHPTUC1	3I< (1)	37-1
High-impedance fault detection	PHIZ1	HIF (1)	HIZ-1
Underpower protection	DUPPDPR1	P< (1)	32U-1
	DUPPDPR2	P< (2)	32U-2
Reverse power/directional overpower protection	DOPPDPR1	P>/Q> (1)	32R/32O-1
	DOPPDPR2	P>/Q> (2)	32R/32O-2
Multifrequency admittance-based ground-fault protection	MFADPSDE1	Io> ->Y (1)	67YN-1
Interconnection functions			
Directional reactive power undervoltage protection	DQPTUV1	Q> ->,3U< (1)	32Q-27
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)	PQI-1
Table continues on next page			

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQVPH-1
	VMHAI2	PQM3U(B)	PQVPH-2
Voltage variation	PHQVVR1	PQMU (1)	PQSS-1
	PHQVVR2	PQ 3U<>(B)	PQSS-2
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB-1
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	52-1
	CBXCBR2	I <-> O CB (2)	52-2
Disconnector control	DCXSWI1	I <-> O DCC (1)	29DS-1
	DCXSWI2	I <-> O DCC (2)	29DS-2
Grounding switch control	ESXSWI1	I <-> O ESC (1)	29GS-1
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	52-TOC
	DCSXSWI2	I <-> O DC (2)	29DS-1
	DCSXSWI3	I <-> O DC (3)	29DS-2
Grounding switch indication	ESSXSWI1	I <-> O ES (1)	29GS-1
	ESSXSWI2	I <-> O ES (2)	29GS-2
Autoreclosing	DARREC1	O -> I (1)	79
Synchronism and energizing check	SECRSYN1	SYNC (1)	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	52CM-1
	SSCBR2	CBCM (2)	52CM-2
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM-1
	TCSSCBR2	TCS (2)	TCM-2
Current circuit supervision	CCSPVC1	MCS 3I (1)	CCM
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC1	MCS I_A(1)	MCS-A
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC1	MCS I_B(1)	MCS-B
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC1	MCS I_C(1)	MCS-C
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60-1
	SEQSPVC2	FUSEF (2)	60-2
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM-1
Measurement			
Load profile record	LDPRLRC1	LOADPROF (1)	LoadProf
Three-phase current measurement	CMMXU1	3I (1)	IA, IB, IC
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Residual current measurement	RESCMMXU1	Io (1)	IG
Three-phase voltage measurement	VMMXU1	3U (1)	VA, VB, VC
	VMMXU2	3U (2)	VA, VB, VC (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	VG
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0
	VSMSQI2	U1, U2, U0(B)	V1, V2, V0 (2)
Single-phase power and energy measurement	SPEMMXU1	SP, SE	SP, SE-1
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E-1
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRECEIVER	SMVRECEIVER	SMVRECEIVER
Other			
Minimum pulse timer	TPGAPC1	TP (1)	62TP-1
	TPGAPC2	TP (2)	62TP-2
	TPGAPC3	TP (3)	62TP-3
	TPGAPC4	TP (4)	62TP-4
Minimum pulse timer (second resolution)	TPSGAPC1	TPS (1)	62TPS-1
Minimum pulse timer (minute resolution)	TPMGAPC1	TPM (1)	62TPM-1
Pulse timer	PTGAPC1	PT (1)	62PT-1
	PTGAPC2	PT (2)	62PT-2
Time delay off	TOFGAPC1	TOF (1)	62TOF-1
	TOFGAPC2	TOF (2)	62TOF-2
	TOFGAPC3	TOF (3)	62TOF-3
	TOFGAPC4	TOF (4)	62TOF-4
Time delay on	TONGAPC1	TON (1)	62TON-1
	TONGAPC2	TON (2)	62TON-2
	TONGAPC3	TON (3)	62TON-3
	TONGAPC4	TON (4)	62TON-4
Set-reset	SRGAPC1	SR (1)	SR-1
	SRGAPC2	SR (2)	SR-2
	SRGAPC3	SR (3)	SR-3
	SRGAPC4	SR (4)	SR-4

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Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Move	MVGAPC1	MV (1)	MV-1
	MVGAPC2	MV (2)	MV-2
Generic control point	SPCGAPC1	SPC (1)	SPC-1
	SPCGAPC2	SPC (2)	SPC-2
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4-1
	SCA4GAPC2	SCA4 (2)	SCA4-2
	SCA4GAPC3	SCA4 (3)	SCA4-3
	SCA4GAPC4	SCA4 (4)	SCA4-4
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4-1
Generic up-down counters	UDFCNT1	UDCNT (1)	CTR-1
	UDFCNT2	UDCNT (2)	CTR-2
	UDFCNT3	UDCNT (3)	CTR-3
	UDFCNT4	UDCNT (4)	CTR-4

Section 2 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 grounded, compensated and solidly grounded 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, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
1.0.1	Product released
1.1	• Circuit breaker condition monitoring • Replaced EFIPTOC3 with EFLPTOC3 • New communication modules COMB11A, COMB12A, COMB13A and COMB14A • IRIG-B • CB interlocking functionality enhanced • TCS functionality in HW enhanced • Non-volatile memory added • Serial communications
2.0	• Support for DNP3 serial or TCP/IP • Voltage measurement and protection • Power and energy measurement • Disturbance recorder upload via WHMI • Fuse failure supervision
4.0	• User programming through Application Configuration • Frequency measurement protection • Load shedding and restoration • Single phase power and energy measurement • Load profile recorder
4.2	• New configurations to tailor for high-impedance current differential and dual breaker autotransfer application • High impedance current differential function • Generic up-down counters • Remnant voltage protection function • Support for HSR/PRP protocol support for a limited configurations
5.0 FP1	• New layout in Application Configuration for all configurations • Support for IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • Fault locator • 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 • 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 • Software closable Ethernet ports • Report summary via WHMI • Multifrequency admittance-based ground-fault protection • 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 2.8 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 http://www.abb.com/substationautomation or directly with Update Manager in PCM600.

2.2 Operation functionality

2.2.1 Optional features

- Arc protection
- Autoreclosing
- Modbus TCP/IP or RTU/ASCII
- DNP3 TCP/IP or serial
- Admittance-based ground-fault protectiont (configurations F, L and N only)
- Wattmetric-based ground-fault protection (configurations F, L and N only)
- Harmonics-based ground-fault protection (configurations F, L and N only)
- Interconnection protection (configurations L and N only)

- Power quality functions (configurations L and N only)
- Fault locator (configurations L and N only)
- RTD/mA measurement (configurations F and N only)
- IEC 61850-9-2 LE (configurations F, 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	Details
Plug-in unit	-	HMI	Large (10 lines, 20 characters) with SLD
	X100	Auxiliary power/BO module	48...250 V DC/100...240 V AC or 24...60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	Optional BIO module	Only with configurations D, F, L, N and P: 8 binary inputs 4 SO contacts
			Only with configurations D, F, L, N and P: 8 binary inputs 3 high-speed SO contacts
	X120	AI/BI module	Only with configurations D, F, N and P: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A) 3 binary inputs
			Only with configurations D, F and N: 3 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)] 3 binary inputs

Table continues on next page

Main unit	Slot ID	Content	Details
Case	X130	Optional RTD/mA module	Optional for configuration D: 2 generic mA inputs 6 RTD sensor inputs
		Optional AI/BI module	Only with configurations F and N: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs Additionally with configuration N: 1 reference voltage input for SECRSYN1 (60...210 V)
		Optional AI/RTD/mA module	Only with configurations F 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 configuration N: 1 reference voltage input for SECRSYN1 (60...210 V)
		Optional BIO module	Optional for configuration D: 6 binary inputs 3 SO contacts
		AI/BI module	Only with configuration P: 6 phase voltage inputs (60...210 V) 3 binary inputs
		Sensor input module	Only with configuration L: 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)[1)]
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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

The rated input levels are selected in the software of the protection relay for phase current and ground current. The binary input thresholds 18...176 V DC are selected by adjusting the protection relay's parameter settings.

The optional BIO module can be added in the protection relay to all standard configurations.

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.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
D	AC/AD	AF	4	-	-	18	4 PO + 9 SO	-	-
		FB	4	-	-	18	4 PO + 5 SO + 3HSO	-	-
	AC/AD FC/FD	AD	4	-	-	12	4 PO + 6 SO	6	2
		FE	4	-	-	12	4 PO + 2 SO + 3 HSO		
F	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
L	DA	AH	1	-	3	8	4 PO + 6 SO	-	-
		FD	1	-	3	8	4 PO + 2 SO + 3 HSO	-	-

Table continues on next page

Std. conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
N	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
P	AK	AK	4	6	-	15	4 PO + 6 SO	-	-
		FH	4	6	-	15	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.

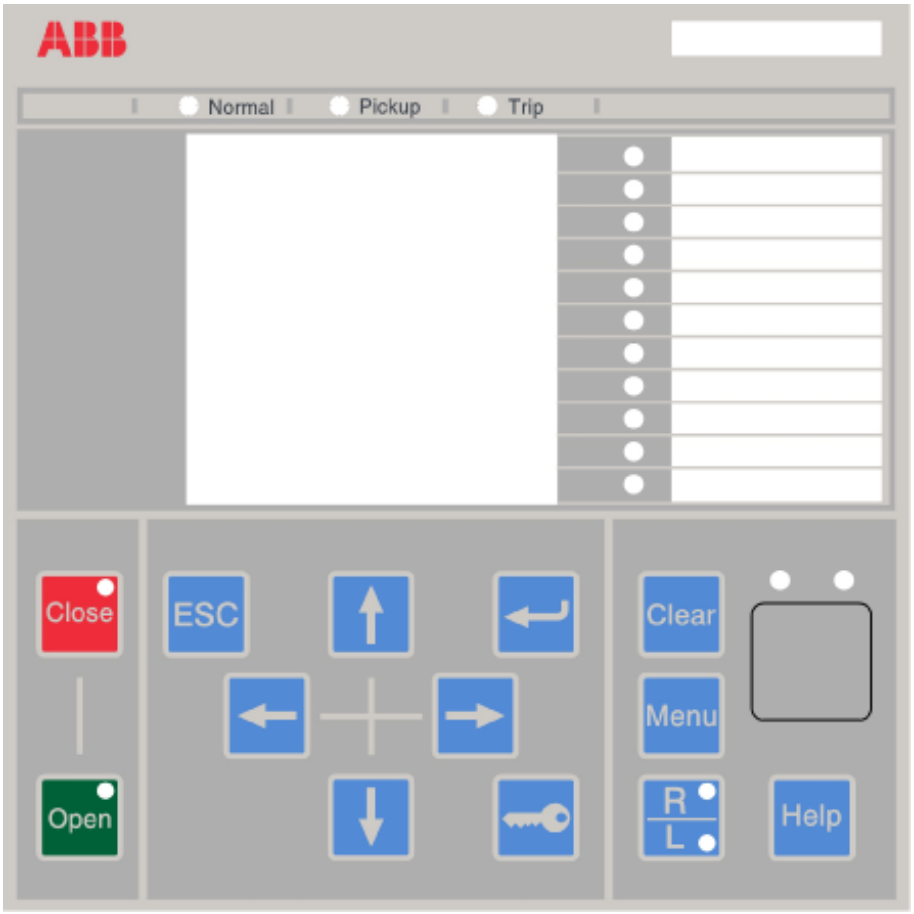


Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Large display

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

1) Depending on the selected language

The display view is divided into four basic areas.

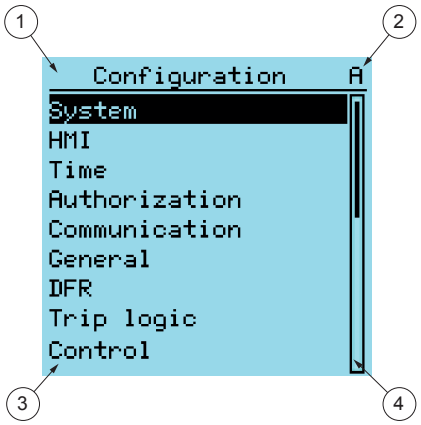


Figure 3: Display layout

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

2.4.2 LEDs

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

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

There are two additional LEDs which are embedded into the control buttons Close and Open. They represent the status of breaker 1 (CBXCBR1).

2.4.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. Using the push buttons, open or close commands can be given to objects in the primary circuit, for example, a circuit breaker, a contactor or a disconnector. The push buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

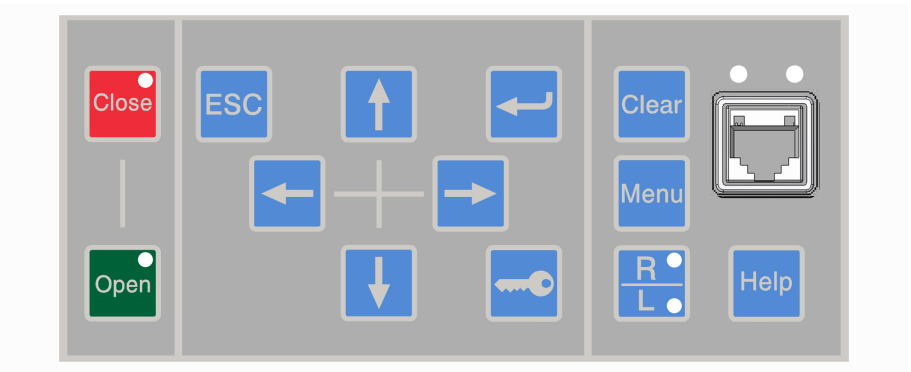


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

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

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

WHMI offers several functions.

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

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

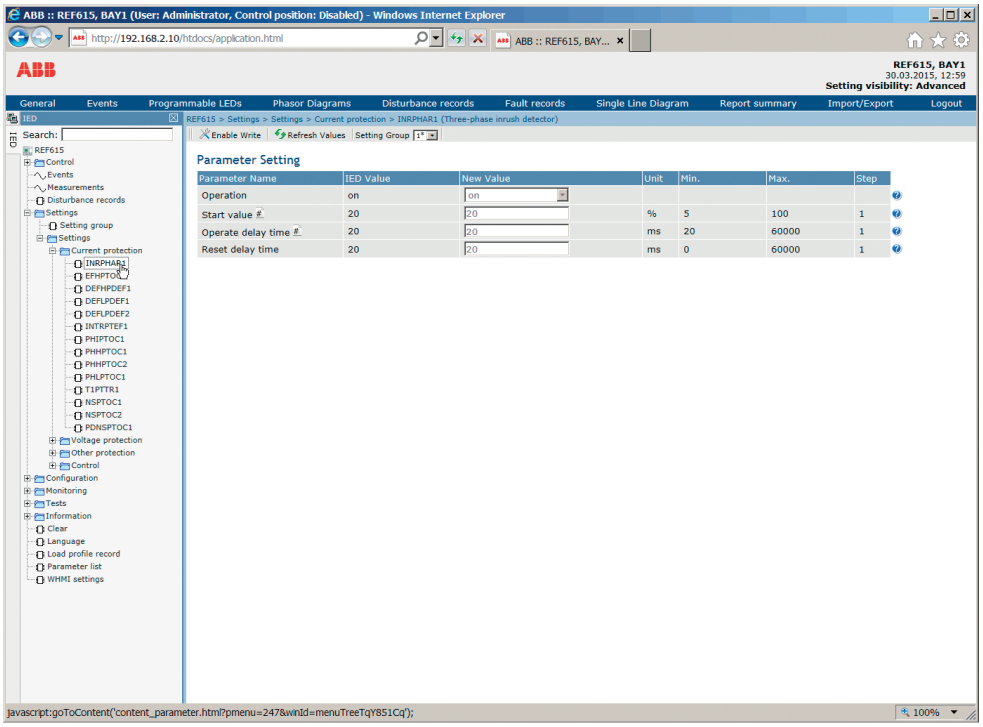


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

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

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

Table 5: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.7 Communication

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

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

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

Table 6: TCP and UDP ports used for different services

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

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

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

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

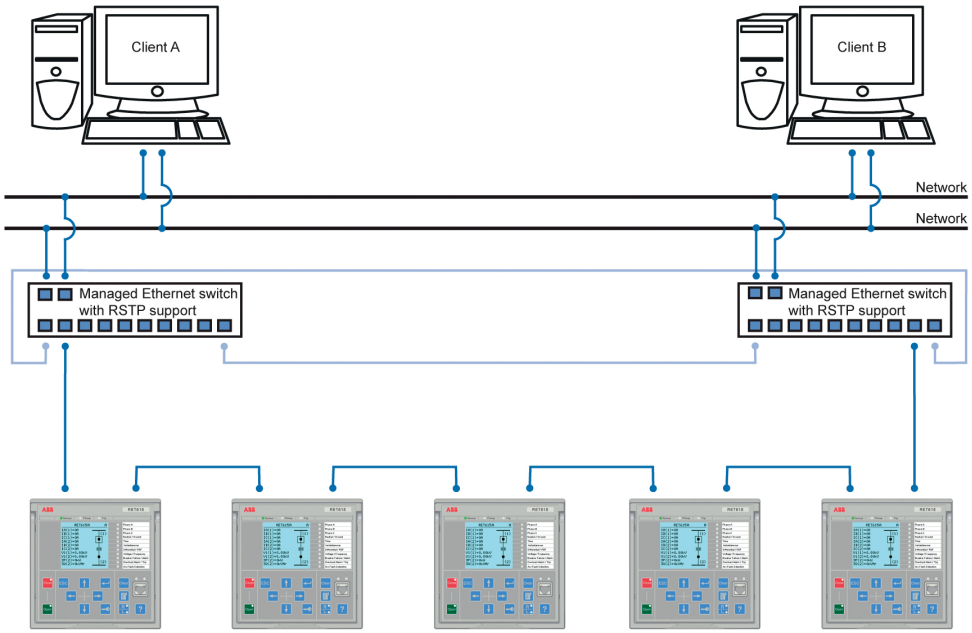


Figure 6: Self-healing Ethernet ring solution

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.

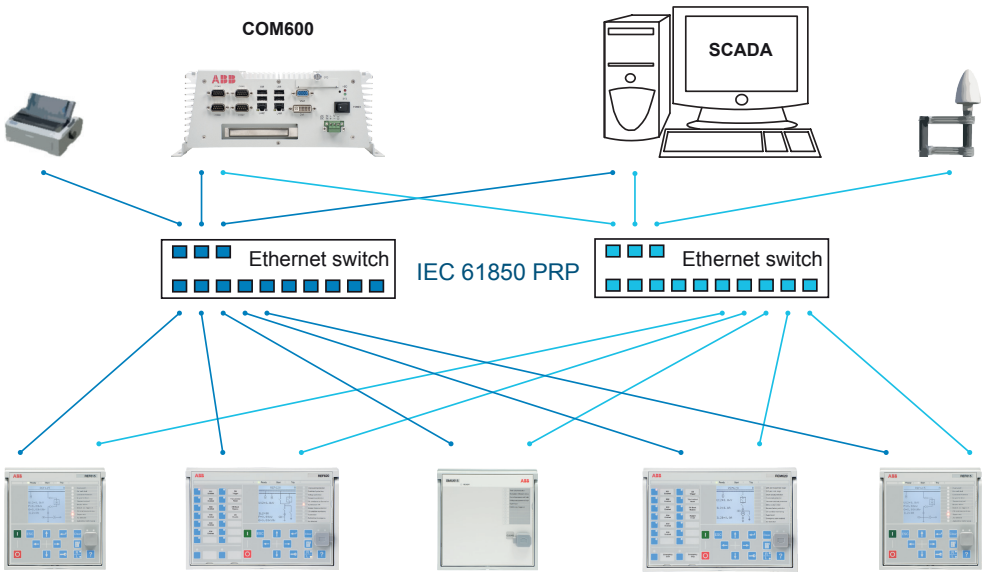


Figure 7: PRP solution

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.

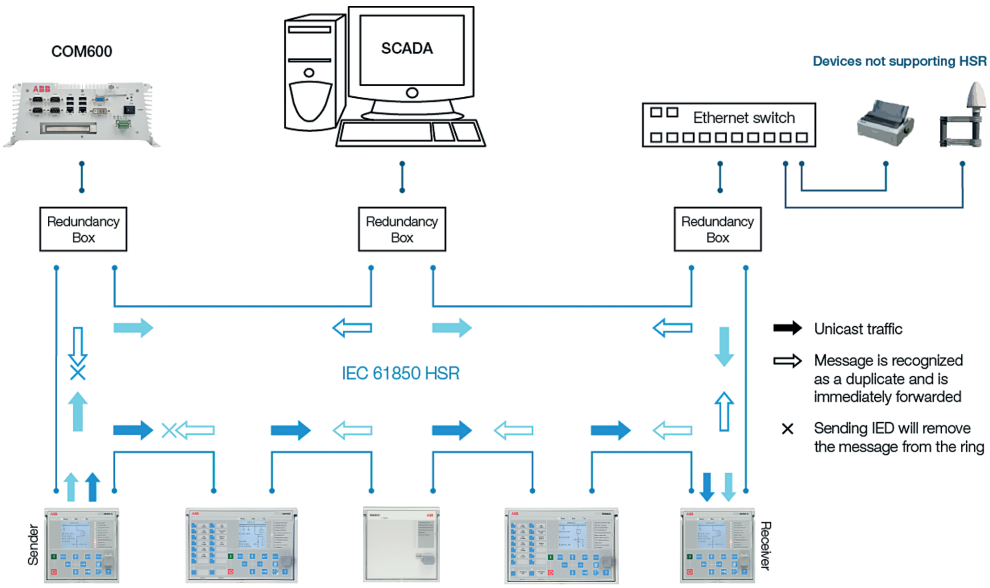


Figure 8: HSR solution

Section 3 REF615 standard configurations

3.1 Standard configurations

REF615 is available with two alternative standard configurations. The standard signal configuration can be altered by means of the signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions 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 7: Standard configurations

Description	Std. conf.
Non-directional overcurrent and ground-fault protection and circuit-breaker condition monitoring (RTD option)	D
Directional overcurrent and ground-fault protection, voltage-based protection and measurements, and circuit-breaker condition monitoring (RTD option)	F
Directional and non-directional overcurrent and ground-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, interconnection protection and synchro-check with IEC 61850-9-2 LE)	L
Directional and non-directional overcurrent and ground-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
Non-directional phase and ground overcurrent, voltage and power directional protection and power system metering for two tie breakers	P

Table 8: Supported functions

Function	IEC 61850	ANSI	D	F	L	N	P
Protection							
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	51P	1		2	2	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	50P-1	2		2	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P		2	2	2	
Three-phase directional overcurrent protection, high stage	DPHHPDOC	67/50P		1	2	2	2
Non-directional ground-fault protection, low stage	EFLPTOC	51G	1		1	1	1
		51N	1		1	1	1
Non-directional ground-fault protection, high stage	EFHPTOC	50G	1	1	2	2	2
		50N			2	2	2
Non-directional ground-fault protection, instantaneous stage	EFIPTOC	50G-3	1		1	1	1
		50N-3			1	1	1
Directional ground-fault protection, low stage	DEFLPDEF	67/51N		2	2	2	
Directional ground-fault protection, high stage	DEFHPDEF	67/50N		1	2	2	2
Admittance-based ground-fault protection[1)]	EFPADM	21YN		(3)	(3)[2)]	(3)	
Wattmetric-based ground-fault protection[1)]	WPWDE	32N		(3)	(3)[2)]	(3)	
Transient/intermittent ground-fault protection	INTRPTEF	67NIEF		1[3)]	1[2)3)]	1[3)]	
Harmonics-based ground-fault protection[1)]	HAEFPTOC	51NHA	(1)[3)]	(1)[3)]	(1)[3)]	(1)[3)]	
Negative-sequence overcurrent protection	NSPTOC	46	2	2	2	2	2
Phase discontinuity protection	PDNSPTOC	46PD	1	1	1	1	
Residual overvoltage protection	ROVPTOV	59G		1	1[2)]	1	
		59N		2	2[2)]	2	2
Three-phase undervoltage protection	PHPTUV	27-1		3	3	3	2
Three-phase overvoltage protection	PHPTOV	59		3	3	3	2
Positive-sequence undervoltage protection	PSPTUV	47U		1	2	2	
Negative-sequence overvoltage protection	NSPTOV	47		1	2	2	2

Table continues on next page

Function	IEC 61850	ANSI	D	F	L	N	P
Three-phase remnant undervoltage protection (source 1)	MSVPR	27R			(1)[4]	1	2
Frequency protection	FRPFRQ	81			6	6	
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	49F	1	1	1	1	
High-impedance differential protection for phase A	HIAPDIF	87A				1	
High-impedance differential protection for phase B	HIBPDIF	87B				1	
High-impedance differential protection for phase C	HICPDIF	87C				1	
Circuit breaker failure protection	CCBRBRF	50BF	1	1	1	1	2
Three-phase inrush detector	INRPHAR	INR	1	1	1	1	1
Switch onto fault	CBPSOF	SOTF	1	1	1	1	
Master trip	TRPPTRC	86/94	2 (3)[5]	2 (3)[5]	2 (3)[5]	2 (3)[5]	2 (3)[5]
Arc protection	ARCSARC	AFD	(3)	(3)	(3)	(3)	(3)
Multipurpose protection	MAPGAPC	MAP	18	18	18	18	18
Fault locator	SCEFRFLO	21FL			(1)	(1)	(1)
Loss of phase	PHPTUC	37					1
High-impedance fault detection	PHIZ	HIZ	1	1		1	
Underpower protection	DUPPDPR	32U			2	2	
Reverse power/directional overpower protection	DOPPDPR	32R/32O			2	2	
Multifrequency admittance-based ground-fault protection	MFADPSDE	67YN			1	1	
Interconnection functions							
Directional reactive power undervoltage protection	DQPTUV	32Q-27			(1)	(1)	
Low-voltage ride-through protection	LVRTPTUV	27RT			(3)	(3)	
Voltage vector shift protection	VVSPPAM	78V			(1)	(1)	
Power quality							
Current total demand distortion	CMHAI	PQI			(1)[6]	(1)[6]	(1)[6]
Voltage total harmonic distortion	VMHAI	PQVPH			(1)[6]	(1)[6]	(2)[6]
Voltage variation	PHQVVR	PQSS			(1)[6]	(1)[6]	(2)[6]
Voltage unbalance	VSQVUB	PQVUB			(1)[6]	(1)[6]	(1)[6]
Control							
Circuit-breaker control	CBXCBR	52	1	1	1	1	2
Disconnector control	DCXSWI	29DS	2	2	2	2	2

Table continues on next page

Function	IEC 61850	ANSI	D	F	L	N	P
Grounding switch control	ESXSWI	29GS	1	1	1	1	1
Disconnector position indication	DCSXSWI	52-TOC	1	1	1	1	1
		29DS	2	2	2	2	2
Grounding switch indication	ESSXSWI	29GS	2	2	2	2	2
Autoreclosing	DARREC	79	(1)	(1)	(1)	(1)	(1)
Synchronism and energizing check	SECRSYN	25			(1)[4)]	1	1
Condition monitoring							
Circuit-breaker condition monitoring	SSCBR	52CM	1	1	1	1	2
Trip circuit supervision	TCSSCBR	TCM	2	2	2	2	2
Current circuit supervision	CCSPVC	CCM		1	1	1	1
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC	MCS-A				1	
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC	MCS-B				1	
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC	MCS-C				1	
Fuse failure supervision	SEQSPVC	60		1	1	1	2
Runtime counter for machines and devices	MDSOPT	OPTM	1	1	1	1	1
Measurement							
Load profile record	LDPRLRC	LoadProf	1	1	1	1	1
Three-phase current measurement	CMMXU	IA, IB, IC	1	1	1	1	1
Sequence current measurement	CSMSQI	I1, I2, I0	1	1	1	1	1
Residual current measurement	RESCMMXU	IG	1	1	1	1	1
Three-phase voltage measurement	VMMXU	VA, VB, VC		1	1 (1)[4)]	2	2
Residual voltage measurement	RESVMMXU	VG		1		1	
Sequence voltage measurement	VSMSQI	V1, V2, V0		1	1	1	2
Single-phase power and energy measurement	SPEMMXU	SP, SE		1	1	1	1
Three-phase power and energy measurement	PEMMXU	P, E		1	1	1	1
RTD/mA measurement	XRGGIO130	X130 (RTD)	(1)	(1)		(1)	
Frequency measurement	FMMXU	f		1	1	1	1
IEC 61850-9-2 LE sampled value sending[7)]	SMVSENDER	SMVSENDER		(1)	(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing)[7)]	SMVRECEIVER	SMVRECEIVER		(1)	(1)	(1)	(1)
Other							

Table continues on next page

Function	IEC 61850	ANSI	D	F	L	N	P
Minimum pulse timer (2 pcs)	TPGAPC	62TP	4	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	62PT	2	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	62TOF	4	4	4	4	4
Time delay on (8 pcs)	TONGAPC	62TON	4	4	4	4	4
Set-reset (8 pcs)	SRGAPC	SR	4	4	4	4	4
Move (8 pcs)	MVGAPC	MV	2	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	SPC	2	2	2	2	2
Analog value scaling	SCA4GAPC	SCA4	3	3	3	3	3
Integer value move	MVI4GAPC	MVI4	1	1	1	1	1
Generic up-down counters	UDFCNT	CTR	4	4	4	4	4
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = Optional							

1) One of the following can be ordered as an option; Admittance based E/F, Wattmetric based E/F or Harmonics based E/F. The option is an addition to the existing E/F of the original configuration. The optional ground-fault protection has a predefined configuration in the relay. The optional ground-fault protection can be set on or off.
2) “Calculated V0” is always used
3) “Measured IG” is always used
4) Only available with IEC 61850-9-2
5) Master Trip included and connected to corresponding HSO in the configuration only when BIO0007 module is used. If additionally the ARC option is selected, then AFD is connected in the configuration to the corresponding Master Trip input.
6) Power quality option includes Current total demand distortion, Voltage total harmonic distortion and Voltage variation.
7) Only available with COM0031...0037

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

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

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

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

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

3.2 Connection diagrams

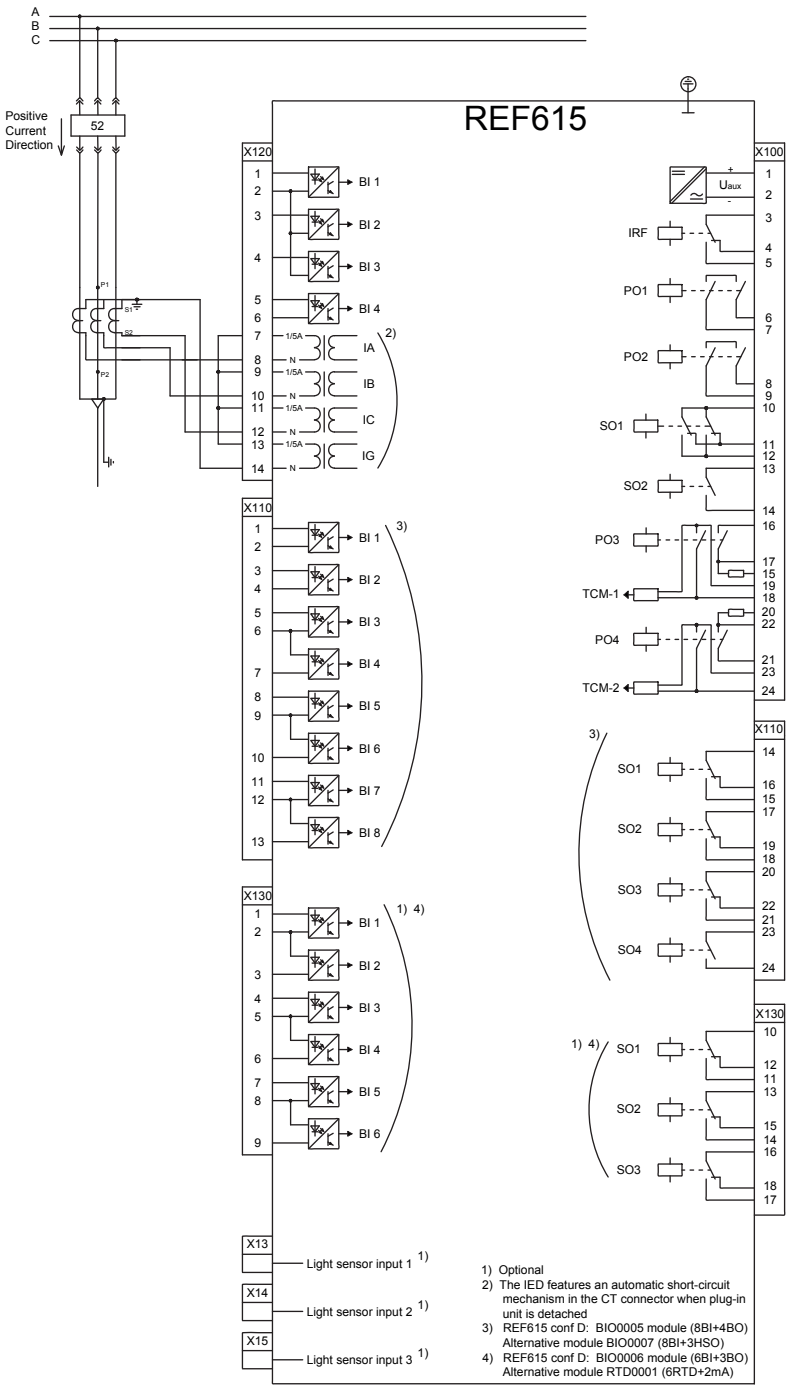


Figure 9: Connection diagram for the D configuration

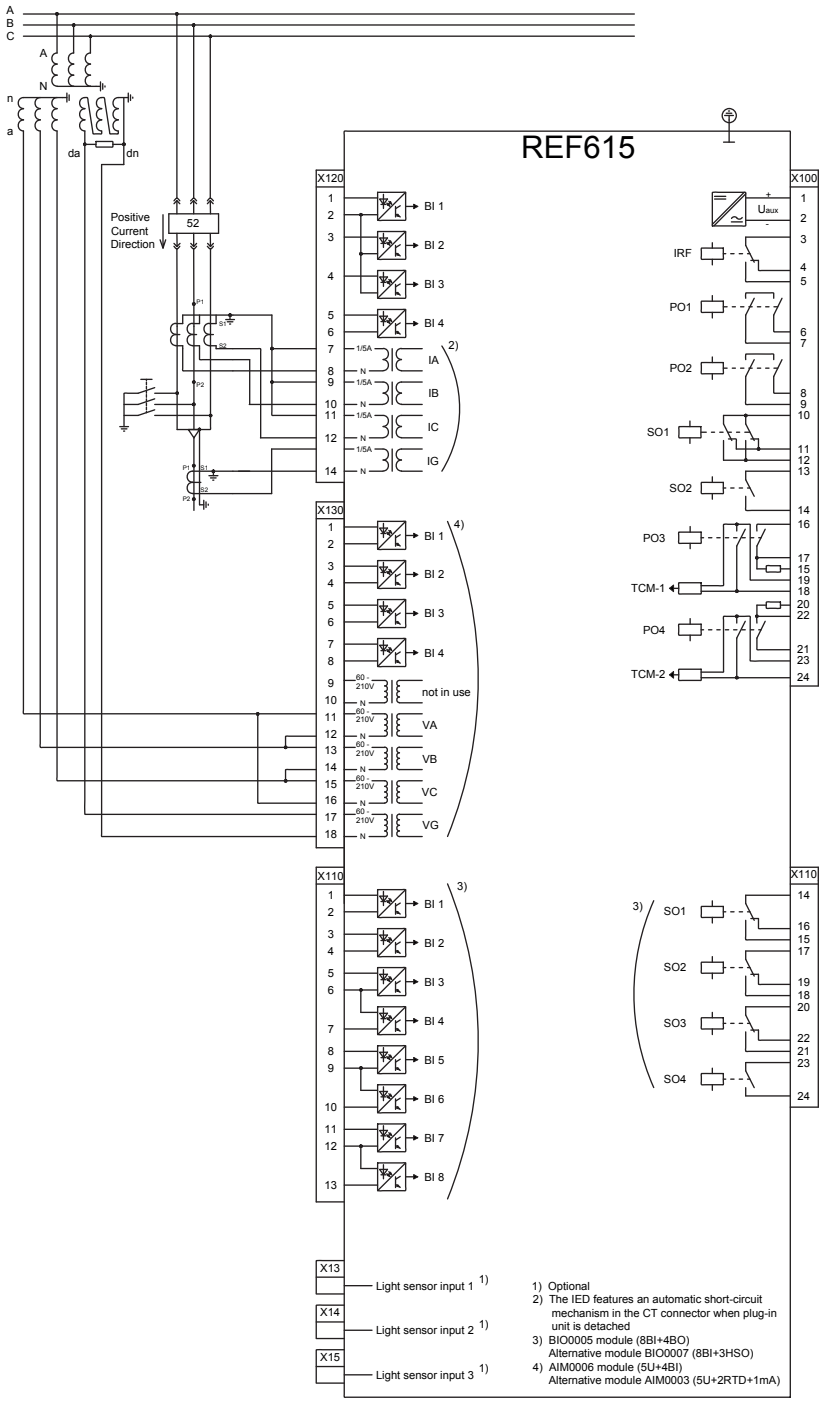


Figure 10: Connection diagram for the F configuration

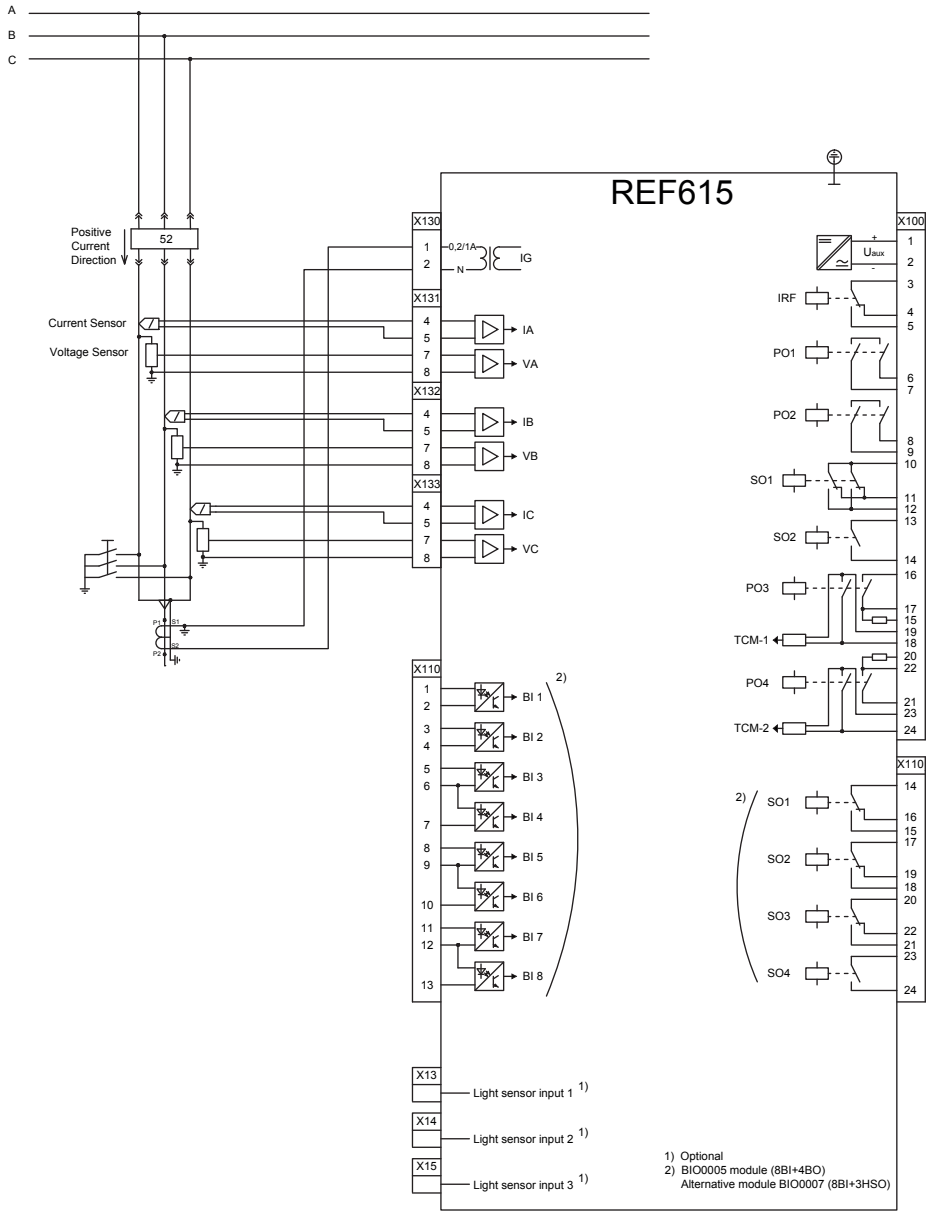


Figure 11: Connection diagram for the L configuration

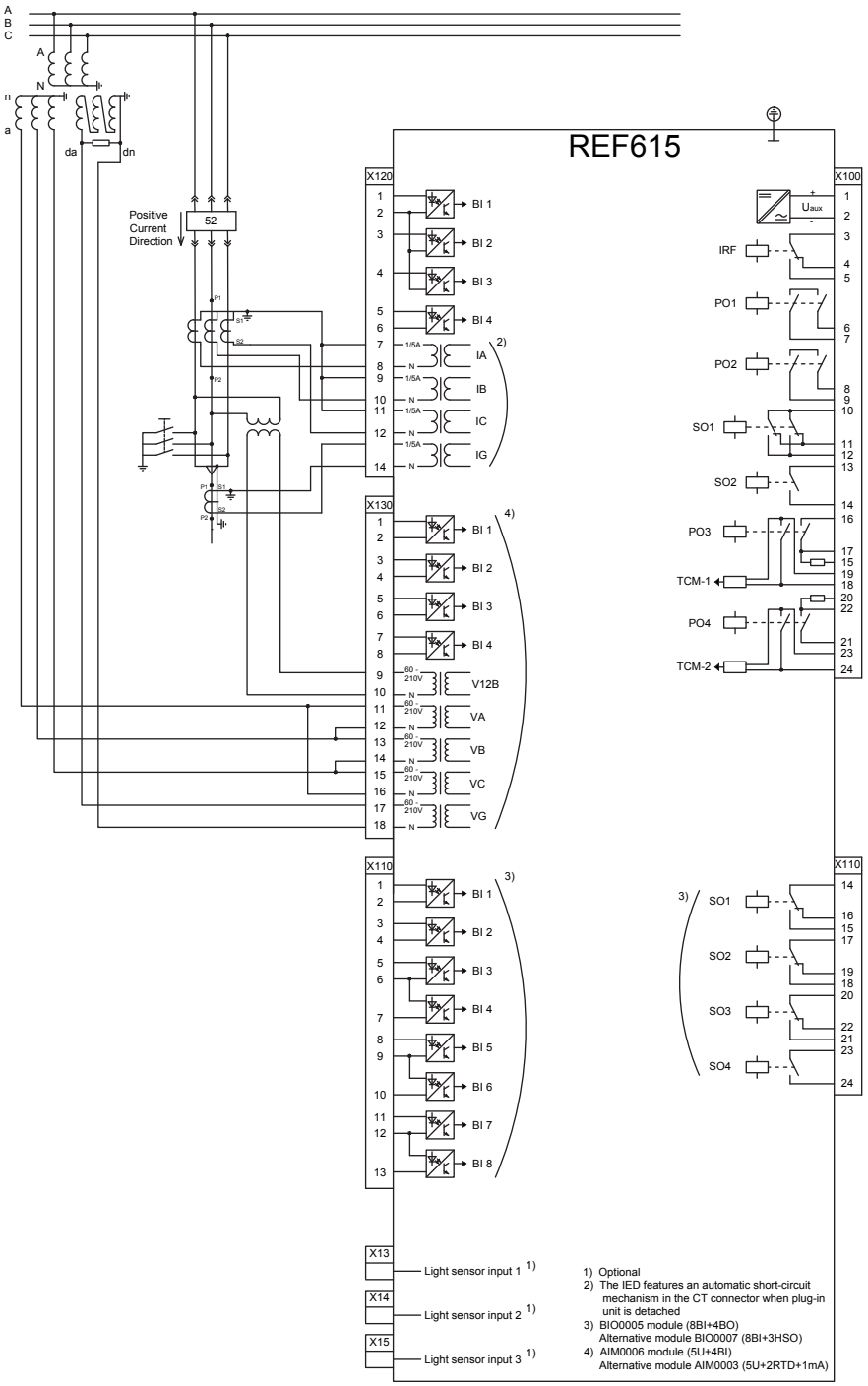


Figure 12: Connection diagram for the N configuration

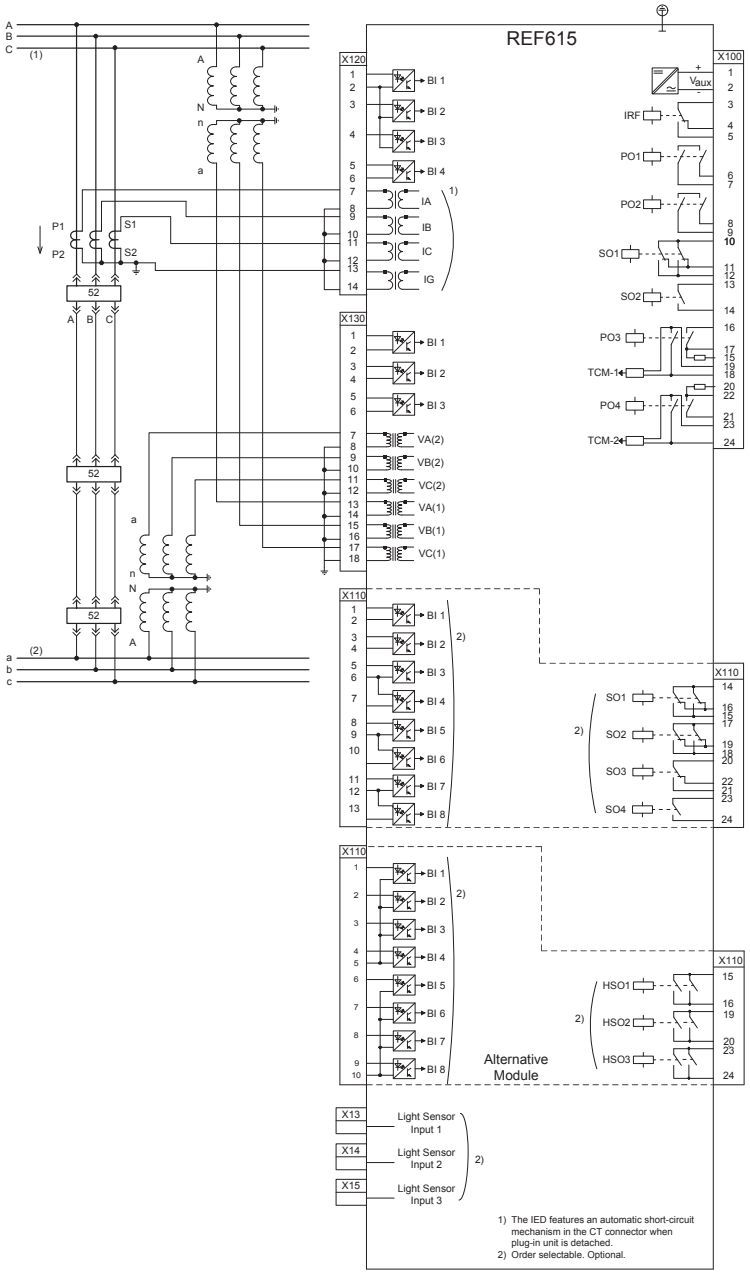


Figure 13: Connection diagram for the P configuration

3.3 Standard configuration D

3.3.1 Applications

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

3.3.2 Functions

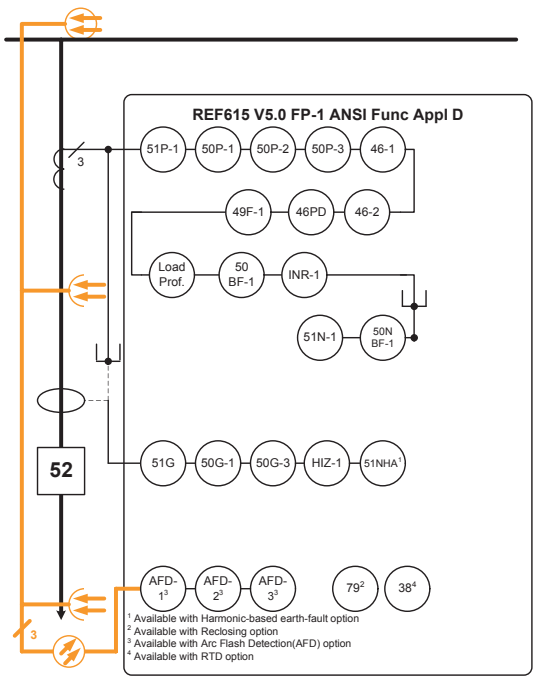


Figure 14: Functionality overview for standard configuration D

3.3.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14

Table 10: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	Autoreclose external pickup command	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10
X120-BI1	Blocking of overcurrent instantaneous stage	X120:1-2	
X120-BI2	Circuit breaker closed position indication	X120:3-2	
X120-BI3	Circuit breaker open position indication	X120:4-2	
X120-BI4	Lock-out reset	X120:5-6	
X130-BI1	-	X130:1-2	
X130-BI2	-	X130:3-2	
X130-BI3	-	X130:4-5	
X130-BI4	-	X130:6-5	
X130-BI5	-	X130:7-8	
X130-BI6	-	X130:9-8	

Table 11: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	General pickup indication	X100:10-11,(12)
X100-SO2	General trip indication	X100:13-14

Table continues on next page

Binary output	Description	Connector pins
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Upstream overcurrent blocking	X110:14-16
X110-SO2	Overcurrent trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	-	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24
X130-SO1	-	X130:10-12
X130-SO2	-	X130:13-15
X130-SO3	-	X130:16-18

Table 12: Default connections for LEDs

LED	Default usage	ID	Label description
1	Non-directional overcurrent trip	LED_Overcurrent_1	Overcurrent
2	Non-directional ground-fault trip	LED_EarthFault_1	Ground-fault
3	Sensitive ground-fault trip	LED_SensitiveEarthFault_1	Sensitive ground-fault
4	Negative sequence overcurrent or phase discontinuity trip	LED_PhaseUnbalance_1	Phase unbalance
5	Thermal overload alarm	LED_ThermalOverload_1	Thermal overload
6	Breaker failure trip	LED_BreakerFailure_1	Breaker failure
7	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
8	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
9	Trip circuit supervision alarm	LED_TripCircuitFailure_1	Trip circuit failure
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Autoreclose in progress	LED_AutorecloseInProgress_1	Autoreclose shot in progr.

3.3.2.2 Default disturbance recorder settings

Table 13: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
Table continues on next page	

Channel	Description
4	Io
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Table 14: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHHPTOC2 - pickup	Positive or Rising
4	PHIPTOC1 - pickup	Positive or Rising
5	NSPTOC1 - pickup	Positive or Rising
6	NSPTOC2 - pickup	Positive or Rising
7	EFLPTOC1 - pickup	Positive or Rising
8	EFHPTOC1 - pickup	Positive or Rising
9	EFIPTOC1 - pickup	Positive or Rising
10	EFLPTOC2 - pickup	Positive or Rising
11	-	-
12	PDNSPTOC1 - pickup	Positive or Rising
13	T1PTTR1 - pickup	Positive or Rising
14	CCBRBRF1 - trret	Level trigger off
15	CCBRBRF1 - trbu	Level trigger off
16	PHxPTOC - trip	Level trigger off
17	NSPTOC - trip	Level trigger off
18	EFxPTOC - trip	Level trigger off
19	X110BI2 - ext pickup AutoReclose	Level trigger off
20	EFL2PTOC - trip	Level trigger off
21	PDNSPTOC1 - trip	Level trigger off
22	INRPHAR1 - blk2h	Level trigger off
23	T1PTTR1 - trip	Level trigger off
24	ARCSARC - ARC flt det	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
25	ARCSARC1 - trip	Positive or Rising
26	ARCSARC2 - trip	Positive or Rising
27	ARCSARC3 - trip	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 open	Level trigger off
34		
35		
36	-	-
37	-	-
38	-	-
39	-	-
40	-	-
41	-	-
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-

Table continues on next page

Channel	ID text	Level trigger mode
61	-	-
62	-	-
63	-	-
64	-	-

3.3.3 Functional diagrams

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

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

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

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

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

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

3.3.3.1 Functional diagrams for protection

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

Four overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional instantaneous stage PHIPTOC1_50P-3 can be blocked by energizing the binary input X120:BI1.

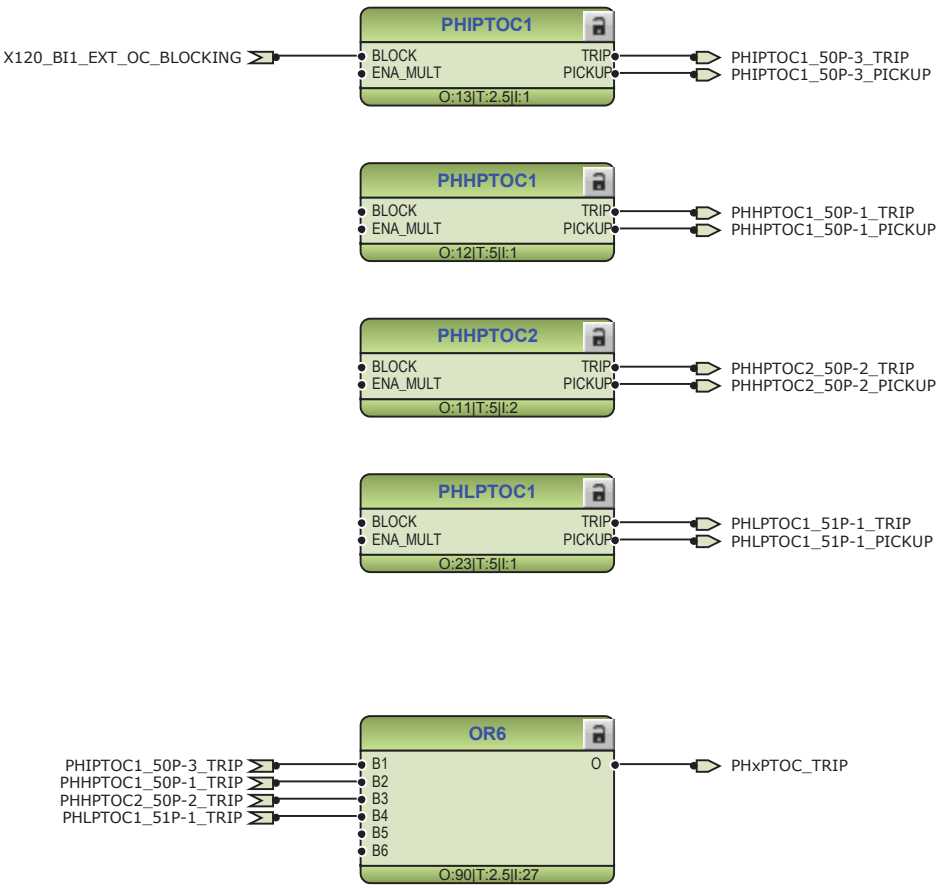


Figure 15: Overcurrent protection functions

The upstream blocking from the pickup of the second high stage of three-phase non-directional overcurrent protection PHHPTOC2_50P-2 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 relay at the infeeding bay.

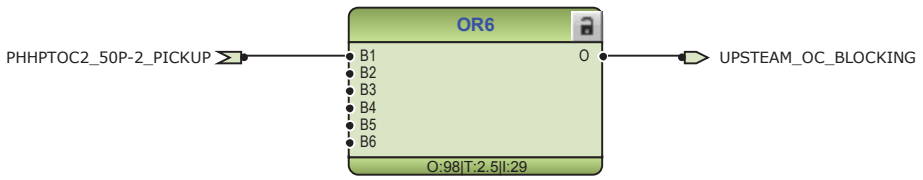


Figure 16: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or ground-fault function blocks.

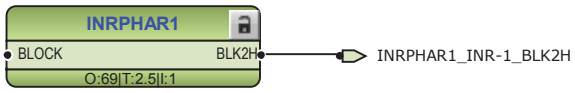


Figure 17: Inrush detector function

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

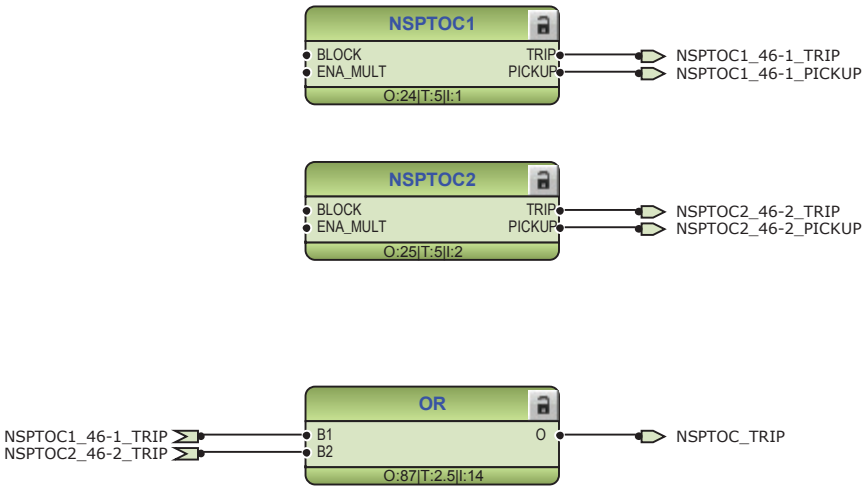


Figure 18: Negative-sequence overcurrent protection function

Three stages are provided for non-directional ground-fault protection. One stage is provided for sensitive ground-fault protection.

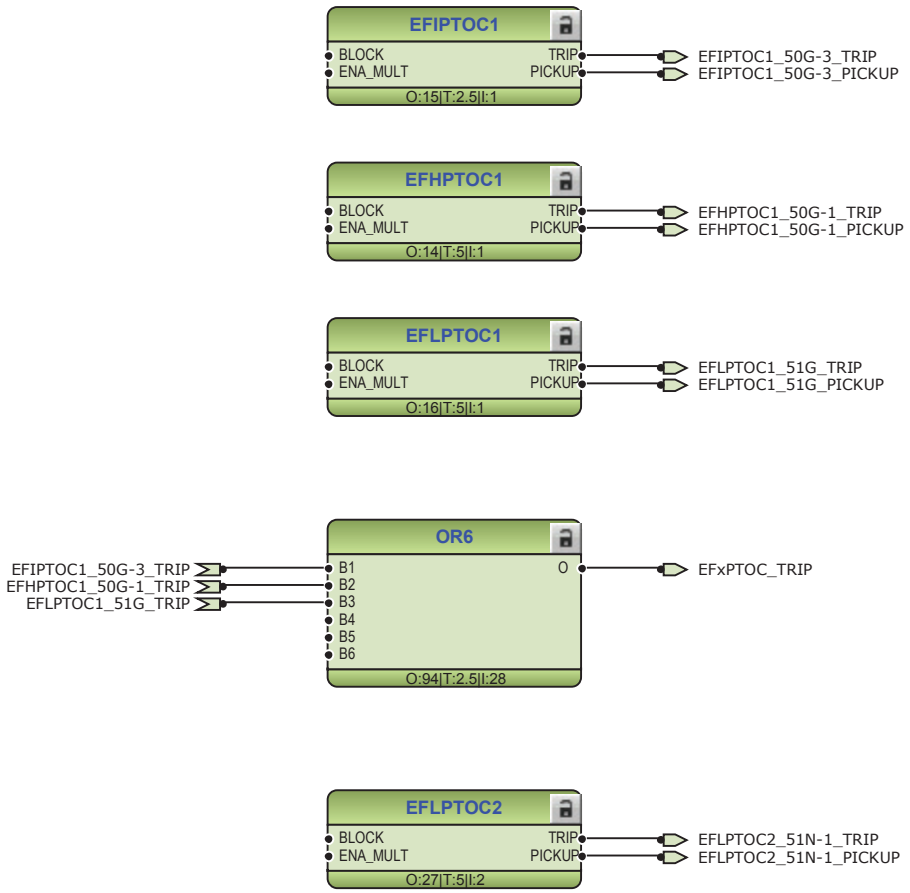


Figure 19: Non-directional ground-fault protection

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

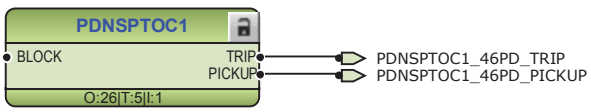


Figure 20: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1_49F-1 detects overloads under varying load conditions.

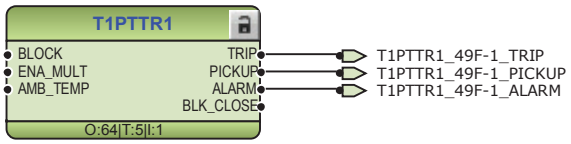


Figure 21: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by number of different protection functions available in the relay. 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 trip output is used for retripping its own breaker through TRPPTRC2_86/94-2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the binary output X100:PO2.

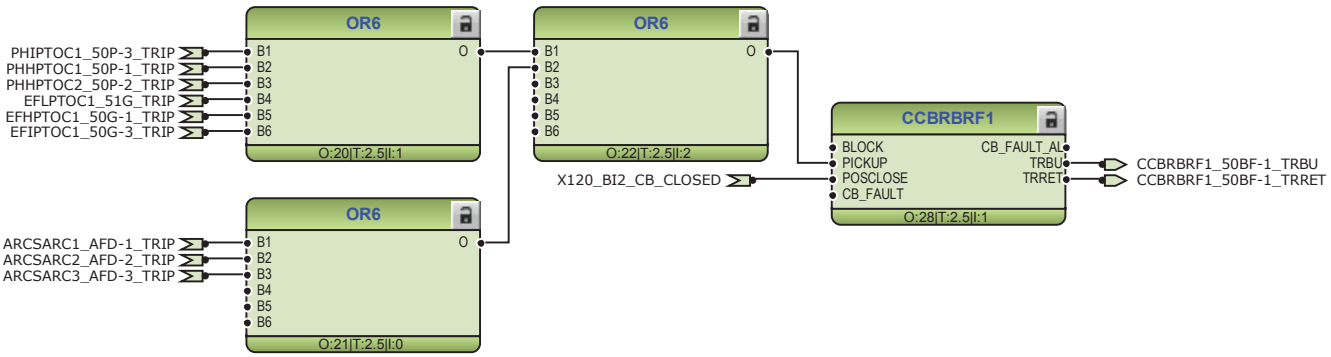


Figure 22: Circuit breaker failure protection function

Three arc protection stages ARCSARC1…3_AFD-1...3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The trip signals from ARCSARC1…3_AFD-1...3 are connected to both trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2.

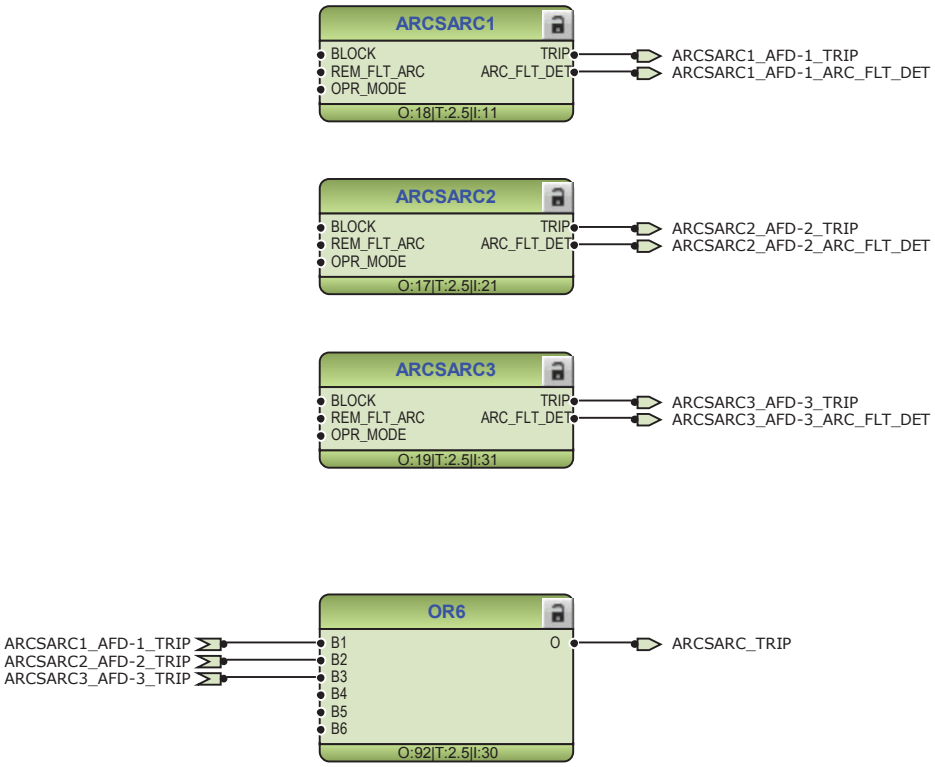


Figure 23: Arc protection

The optional autoreclosing function is configured to be initiated by trip signals from a number of protection stages through the INIT_1...5 inputs. It is possible to create individual autorecloseing sequences for each input.

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

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1_79. 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_79 properly.

Check the initialization signals of DARREC1_79.

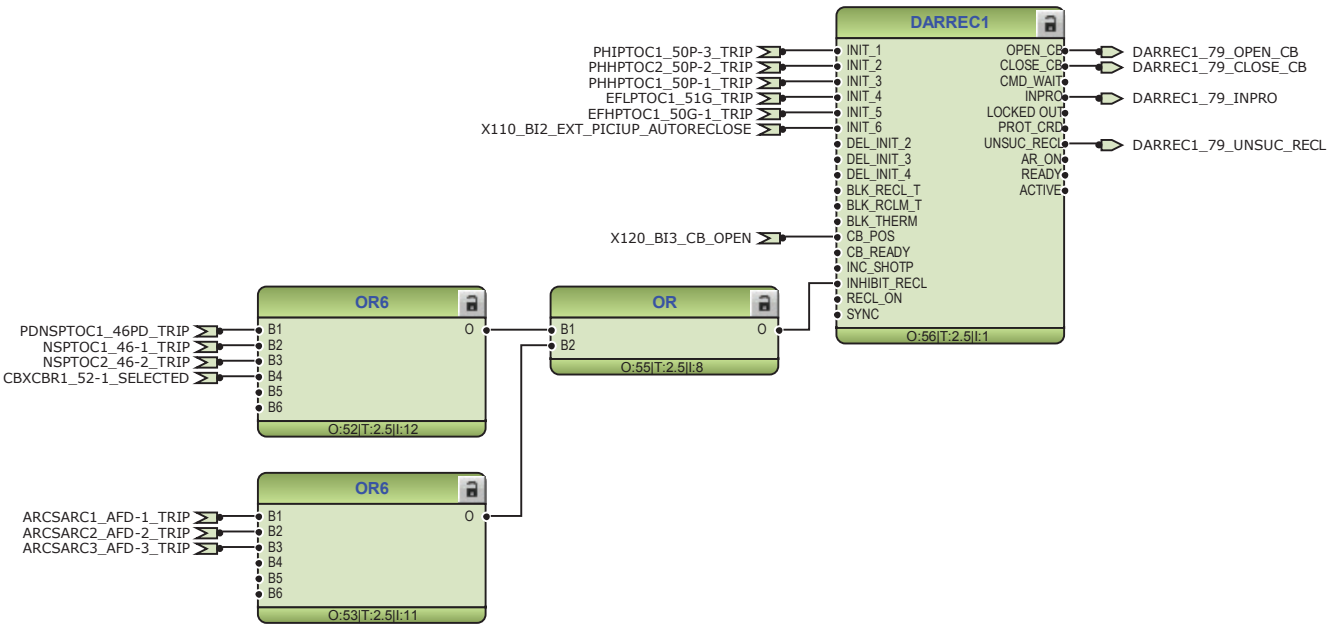


Figure 24: Autoreclosing function

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

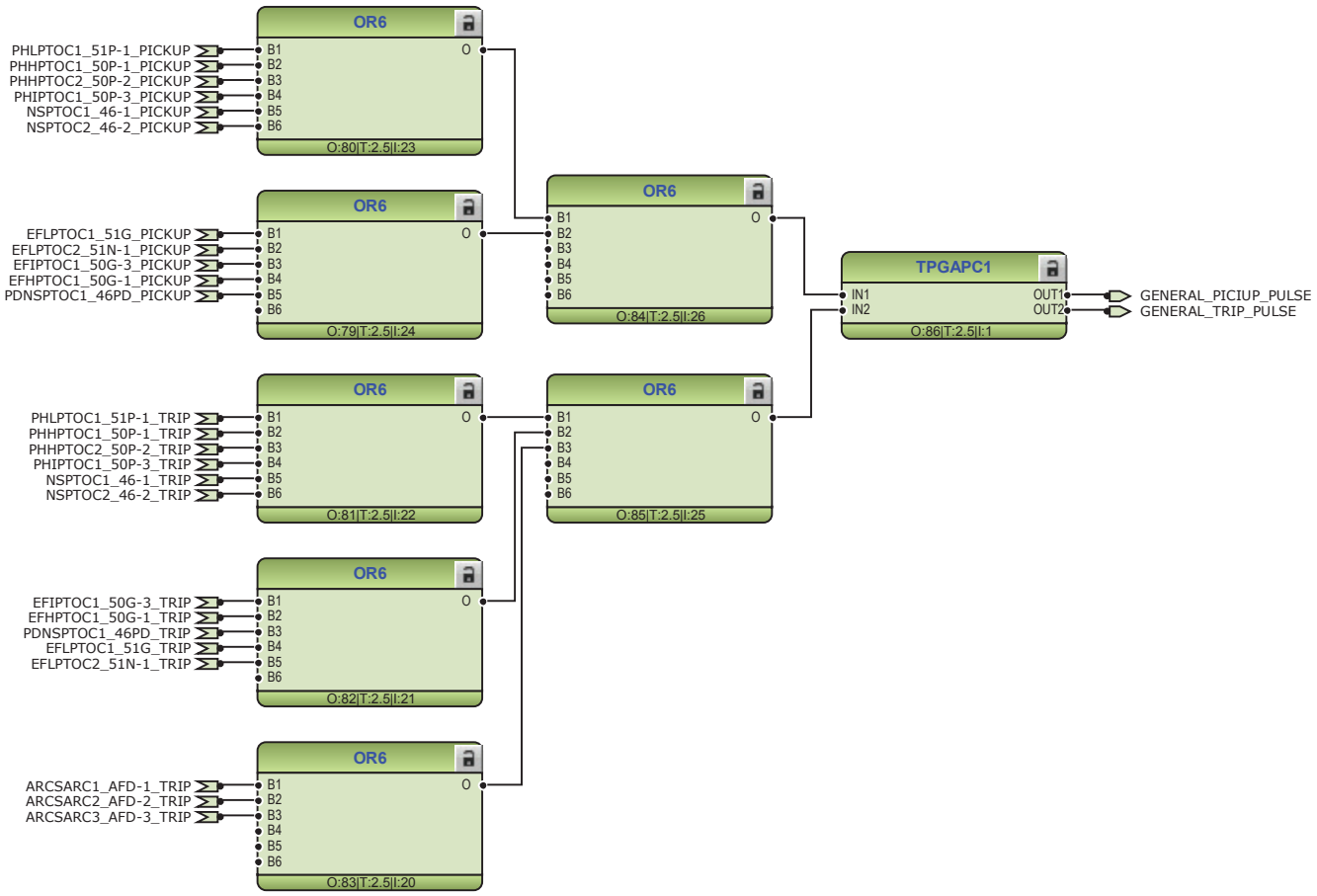


Figure 25:

The trip signals from the protection functions are connected to the two trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions 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...5_86/94-3…5 are also available if the relay is ordered with high speed binary outputs options.

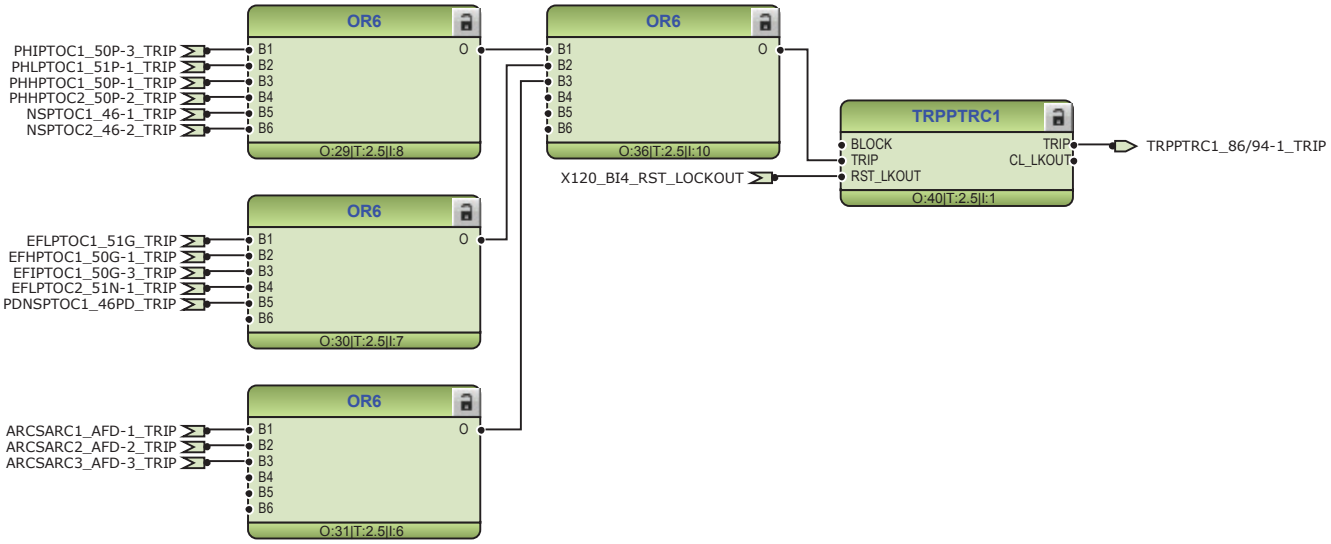


Figure 26: Trip logic TRPPTRC1

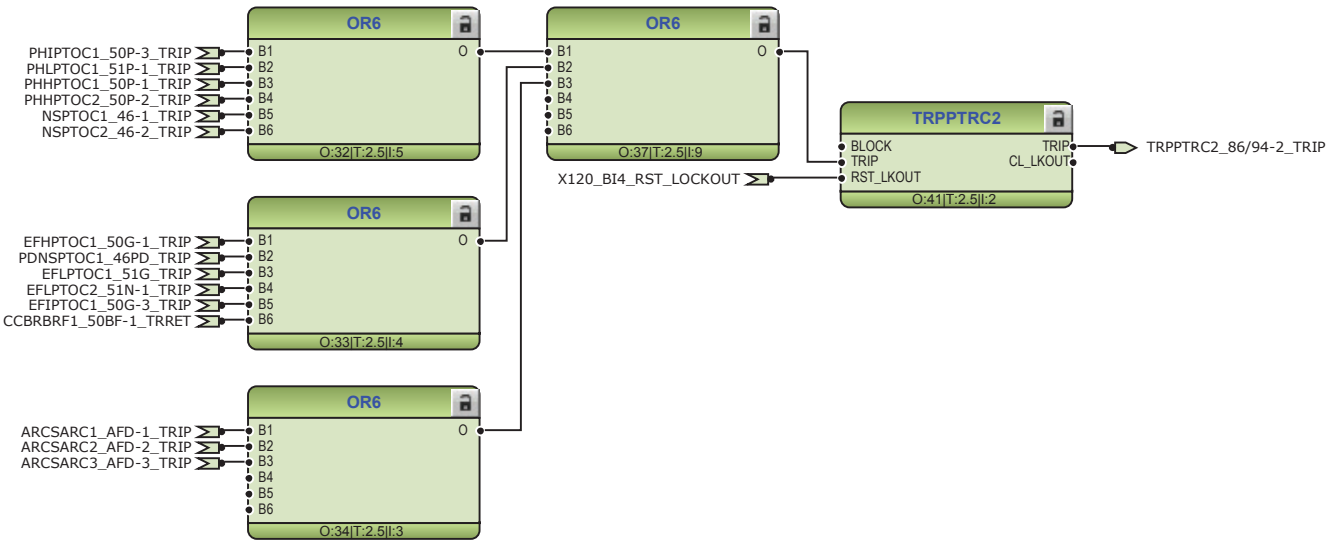


Figure 27: Trip logic TRPPTRC2

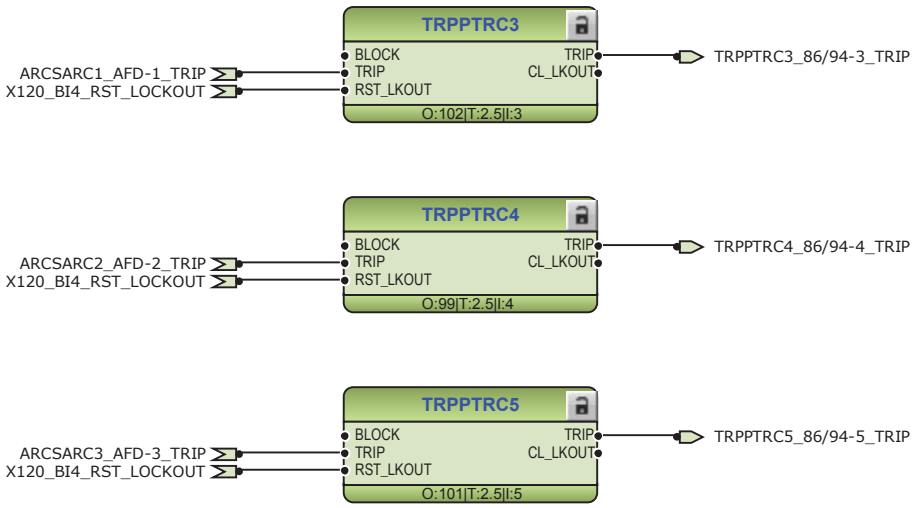


Figure 28: Trip logic TRPPTRC3/4/5

3.3.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

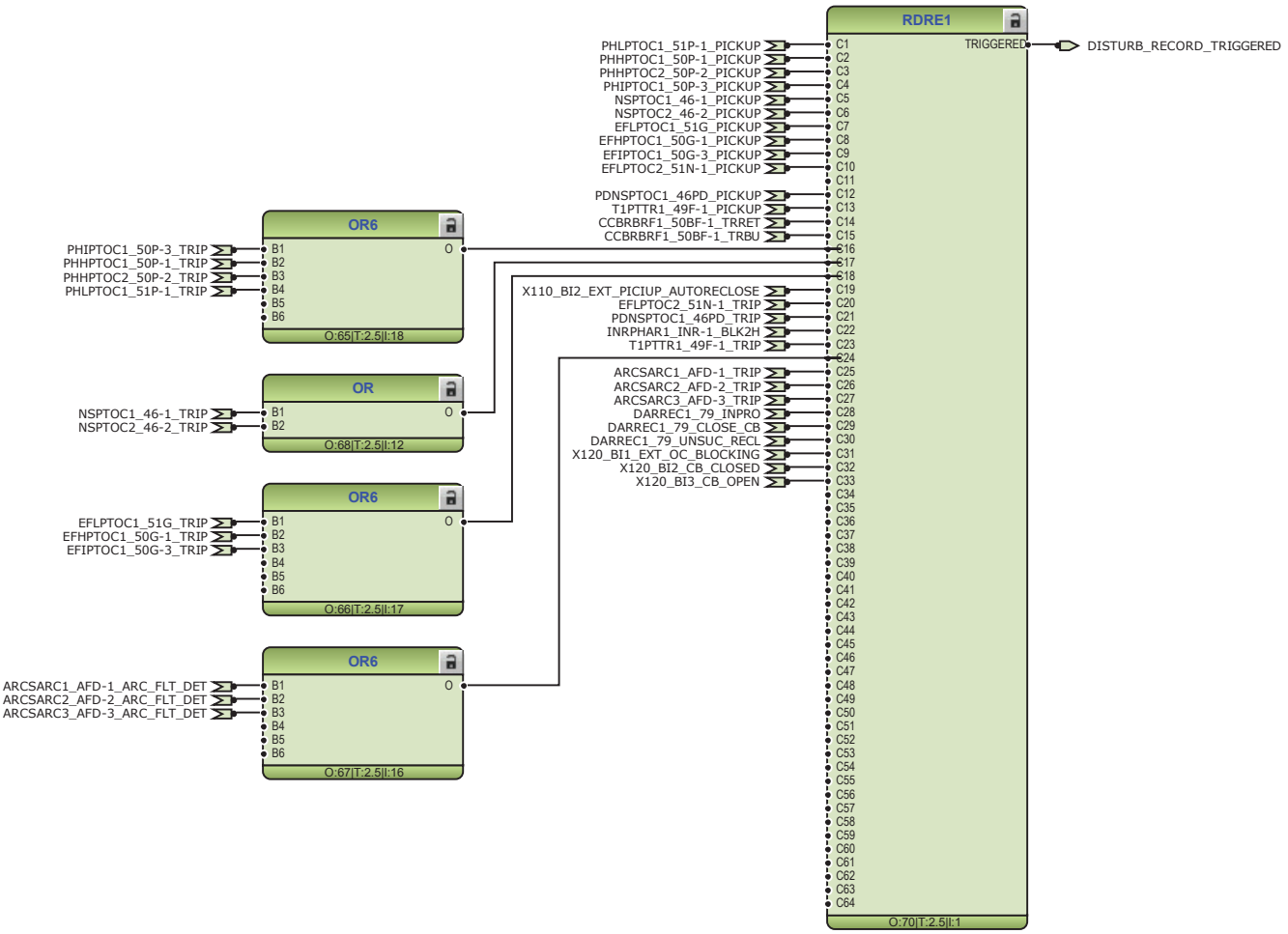


Figure 29: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1_52CM-1 properly.

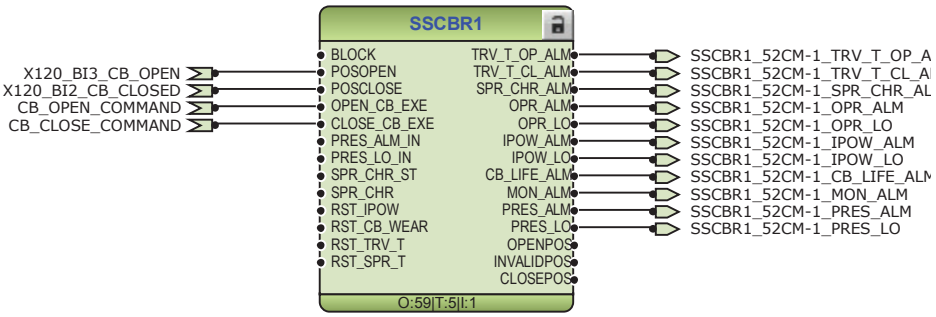


Figure 30: Circuit-breaker condition monitoring function

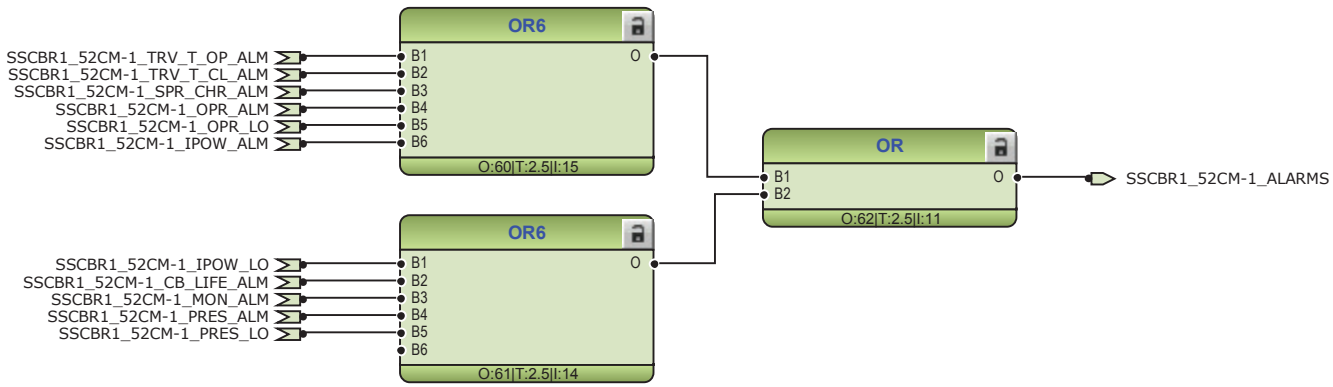


Figure 31: Logic for circuit breaker monitoring alarm

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

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

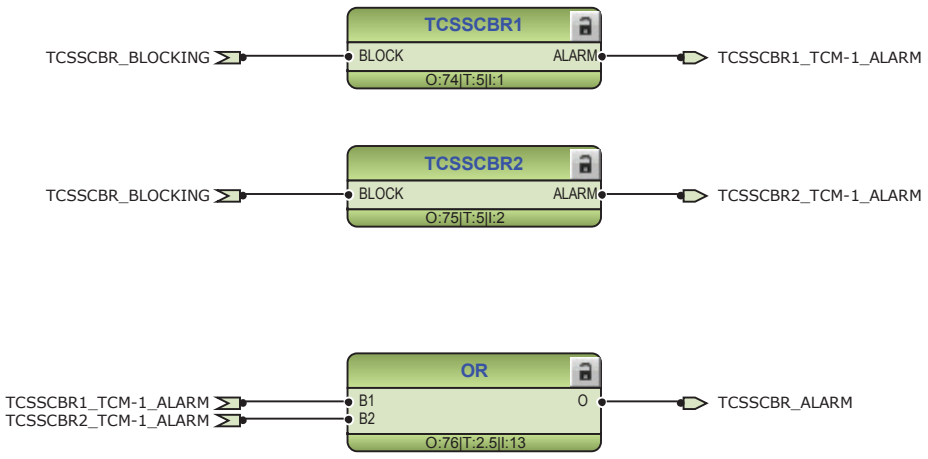


Figure 32: Trip circuit supervision function

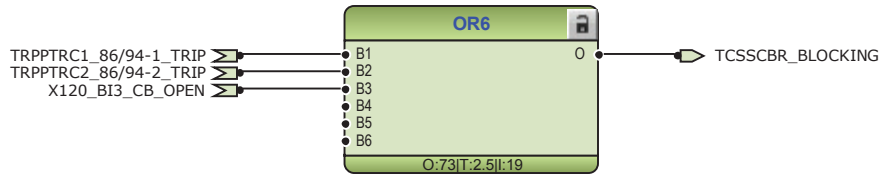


Figure 33: Logic for blocking of trip circuit supervision

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.

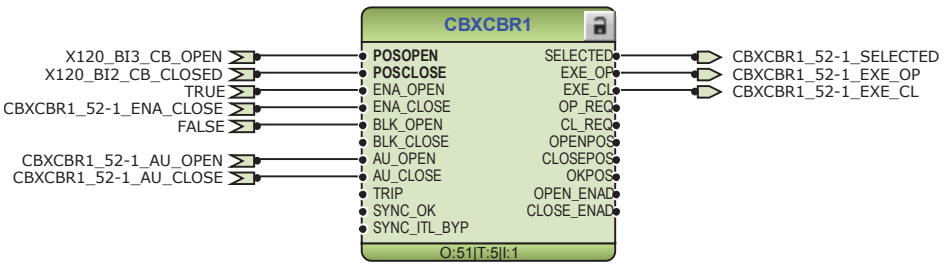


Figure 34: Circuit breaker control logic: Circuit breaker 1

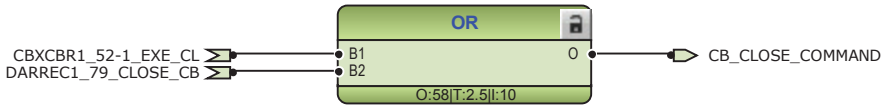


Figure 35: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

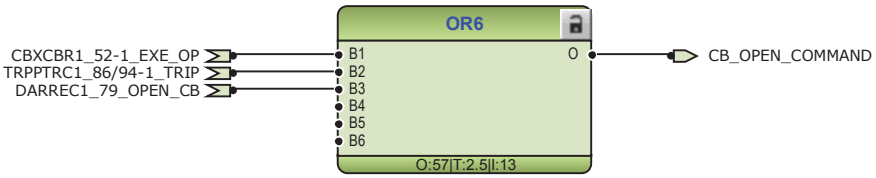


Figure 36: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

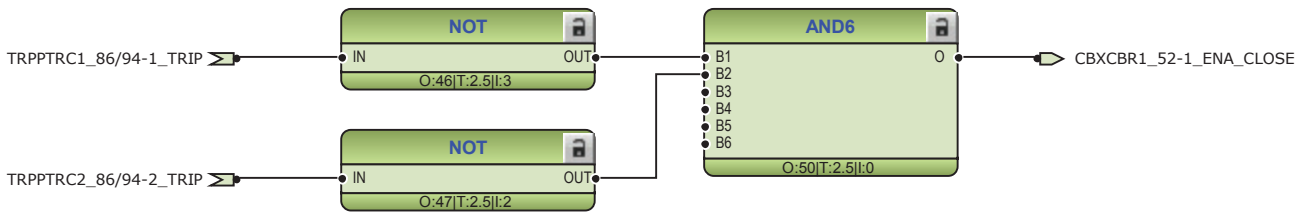


Figure 37: Circuit breaker close enable logic

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

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

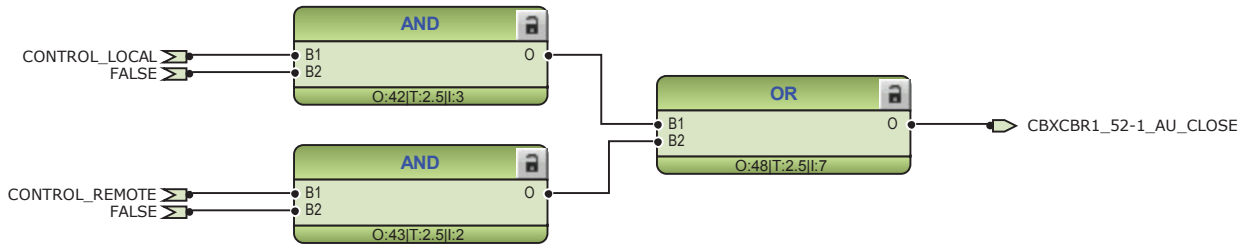


Figure 38: External closing command for circuit breaker

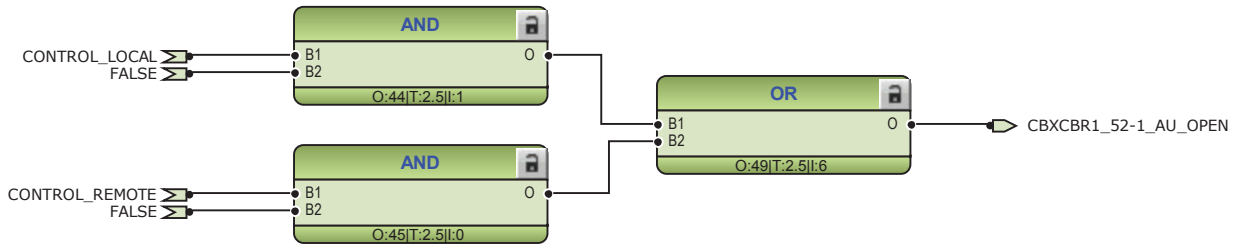


Figure 39: External opening command for circuit breaker

3.3.3.5 Functional diagrams for measurement functions

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

The 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.

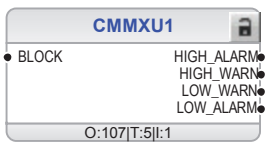


Figure 40: Three-phase current measurement

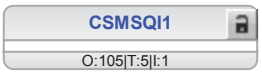


Figure 41: Sequence current measurements

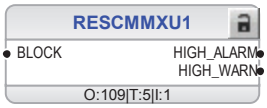


Figure 42: Ground current measurements

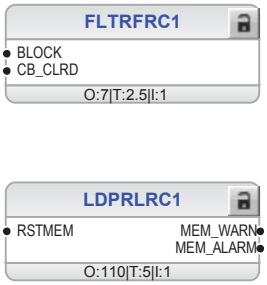


Figure 43: Data monitoring and load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

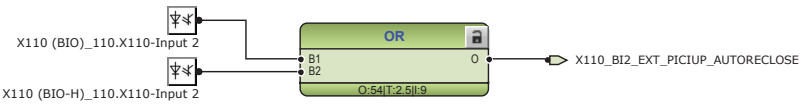


Figure 44: Default binary inputs - X110

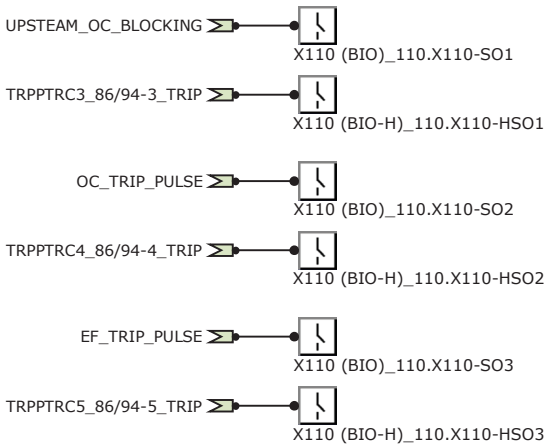


Figure 45: Default binary outputs - X110

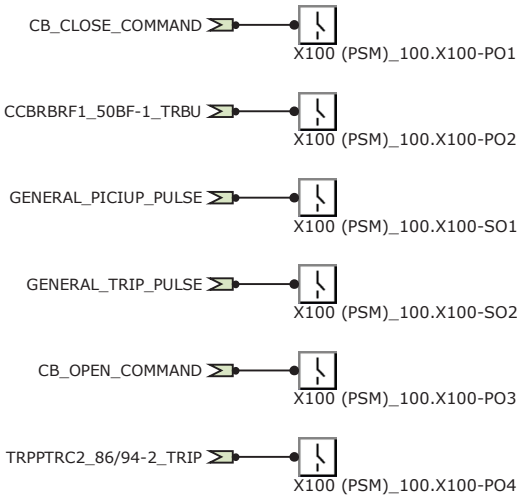


Figure 46: Default binary outputs - X100

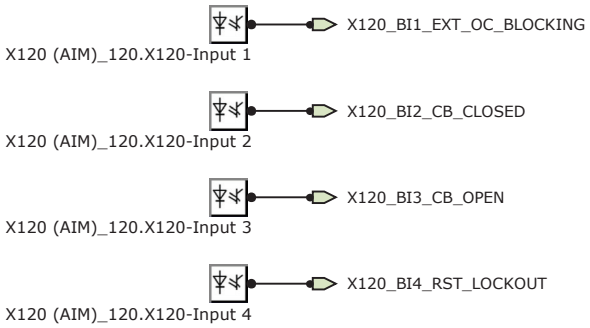


Figure 47: Default binary inputs - X120

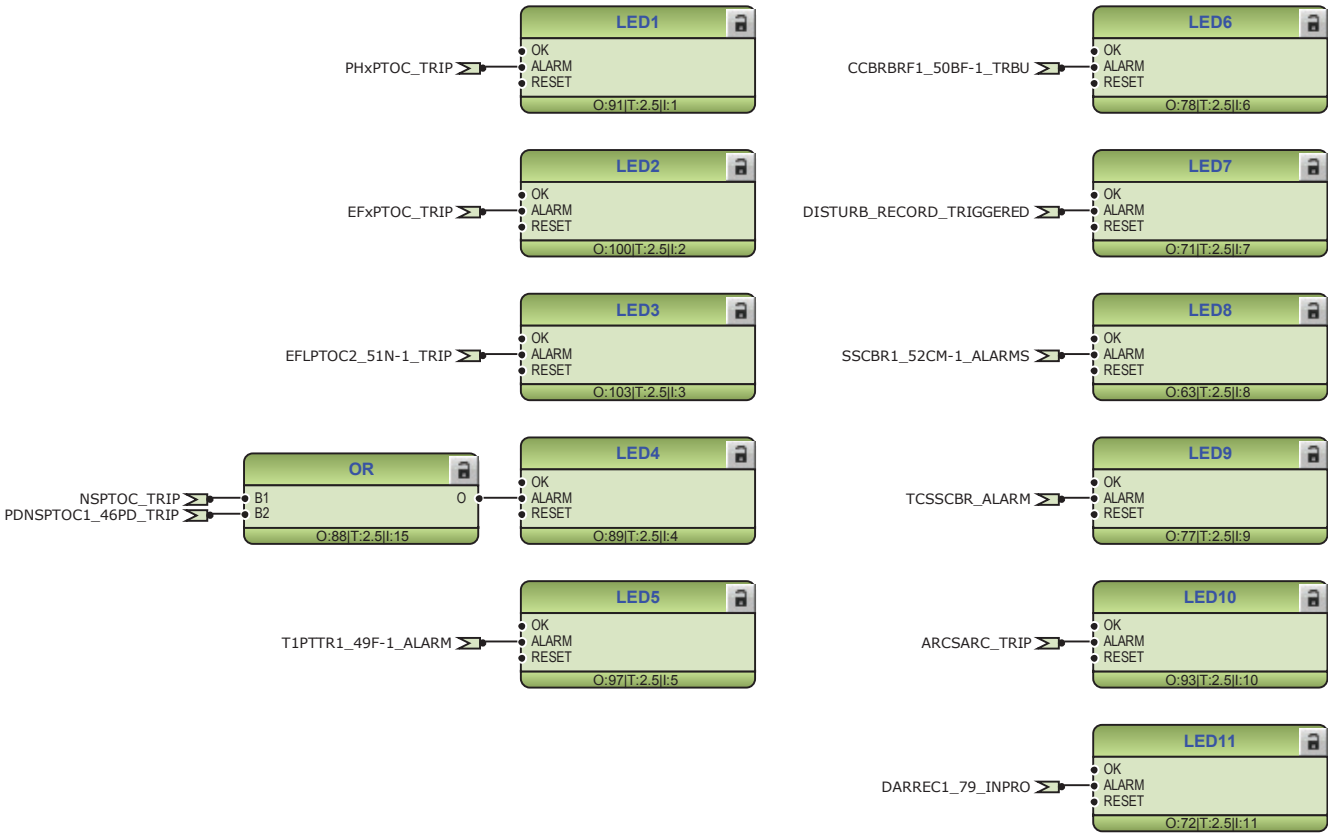


Figure 48: Default LED connection

3.3.3.7 Functional diagrams for other functions

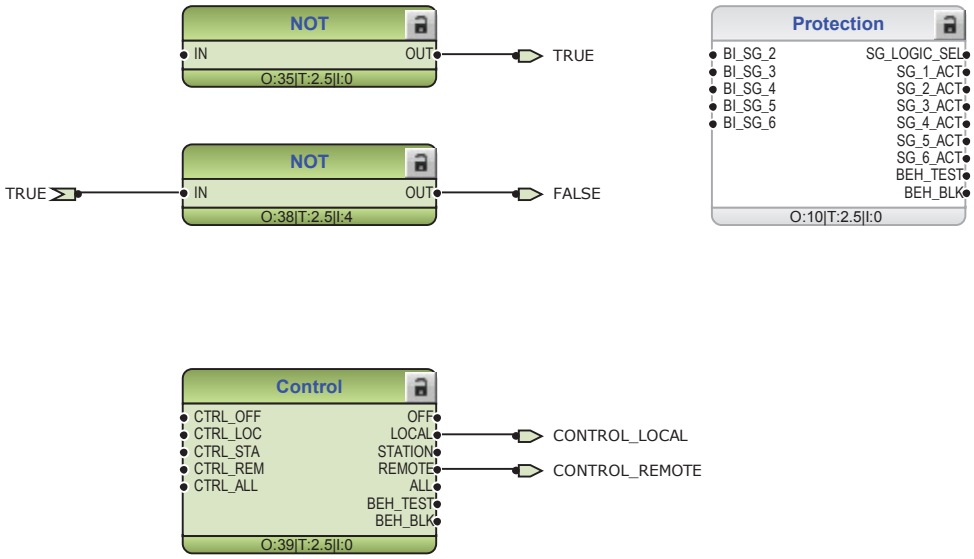


Figure 49: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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

3.3.3.8 Functional diagrams for other timer logics

The configuration also includes the overcurrent trip and ground-fault trip logic. The trip 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.

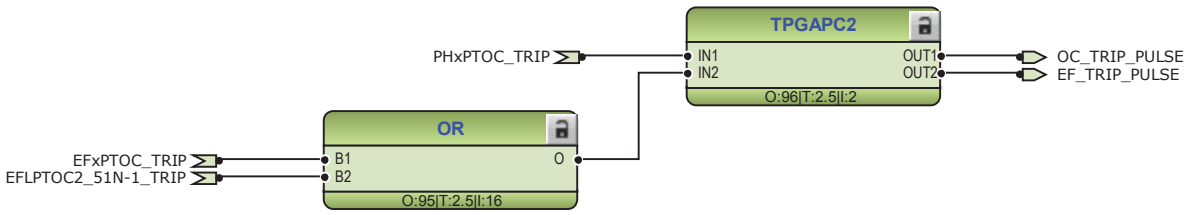


Figure 50: Timer logic for overcurrent and ground-fault trip pulse

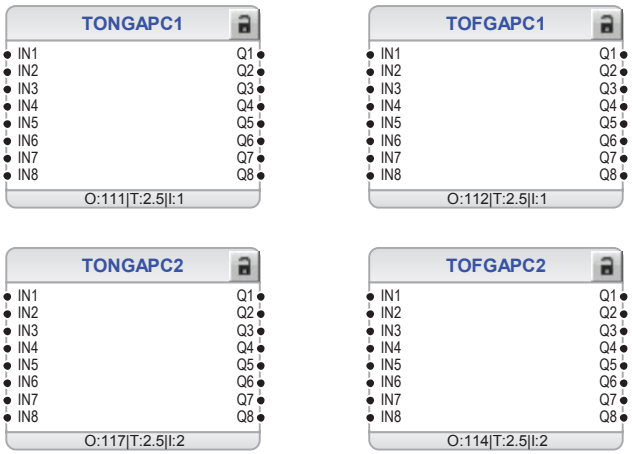


Figure 51: Programmable timers

3.3.3.9 Functional diagrams for communication

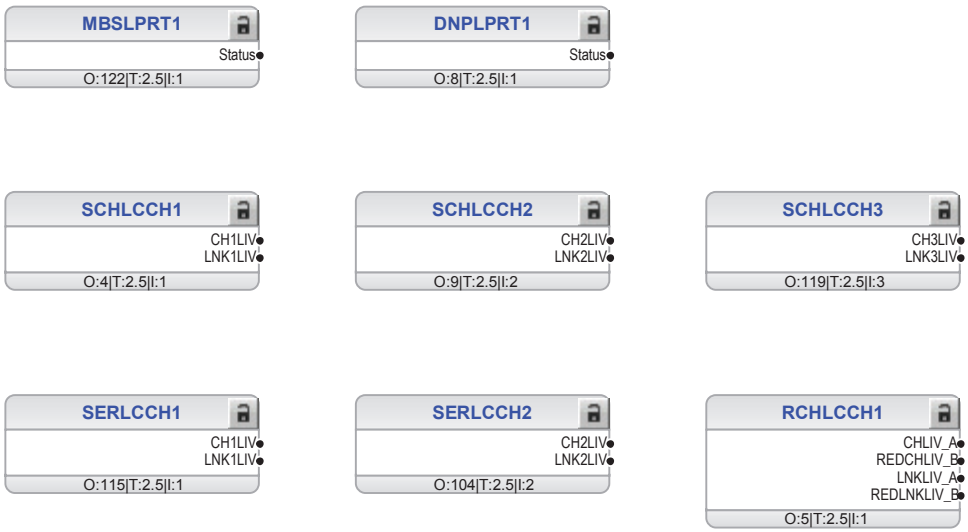


Figure 52: Default communication function connection

3.4 Standard configuration F

3.4.1 Applications

The standard configuration includes directional overcurrent and directional ground-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 grounded distribution networks. The configuration also includes additional options for selecting ground-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

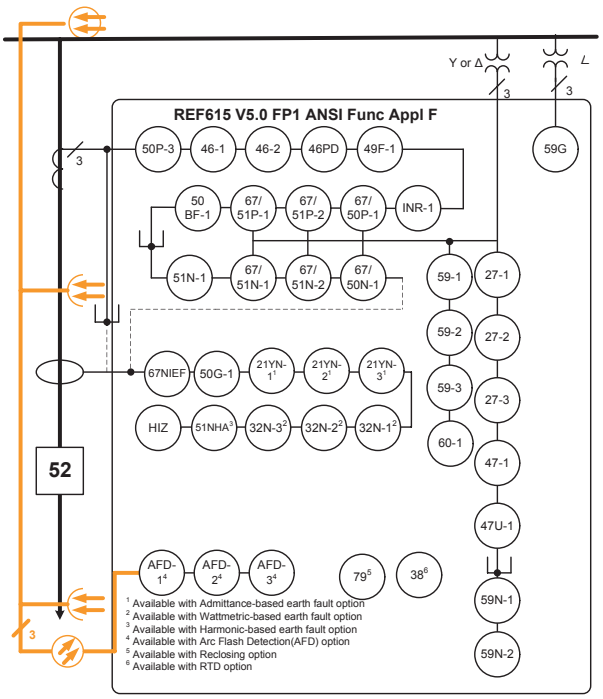


Figure 53: Functionality overview for standard configuration F

3.4.2.1 Default I/O connections

Table 15: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
VA	Phase voltage VA	X130:11-12
VB	Phase voltage VB	X130:13-14
VC	Phase voltage VC	X130:15-16
VG	Residual voltage VG	X130:17-18

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	MCB open	X110:1-2	X110:1,5
X110-BI2	Directional ground-fault protection's basic angle control	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10
X120-BI1	Blocking of overcurrent instantaneous stage	X120:1-2	
X120-BI2	Circuit breaker closed position indication	X120:3-2	
X120-BI3	Circuit breaker open position indication	X120:4-2	
X120-BI4	Lock-out reset	X120:5-6	
X130-BI1	-	X130:1-2	
X130-BI2	-	X130:3-4	
X130-BI3	-	X130:5-6	
X130-BI4	-	X130:7-8	

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	General pickup indication	X100:10-11,(12)
X100-SO2	General trip indication	X100:13-14
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Upstream overcurrent blocking	X110:14-16
X110-SO2	Overcurrent trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	Voltage protection trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 18: Default connections for LEDs

LED	Default usage	ID	Label description
1	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
2	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
3	Voltage protection trip	LED_OverUnderVoltage_1	Over/under voltage
4	Negative sequence overcurrent or phase discontinuity protection trip	LED_PhaseUnbalance_1	Phase unbalance
5	Thermal overload alarm	LED_ThermalOverload_1	Thermal overload
6	Circuit breaker failure protection backup protection trip	LED_BreakerFailure_1	Breaker failure
7	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
8	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
9	Supervision alarm	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Autoreclose in progress	LED_AutorecloseInProgress_1	Autoreclose shot in progr.

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	U1
7	U2
8	U3
9	-
10	-
11	-
12	-

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	DPHLPDOC1 - pickup	Positive or Rising
2	DPHLPDOC2 - pickup	Positive or Rising
3	DPHHPDOC1 - pickup	Positive or Rising
4	PHIPTOC1 - pickup	Positive or Rising
5	NSPTOC1 - pickup	Positive or Rising
6	NSPTOC2 - pickup	Positive or Rising
7	DEFLPDEF1/WPWDE1/EFPADM1 - pickup	Positive or Rising
8	DEFLPDEF2/WPWDE2/EFPADM2 - pickup	Positive or Rising
9	DEFHPDEF1/WPWDE3/EFPADM3 - pickup	Positive or Rising
10	INTRPTEF1 - pickup	Positive or Rising
11	EFHPTOC1 - pickup	Positive or Rising
12	PDNSPTOC1 - pickup	Positive or Rising
13	T1PTTR1 - pickup	Positive or Rising
14	PHPTOV1 - pickup	Positive or Rising
15	PHPTOV2 - pickup	Positive or Rising
16	PHPTOV3 - pickup	Positive or Rising
17	PSPTUV1 - pickup	Positive or Rising
18	NSPTOV1 - pickup	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
19	PHPTUV1 - pickup	Positive or Rising
20	PHPTUV2 - pickup	Positive or Rising
21	PHPTUV3 - pickup	Positive or Rising
22	ROVPTOV1 - pickup	Positive or Rising
23	ROVPTOV2 - pickup	Positive or Rising
24	ROVPTOV3 - pickup	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHxPTOC - trip	Level trigger off
28	NSPTOC - trip	Level trigger off
29	DEFxPDEF/WPWDE/EFPADM - trip	Level trigger off
30	INTRPTEF1 - trip	Level trigger off
31	EFHPTOC1 - trip	Level trigger off
32	PDNSPTOC1 - trip	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off
34	T1PTTR1 - trip	Level trigger off
35	PHPTOV - trip	Level trigger off
36	PHPTUV - trip	Level trigger off
37	ROVPTOV/PSPTUV1/NSPTOV1 - trip	Level trigger off
38	SEQSPVC1 - fusef 3ph	Level trigger off
39	SEQSPVC1 - fusef u	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 open	Level trigger off
44	ARCSARC - ARC flt det	Level trigger off
45	DARREC1 - close CB/unsuc recl	Level trigger off
46	ARCSARC1 - trip	Positive or Rising
47	ARCSARC2 - trip	Positive or Rising
48	ARCSARC3 - trip	Positive or Rising
49	DARREC1 - inpro	Level trigger off
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-

Table continues on next page

Channel	ID text	Level trigger mode
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

3.4.3 Functional diagrams

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

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

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

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

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

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

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

3.4.3.1 Functional diagrams for protection

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

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

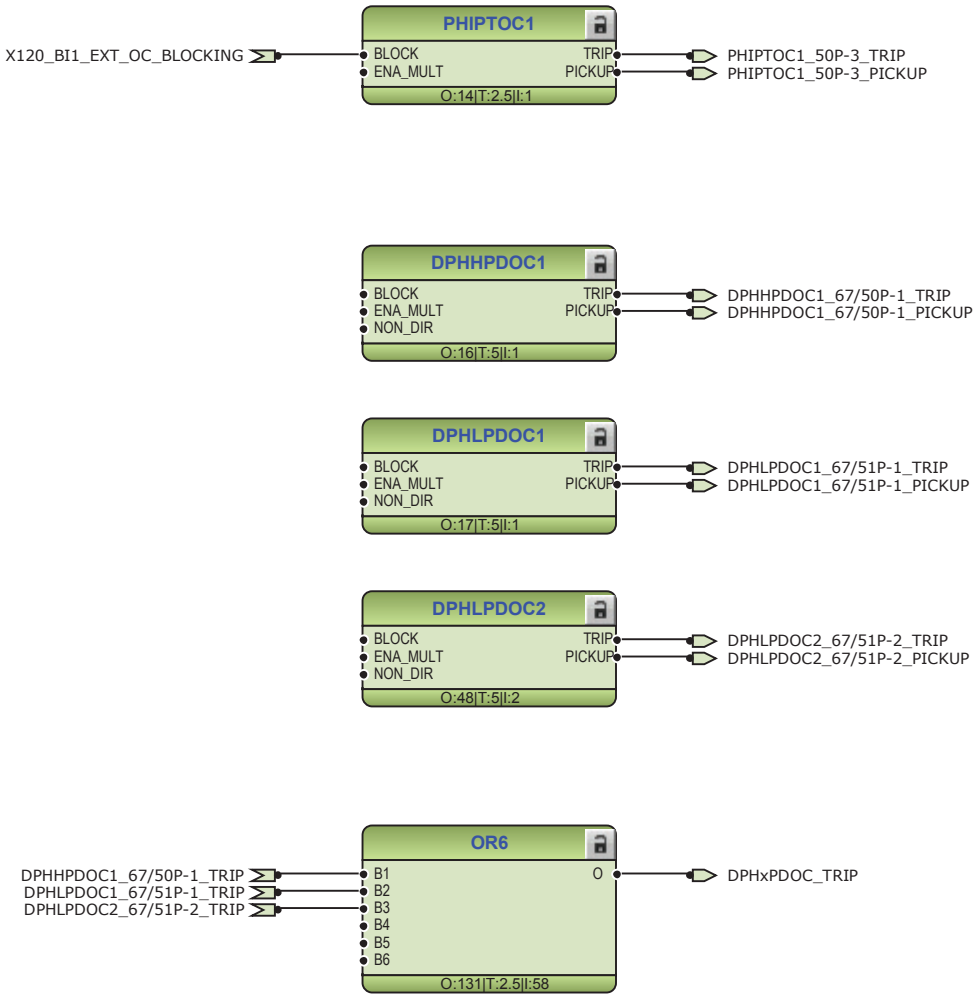


Figure 54: Overcurrent protection functions

The upstream blocking from the pickup of the second low stage of three-phase directional overcurrent protection DPHLPDOC2_67/51P-2 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 relay at the infeeding bay.

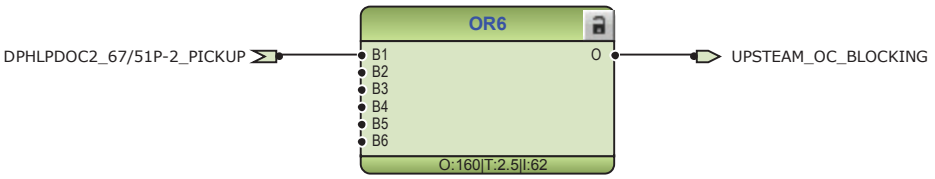


Figure 55: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or ground-fault function blocks.

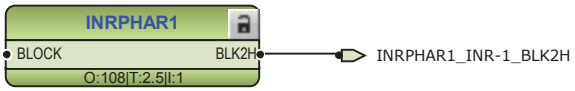


Figure 56: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1_46-1 and NSPTOC2_46-2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. Both the negative-sequence overcurrent protections are blocked in case of detection in failure in secondary circuit of current transformer.

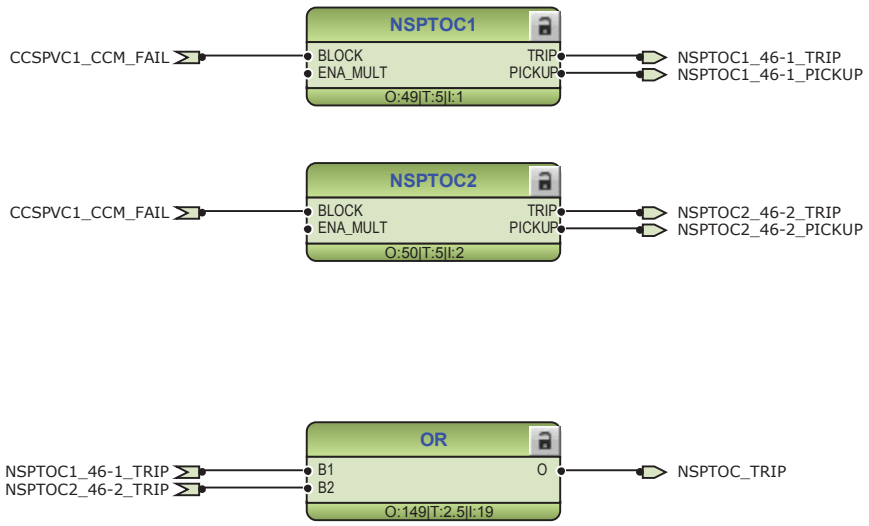


Figure 57: Negative-sequence overcurrent protection function

Three stages are provided for directional ground-fault protection DEFxPDEF_67/5xN. One stage is provided for non-directional ground-fault protection EFHPTOC1_50G-1. According to the relay's order code, the directional ground-fault protection method can be

based on conventional directional ground-fault DEFxPDEF_67/5xN only or alternatively used together with admittance-based ground-fault protection EFPADM_21YN or wattmetric-based ground-fault protection WPWDE_32N. A dedicated protection stage INTRPTEF_67NIEF is used either for transient-based ground-fault protection or for cable intermittent ground-fault protection in compensated networks. The binary input X110:BI2 is intended for controlling directional ground-fault protection blocks' relay characteristic angle (RCA: 0°, -90°) or operation mode (IoSinφ, IoCosφ) change. The same input is also available for wattmetric protection.

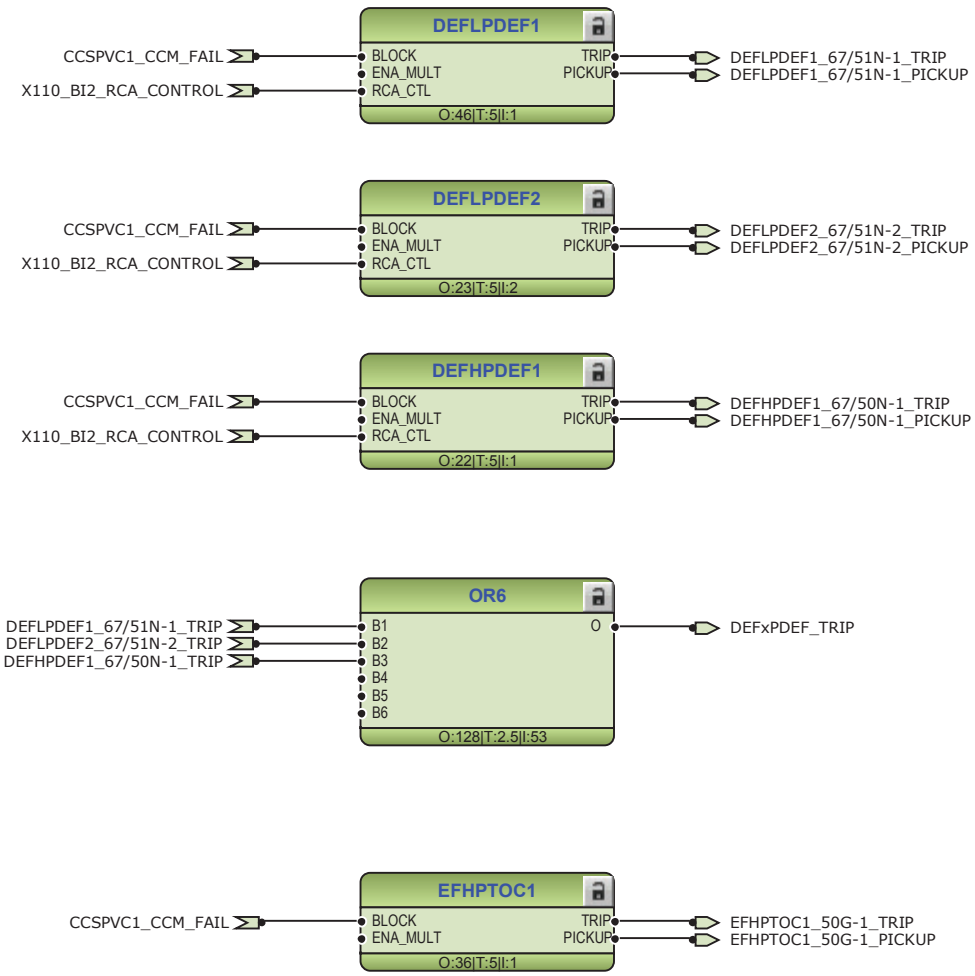


Figure 58: Non-directional ground-fault protection

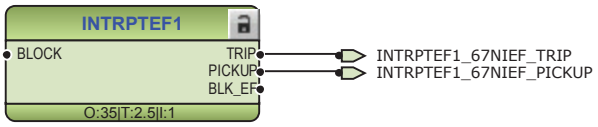


Figure 59: Transient or intermittent ground-fault protection functions

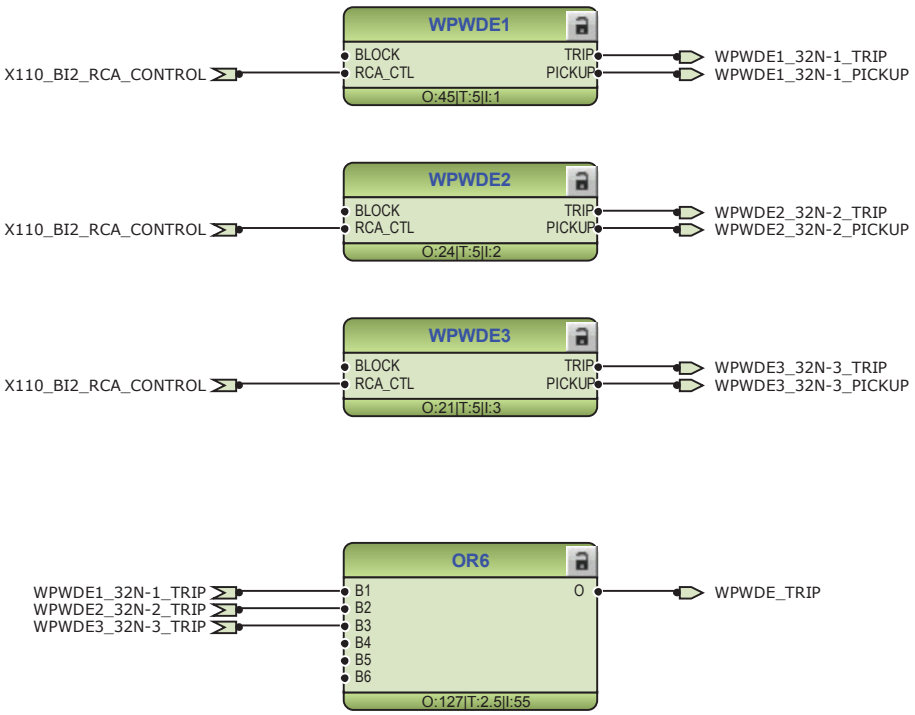


Figure 60: Wattmetric protection function

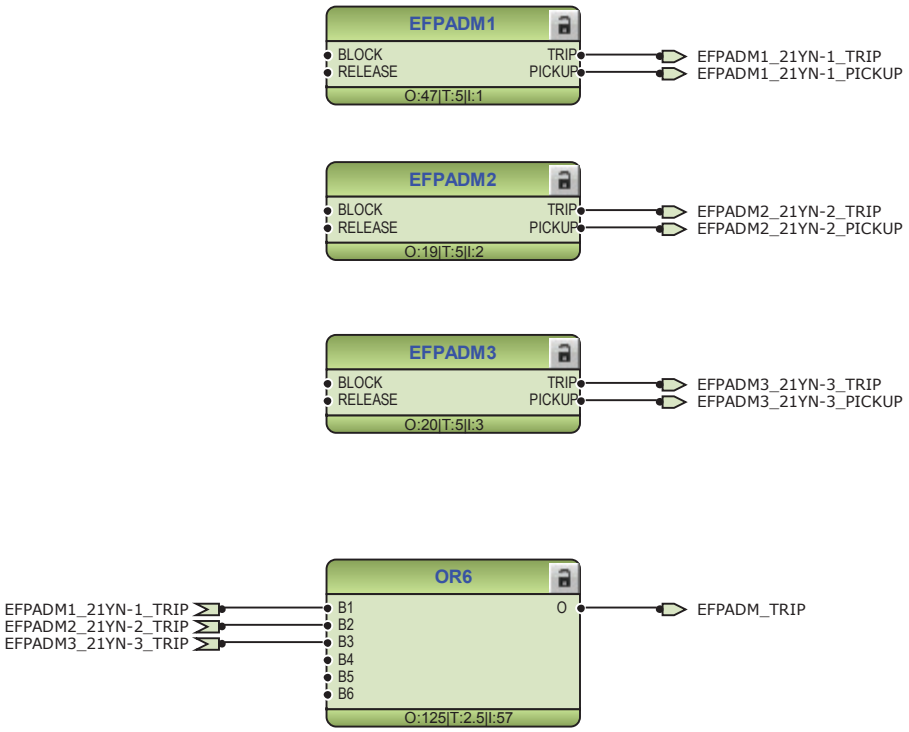


Figure 61: Admittance-based ground-fault protection function

Phase discontinuity protection PDNSPTOC1_46PD 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.

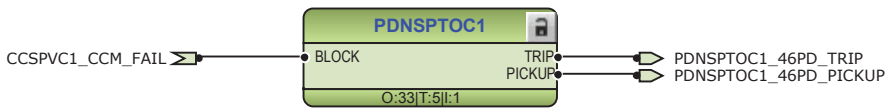


Figure 62: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1_49F-1 detects overloads under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

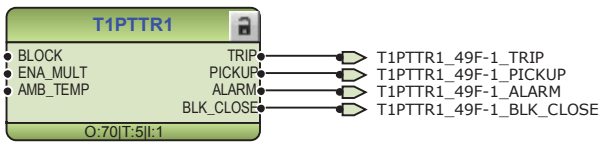


Figure 63: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by number of different protection functions available in the relay. 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 trip output is used for retripping its own breaker through TRPPTRC2_86/94-2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the binary output X100:PO2.

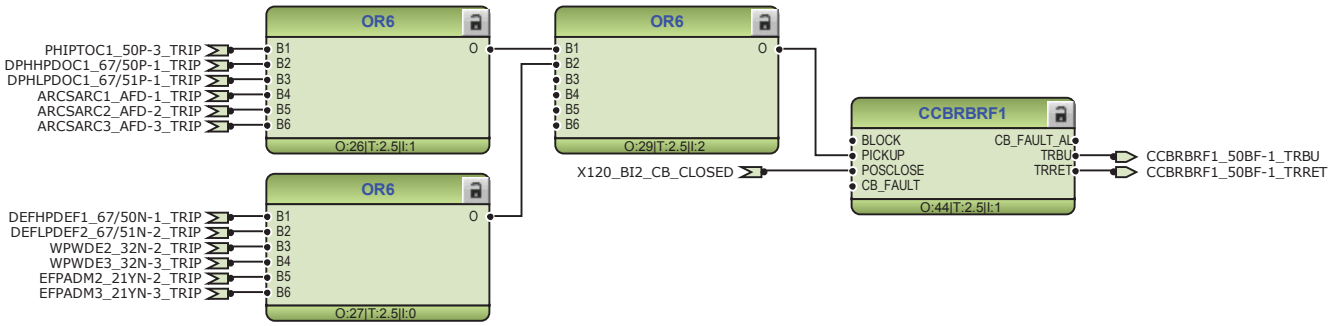


Figure 64: Circuit breaker failure protection function

Three arc protection stages ARCSARC-1…3_AFD-1...3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The trip signals from ARCSARC-1…3_AFD-1...3 are connected to both trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2.

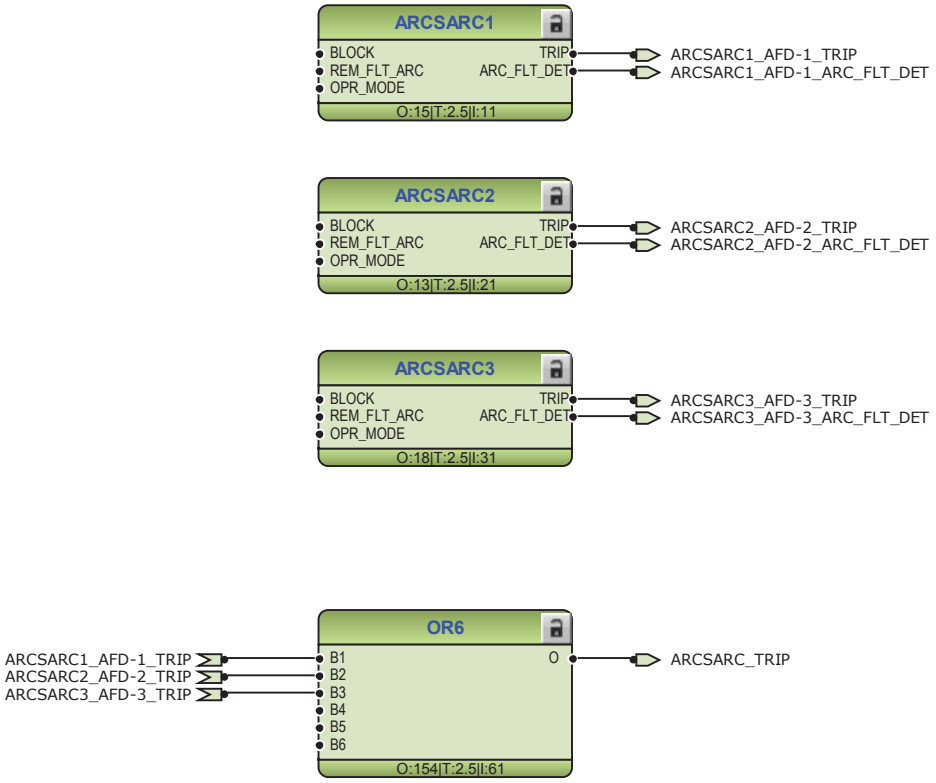


Figure 65: Arc protection

The optional autoreclosing function is configured to be initiated by trip 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_52-1_SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1_79. 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_79 properly.

Check the initialization signals of DARREC1_79.

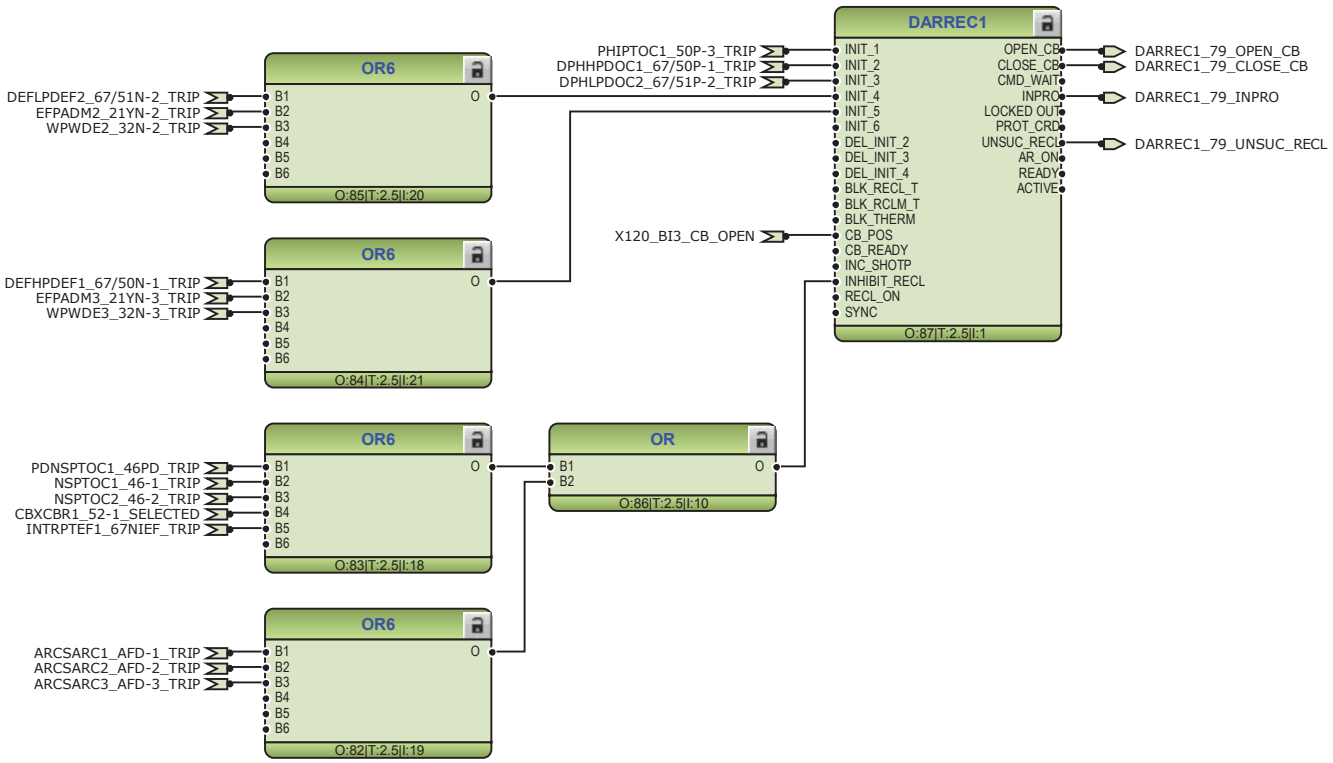


Figure 66: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV_47U and negative-sequence overvoltage protection NSPTOV_47 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.

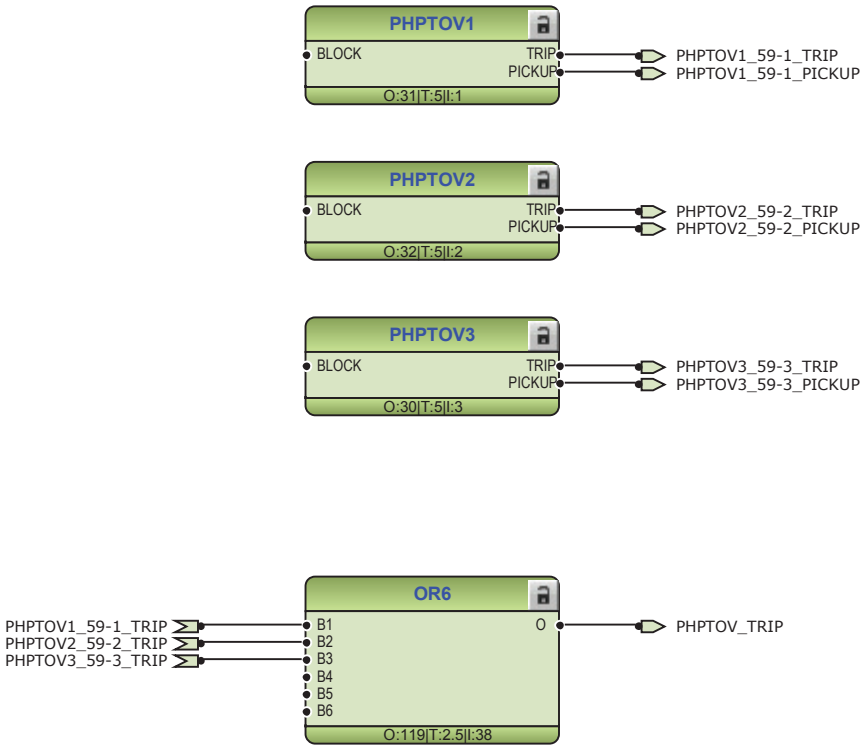


Figure 67: Overvoltage protection function

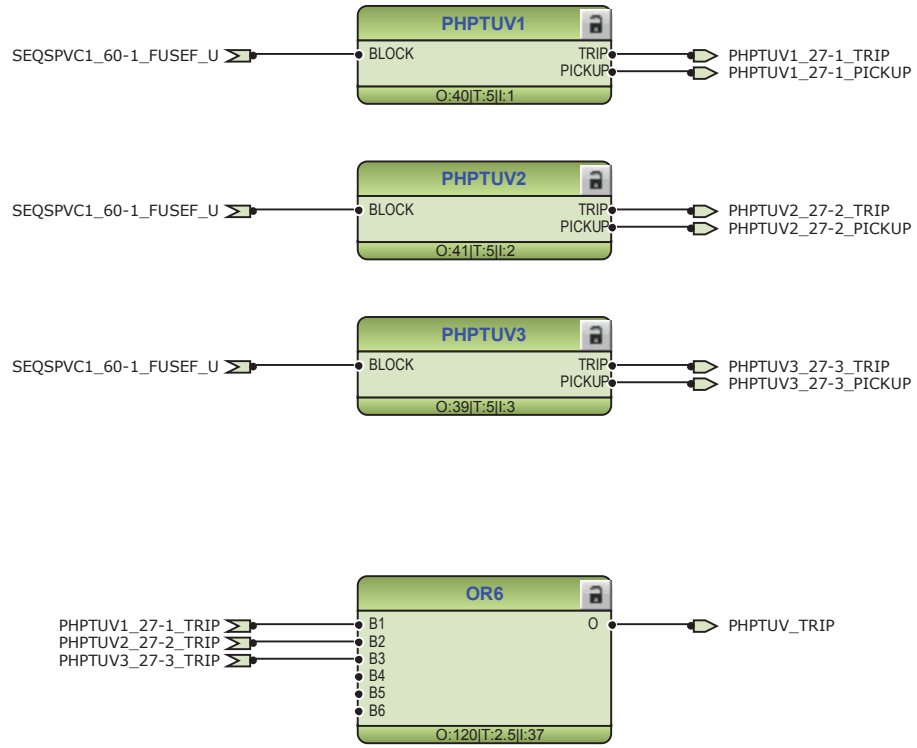


Figure 68: Undervoltage protection function

Figure 69: Negative-sequence overvoltage protection function

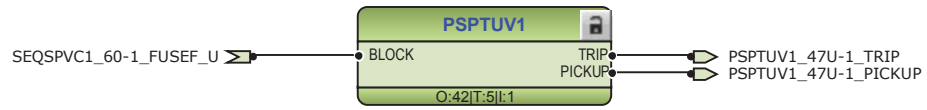


Figure 70: Positive-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV_59G,59N provides ground-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

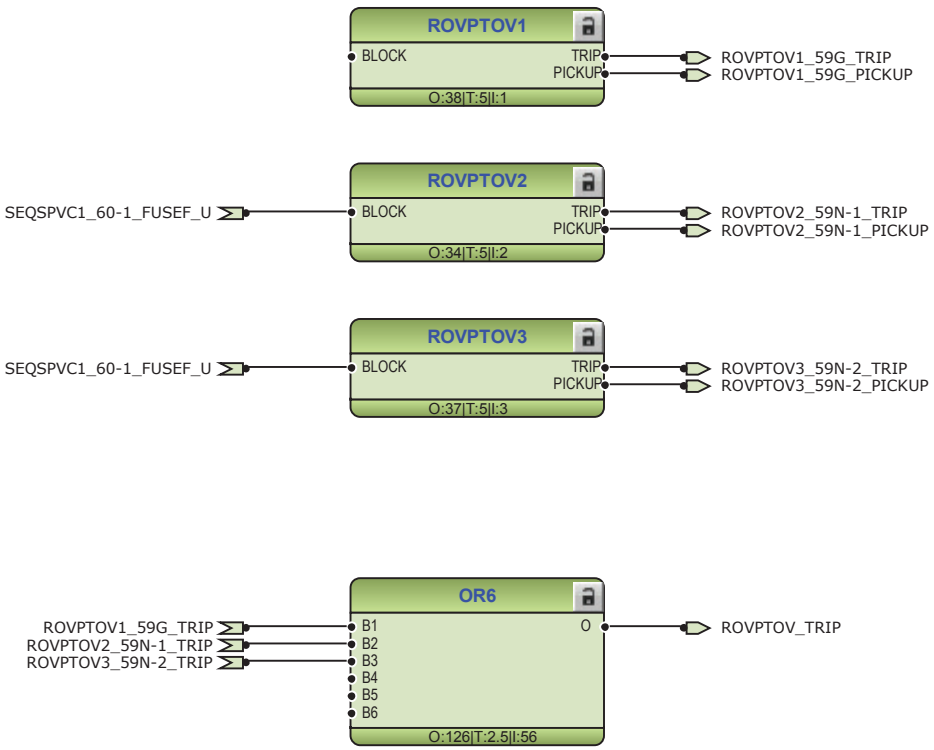


Figure 71: Residual voltage protection function

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

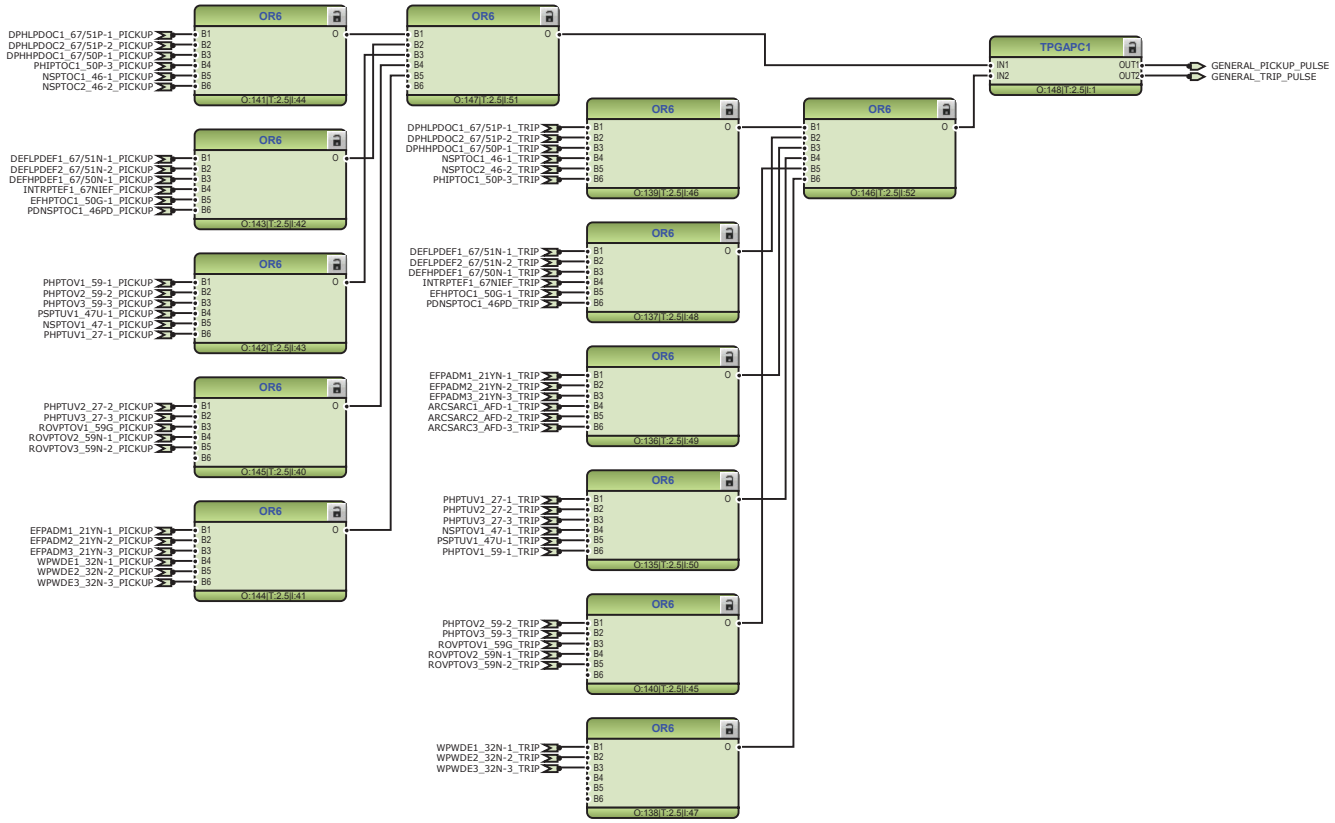


Figure 72: General pickup and trip signals

The trip signals from the protection functions are connected to the two trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions 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...5_86/94-3…5 are also available if the relay is ordered with high speed binary outputs options.

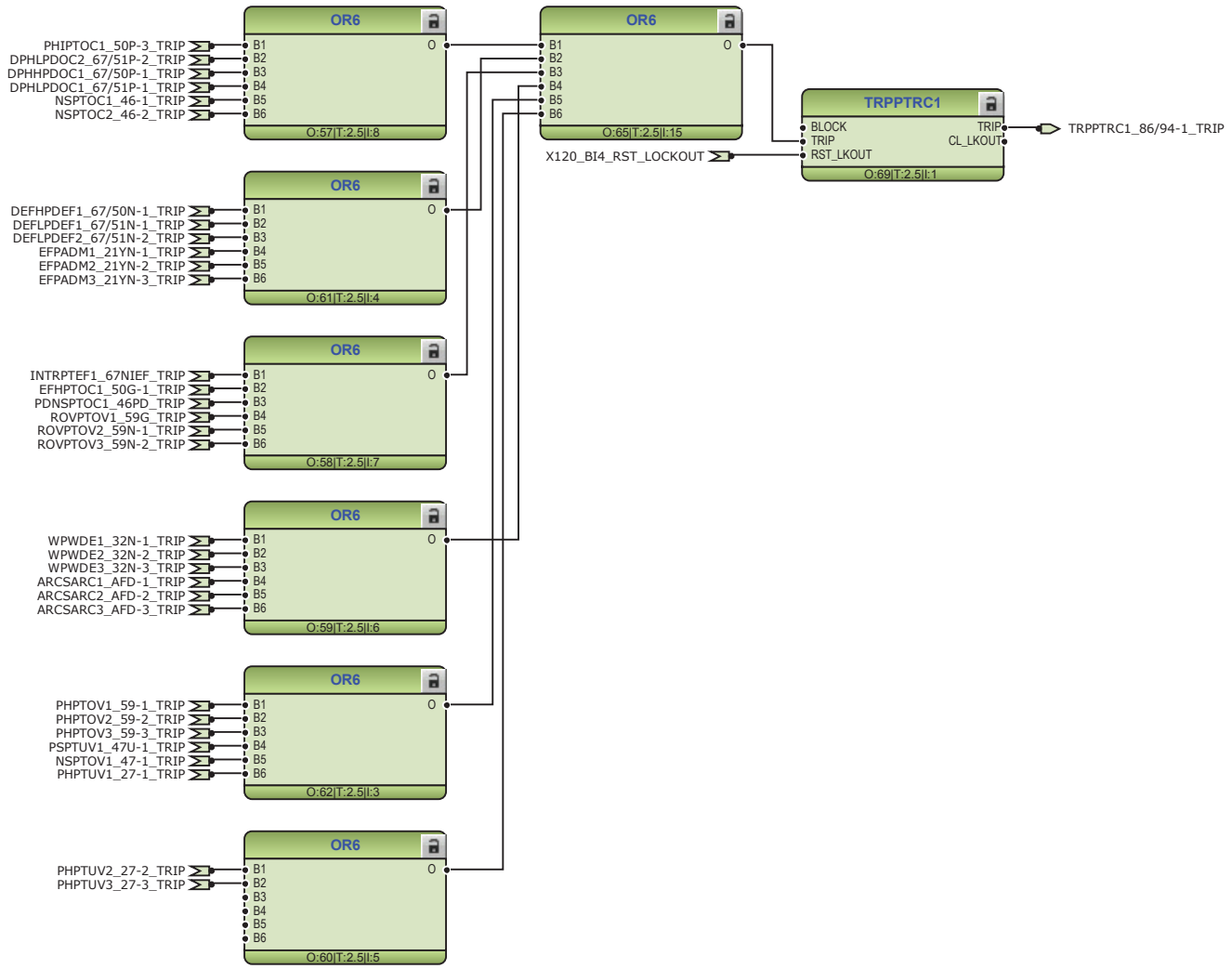


Figure 73: Trip logic TRPPTRC1

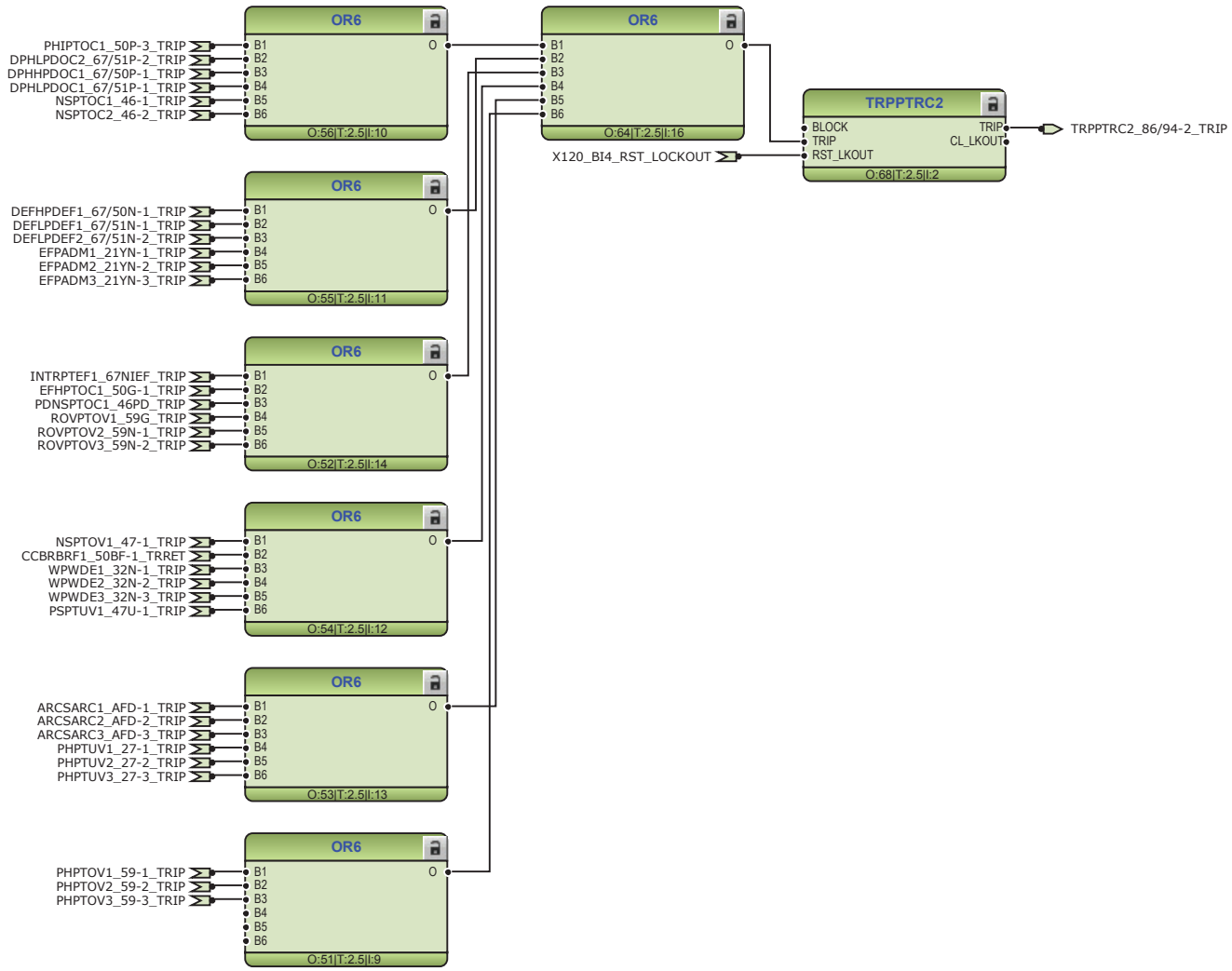


Figure 74: Trip logic TRPPTRC2

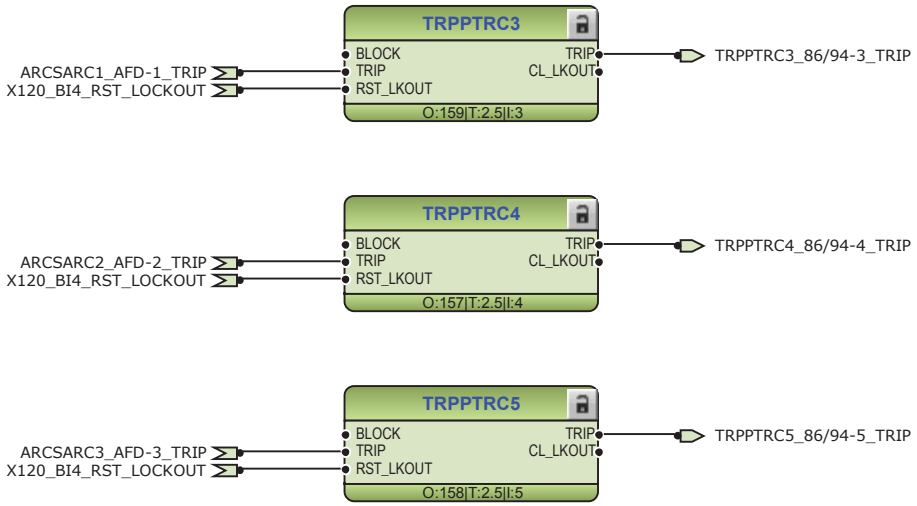


Figure 75: Trip logic TRPPTRC3/4/5

3.4.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

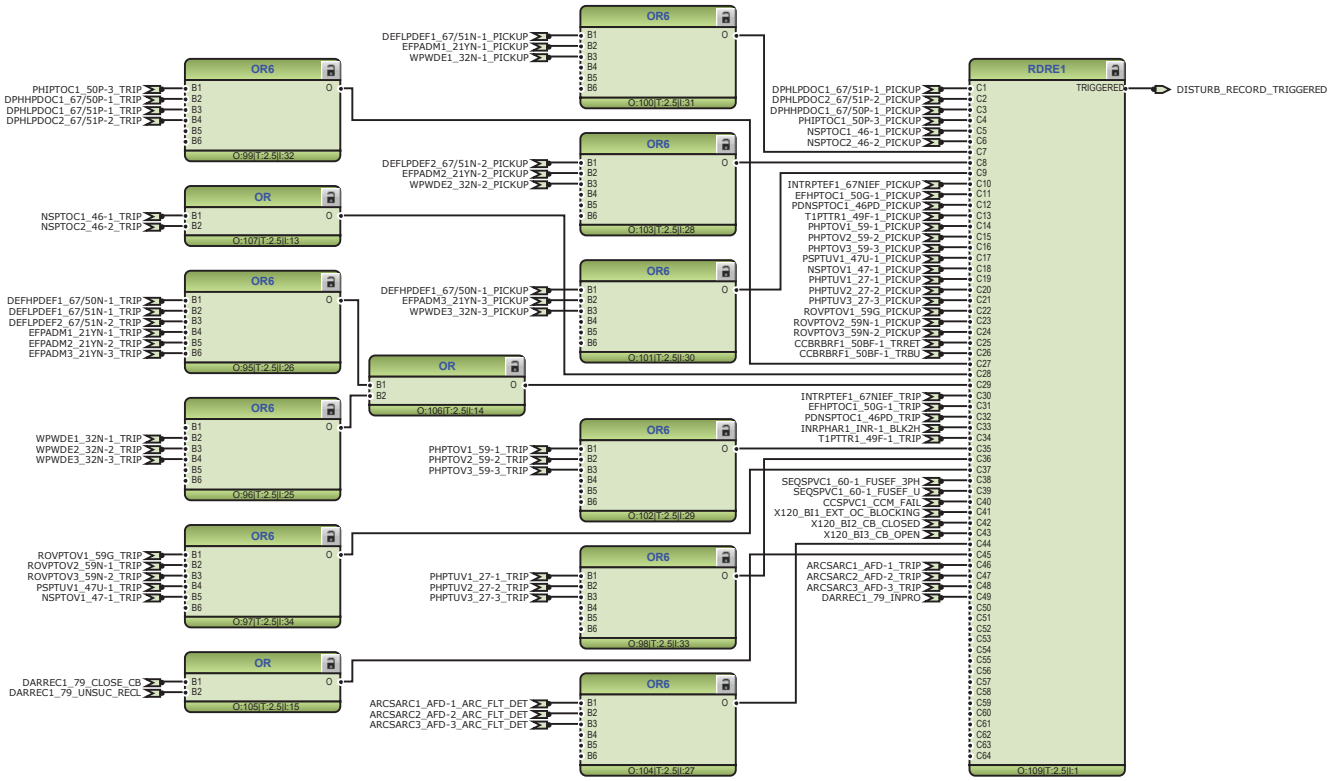


Figure 76: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

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

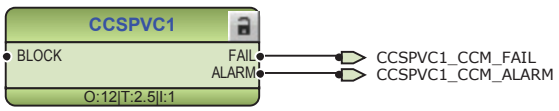


Figure 77: Current circuit supervision function

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

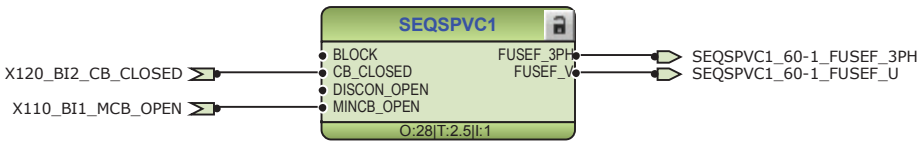


Figure 78: Fuse failure supervision function

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

Set the parameters for SSCBR1_52CM-1 properly.

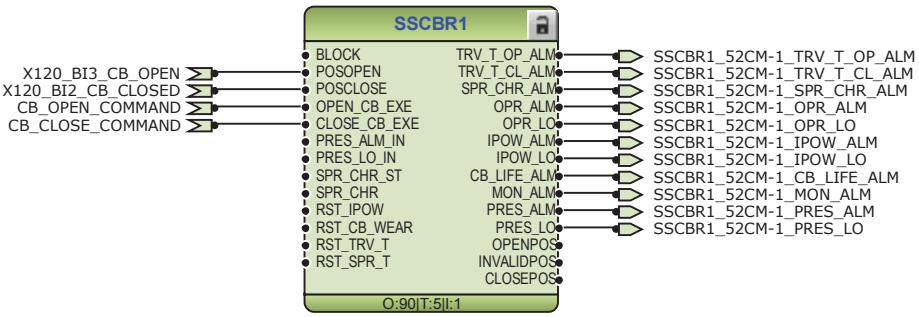


Figure 79: Circuit-breaker condition monitoring function

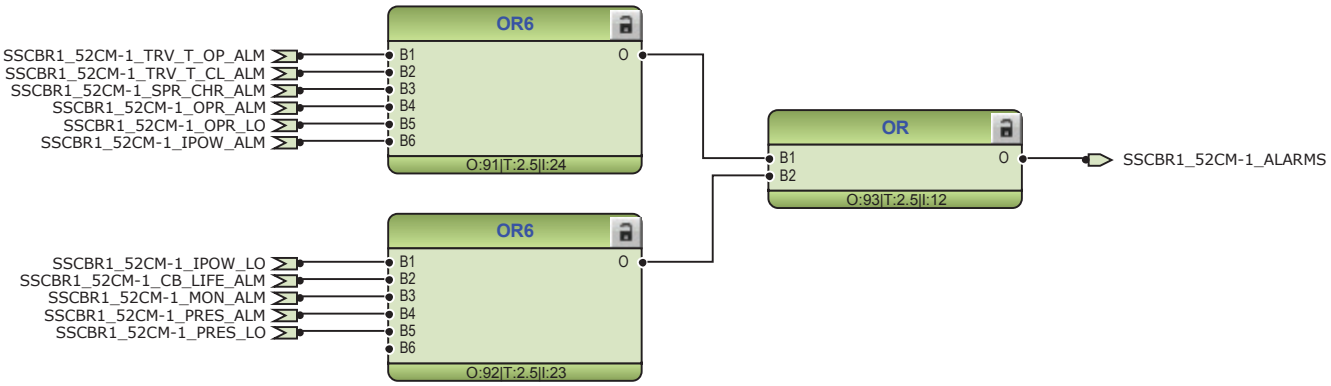


Figure 80: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. Both the

functions are blocked by the master trips TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 and the circuit breaker open signal.

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

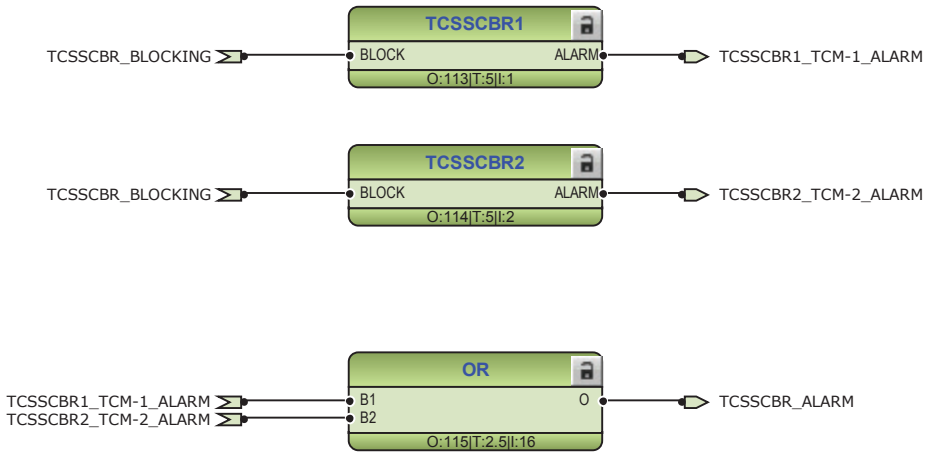


Figure 81: Trip circuit supervision function

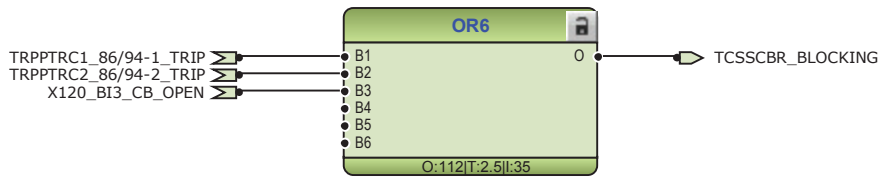


Figure 82: Logic for blocking of trip circuit supervision

3.4.3.4 Functional diagrams for control and interlocking

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated 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.

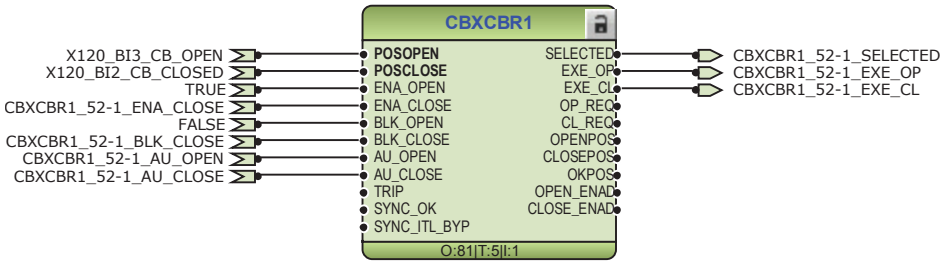


Figure 83: Circuit breaker control logic: Circuit breaker 1

Figure 84: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

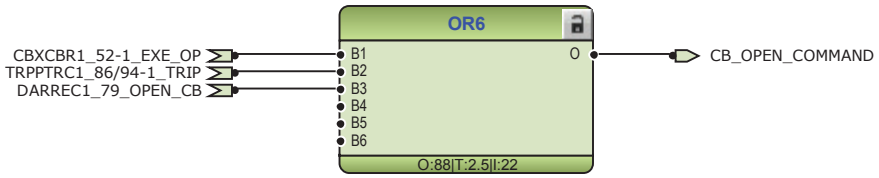


Figure 85: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

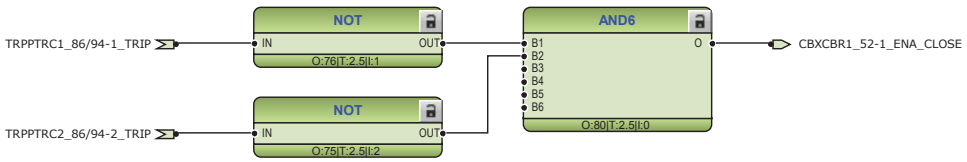


Figure 86: Circuit breaker close enable logic

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

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

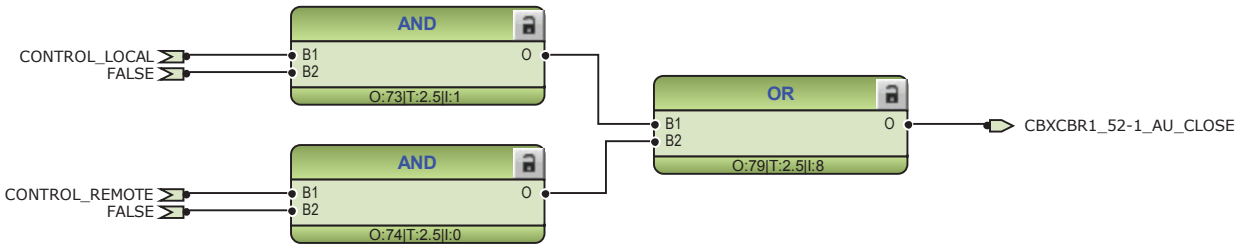


Figure 87: External closing command for circuit breaker

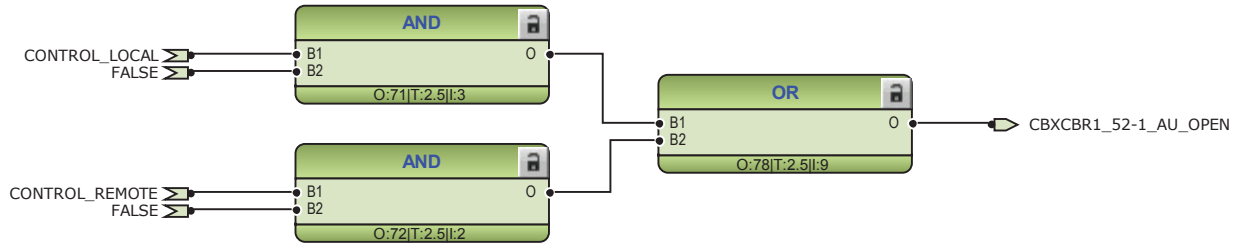


Figure 88: External opening command for circuit breaker

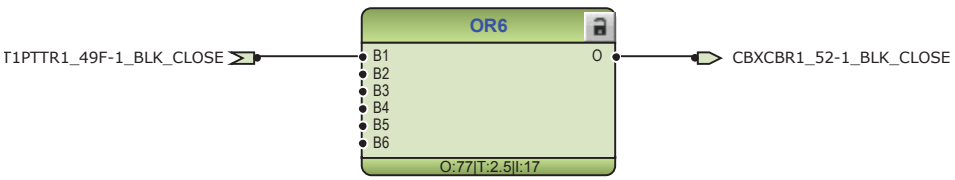


Figure 89: Circuit breaker 1 close blocking logic

3.4.3.5 Functional diagrams for measurement functions

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

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

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

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

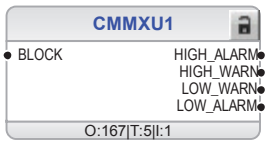


Figure 90: Three-phase current measurement

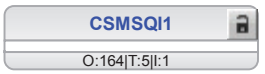


Figure 91: Sequence current measurements

Figure 92: Ground current measurements

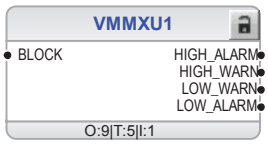


Figure 93: Three-phase voltage measurement

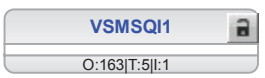


Figure 94: Sequence voltage measurements

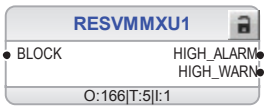


Figure 95: Ground voltage measurements

Figure 96: Frequency measurement

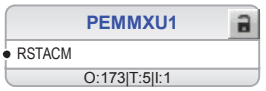


Figure 97: Three-phase power and energy measurement

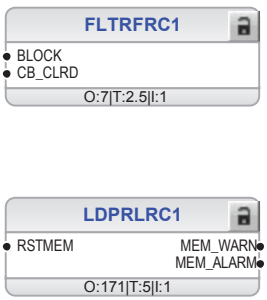


Figure 98: Data monitoring and load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

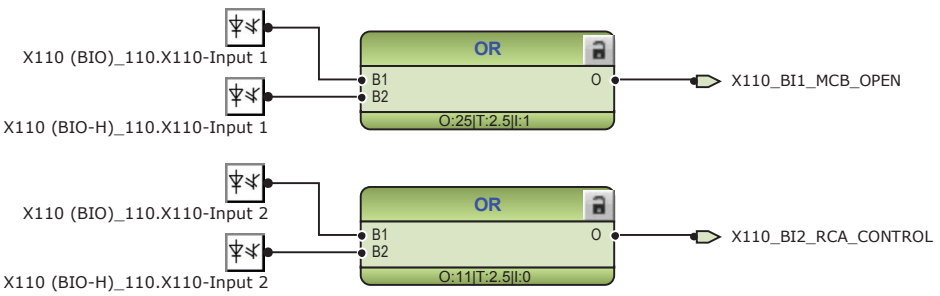


Figure 99: Default binary inputs - X110

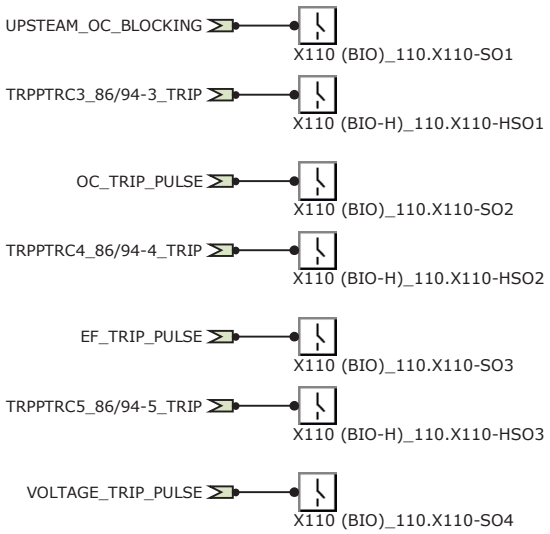


Figure 100: Default binary outputs - X110

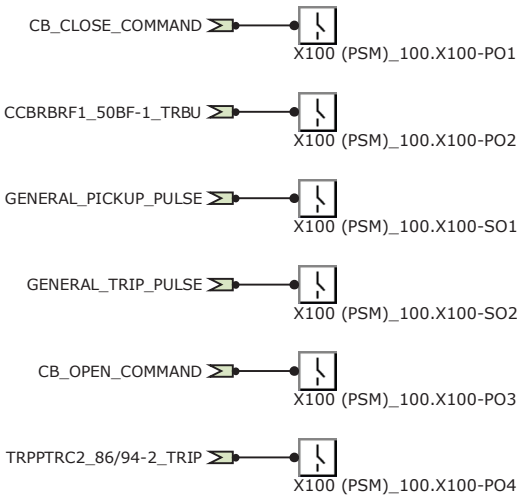


Figure 101: Default binary outputs - X100

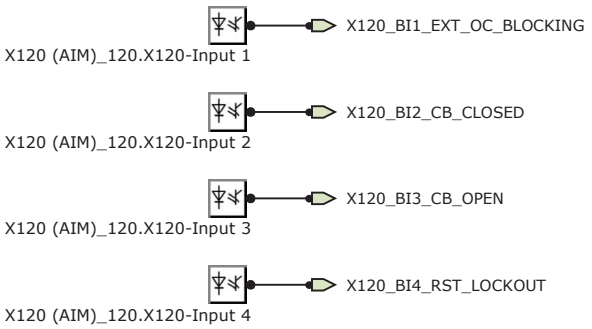


Figure 102: Default binary inputs - X120

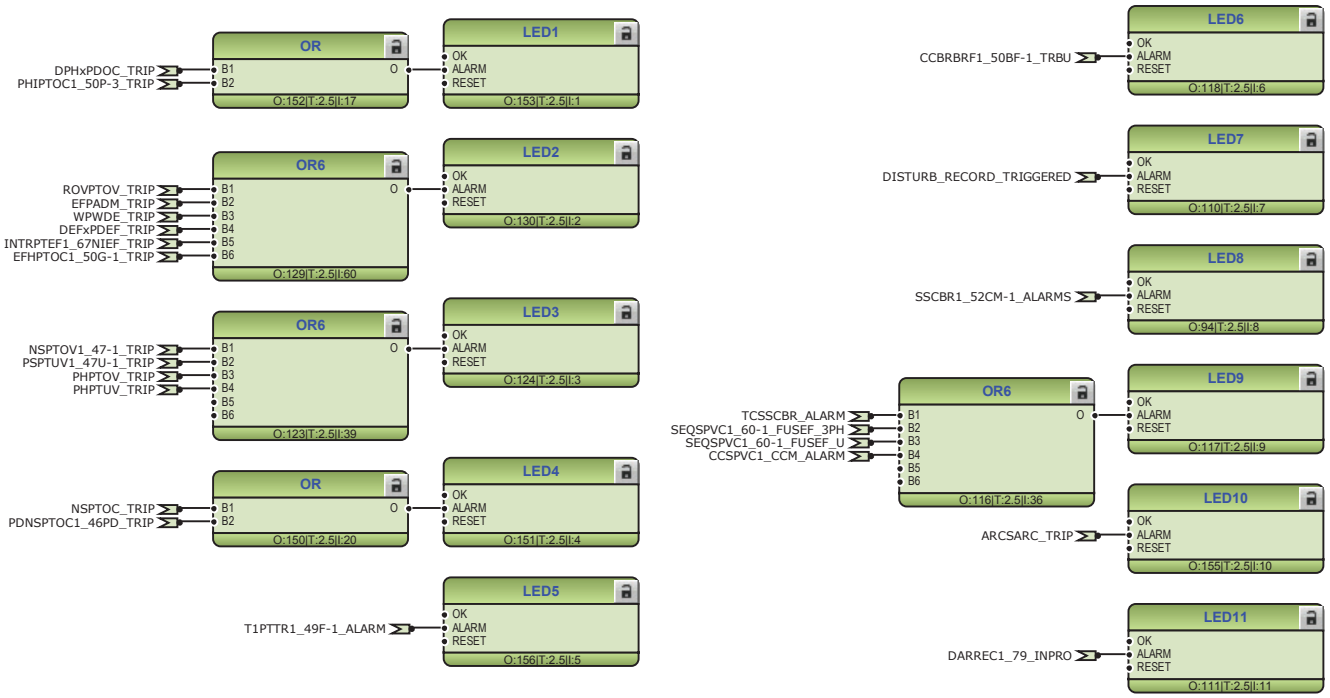


Figure 103: Default LED connection

3.4.3.7 Functional diagrams for other functions

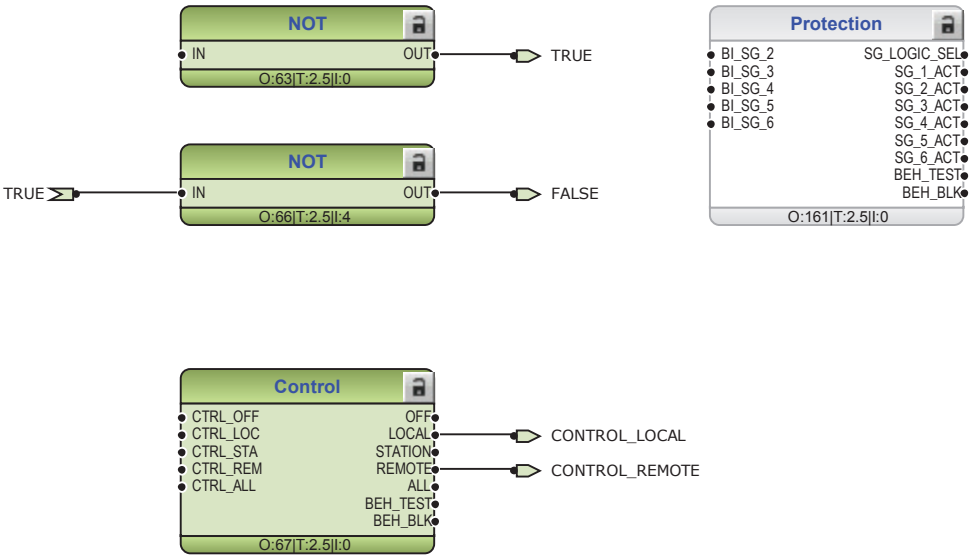


Figure 104: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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

3.4.3.8 Functional diagrams for other timer logics

The configuration also includes the overcurrent trip and ground-fault trip logic.

The trip 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.

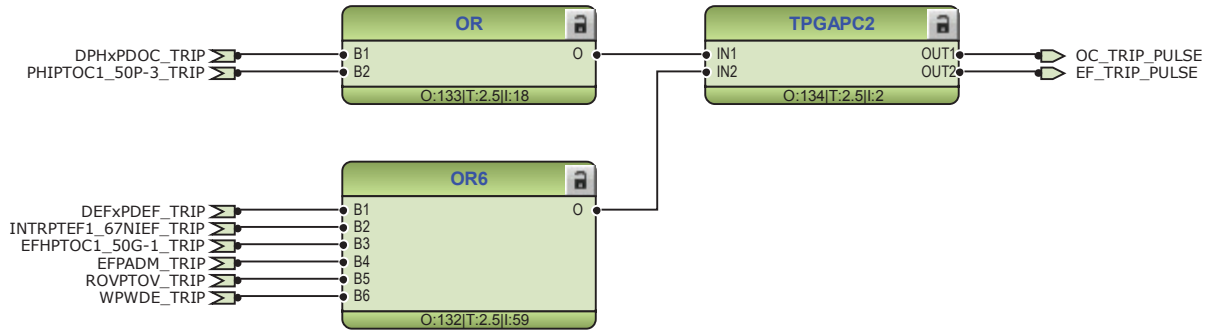


Figure 105: Timer logic for overcurrent and ground-fault trip pulse

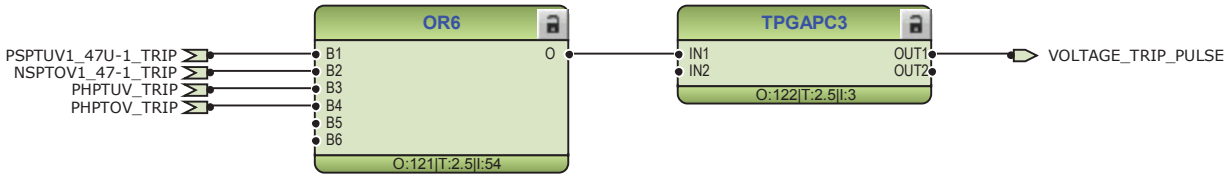


Figure 106: Timer logic for voltage trip pulse

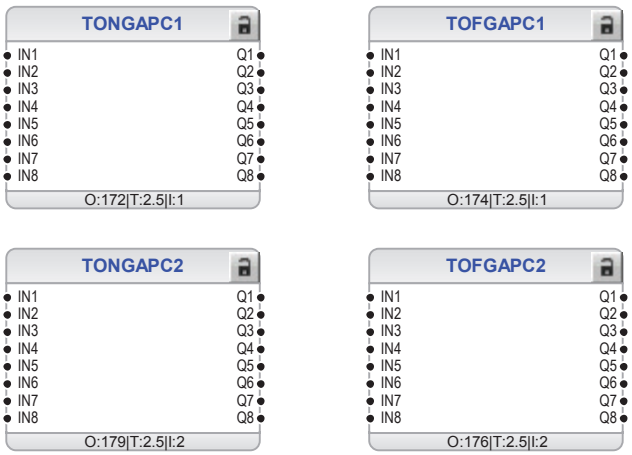


Figure 107: Programmable timers

3.4.3.9 Functional diagrams for communication

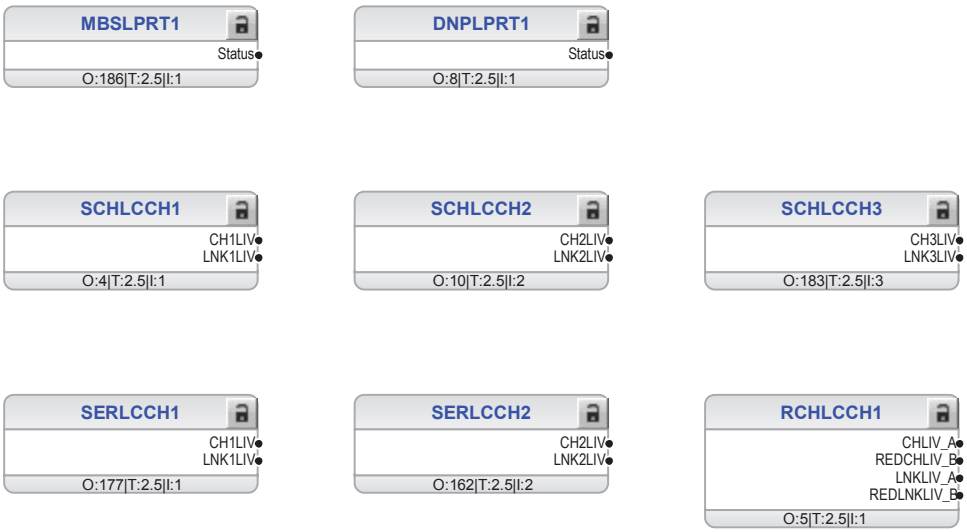


Figure 108: Default communication function connection

3.5 Standard configuration L

3.5.1 Applications

The standard configuration for directional overcurrent and directional ground-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-grounded distribution networks. The configuration also includes additional options for selecting ground-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 protection relay at the same time. To ensure the performance of the protection relay, the user specific configuration load is verified with the Application Configuration tool of PCM600.

3.5.2 Functions

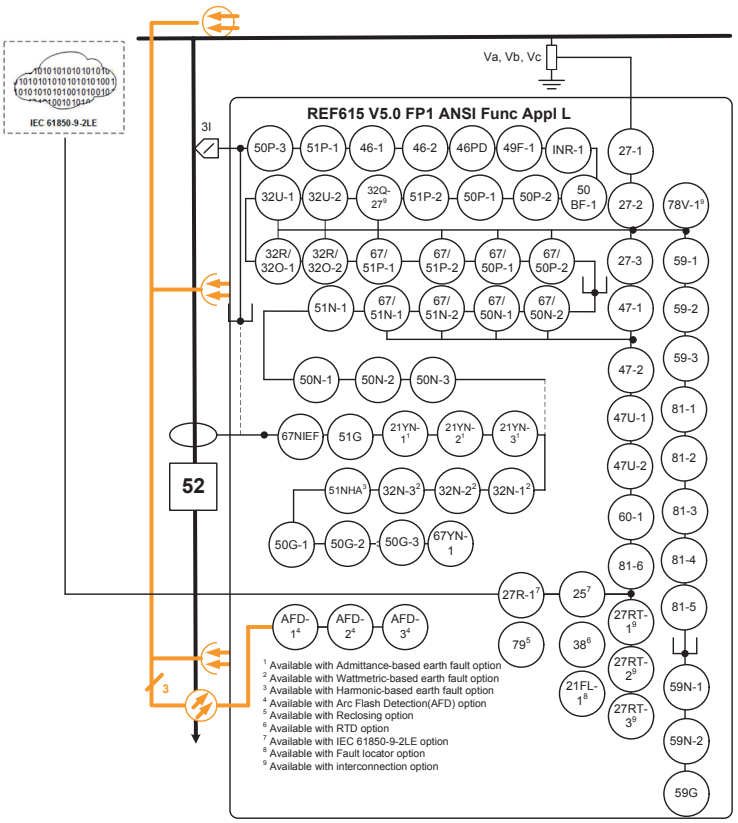


Figure 109: Functionality overview for standard configuration L

3.5.2.1 Default I/O connections

Table 21: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X131:4-5
IB	Phase B current	X132:4-5
IC	Phase C current	X133:4-5
IG	Residual current IG	X130:1-2

Table continues on next page

Analog input	Description	Connector pins
VA	Phase voltage VA	X131:7-8
VB	Phase voltage VB	X132:7-8
VC	Phase voltage VC	X133:7-8

Table 22: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	-	X110:3-4	X110:2,5
X110-BI3	Circuit breaker open position indication	X110:5-6	X110:3,5
X110-BI4	Circuit breaker closed position indication	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10

Table 23: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	General pickup indication	X100:10-11,(12)
X100-SO2	General trip indication	X100:13-14
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Upstream overcurrent blocking	X110:14-16
X110-SO2	Overcurrent trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	Voltage protection trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 24: Default connections for LEDs

LED	Default usage	ID	Label description
1	Circuit breaker close enabled	LED_CBcloseenabled_1	CB close enabled
2	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
3	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
4	Current unbalance protection trip	LED_PhaseUnbalance_1	Phase unbalance
5	Sequence voltage protection trip	LED_NPSOrPPSvoltage_1	Sequence voltage
6	Overvoltage or residual overvoltage protection trip	LED_OVorResidualVoltage_1	OV / Residual voltage
7	Thermal overload alarm	LED_ThermalOverload_1	Thermal overload
8	Undervoltage or frequency protection trip	LED_UVorFrequency_1	UV / Frequency
9	Supervision alarm	LED_Supervision_1	Supervision
10	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
11	-	-	-

3.5.2.2 Default disturbance recorder settings

Table 25: 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 26: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	DPHLPDOC1 - pickup	Positive or Rising
2	DPHLPDOC2 - pickup	Positive or Rising
3	DPHHPDOC1 - pickup	Positive or Rising
4	PHIPTOC1 - pickup	Positive or Rising
5	NSPTOC1 - pickup	Positive or Rising
6	NSPTOC2 - pickup	Positive or Rising
7	DEFLPDEF1/WPWDE1/EFPADM1 - pickup	Positive or Rising
8	DEFLPDEF2/WPWDE2/EFPADM2 - pickup	Positive or Rising
9	DEFHPDEF1/WPWDE3/EFPADM3 - pickup	Positive or Rising
10	INTRPTEF1 - pickup	Positive or Rising
11	EFHPTOC1 - pickup	Positive or Rising
12	PDNSPTOC1 - pickup	Positive or Rising
13	T1PTTR1 - pickup	Positive or Rising
14	PHPTOV1 - pickup	Positive or Rising
15	PHPTOV2 - pickup	Positive or Rising
16	PHPTOV3 - pickup	Positive or Rising
17	PSPTUV1 - pickup	Positive or Rising
18	NSPTOV1 - pickup	Positive or Rising
19	PHPTUV1 - pickup	Positive or Rising
20	PHPTUV2 - pickup	Positive or Rising
21	PHPTUV3 - pickup	Positive or Rising
22	ROVPTOV1 - pickup	Positive or Rising
23	ROVPTOV2 - pickup	Positive or Rising
24	ROVPTOV3 - pickup	Positive or Rising
25	CCBRBRF1 - trret	Level trigger off
26	CCBRBRF1 - trbu	Level trigger off
27	PHxPTOC - trip	Level trigger off
28	NSPTOC - trip	Level trigger off
29	DEFxPDEF/WPWDE/EFPADM - trip	Level trigger off
30	INTRPTEF1 - trip	Level trigger off
31	EFHPTOC - trip	Level trigger off
32	PDNSPTOC1 - trip	Level trigger off
33	INRPHAR1 - blk2h	Level trigger off
34	T1PTTR1 - trip	Level trigger off
35	PHPTOV - trip	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
36	PHPTUV - trip	Level trigger off
37	ROVPTOV/PSPTUV1/NSPTOV1 - trip	Level trigger off
38	SEQSPVC1 - fusef 3ph	Level trigger off
39	SEQSPVC1 - fusef u	Level trigger off
40	CCSPVC1 - fail	Level trigger off
41	X110BI4 - CB closed	Level trigger off
42	X110BI3 - CB open	Level trigger off
43	ARCSARC - ARC flt det	Level trigger off
44	DARREC1 - close CB/unsuc recl	Level trigger off
45	ARCSARC1 - trip	Positive or Rising
46	ARCSARC2 - trip	Positive or Rising
47	ARCSARC3 - trip	Positive or Rising
48	DARREC1 - inpro	Level trigger off
49	FRPFRQ1 - pickup	Positive or Rising
50	FRPFRQ2 - pickup	Positive or Rising
51	FRPFRQ3 - pickup	Positive or Rising
52	FRPFRQ - trip	Level trigger off
53	DPHHPDOC2 - pickup	Positive or Rising
54	EFHPTOC2 - pickup	Positive or Rising
55	EFHPTOC3 - pickup	Positive or Rising
56	EFHPTOC4 - pickup	Positive or Rising
57	DEFHPDEF2 - pickup	Positive or Rising
58	DUPPDPR1 - pickup	Positive or Rising
59	DUPPDPR2 - pickup	Positive or Rising
60	DUPPDPR1 - trip	Level trigger off
61	MSVPR1 - U_LO	Level trigger off
62	-	-
63	-	-
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 Rogowski or Combi sensors. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

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

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

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

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

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

3.5.3.1 Functional diagrams for protection

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

Five overcurrent stages are offered for overcurrent and short-circuit protection. Three of them include directional functionality DPHxPDOC_5xP-1/2.

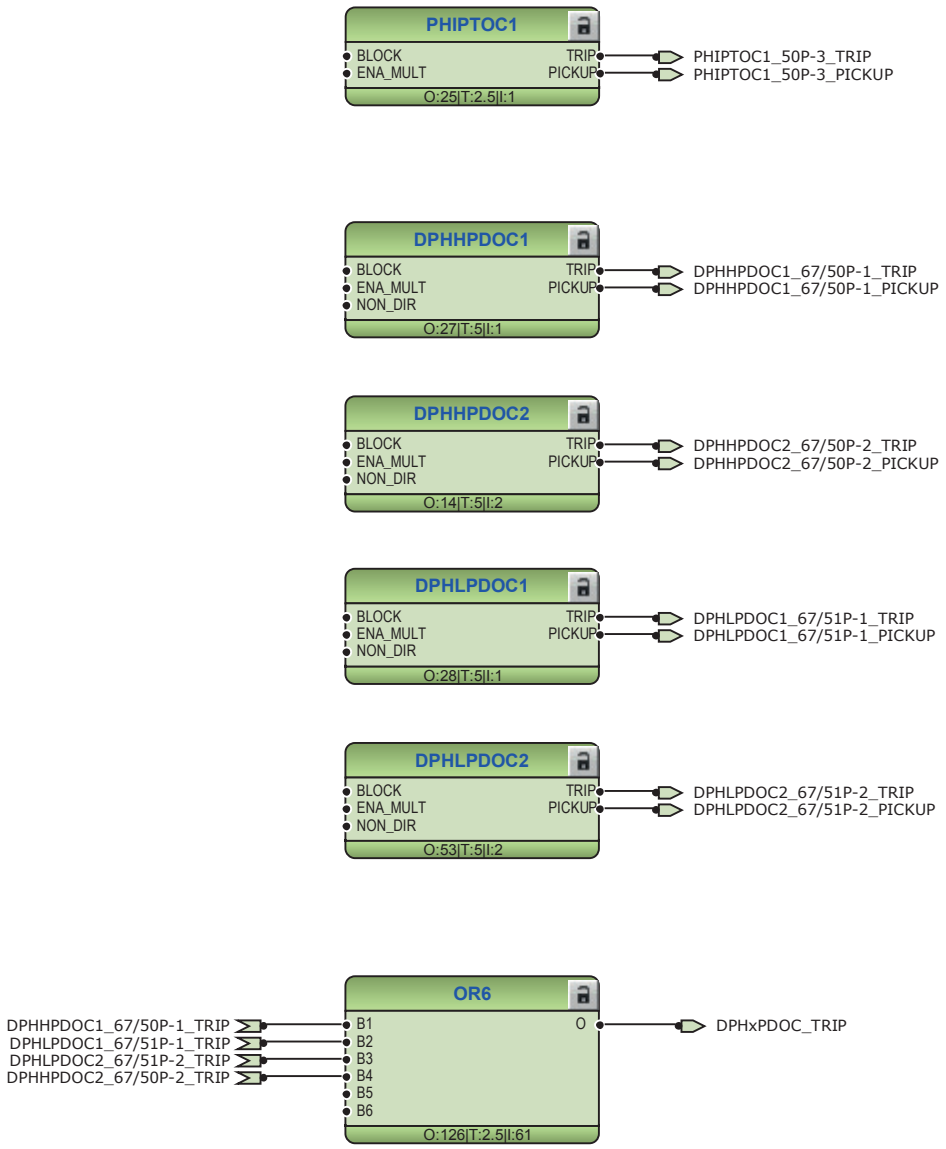


Figure 110: Overcurrent protection functions

The upstream blocking from the pickup of the second low stage of three-phase directional overcurrent protection DPHLPDOC2_67/51P-2 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 relay at the infeeding bay.

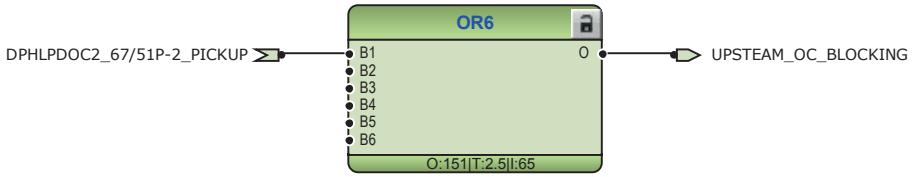


Figure 111: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or ground-fault function blocks.

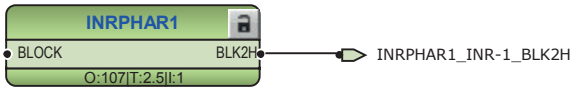


Figure 112: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1_46-1 and NSPTOC2_46-2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. Both the negative-sequence overcurrent protections are blocked in case of detection in failure in secondary circuit of current transformer.

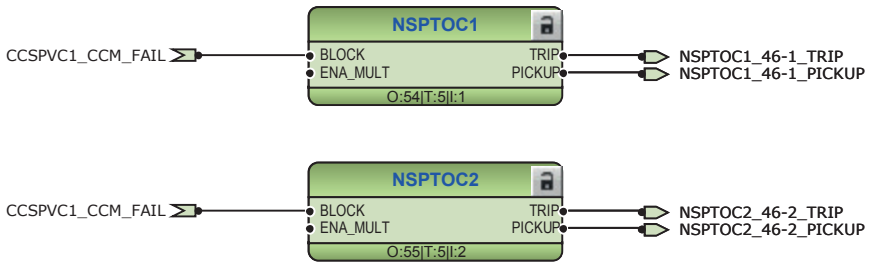


Figure 113: Negative-sequence overcurrent protection function

Four stages are provided for non-directional ground-fault protection EFHPTOC1…. 4_50G-1/2, 50N-1/2. Three stages are provided for directional ground-fault protection. According to the relay's order code, the directional ground-fault protection method can be based on conventional directional ground-fault DEFxPDEF_67/51N-1/2, 67/50N-1/2, only or alternatively used together with admittance-based ground-fault protection EFPADM_21YN or wattmetric-based ground-fault protection WPWDE_32N. A dedicated protection stage INTRPTEF_67NIEF is used either for transient-based ground-fault protection or for cable intermittent ground-fault protection in compensated networks.

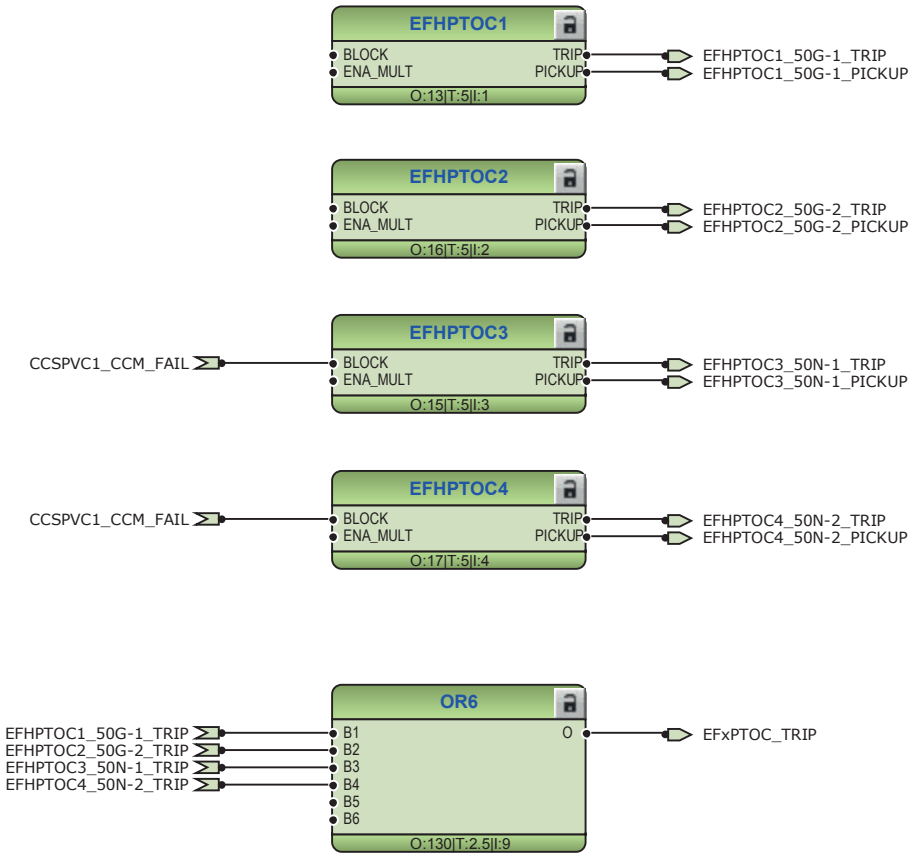


Figure 114: Ground fault protection function

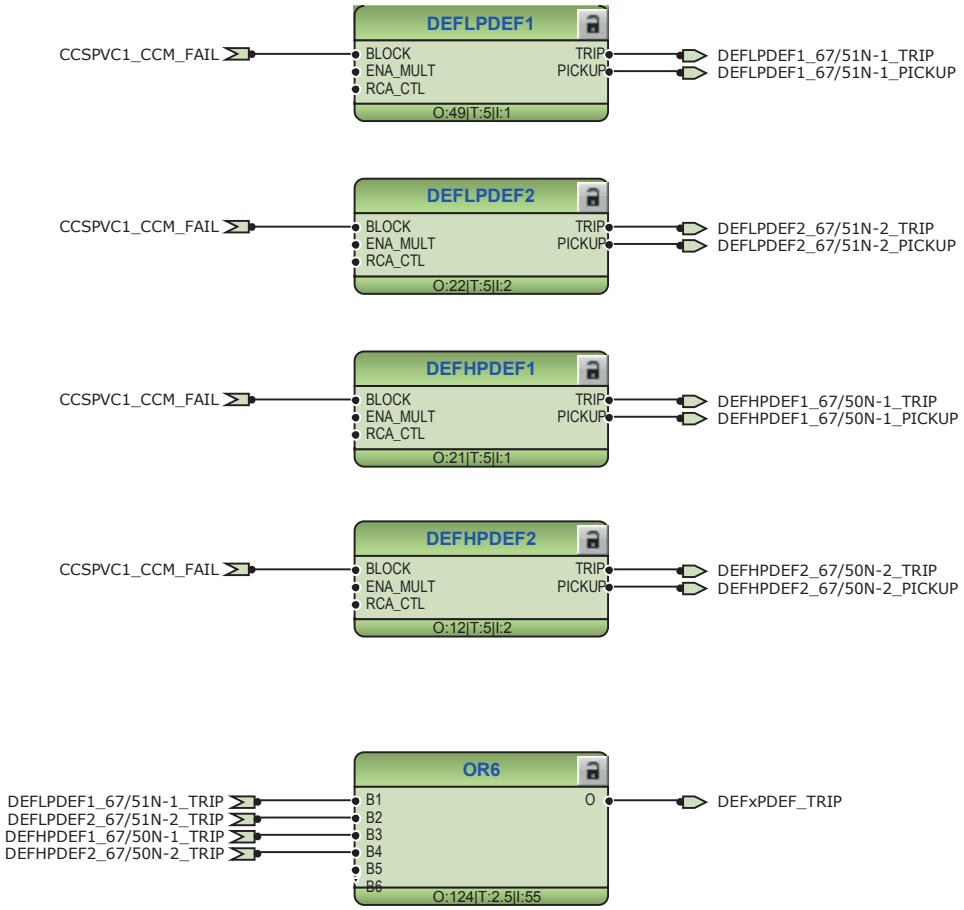


Figure 115: Directional Ground fault protection function

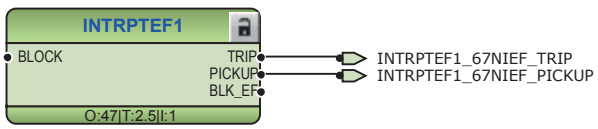


Figure 116: Transient or intermittent ground-fault protection functions

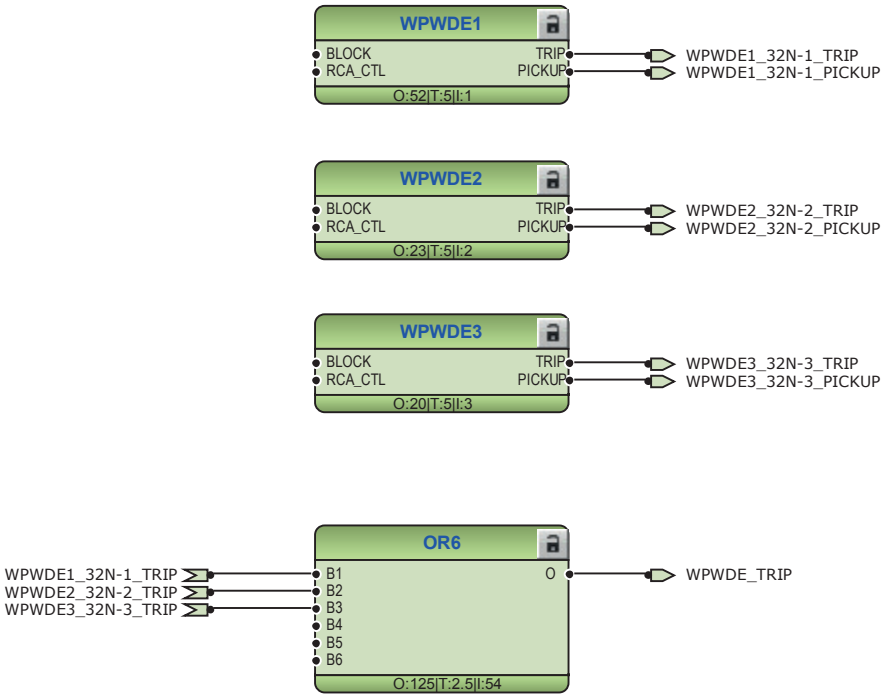


Figure 117: Wattmetric protection function

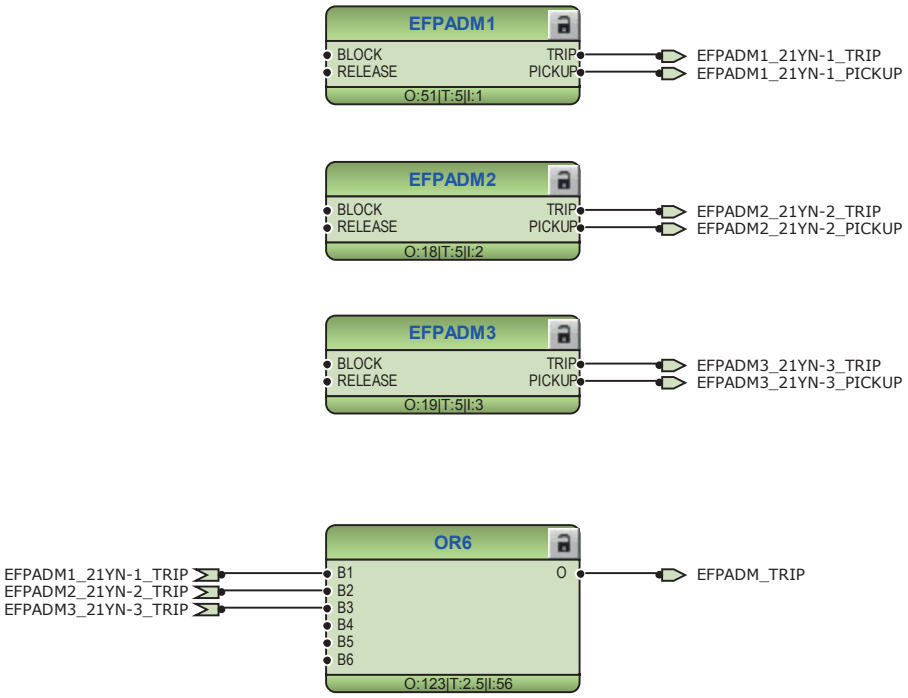


Figure 118: Admittance-based ground-fault protection function

Phase discontinuity protection PDNSPTOC1_46PD 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.

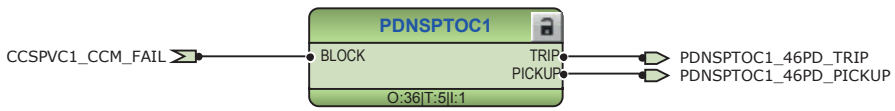


Figure 119: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1_49F-1 detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

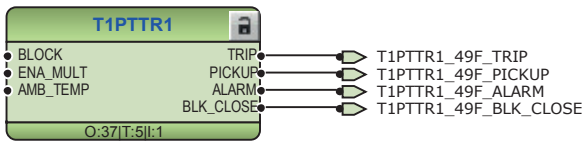


Figure 120: Thermal overcurrent protection function

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

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET trip output is used for retripping its own breaker through TRPPTRC2_TRIP. The same TRRET output is also connected to the binary output X100:PO4.

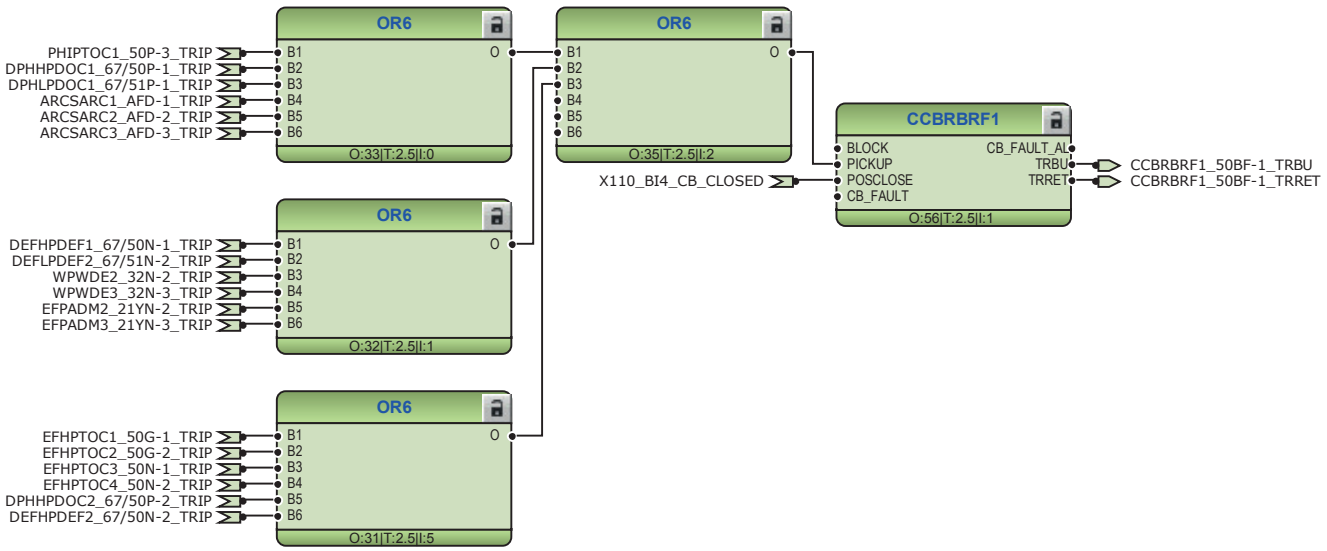


Figure 121: Circuit breaker failure protection function

Three arc protection stages ARCSARC1...3_AFD-1…3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to both trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. If the relay has been ordered with high-speed binary outputs, the individual trip signals from ARCSARC1...3_AFD-1…3 are connected to dedicated trip logic TRPPTRC3...5_ 86/94-3…5. The output of TRPPTRC3...5_ 86/94-3…5 is available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

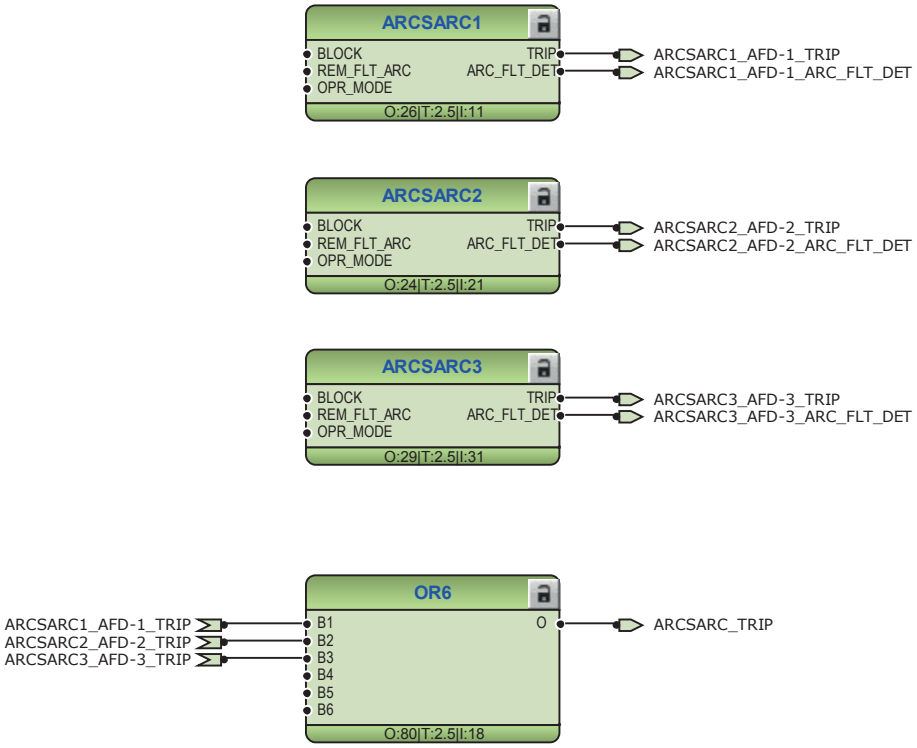


Figure 122: Arc protection

The optional autoreclosing function is configured to be initiated by trip 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_79. The signal, and other required signals, are connected to the CB spring charged binary inputs in this configuration. The open command from the autorecloser is connected directly to binary output X100:PO3, whereas the close command is connected directly to the binary output X100:PO2.

Set the parameters for DARREC1_79 properly.

Check the initialization signals of DARREC1_79.

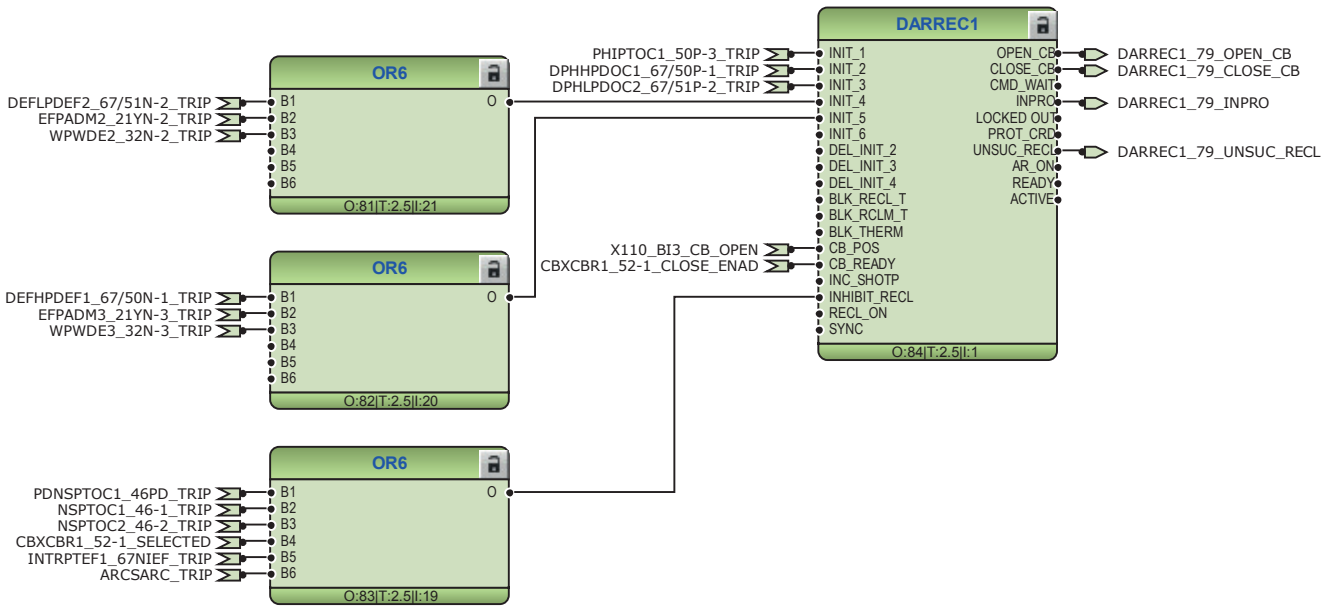


Figure 123: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV_47U and negative-sequence overvoltage protection NSPTOV_47 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.

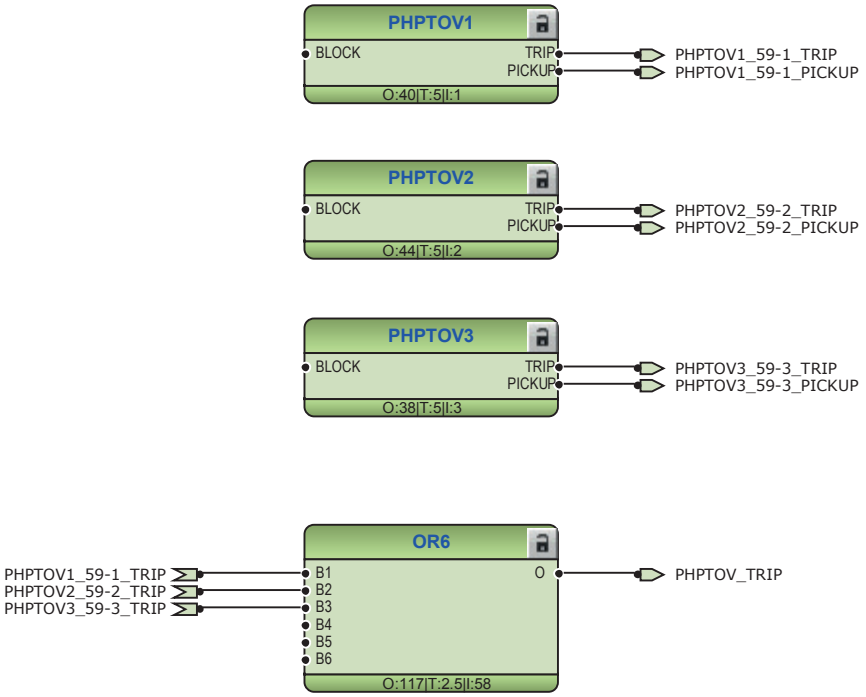


Figure 124: Overvoltage protection function

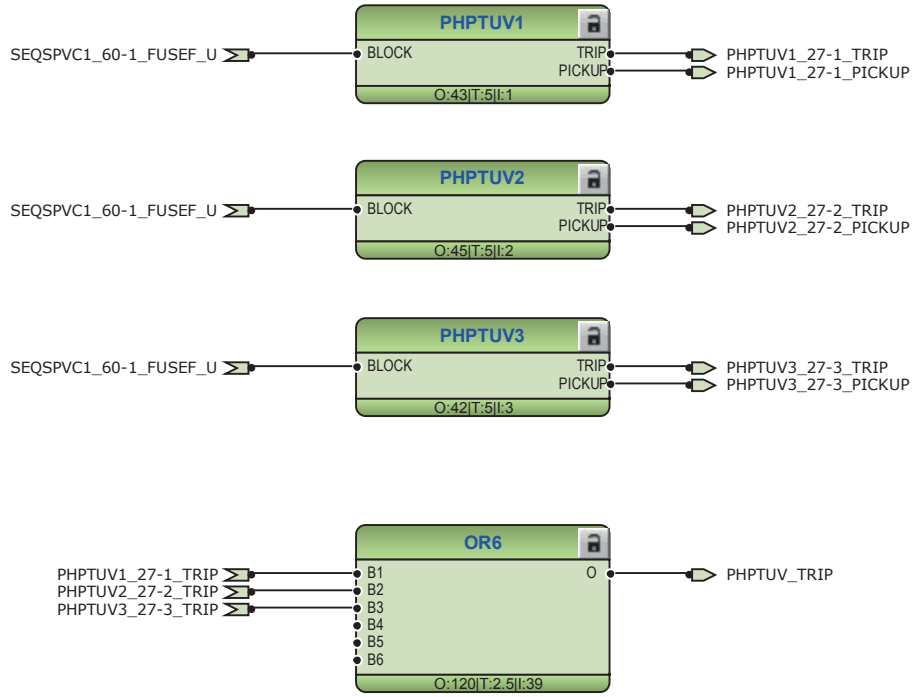


Figure 125: Undervoltage protection function

Figure 126: Negative-sequence overvoltage protection function

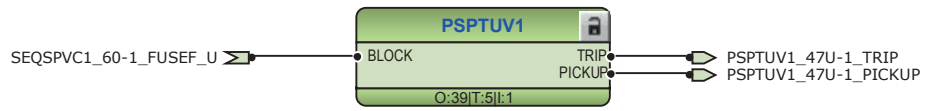


Figure 127: Positive-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV_59G,59N-1/2 provides ground-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

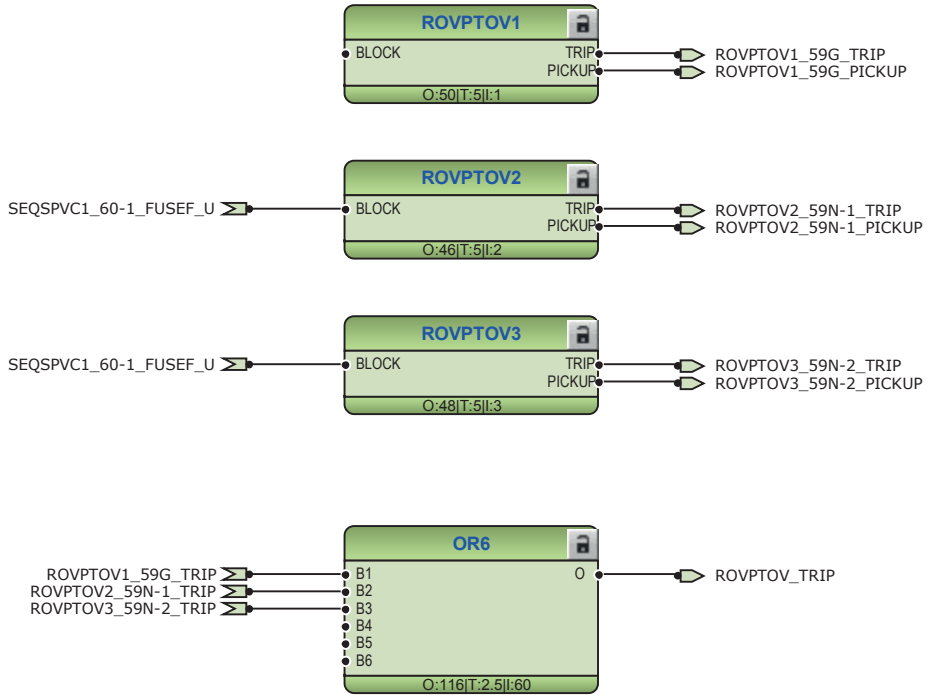


Figure 128: Residual voltage protection function

The MSVPR1_27R-1 function is used to monitor the remanent voltage over a decaying frequency after power supply is lost, before allowing connection of backup power. It provides a permissive signal indicating when connecting of backup power can be completed safely.

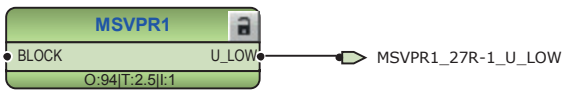


Figure 129: Three-phase remnant undervoltage protection function

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

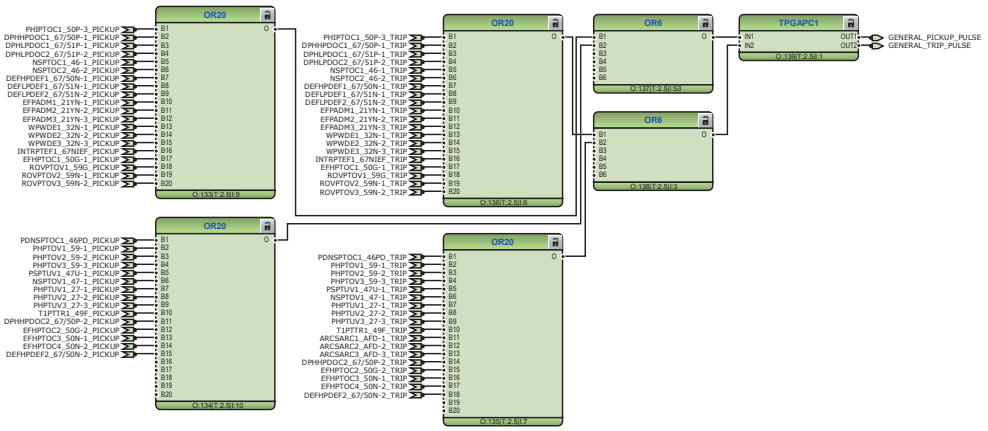


Figure 130: General pickup and trip signals

The trip signals from the protection functions are connected to the two trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions 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...5_86/94-3…5 are also available if the relay is ordered with high speed binary outputs options.

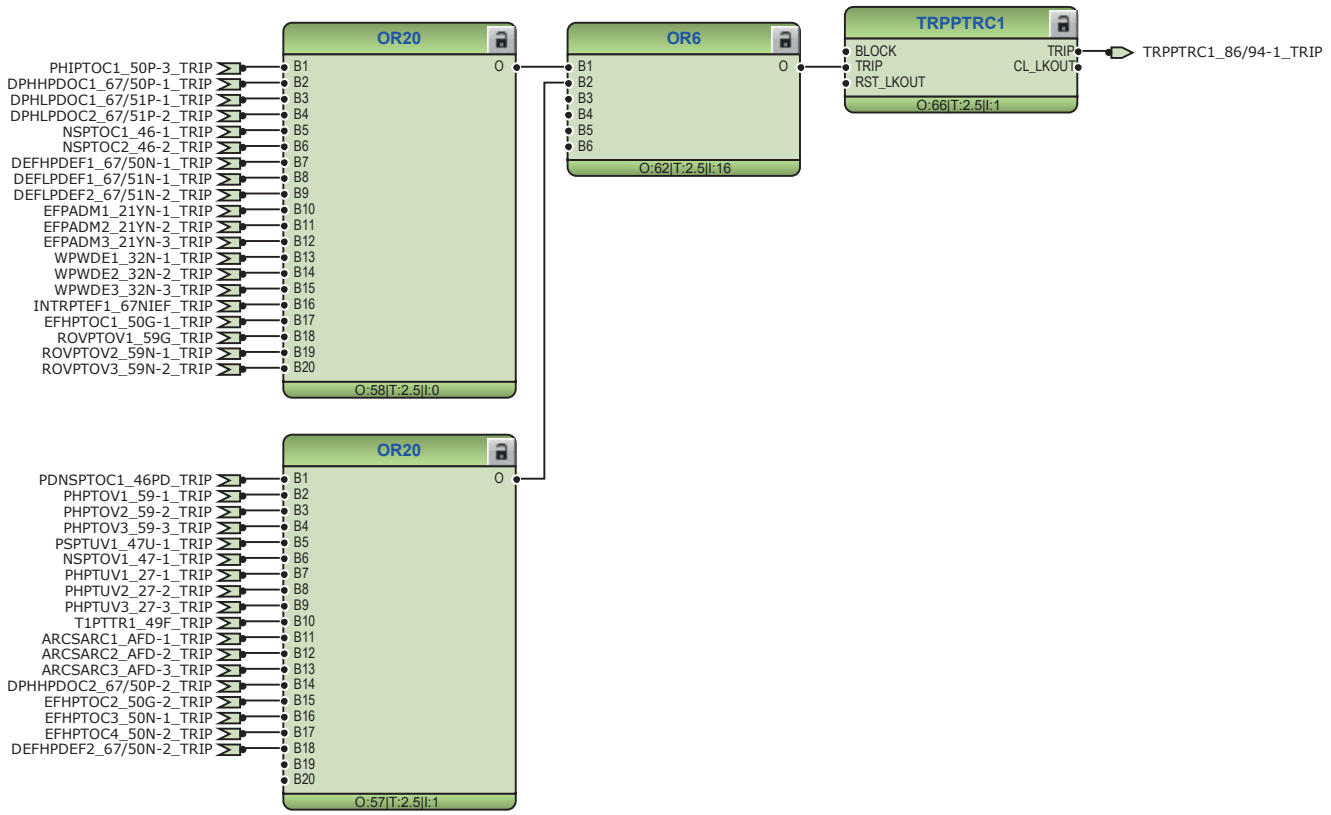


Figure 131: Trip logic TRPPTRC1

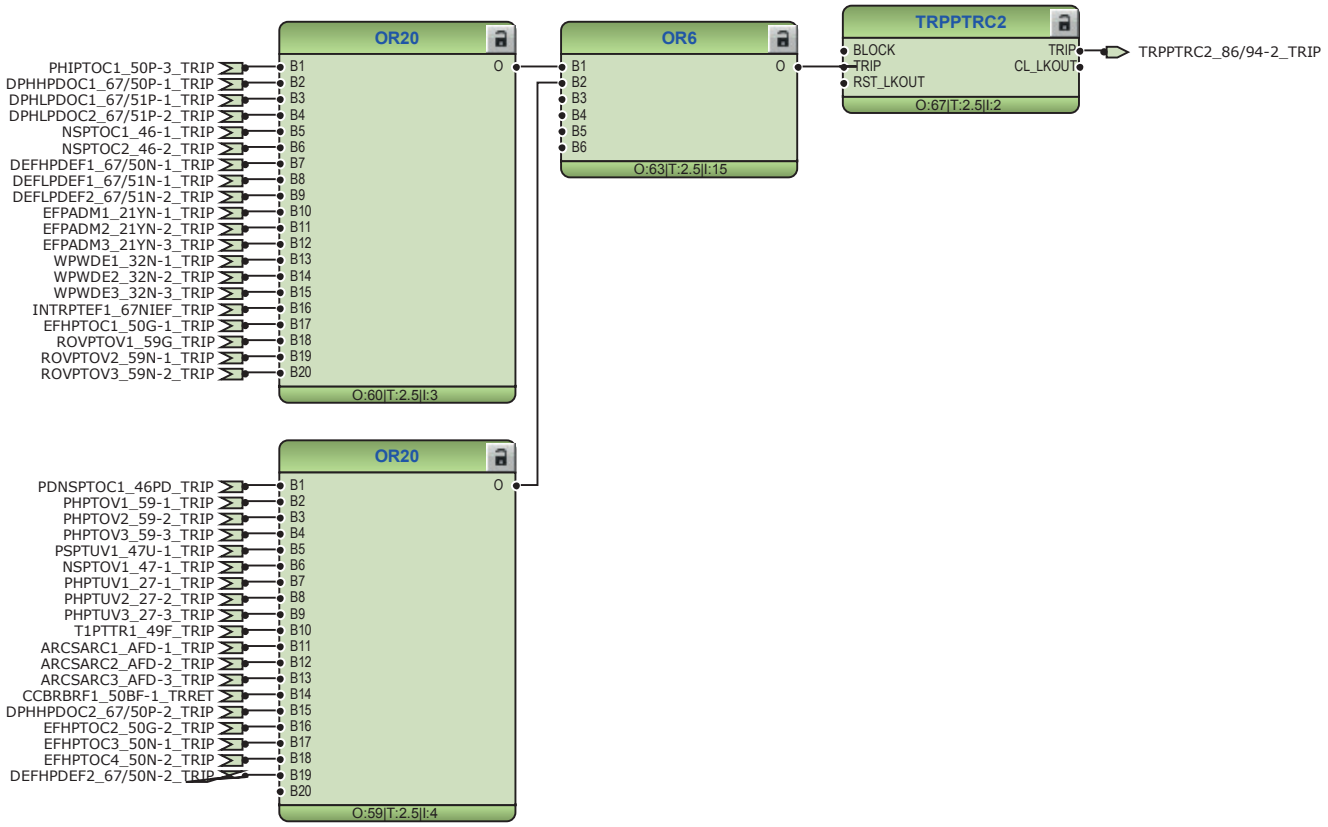


Figure 132: Trip logic TRPPTRC2

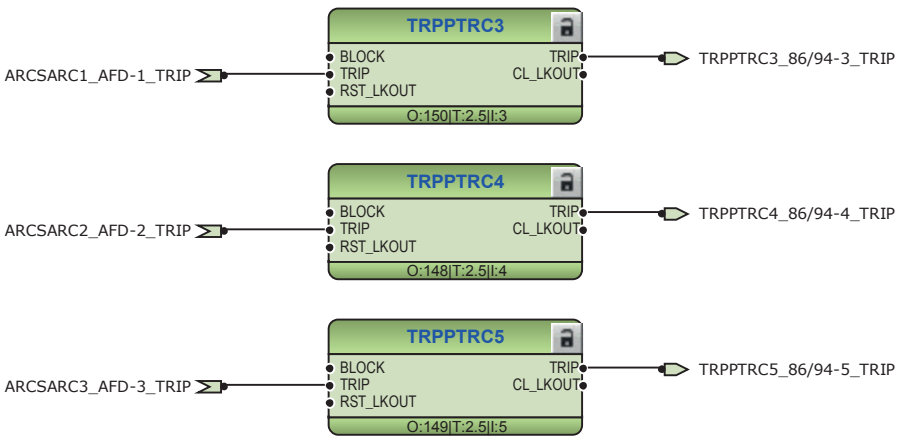


Figure 133: Trip logic TRPPTRC3/4/5

3.5.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

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

Once the order of signals connected to the binary inputs of RDRE1 is changed, make the changes to the Parameter Setting tool.

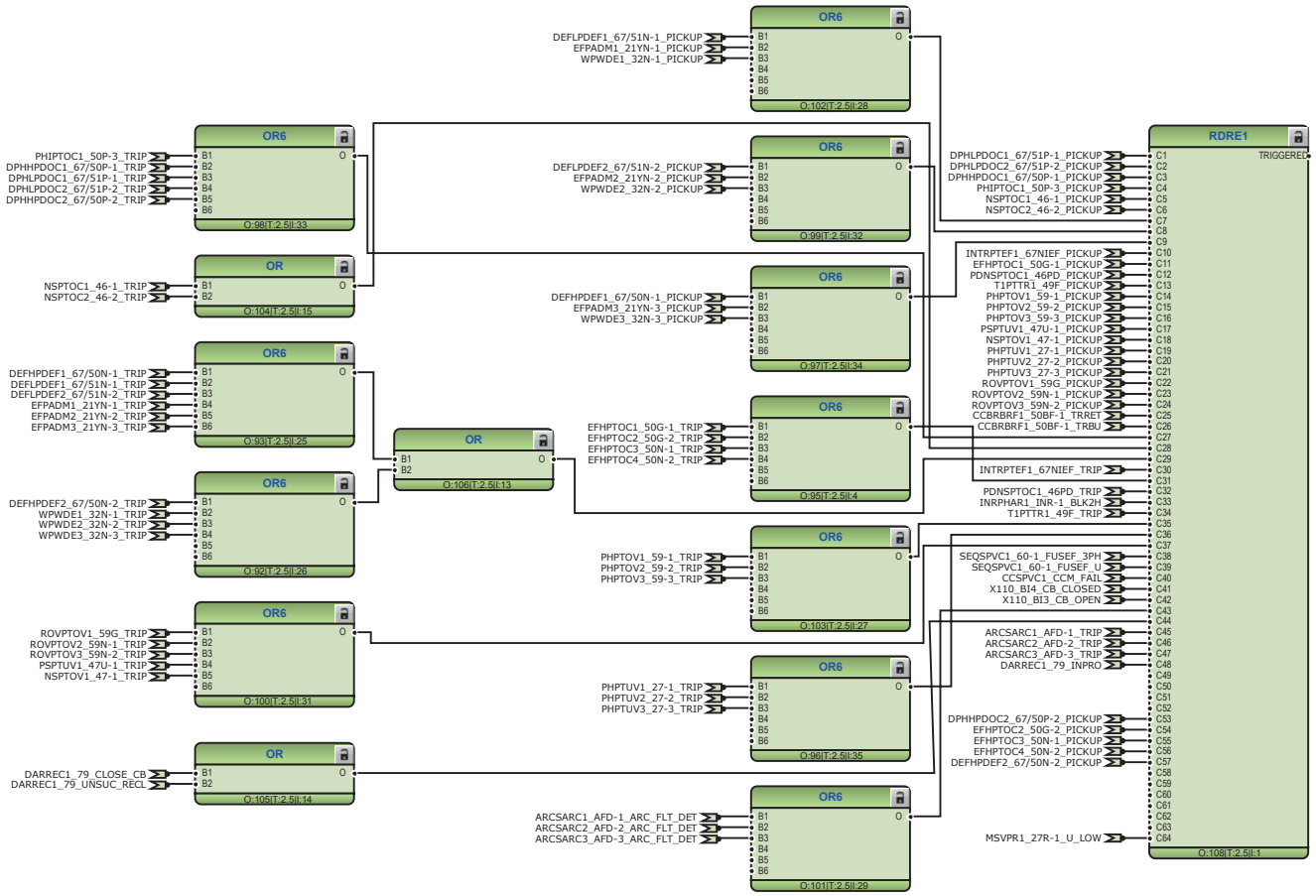


Figure 134: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

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

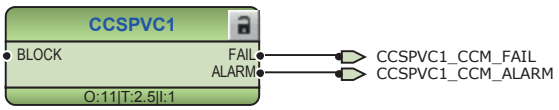


Figure 135: Current circuit supervision function

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

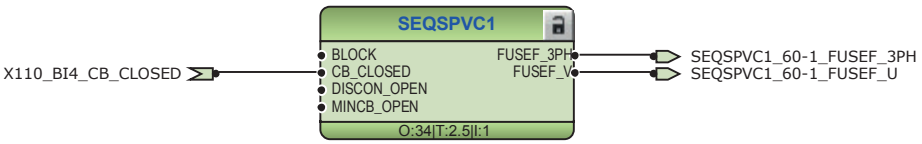


Figure 136: Fuse failure supervision function

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

Set the parameters for SSCBR1_52CM-1 properly.

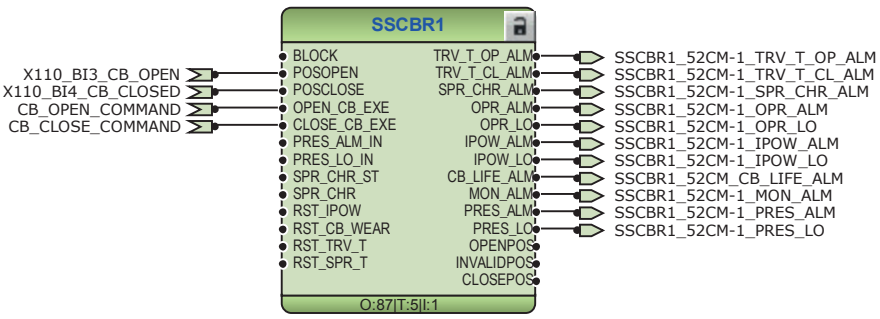


Figure 137: Circuit-breaker condition monitoring function

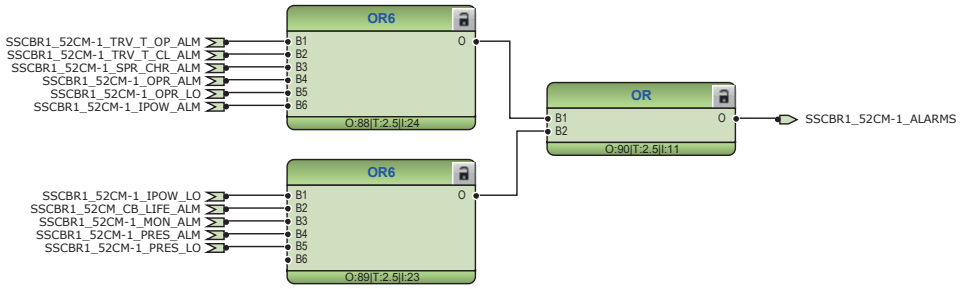


Figure 138: Logic for circuit breaker monitoring alarm

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

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

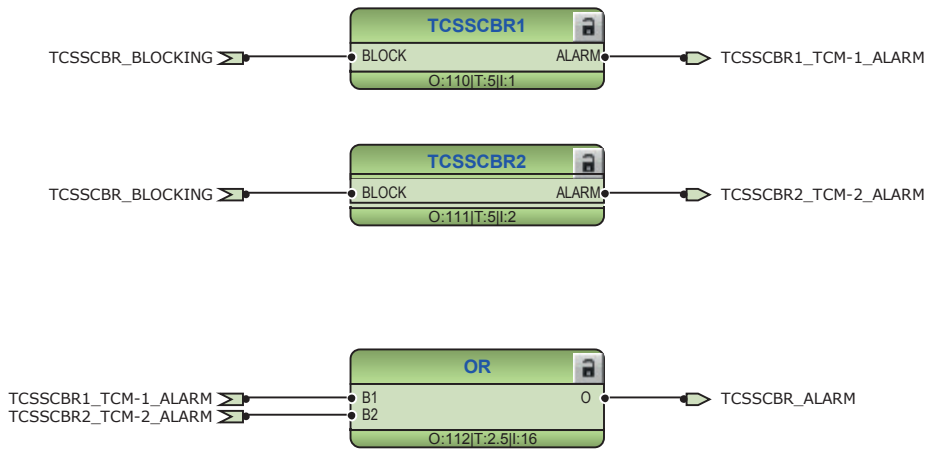


Figure 139: Trip circuit supervision function

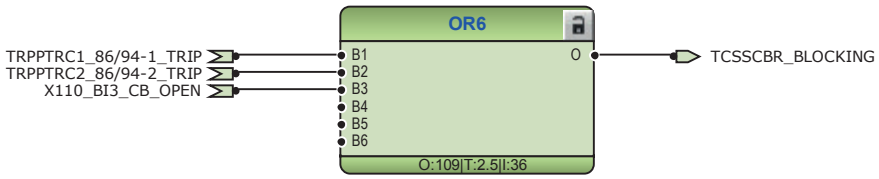


Figure 140: Logic for blocking of trip circuit supervision

3.5.3.4 Functional diagrams for control and interlocking

The main purpose of the synchronism and energizing check SECRSYN1 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.

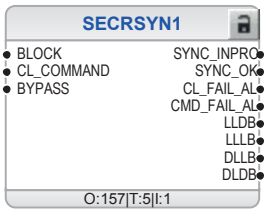


Figure 141: Synchronism and energizing check

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 ground 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 ground switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for circuit breaker is always enabled.

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.

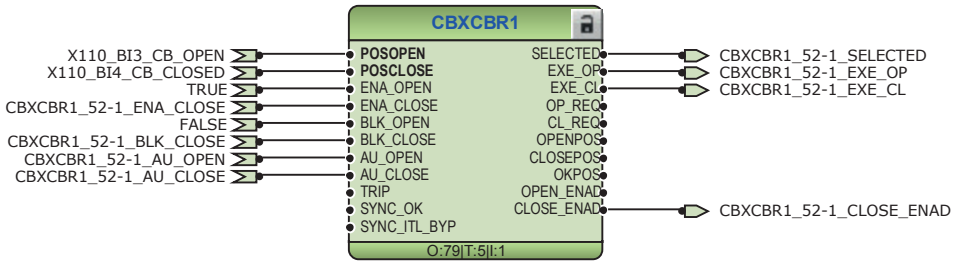


Figure 142: Circuit breaker control logic: Circuit breaker 1

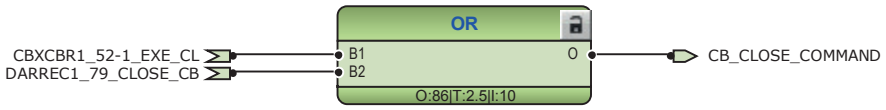


Figure 143: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

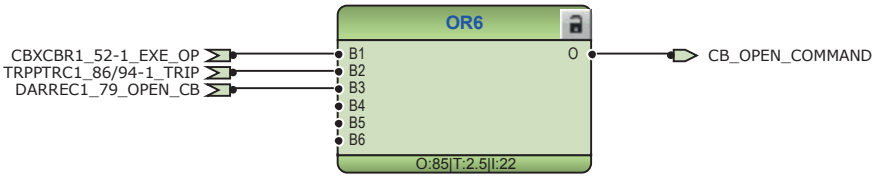


Figure 144: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

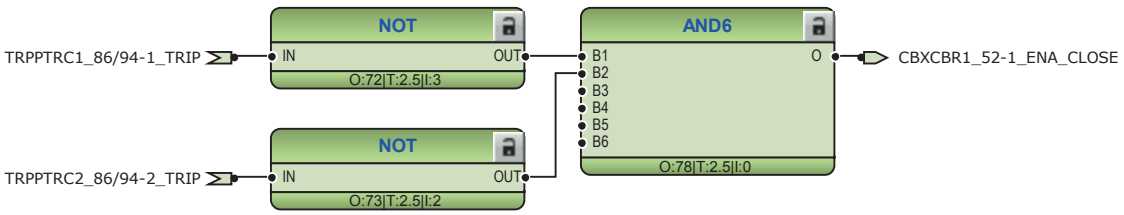


Figure 145: Circuit breaker close enable logic

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

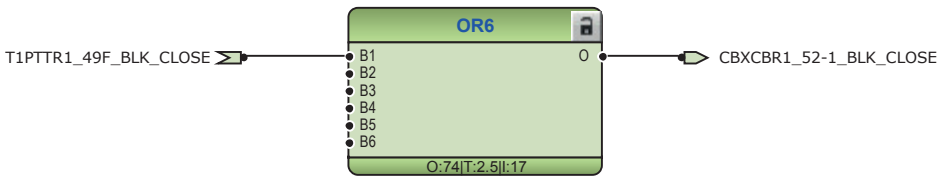


Figure 146: Circuit breaker close blocking logic

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

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

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

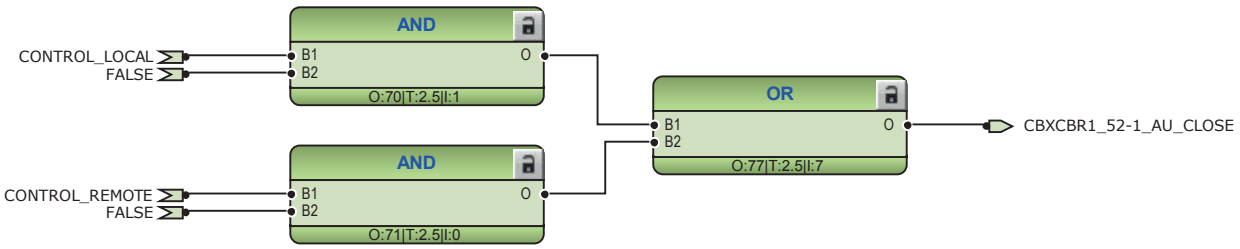


Figure 147: External closing command for circuit breaker

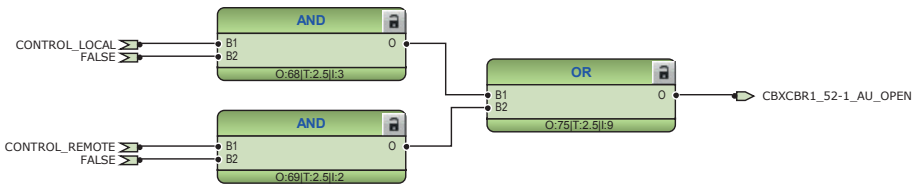


Figure 148: External opening command for circuit breaker

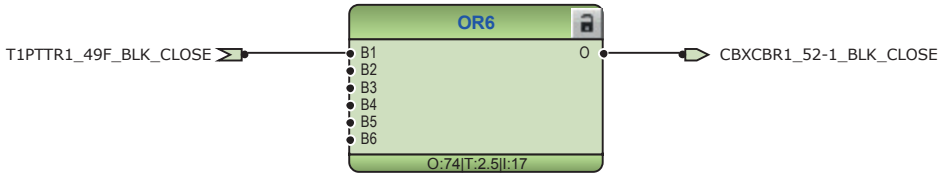


Figure 149: Circuit breaker 1 close blocking logic

3.5.3.5 Functional diagrams for measurement functions

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1. The 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 relay 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.

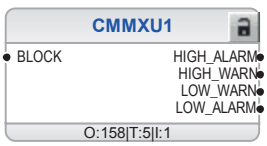


Figure 150: Three-phase current measurement

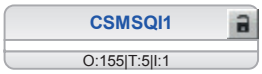


Figure 151: Sequence current measurements

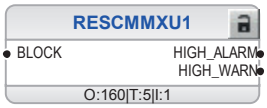


Figure 152: Ground current measurements

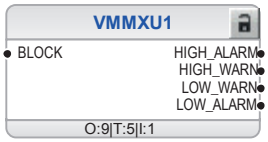


Figure 153: Three-phase voltage measurement

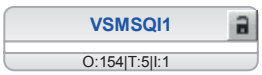


Figure 154: Sequence voltage measurements

Figure 155: Frequency measurement

Figure 156: Three-phase power and energy measurement

Figure 157: Data monitoring and load profile record

3.5.3.6 Functional diagrams for I/O and alarm LEDs

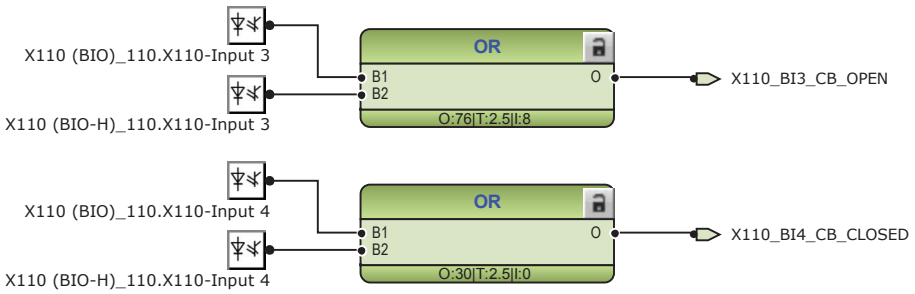


Figure 158: Default binary inputs - X110 terminal block

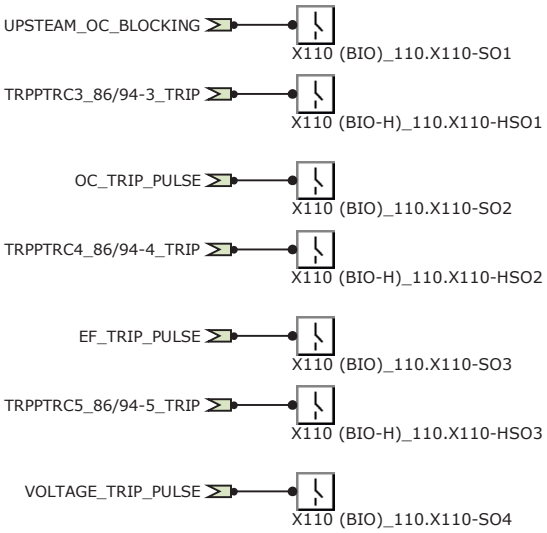


Figure 159: Default binary outputs - X110 terminal block

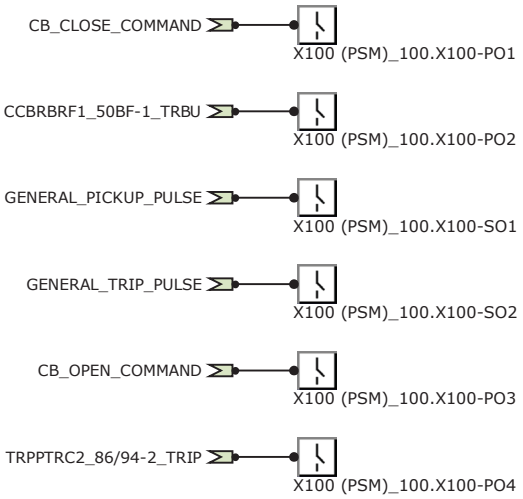


Figure 160: Default binary outputs - X100 terminal block

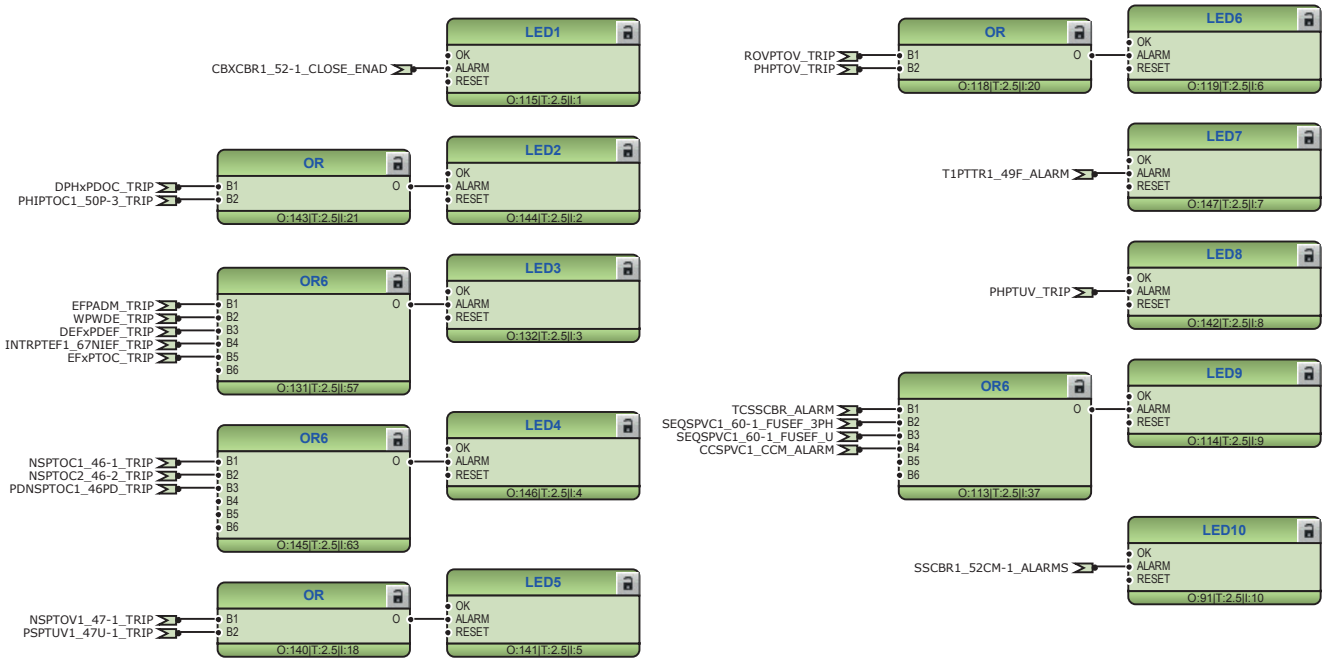


Figure 161: Default LED connection

3.5.3.7 Functional diagrams for other functions

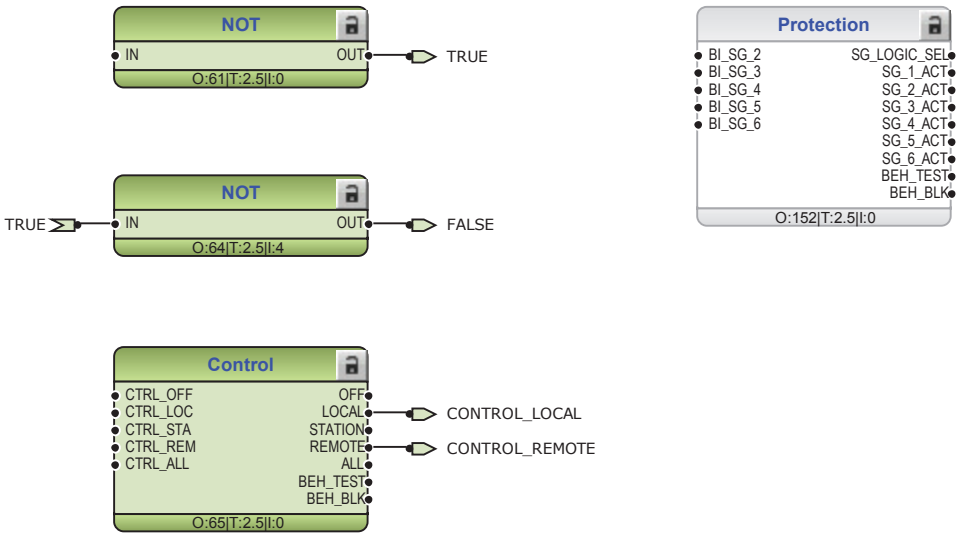


Figure 162: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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

3.5.3.8 Functional diagrams for other timer logics

The configuration also includes the overcurrent trip and ground-fault trip logic.

The trip 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.

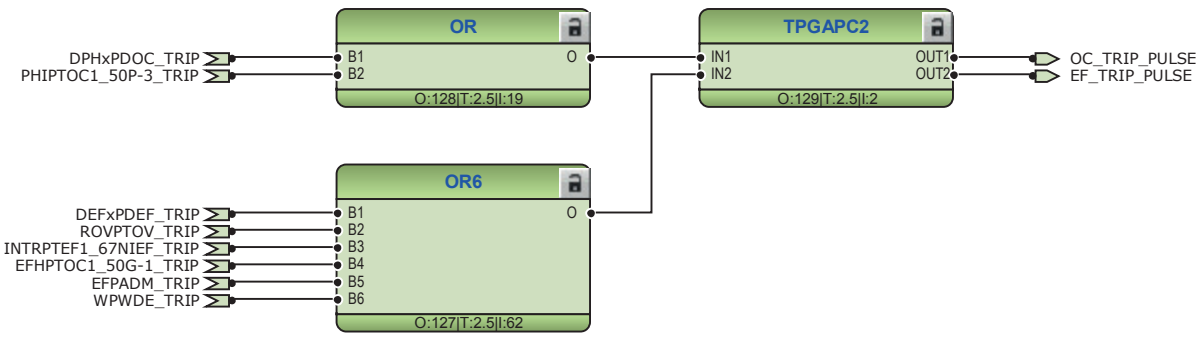


Figure 163: Timer logic for overcurrent and ground-fault trip pulse

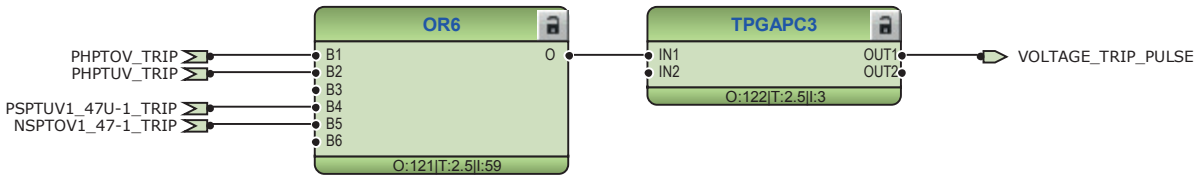


Figure 164: Timer logic for voltage trip and frequency protection trip alarm

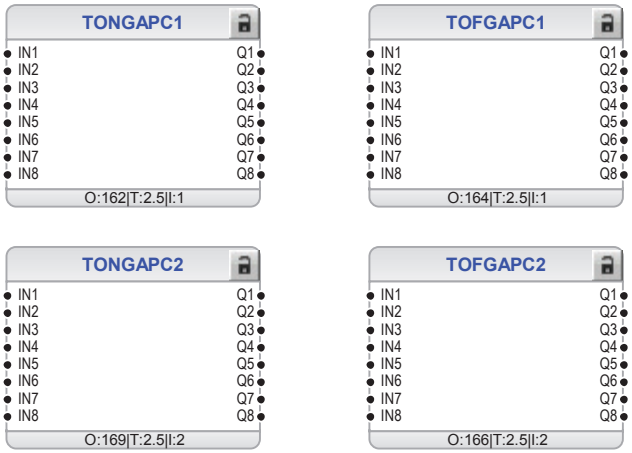


Figure 165: Programmable timers

3.5.3.9 Functional diagrams for communication

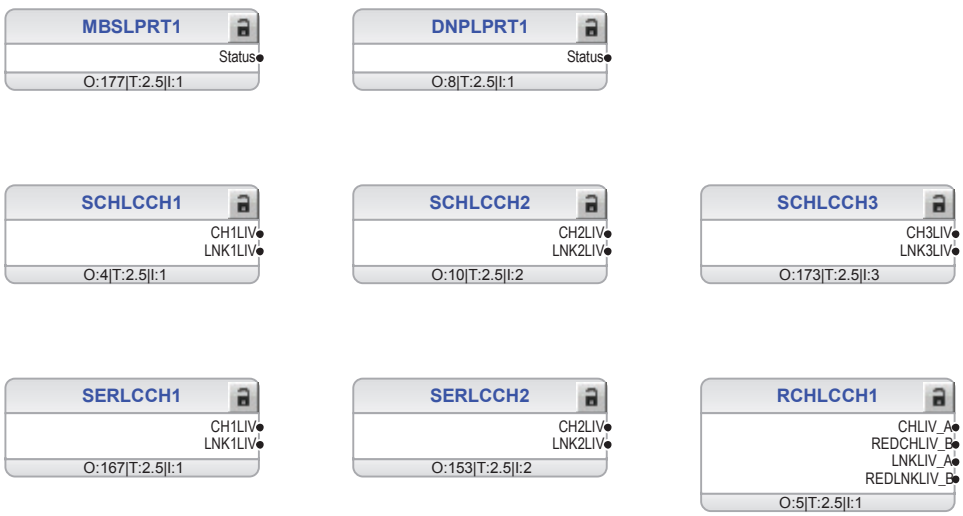


Figure 166: Default communication function connection

3.6 Standard configuration N

3.6.1 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 protection relay. To ensure the performance of the protection relay, the user specific configuration load needs to be verified with the Application Configuration tool in PCM600.

3.6.2 Functions

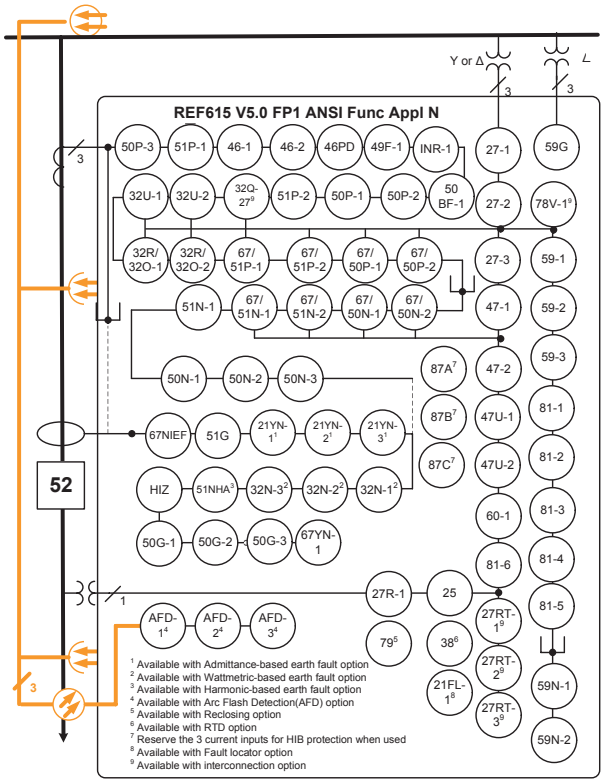


Figure 167: Functionality overview for standard configuration N

3.6.2.1 Default I/O connections

Table 27: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
V12B	Phase-to-phase voltage VAB(2)	X130:9-10
VA	Phase voltage VA	X130:11-12
VB	Phase voltage VB	X130:13-14
VC	Phase voltage VC	X130:15-16
VG	Residual voltage VG	X130:17-18

Table 28: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	Autoreclose external pickup command	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10
X120-BI1	Blocking of overcurrent instantaneous stage	X120:1-2	
X120-BI2	Circuit breaker closed position indication	X120:3-2	
X120-BI3	Circuit breaker open position indication	X120:4-2	
X120-BI4	Lock-out reset	X120:5-6	
X130-BI1	-	X130:1-2	
X130-BI2	-	X130:3-2	
X130-BI3	-	X130:4-5	
X130-BI4	-	X130:6-5	
X130-BI5	-	X130:7-8	
X130-BI6	-	X130:9-8	

Table 29: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	General pickup indication	X100:10-11,(12)
X100-SO2	General trip indication	X100:13-14
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Upstream overcurrent blocking	X110:14-16
X110-SO2	Overcurrent trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	Voltage protection trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24
X130-SO1	-	X130:10-12
X130-SO2	-	X130:13-15
X130-SO3	-	X130:16-18

Table 30: Default connections for LEDs

LED	Default usage	ID	Label description
1	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
2	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
3	Sensitive ground-fault trip	LED_SensitiveEarthFault_1	Sensitive ground-fault
4	Negative sequence overcurrent or phase discontinuity	LED_PhaseUnbalance_1	Phase unbalance
5	Thermal overload alarm	LED_ThermalOverload_1	Thermal overload
6	Circuit breaker failure protection backup protection trip	LED_BreakerFailure_1	Breaker failure
7	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
8	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
9	Supervision alarm	LED_TripCircuitFailure_1	Trip circuit failure
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Autoreclose in progress	LED_AutorecloseInProgress_1	Autoreclose shot in progr.

3.6.2.2 Default disturbance recorder settings

Table 31: Default disturbance recorder analog channels

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

Table 32: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHLPTOC2 - pickup	Positive or Rising
4	PHIPTOC1 - pickup	Positive or Rising
5	NSPTOC1 - pickup	Positive or Rising
6	NSPTOC2 - pickup	Positive or Rising
7	EFLPTOC1 - pickup	Positive or Rising
8	EFHPTOC1 - pickup	Positive or Rising
9	EFIPTOC1 - pickup	Positive or Rising
10	EFLPTOC2 - pickup	Positive or Rising
11	-	-
12	PDNSPTOC1 - pickup	Positive or Rising
13	T1PTTR1 - pickup	Positive or Rising
14	CCBRBRF1 - trret	Level trigger off
15	CCBRBRF1 - trbu	Level trigger off
16	PHxPTOC1 - trip	Level trigger off
17	NSPTOC - trip	Level trigger off
18	EFxPTOC1 - trip	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
19	X110BI2 - ext pickup AutoReclose	Level trigger off
20	EFLPTOC2 - trip	Level trigger off
21	PDNSPTOC1 - trip	Level trigger off
22	INRPHAR1 - blk2h	Level trigger off
23	T1PTTR1 - trip	Level trigger off
24	ARCSARC - ARC flt det	Level trigger off
25	ARCSARC1 - trip	Positive or Rising
26	ARCSARC2 - trip	Positive or Rising
27	ARCSARC3 - trip	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 open	Level trigger off
34	PHHPTOC2 - pickup	Positive or Rising
35	EFHPTOC2 - pickup	Positive or Rising
36	EFHPTOC3 - pickup	Positive or Rising
37	EFHPTOC4 - pickup	Positive or Rising
38	EFIPTOC2 - pickup	Positive or Rising
39	DUPPDPR1 - pickup	Positive or Rising
40	DUPPDPR2 - pickup	Positive or Rising
41	DUPPDPR1 - trip	Level trigger off
42	MSVPR1 - U_LO	Level trigger off
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-

Table continues on next page

Channel	ID text	Level trigger mode
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
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 signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

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

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

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

3.6.3.1 Functional diagrams for protection

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

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

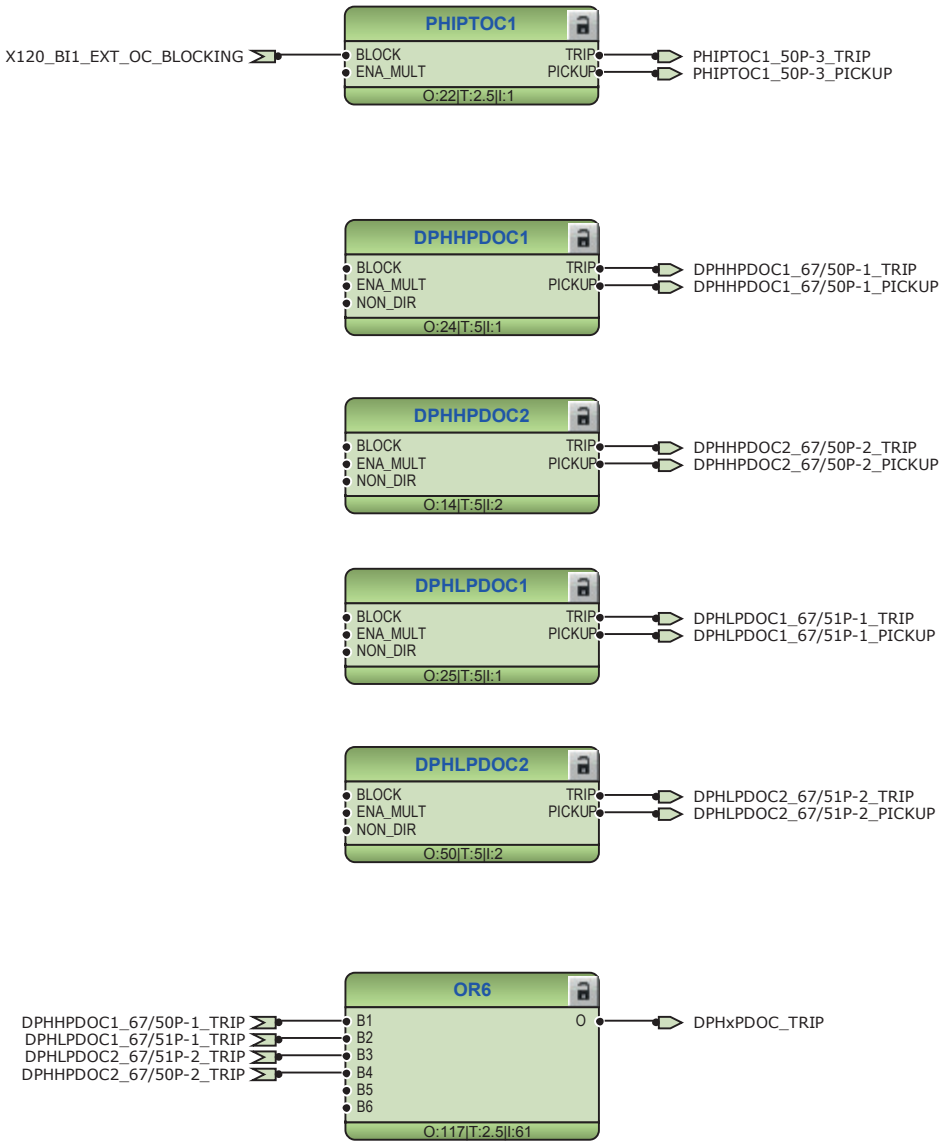


Figure 168: Overcurrent protection functions

The upstream blocking from the pickup of the second low stage of three-phase directional overcurrent protection DPHLPDOC2_67/51P-2 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 relay at the infeeding bay.

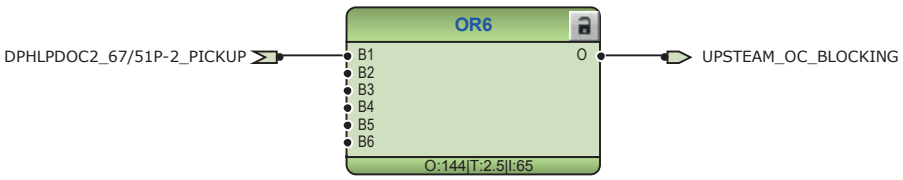


Figure 169: Upstream blocking logic

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 enables either blocking the function or multiplying the active settings for any of the available overcurrent or ground-fault function blocks.

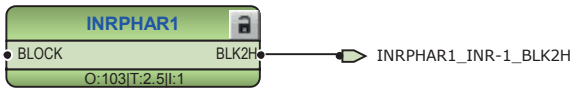


Figure 170: Inrush detector function

Two negative-sequence overcurrent protection stages NSPTOC1_46-1 and NSPTOC2_46-2 are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. Both the negative-sequence overcurrent protections are blocked in case of detection in failure in secondary circuit of current transformer.

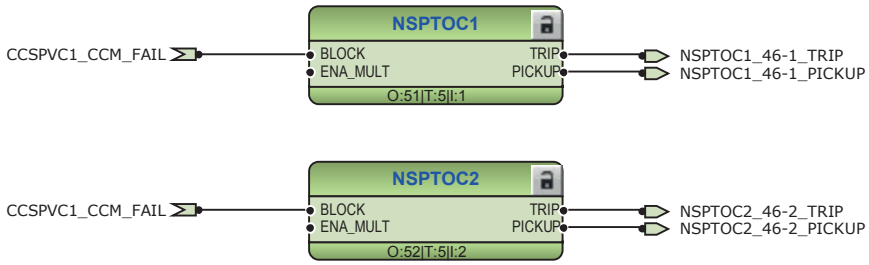


Figure 171: Negative-sequence overcurrent protection function

Three stages are provided for directional ground-fault protection. According to the relay's order code, the directional ground-fault protection method can be based on conventional directional ground-fault DEFxPDEF_67/5xN only or alternatively used together with admittance-based ground-fault protection EFPADM_21YN or wattmetric-based ground-fault protection WPWDE_32N. A dedicated protection stage INTRPTEF_67NIEF is used either for transient-based ground-fault protection or for cable intermittent ground-fault

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

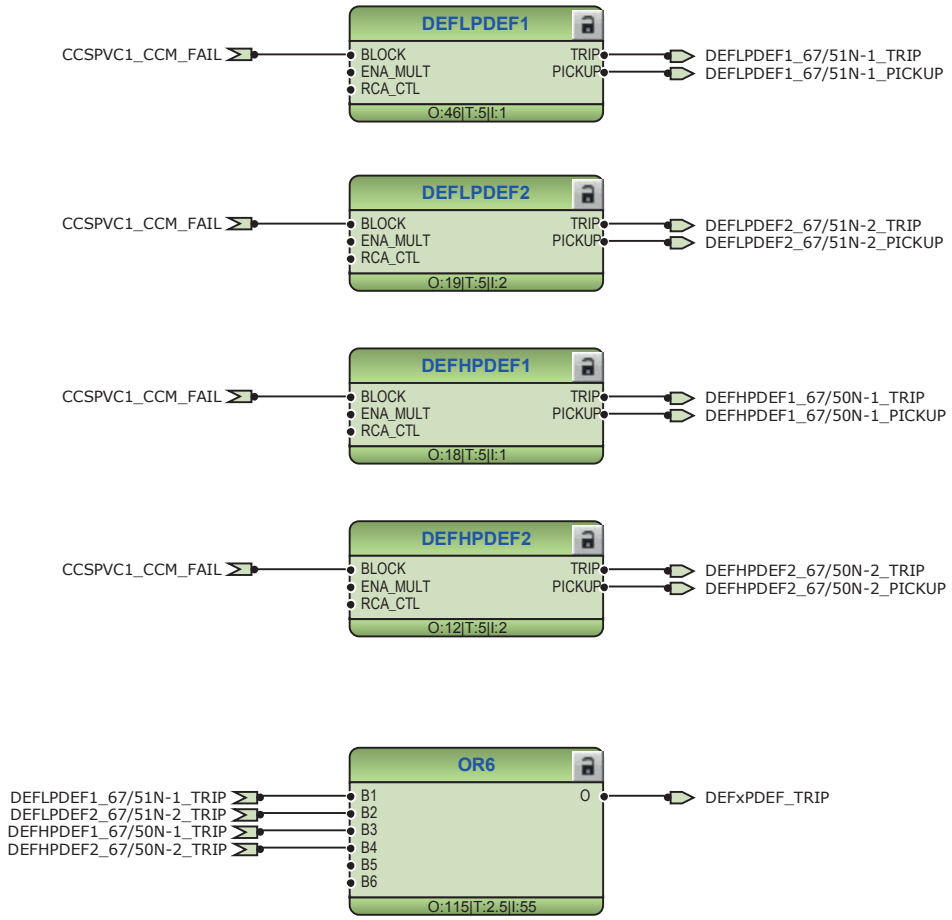


Figure 172: Directional ground-fault protection function

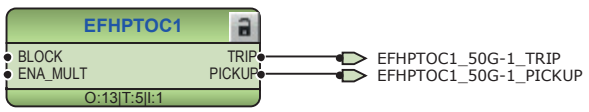


Figure 173: Non-directional ground-fault protection

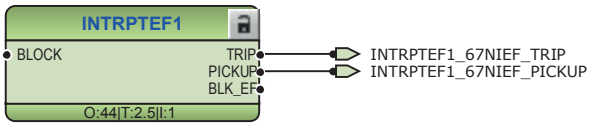


Figure 174: Transient or intermittent ground-fault protection functions

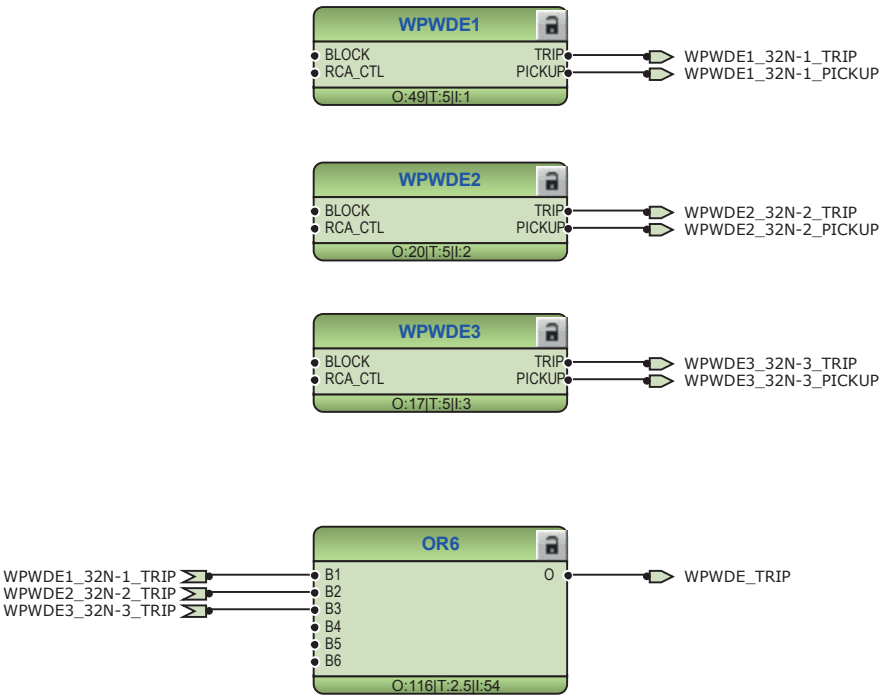


Figure 175: Wattmetric protection function

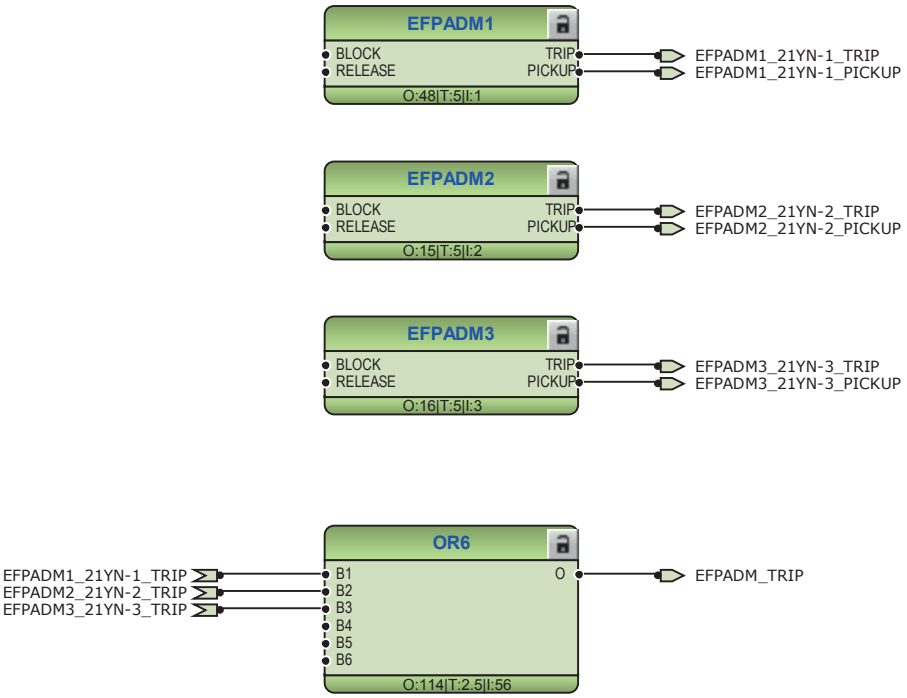


Figure 176: Admittance-based ground-fault protection function

Phase discontinuity protection PDNSPTOC1_46PD 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.

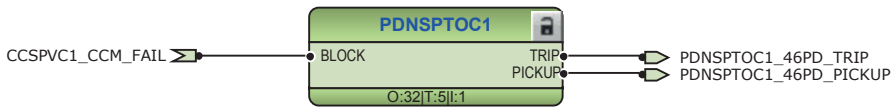


Figure 177: Phase discontinuity protection

Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR1_49F detects overloads under varying load conditions. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

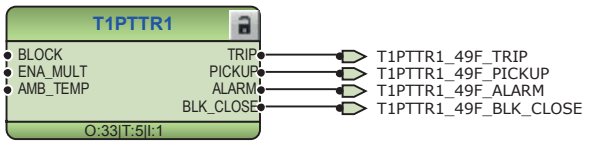


Figure 178: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by number of different protection functions available in the relay. 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 trip output is used for retripping its own breaker through TRPPTRC2_86/94-2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the binary output X100:PO2.

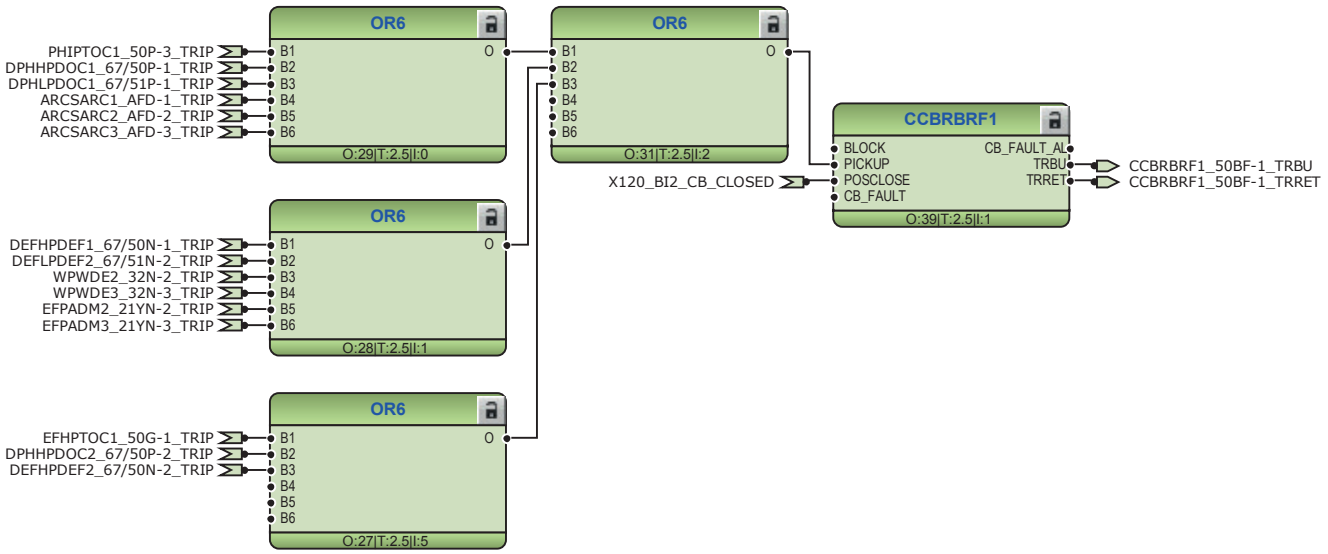


Figure 179: Circuit breaker failure protection function

Three arc protection stages ARCSARC-1…3_AFD-1...3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The trip signals from ARCSARC-1…3AFD-1...3 are connected to both trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2.

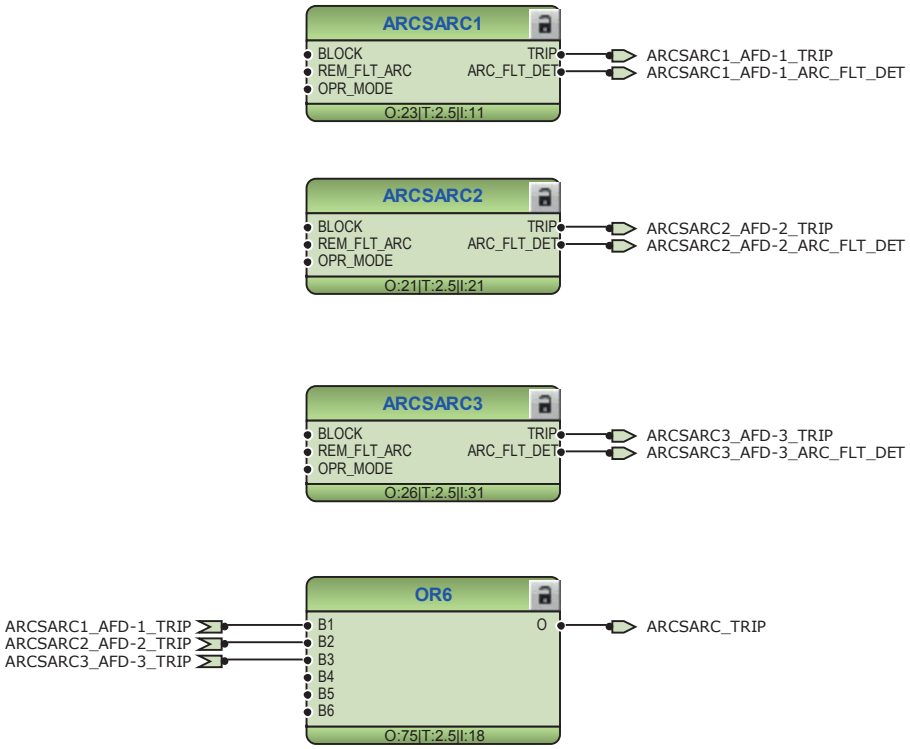


Figure 180: Arc protection

The optional autoreclosing function is configured to be initiated by trip 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_52-1_SELECTED signal.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1_79. 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_79 properly.

Check the initialization signals of DARREC1_79.

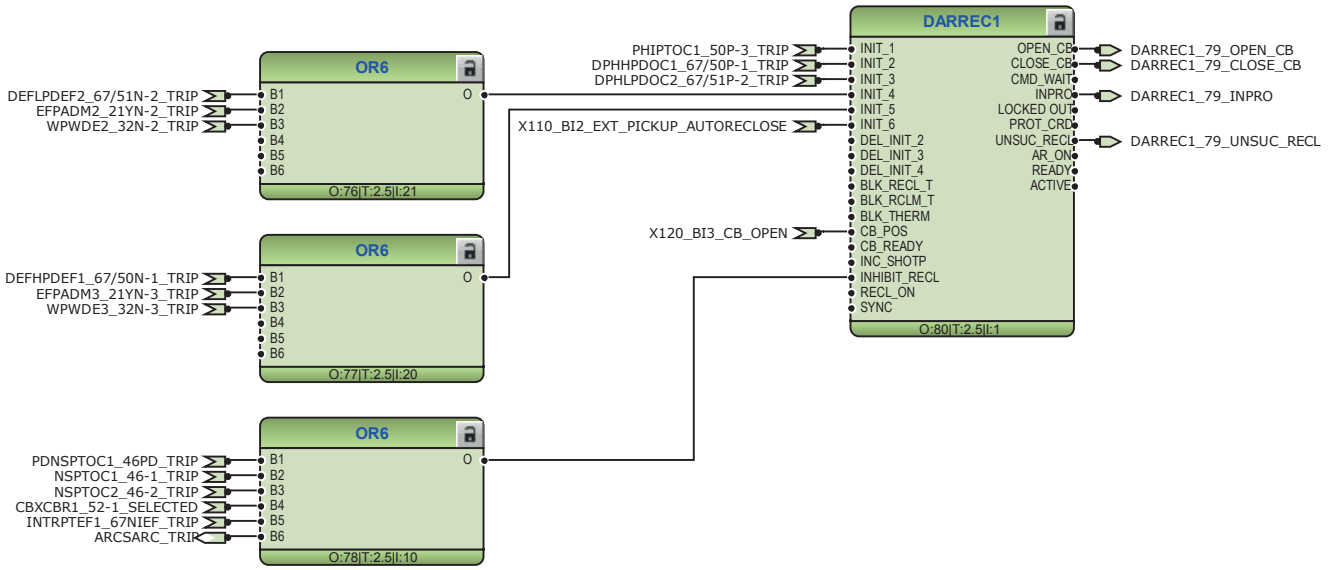


Figure 181: Autoreclosing function

Three overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV_47U and negative-sequence overvoltage protection NSPTOV_47 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.

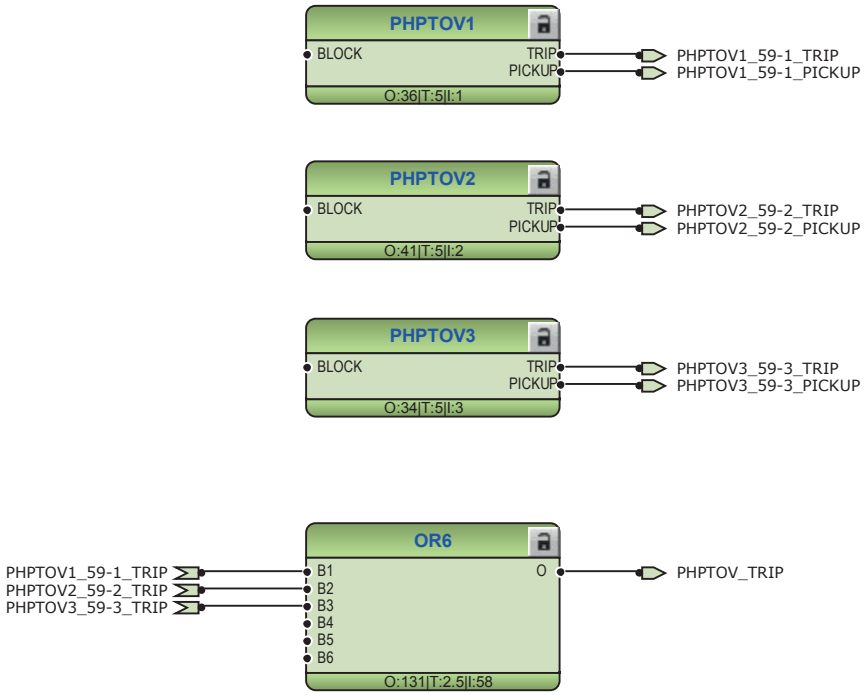


Figure 182: Overvoltage protection function

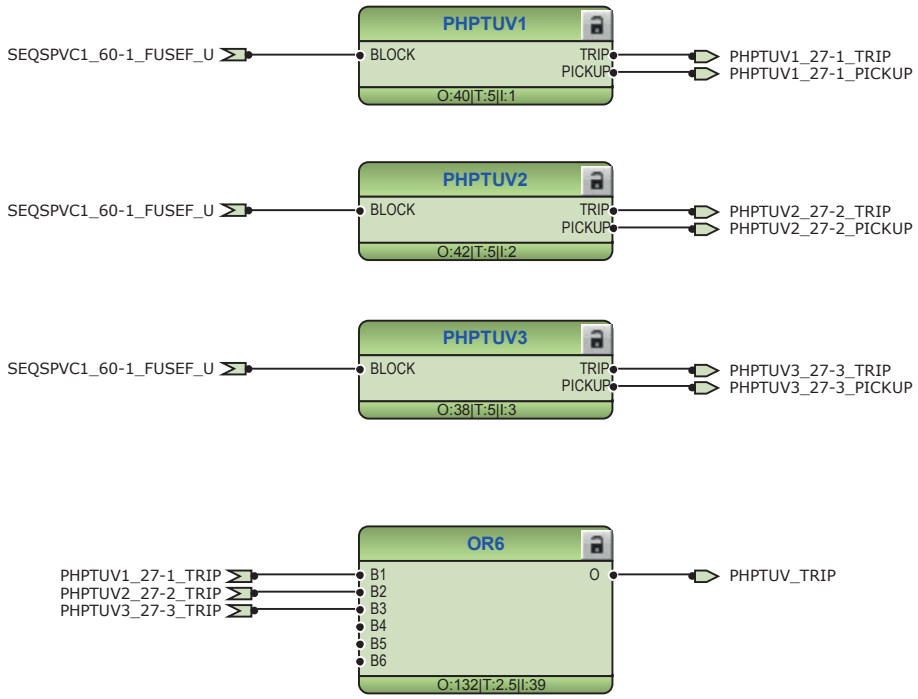


Figure 183: Undervoltage protection function

Figure 184: Negative-sequence overvoltage protection function

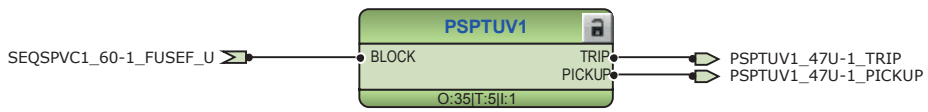


Figure 185: Positive-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV_59G,59N provides ground-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

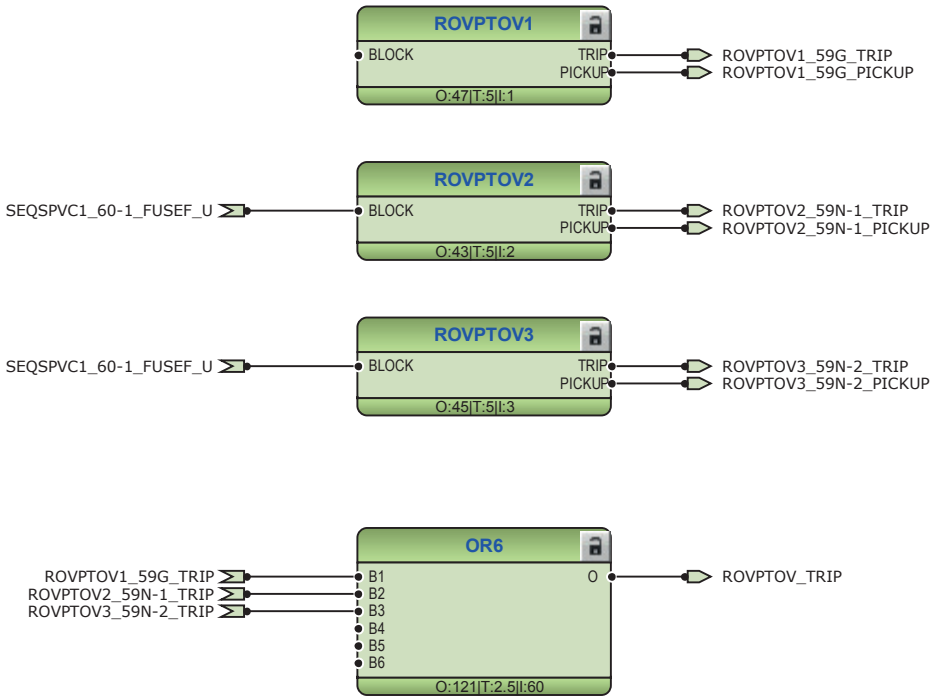


Figure 186: Residual voltage protection function

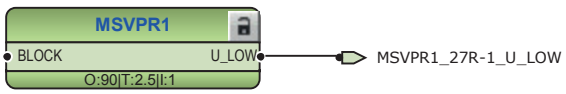


Figure 187: Three-phase remnant undervoltage protection function

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

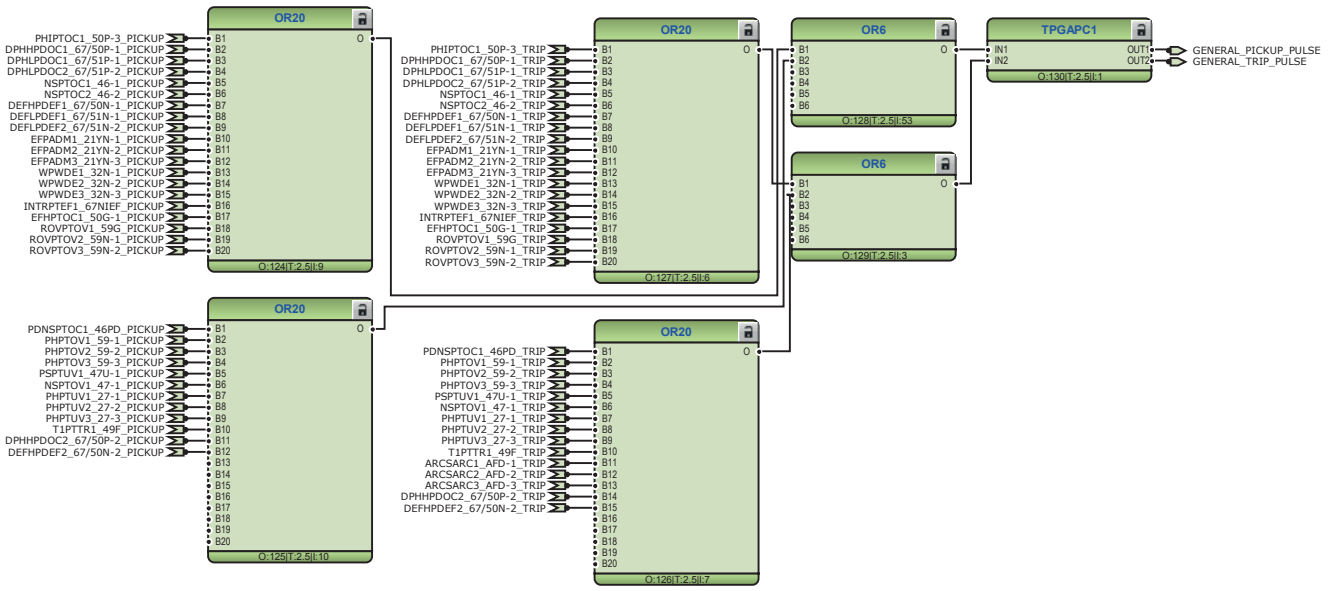


Figure 188: General pickup and trip signals

The trip signals from the protection functions are connected to the two trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions 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...5_86/94-3…5 are also available if the relay is ordered with high speed binary outputs options.

Figure 189: Trip logic TRPPTRC1

Figure 190: Trip logic TRPPTRC2

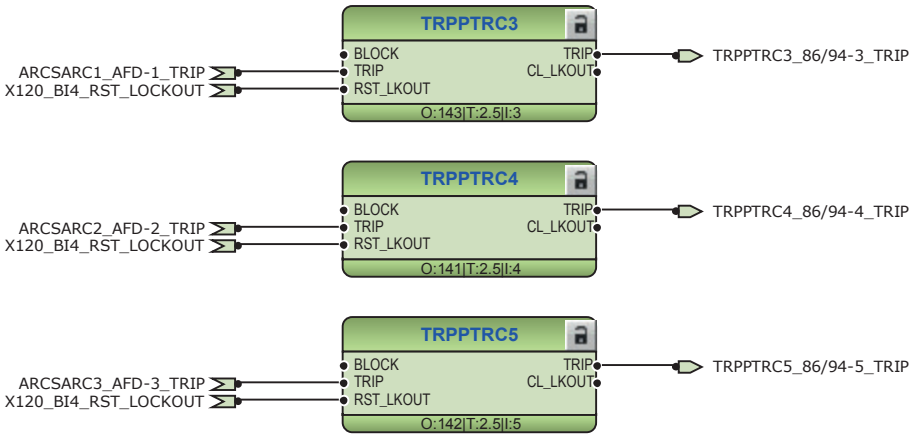


Figure 191: Trip logic TRPPTRC3/4/5

3.6.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

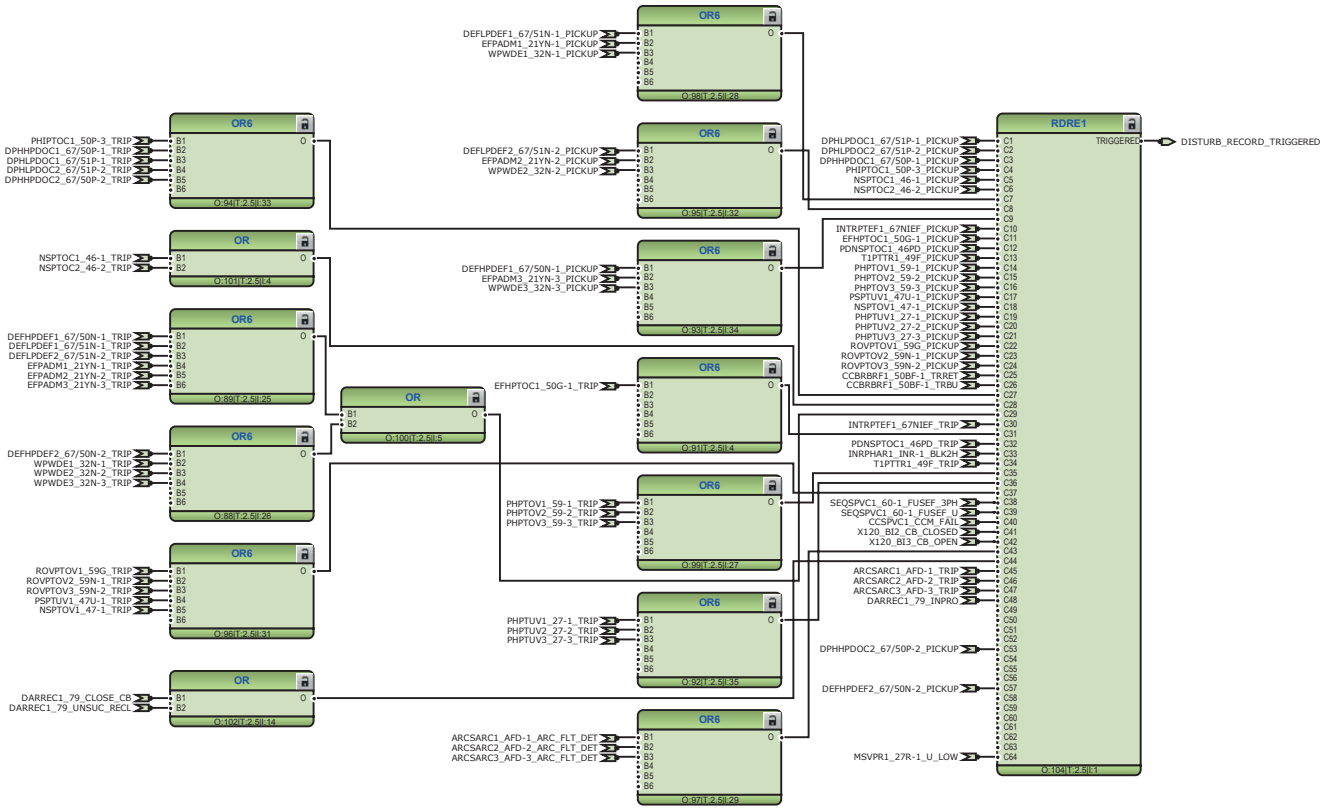


Figure 192: Disturbance recorder

3.6.3.3 Functional diagrams for condition monitoring

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

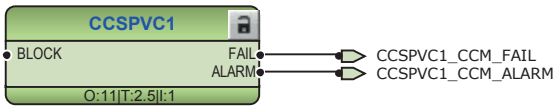


Figure 193: Current circuit supervision function

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

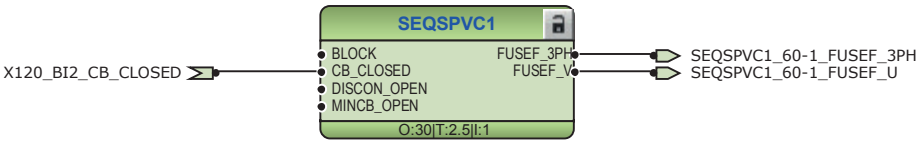


Figure 194: Fuse failure supervision function

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

Set the parameters for SSCBR1_52CM-1 properly.

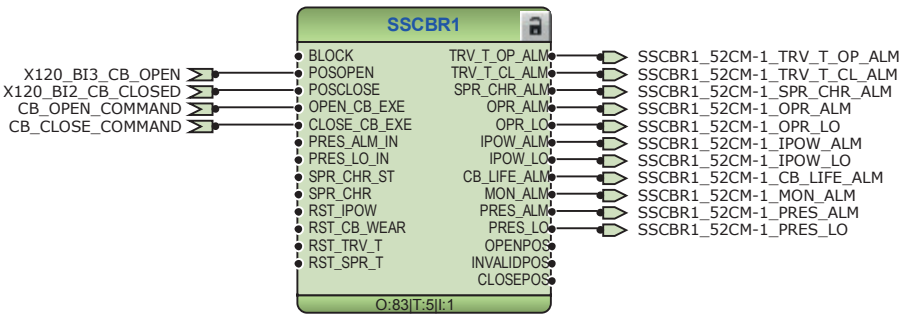


Figure 195: Circuit-breaker condition monitoring function

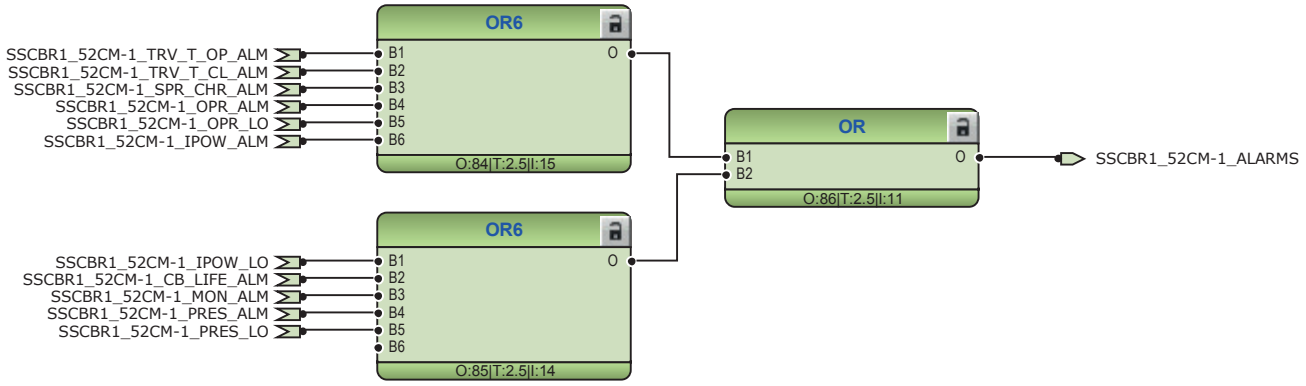


Figure 196: Logic for circuit breaker monitoring alarm

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

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

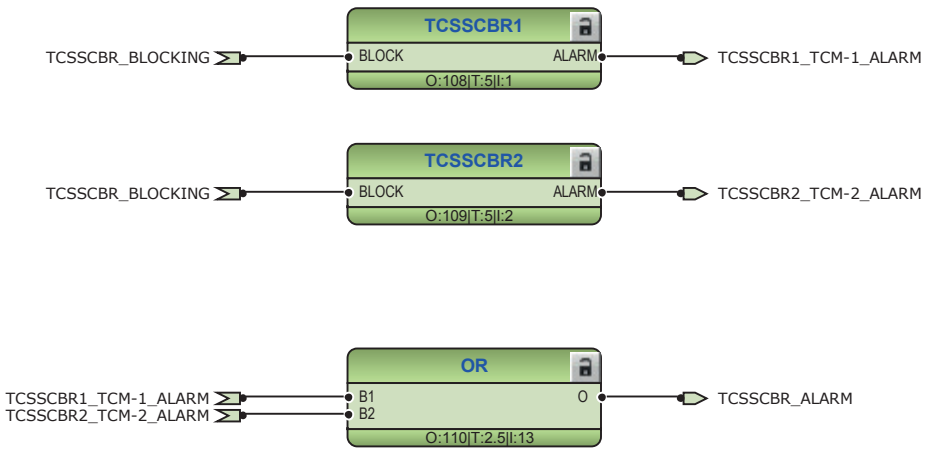


Figure 197: Trip circuit supervision function

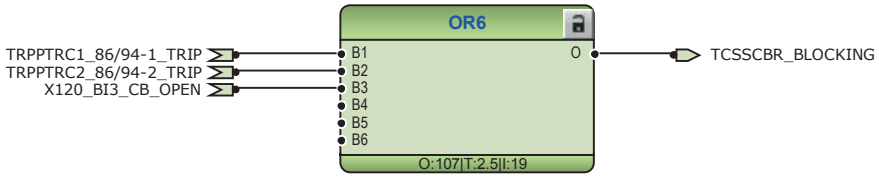


Figure 198: Logic for blocking of trip circuit supervision

3.6.3.4 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.

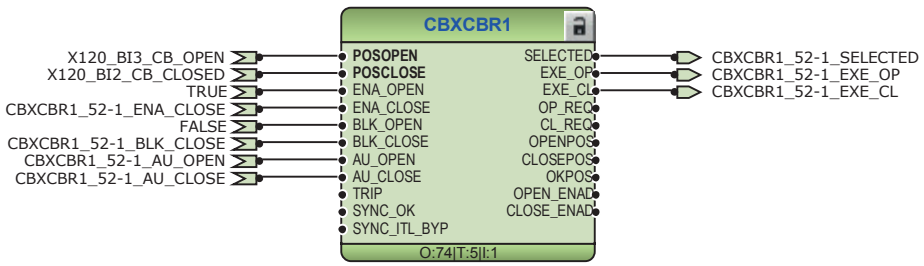


Figure 199: Circuit breaker control logic: Circuit breaker 1

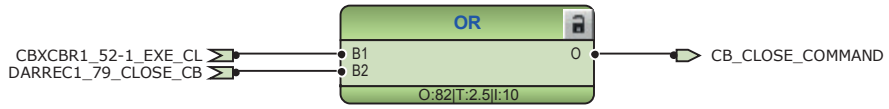


Figure 200: Circuit breaker control logic: Signals for the closing coil of circuit breaker 1

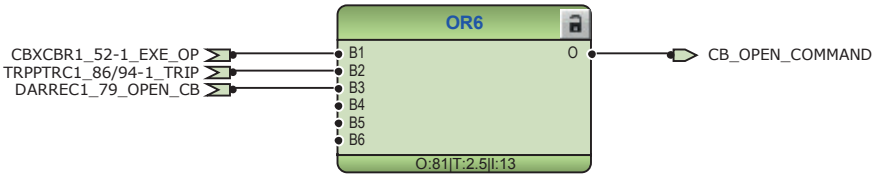


Figure 201: Circuit breaker control logic: Signals for the opening coil of circuit breaker 1

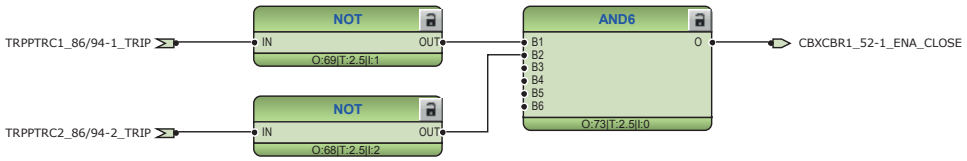


Figure 202: Circuit breaker close enable logic

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

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

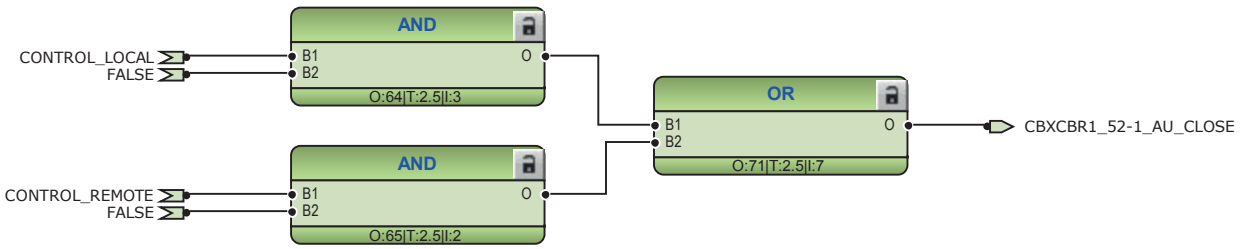


Figure 203: External closing command for circuit breaker

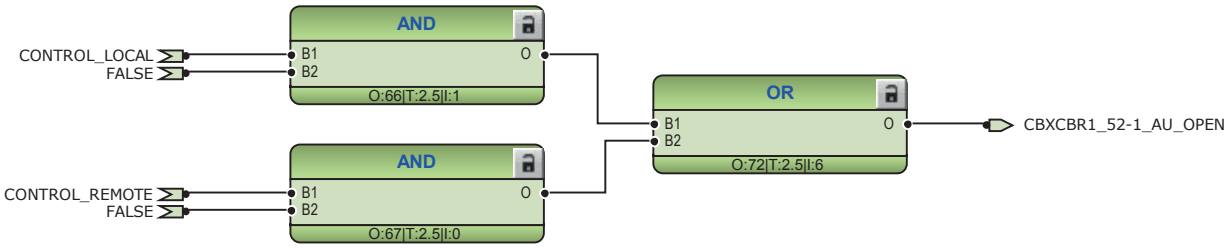


Figure 204: External opening command for circuit breaker

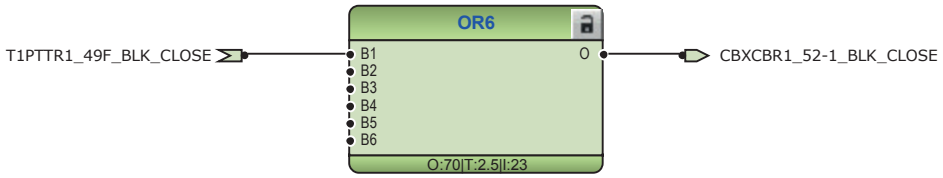


Figure 205: Circuit breaker 1 close blocking logic

3.6.3.5 Functional diagrams for measurement functions

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

The three-phase bus side phase voltage and single phase line side phase voltage inputs to the protection relay 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 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.

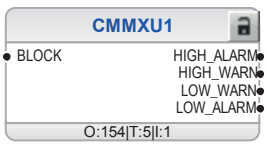


Figure 206: Three-phase current measurement

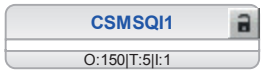


Figure 207: Sequence current measurements

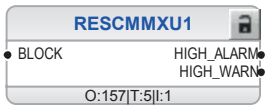


Figure 208: Ground current measurements

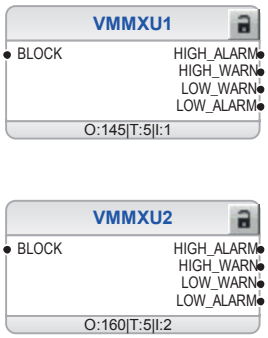


Figure 209: Three-phase voltage measurement

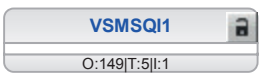


Figure 210: Sequence voltage measurements

Figure 211: Ground voltage measurements

Figure 212: Frequency measurement

Figure 213: Three-phase power and energy measurement

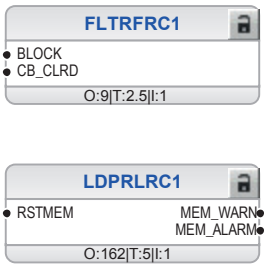


Figure 214: Data monitoring and load profile record

3.6.3.6 Functional diagrams for I/O and alarm LEDs

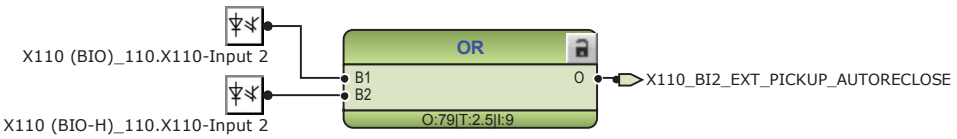


Figure 215: Default binary inputs - X110

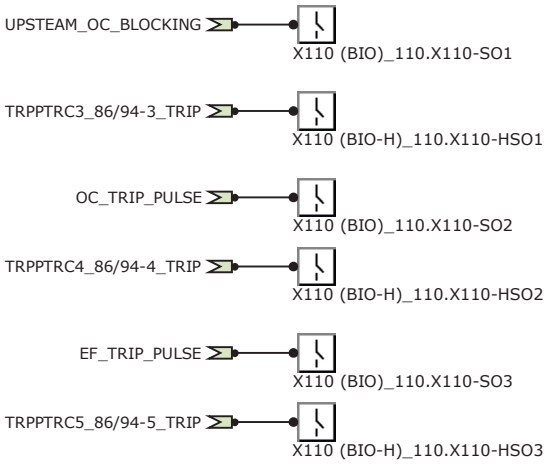


Figure 216: Default binary outputs - X110

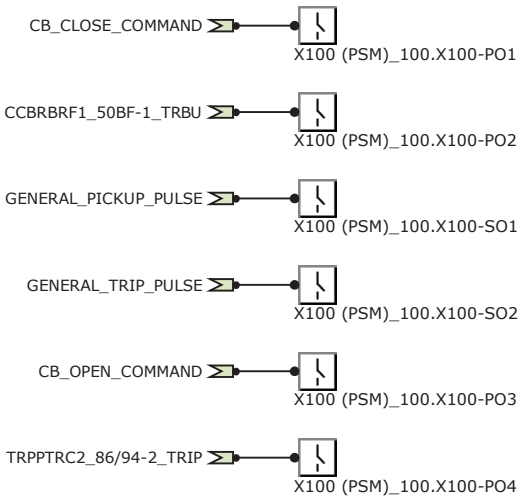


Figure 217: Default binary outputs - X100

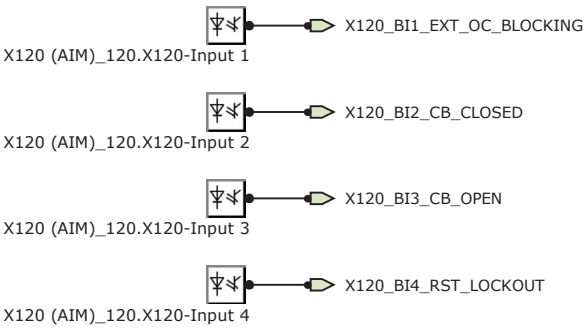


Figure 218: Default binary inputs - X120

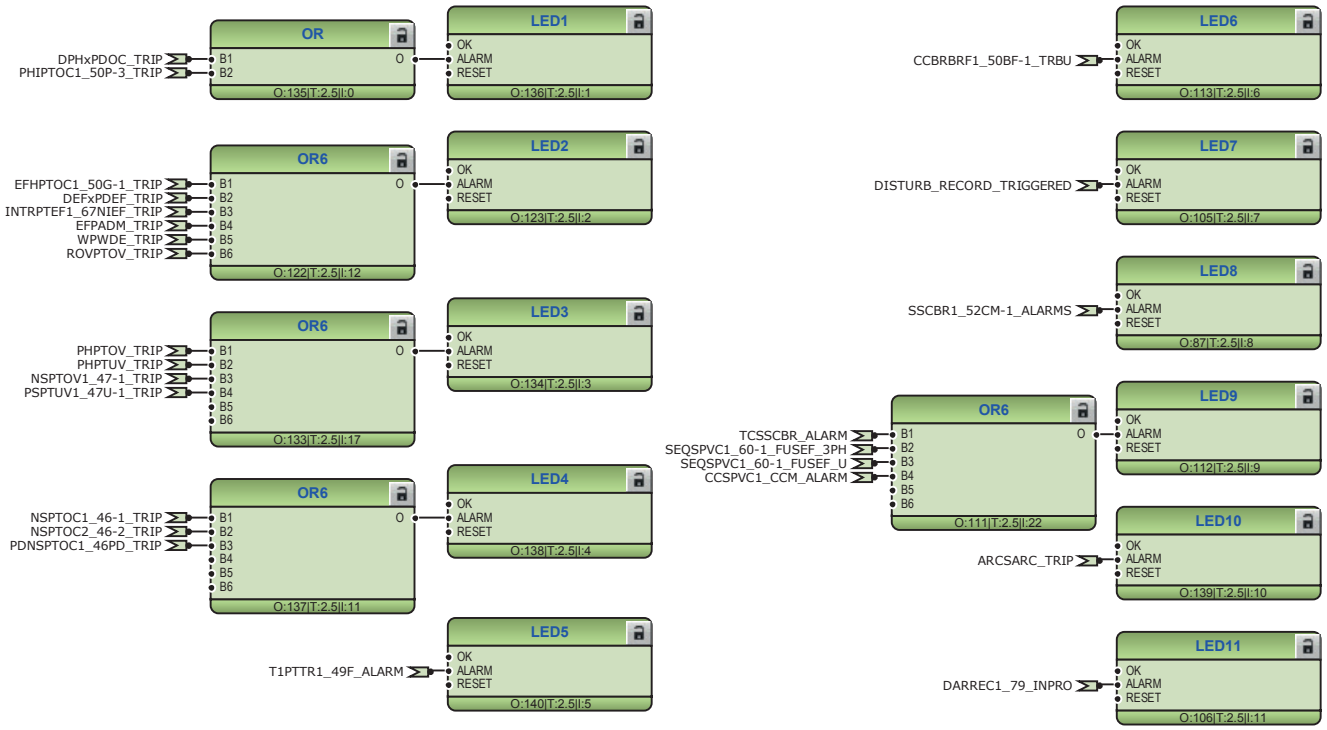


Figure 219: Default LED connection

3.6.3.7 Functional diagrams for other functions

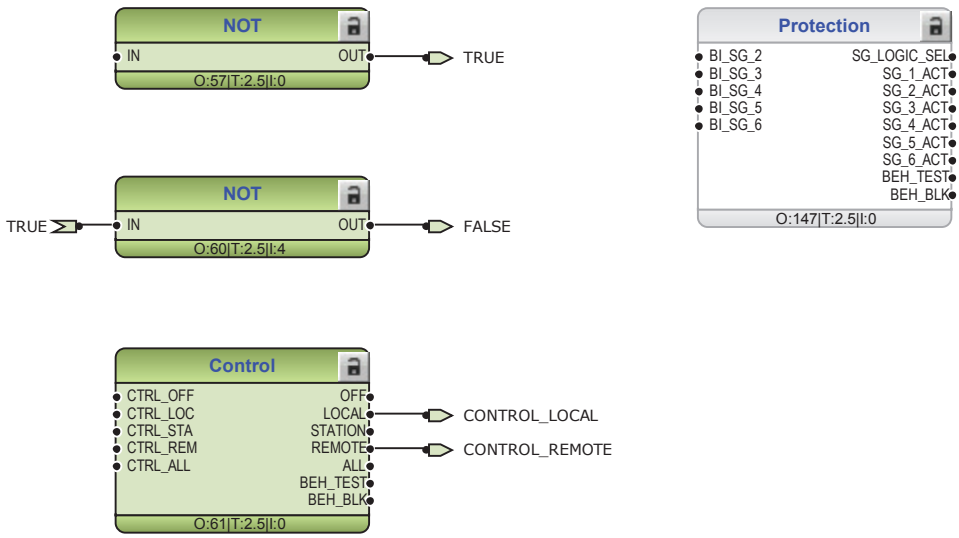


Figure 220: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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

3.6.3.8 Functional diagrams for other timer logics

The configuration also includes the overcurrent trip and ground-fault trip logic.

The trip 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.

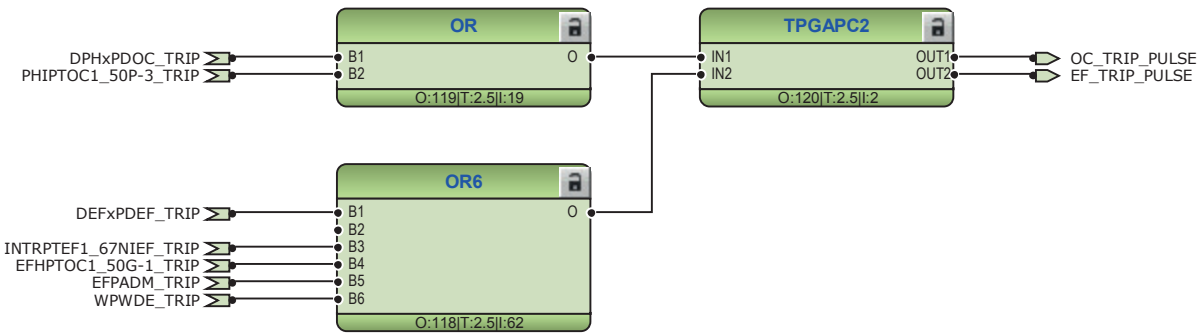


Figure 221: Timer logic for overcurrent and ground-fault trip pulse

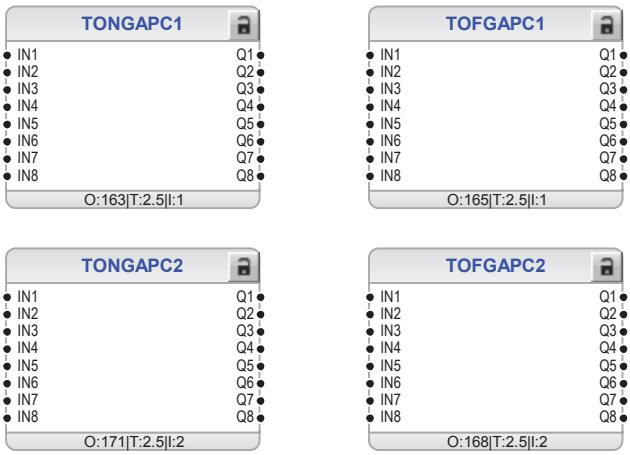


Figure 222: Programmable functions

3.6.3.9 Functional diagrams for communication

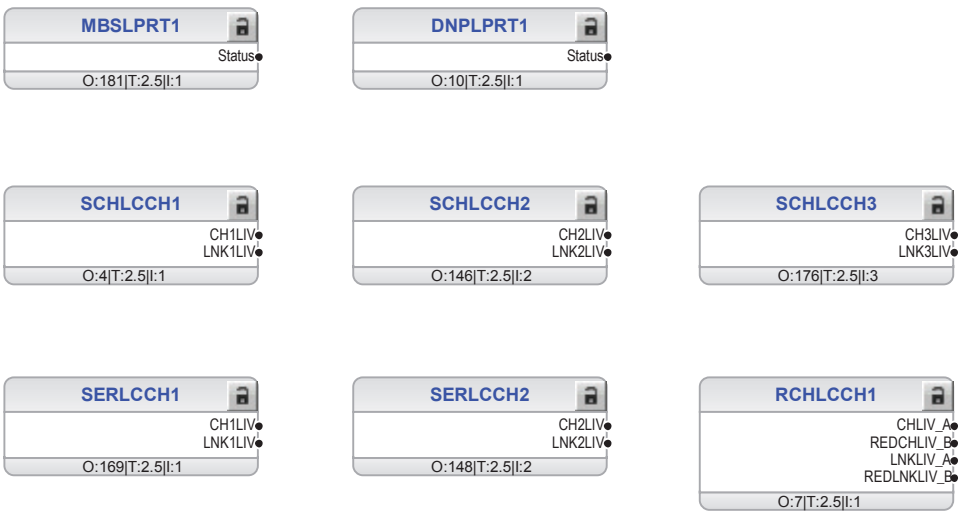


Figure 223: Default communication function connection

3.7 Standard configuration P

3.7.1 Applications

This standard configuration is mainly intended for single or double tie breaker control in power distribution systems. With the directional phase and ground overcurrent, voltage protection, synch check and power system metering, this configuration can be applied for radial and loop feeders and intertie connections. In particular, this configuration provides two sets of the remnant under voltage functions that can monitor two bus voltages with a wide frequency range. As a result, it can be conveniently applied for automatic bus transfer schemes.

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

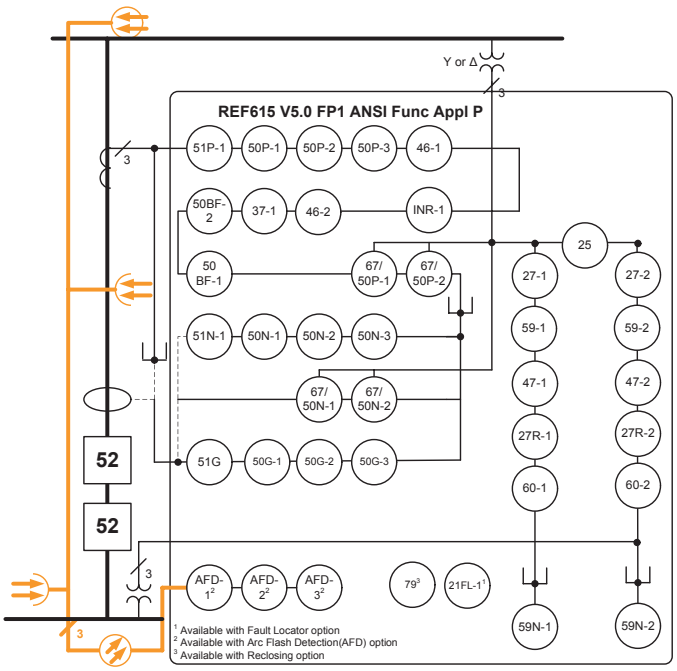


Figure 224: Functionality overview for standard configuration P

3.7.2.1 Default I/O connections

Table 33: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
VA(2)	Phase voltage VA(2)	X130:7-8
VB(2)	Phase voltage VB(2)	X130:9-10
VC(2)	Phase voltage VC(2)	X130:11-12
VA(1)	Phase voltage VA(1)	X130:13-14
VB(1)	Phase voltage VB(1)	X130:15-16
VC(1)	Phase voltage VC(1)	X130:17-18

Table 34: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	-	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	Circuit Breaker 2 closed position indication	X110:8-9	X110:6,10
X110-BI6	Circuit Breaker 2 open position indication	X110:10-9	X110:7,10
X110-BI7	Circuit Breaker 1 closed position indication	X110:11-12	X110:8,10
X110-BI8	Circuit Breaker 1 open position indication	X110:13-12	X110:9-10
X120-BI1	-	X120:1-2	
X120-BI2	-	X120:3-2	
X120-BI3	-	X120:4-2	
X120-BI4	-	X120:5-6	
X130-BI1	-	X130:1-2	
X130-BI2	-	X130:3-4	
X130-BI3	-	X130:5-6	

Table 35: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker 1	X100:6-7
X100-PO2	Close circuit breaker 2	X100:8-9
X100-SO1	Circuit breaker failure protection trip to upstream breaker	X100:10-11,(12)
X100-SO2	-	X100:13-14
X100-PO3	Open circuit breaker 1/ Master Trip (1)	X100:15-19
X100-PO4	Open circuit breaker 2/ Master Trip (2)	X100:20-24
X110-SO1	-	X110:14-16
X110-SO2	-	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 36: Default connections for LEDs

LED	Default usage	ID	Label description
1	Phase A	LED_Phase_A	Phase A overcurrent
2	Phase B	LED_Phase_B	Phase B overcurrent
3	Phase C	LED_Phase_C	Phase C overcurrent
4	Neutral / Ground	LED_Neutral	Ground-fault
5	Time	LED_Time	Time overcurrent
6	Instantaneous	LED_Instantaneous	Instantaneous overcurrnt
7	Breaker 1 Failure/Alarm	LED_Breaker_1_Failure_Alarm	Breaker1 failure/alarm
8	Breaker 2 Failure/Alarm	LED_Breaker_2_Failure_Alarm	Breaker2 failure/alarm
9	Synchronism	LED_Synchronism	Synchronism OK
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Voltage	LED_Voltage	Voltage protection

3.7.2.2 Default disturbance recorder settings

Table 37: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	U1
6	U2
7	U3
8	U1B
9	U2B
10	U3B
11	-
12	-

Table 38: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	TRPPTRC1_86/94-1_TRIP	Positive or Rising
2	TRPPTRC2_86/94-2_TRIP	Positive or Rising
3	CBXCBR1_52-1_EXE_OP	Positive or Rising
4	CBXCBR1_52-1_EXE_CL	Positive or Rising
5	CBXCBR2_52-2_EXE_OP	Positive or Rising
6	CBXCBR2_52-2_EXE_CL	Positive or Rising
7	CCBRBRF1_50BF-1_TRBU	Positive or Rising
8	CCBRBRF1_50BF-2_TRBU	Positive or Rising
9	ARCSARC1 - ARC flt det	Positive or Rising
10	ARCSARC2 - ARC flt det	Positive or Rising
11	ARCSARC3 - ARC flt det	Positive or Rising
12	OC(1)_PICKUP_ALARM	Positive or Rising
13	PHPTUC1_37-1_TRIP	Positive or Rising
14	PHPTOV2_59-2_TRIP	Positive or Rising
15	REMPTUV1_27R_TRIP	Positive or Rising
16	NSPTOV1_47-1_TRIP	Positive or Rising
17	NSPTOV2_47-2_TRIP	Positive or Rising
18	ROVPTOV2_59N-1_TRIP	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
19	ROVPTOV3_59N-2_TRIP	Positive or Rising
20	PHPTUV1_27-1_TRIP	Positive or Rising
21	PHPTUV2_27-2_TRIP	Positive or Rising
22	REMPTUV1_27R-1_TRIP	Positive or Rising
23	REMPTUV2_27R-2_TRIP	Positive or Rising
24	CCSPVC1_CCM_FAIL	Positive or Rising
25	MSVPR1 - U_LO	Positive or Rising
26	MSVPR2 - U_LO	Positive or Rising
27	-	-
28	-	-
29	-	
30	-	-
31	-	-
32	-	-
33	-	-
34	-	-
35	-	-
36	-	-
37	-	-
38	-	-
39	-	-
40	-	-
41	-	-
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-

Table continues on next page

Channel	ID text	Level trigger mode
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

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

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

The signal marked with (1) and (2) represents the voltage levels, for example, in transformer application or in the tie breaker control application it represents the name of the bus.

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

Four overcurrent stages for phase, neutral and ground are offered for non-directional overcurrent and short-circuit protection. The non-directional high stage PHHPTOC1_50P-1 is blocked by cold load detection logic. The cold load detection logic starts from closing of the circuit breaker and is active during set time. The cold load detection logic's active time can be set in a resolution of minutes or seconds to the functions TPSGAPC1 and TPMGAPC1.

For dual tie breaker application, since two breakers are in series, both the breakers must be closed to initiate the cold load pickup timer.

The directional overcurrent and short circuit protection are blocked by default also if the fuse failure situation is detected.

The inrush detection block's INRPHAR1_INR-1 output `BLK2H` offers the possibility to either block the function or multiply the active settings for any of the shown protection function blocks. By default, the output `BLK2H` is not connected to anywhere.

All trip signals are connected to the Master Trip and also to the alarm LEDs. The pickup information of all overcurrent functions is collected to the variable OC_PICKUP_ALARM and connected to the disturbance recorder. This signal can be mapped to the signal outputs depending on the application needs.

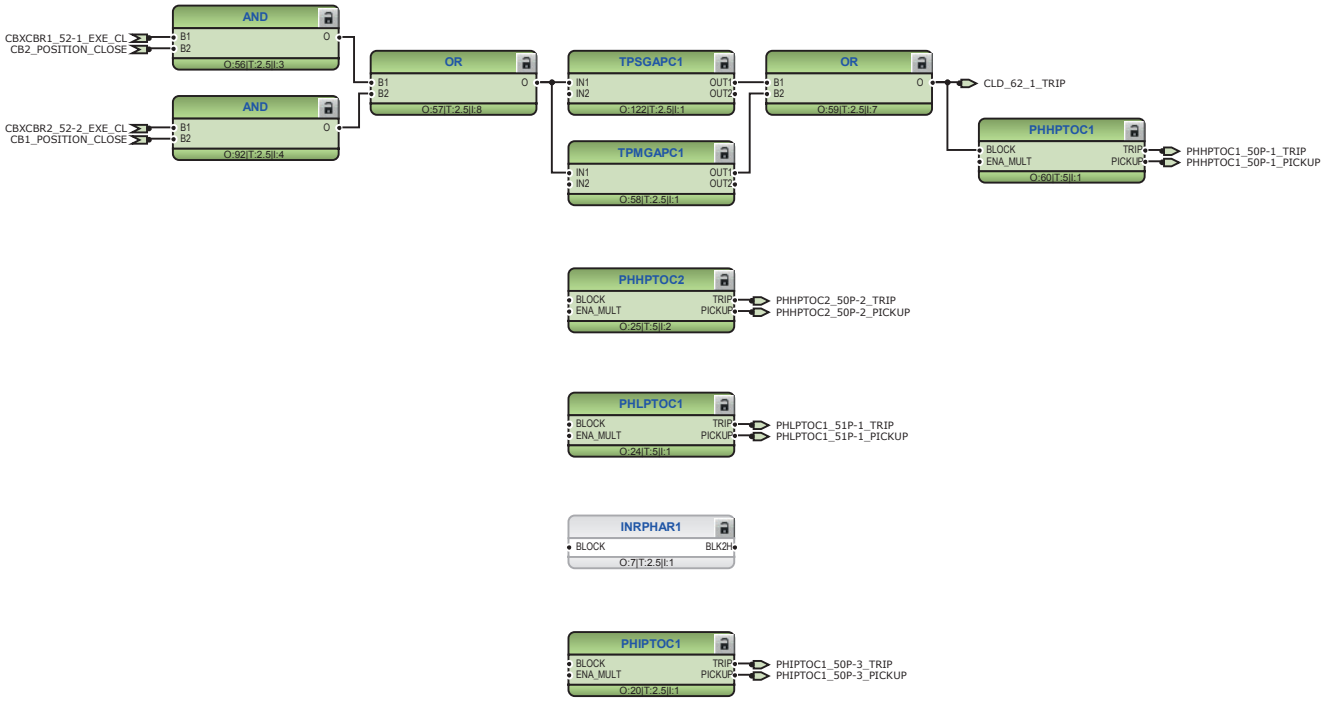


Figure 225: Three-phase overcurrent protection

The undercurrent protection function PHPTUC1_37-1 is offered for protection against loss of phase situations. The trip signal is connected to the disturbance recorder only by default.

Two stages are offered for directional ground-fault protection. By default, the stages DPHHPDOC1_67/50P-1 and DPHHPDOC2_67/50P-2 are blocked by the fuse failure detection. Also by default, these two functions are also not blocked by a cold load situation.

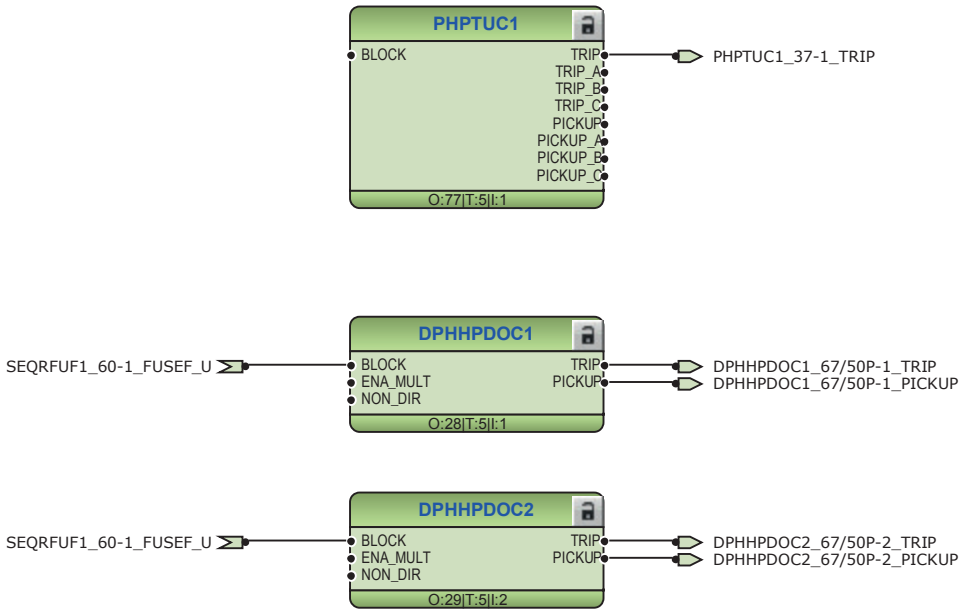


Figure 226: Under current and directional overcurrent protections

Four stages are provided to non-directional neutral overcurrent protection. Additionally depending on order option, one stage is offered as a sensitive ground-fault protection. The neutral overcurrent protection uses calculated residual current component.

The operation of EFLPTOC1_51N-1, EFHPTOC1_50N-1, EFHPTOC2_50N-2 and EFHPTOC3_50N-3 are by default, not blocked by an external blocking input, but this can be done through a binary input. EFHPTOC1_50N-1 is also blocked if the cold load detection logic is activated.

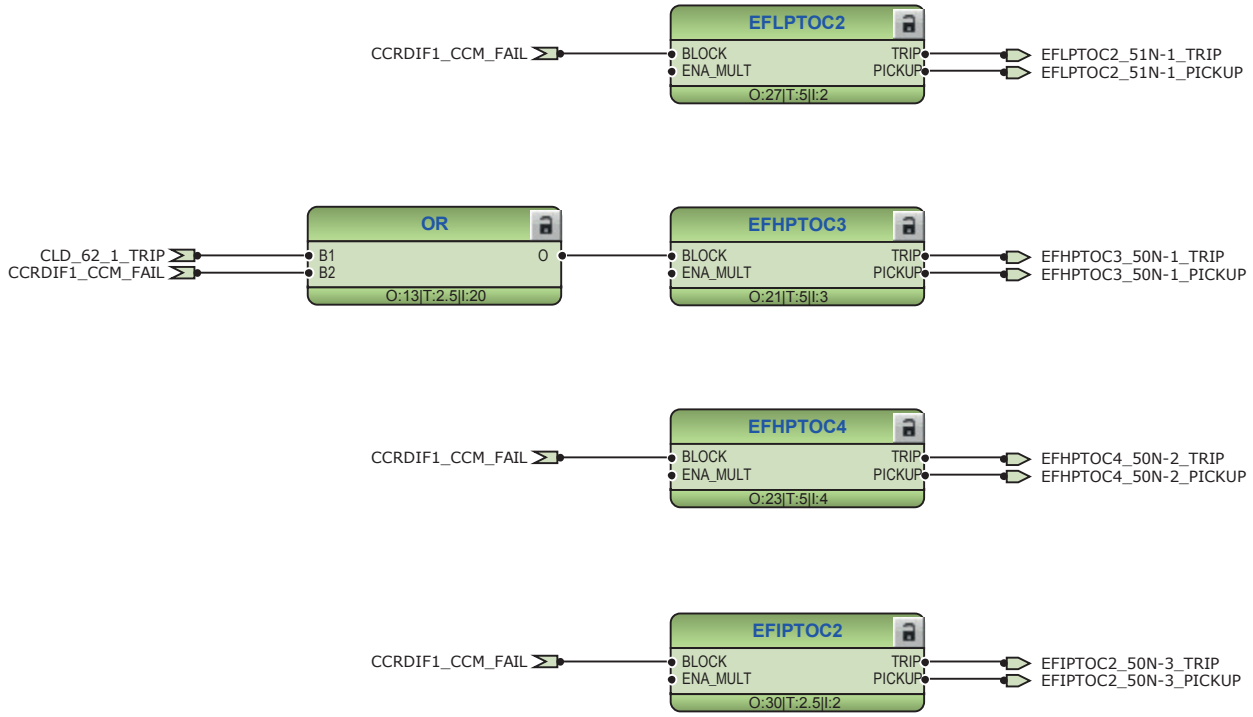


Figure 227: Non-directional calculated neutral overcurrent protection

Four stages are provided to non-directional ground-fault protection. Additionally depending on order option, one stage is offered as a sensitive ground-fault protection. The ground-fault protection uses measured residual current component.

The operation of EFLPTOC1_51G, EFHPTOC2_51G-2 and EFHPTOC3_51G-3 are by default, not blocked by an external blocking input, but this can be done through a binary input.

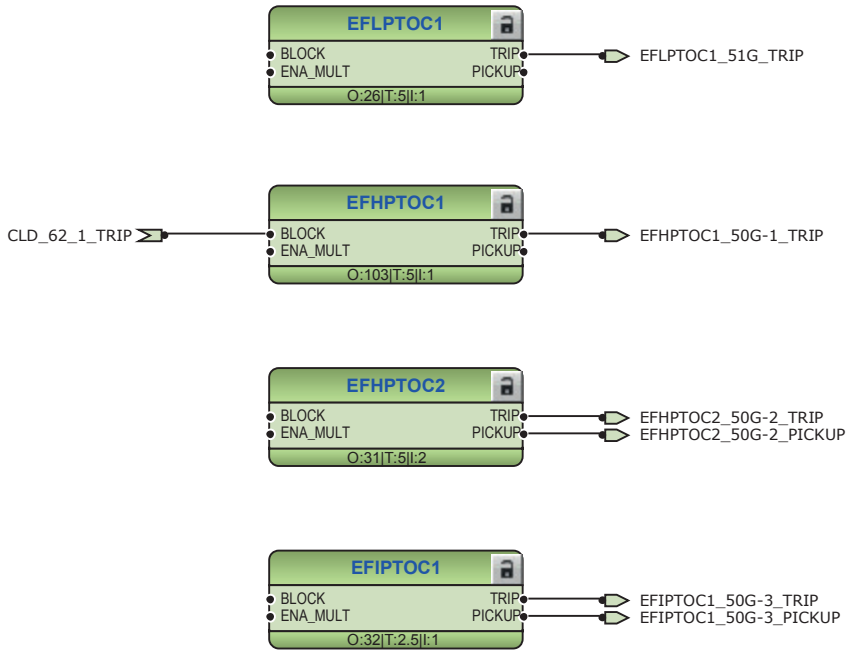


Figure 228: Non-directional ground-fault protection

Two stages are offered for directional ground-fault protection. By default the stages DEFHPDEF1_67/50N-1 and DEFHPDEF2_67/50N-2 are blocked by the fuse failure detection and the polarization choice is set to negative sequence voltage. Also by default, these two functions are also not blocked by a cold load situation.

The polarization should never be set to “measured” as there is no dedicated Vg input for this configuration. Setting polarization to Vg will result in a settings error.

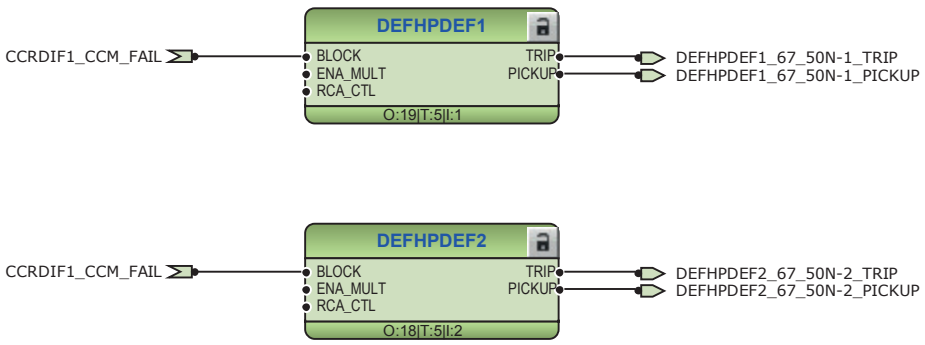


Figure 229: Directional calculated neutral overcurrent protections

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

The operation of NSPTOC1_46-1 and NSPTOC2_46-2 is not blocked as default by any functionality. The pickup signals are connected to OC_PICKUP_ALARM variable in logic.

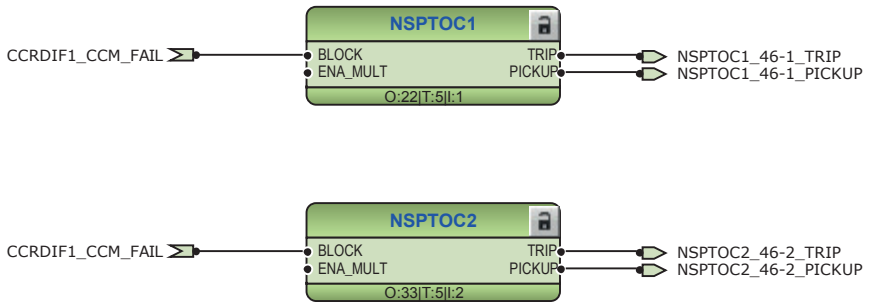


Figure 230: Negative-sequence overcurrent protection

All overcurrent pickup signals are merged together as variable OC_PICKUP_ALARM. This alarm is by default connected to disturbance recorder channel. It can be mapped also, for example, for alarming or blocking purposes to the binary output relays.

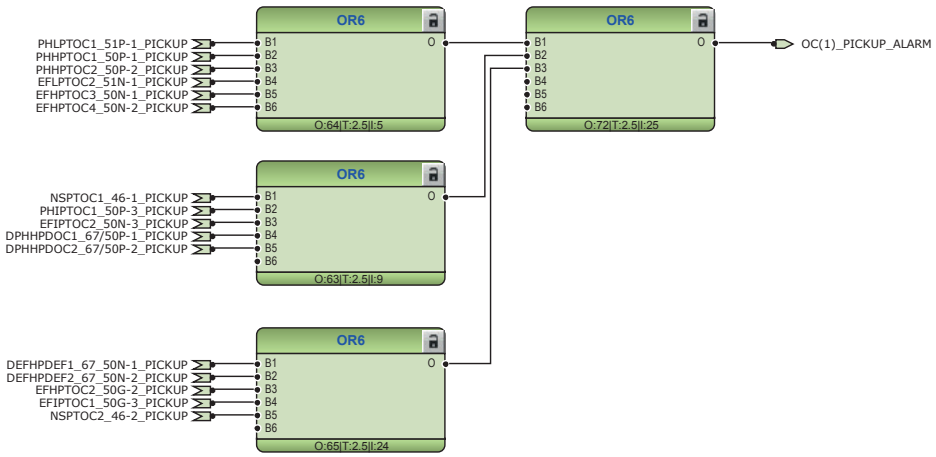


Figure 231: Overcurrent pickup alarm

Two overvoltage and undervoltage protection stages PHPTUV1_27-1, PHPTUV2_27-2 and PHPTOV1_59-1, PHPTOV2_59-2 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 undervoltage protection functions to avoid faulty undervoltage tripping.

Negative-sequence overvoltage NSPTOV1_47-1 and NSPTOV2_47-2 protection functions enable voltage-based unbalance protection.

The residual overvoltage protections ROVPTOV1_59N-1 and ROVPTOV2_59N-2 provide ground-fault protection by detecting abnormal level of residual voltage. They can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality.

PHPTUV1_27-1, PHPTOV1_59-1, NSPTOV1_47-1 and ROVPTOV1_59N-1use the source 1 (bus 1) voltages whereas PHPTUV2_27-2, PHPTOV2_59-2, NSPTOV2_47-2 and ROVPTOV2_59N-2 use the source 2 (bus 2) voltages.

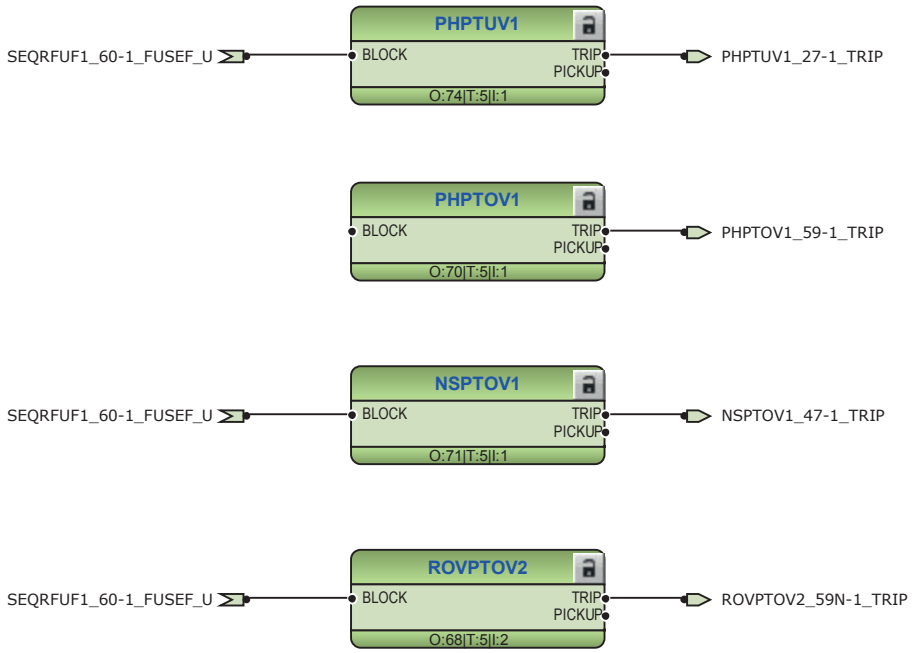


Figure 232: Voltage functions on bus 1

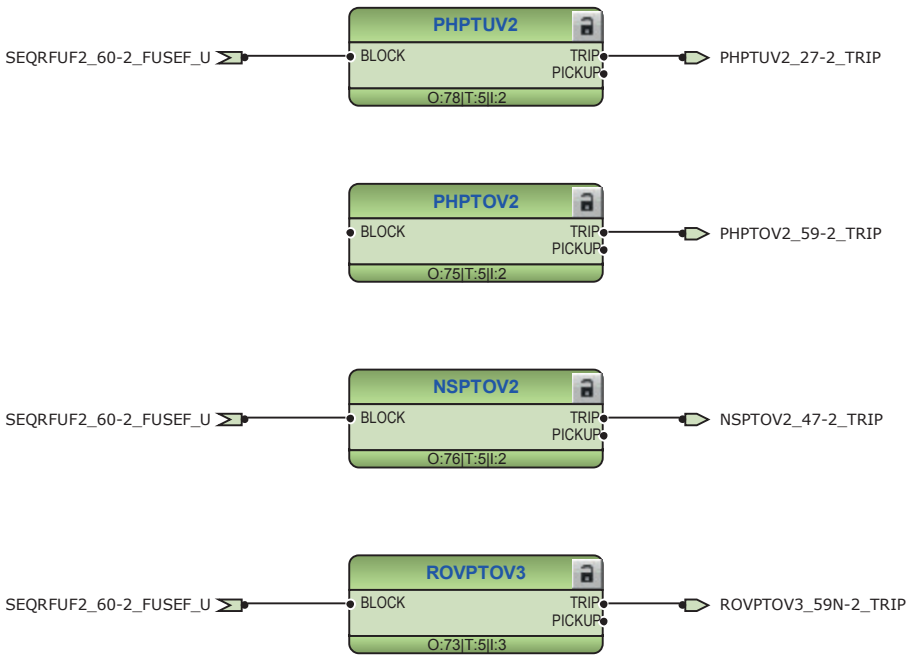


Figure 233: Voltage functions on bus 2

The circuit-breaker failure protection CCBRBRF_50BF is initiated via the PICKUP input by a functions connected to the Master Trip 1 and by opening command of the circuit breaker. CCBRBRF_50BF offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF_50BF has two operating outputs: TRRET and TRBU. The TRBU output can be used to give a backup trip to the circuit breaker feeding upstream. In the configuration the TRBU output signal is connected to the output SO1 (X100: 14, 15, 16).

CCBRBRF1_50BF-1 use the source 1 (bus 1) voltages whereas CCBRBRF2_50BF-2 use the source 2 (bus 2) voltages.

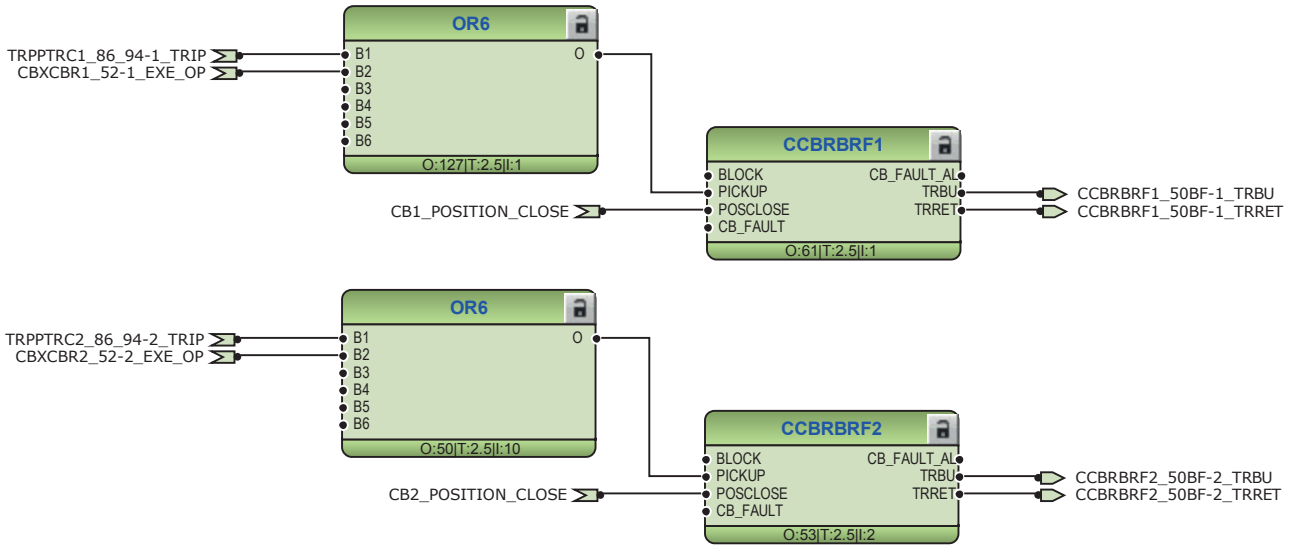


Figure 234: Circuit breaker failure protections

The TRRET trip output can be used for retripping its own circuit breaker through the Master Trip again. However, this is not connected in present configuration.

In case of dual tie breaker application, the TRBU trip output from one tiebreaker can be used for tripping other tie breaker first to minimize the poweroutage area. However, this is not connected in present configuration.

Three arc protection stages ARCSARC1…3_AFD-1…3 are included as an optional function. The arc protection offers individual function blocks for three ARC sensors that can be connected to the relay. Each arc protection function block has two different operation modes, with or without the phase and residual current check.

Trip signal from ARCSARC1_AFD-1 is connected to Master trip 1, available at PO3 (X100: 15-19). Whereas the trip signal from ARCSARC2_AFD-2 and ARCSARC3_AFD-3 is connected to master trip 2, available at PO4 (X100: 20-24).

If the relay has been ordered with high-speed binary outputs, the trip signal from ARCSARC2_AFD-2 and ARCSARC3_AFD-3 are connected directly to high-speed output HSO2 (X110:19-20) and HS03(X110:23-24) respectively.

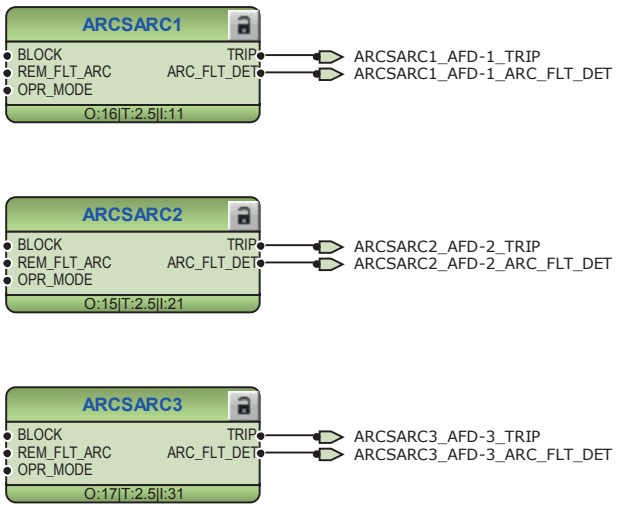


Figure 235: Arc protection

Two master trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 are provided as a trip command collector. TRPPTRC1_86/94-1 is dedicated for the breaker 1 and TRPPTRC2_86/94-2 for breaker 2.

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by a number of different protection functions available in the relay and 50BF-1 protection functions and is connected to trip output contact PO3 (X100:16-19), and TRPPTRC2_86/94-2 collects the almost the same trip signals except the one for CCBRBRF1_50BF-1, instead, CCBRBRF1_50BF-1 being replaced with CCBRBRF2_50BF-2 and is connected to trip output (X100:21-24).

Open control commands from circuit breaker control CBXCBR1_52 function block to the circuit breaker from the local or remote are also connected directly to the outputs PO3 (X100:16-19) and PO4 (X100:21-24) respectively.

With a high-speed binary output card, ARCSARC1…3_AFD-1…3 are connected to high-speed output HSO1 (X110:15-16), HSO1 (X110:19-20) and HSO1 (X110:23-24) respectively. Without the high-speed output card, it is the user's choice to connect the arc protection outputs to whatever outputs available.

TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

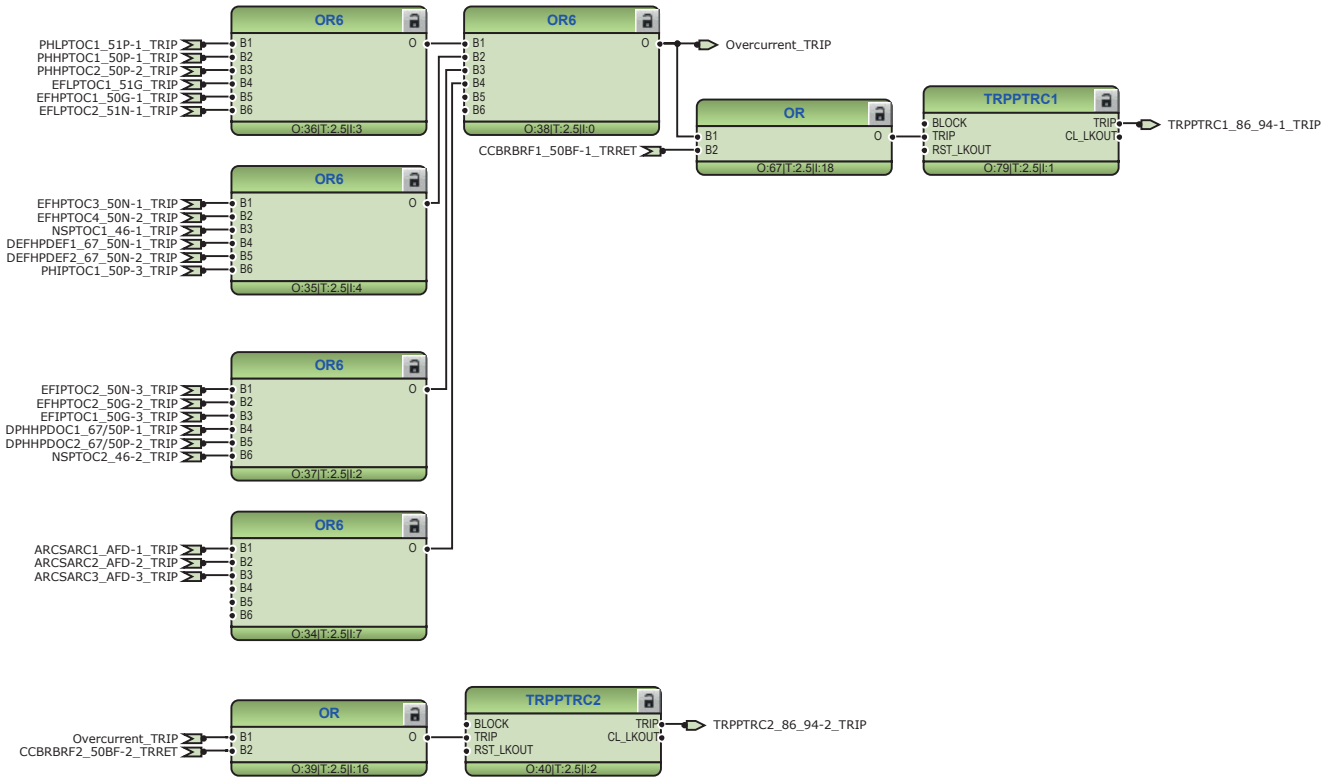


Figure 236: Master trip logic 1/2

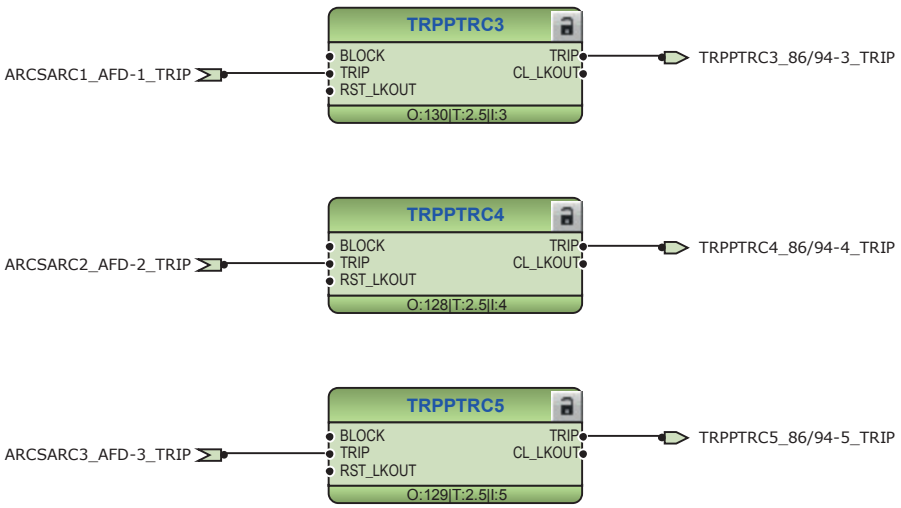


Figure 237: Master trip logic 3/4/5

3.7.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

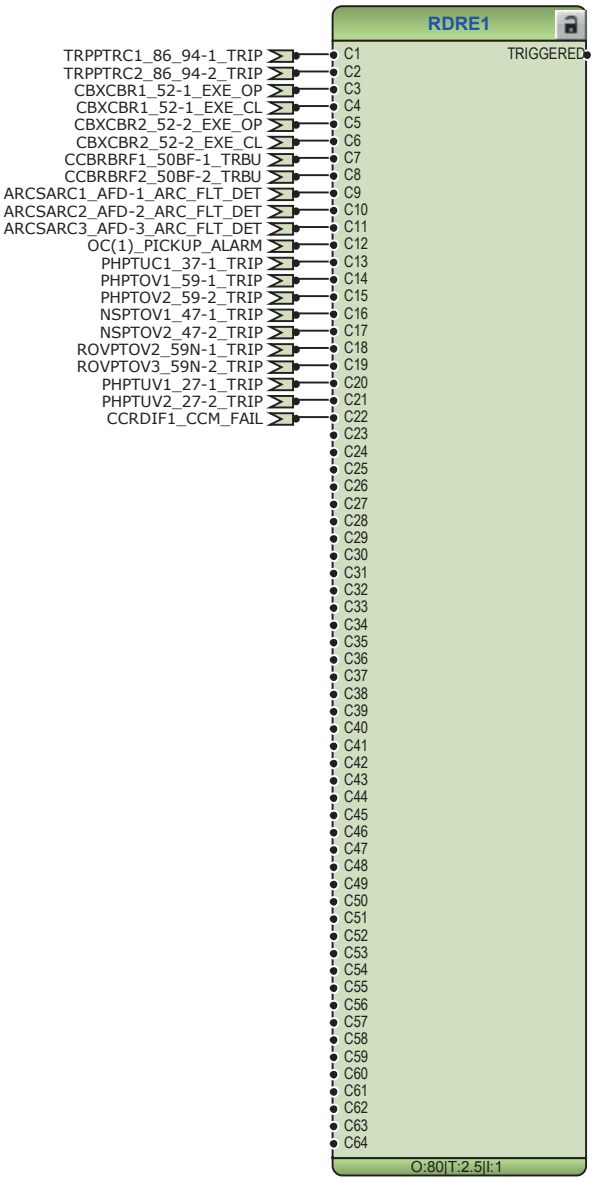


Figure 238: Disturbance recorder

3.7.3.3 Functional diagrams for condition monitoring

Two trip circuit monitoring stages TCSSCBR1_TCM-1 and TCSSCBR2_TCM-2 are provided to supervise the trip circuit of the circuit breaker connected at PO3 (X100:15-19) and PO4 (X100:20-24).

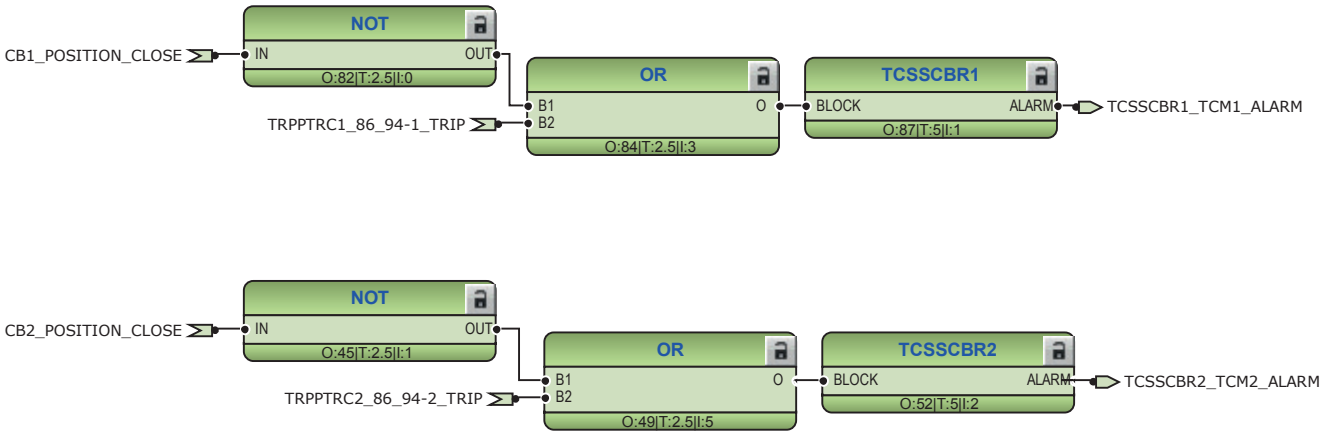


Figure 239: Trip circuit monitoring

The TCSSCBR1_TCM-1 and TCSSCBR2_TCM-2 functions are blocked by TRPPTRC1_86/94-1, TRPPTRC2_86/94-2 and when the circuit-breaker is not in closed position.

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

The circuit breaker condition monitoring function SSCBR1_52CM supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision alarms.

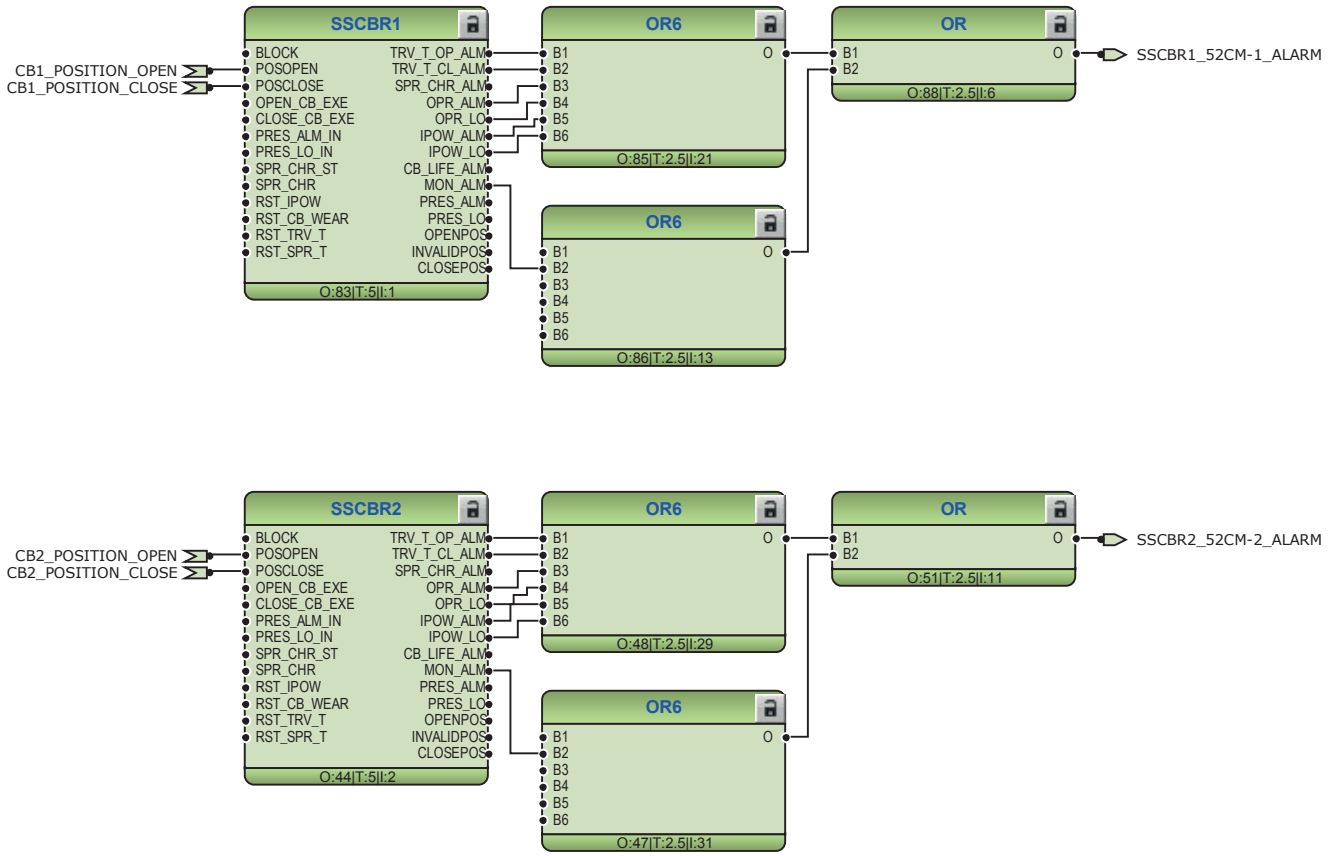


Figure 240: Circuit breaker condition monitoring

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

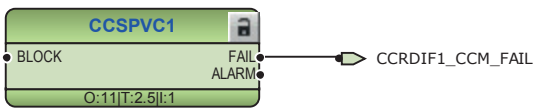


Figure 241: Current circuit supervision function

The fuse failure supervision SEQRFUF1_60-1 and SEQRFUF2_60-2 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the few voltage based protection functions to avoid misoperation.

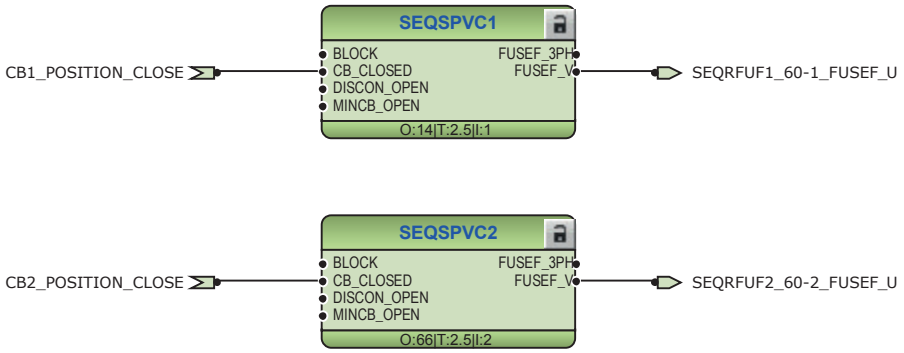


Figure 242: Fuse failure monitoring

Note that BUS1_Voltage_Presence and BUS2_Voltage_Presence reflect Bus 1 and 2 voltage status respectively. Depending on the application, these signals can be built on the status of all the breakers that are connected to voltage sources. Take the Main-Tie-Tie-Main application as an example and consider a rotating machine on the buses.

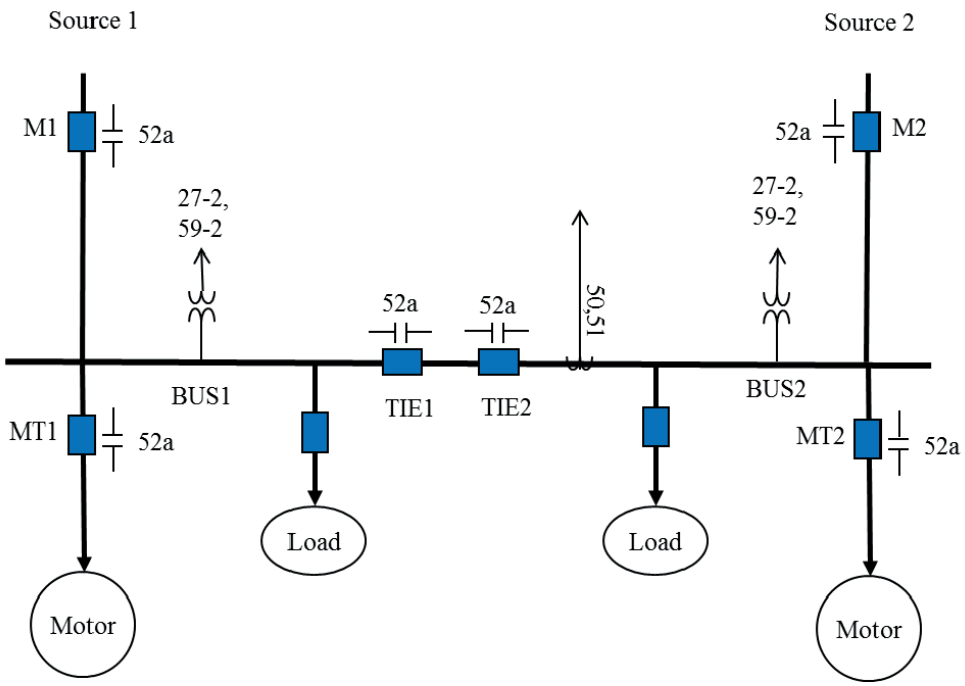


Figure 243: Main-Tie-Tie-Main system

To properly determine the voltage presence on a bus, the positions of all the breakers that are connected to the bus must be known. For example, consider the Bus 1 in the above diagram, the incomer source 1, MT1 and other voltage through the tie breakers are

considered as the potential voltage sources. In this case, the input logic to CB_CLOSED of SEQRFUF1_60-1 for bus 1 should be

(M1_52a OR MT1_52a OR (TIE1_52a AND TIE2_52a)).

Similarly for SEQRFUF2 for bus 2, it is (M2_52a OR MT2_52a

OR (TIE1_52a AND TIE2_52a)).

If it is convenient and the binary inputs are available, all the necessary breaker close positions can be wired to the relay. The other option is to use GOOSE to reduce the wiring connections. Usually all the breakers connected to the same bus are located in the same location, it would be easy to set up the GOOSE communication between the relays that control individual breaker respectively.

3.7.3.4 Functional diagrams for control and interlocking

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is for example a combination of the disconnector or breaker truck and ground switch position status and the status of the Master Trip logics and gas pressure alarm and circuit-breaker spring charging. With the present configuration, the activation of ENA_CLOSE input is configured using only Master Trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2, that is, the circuit breaker cannot be closed in case master trip is active.

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

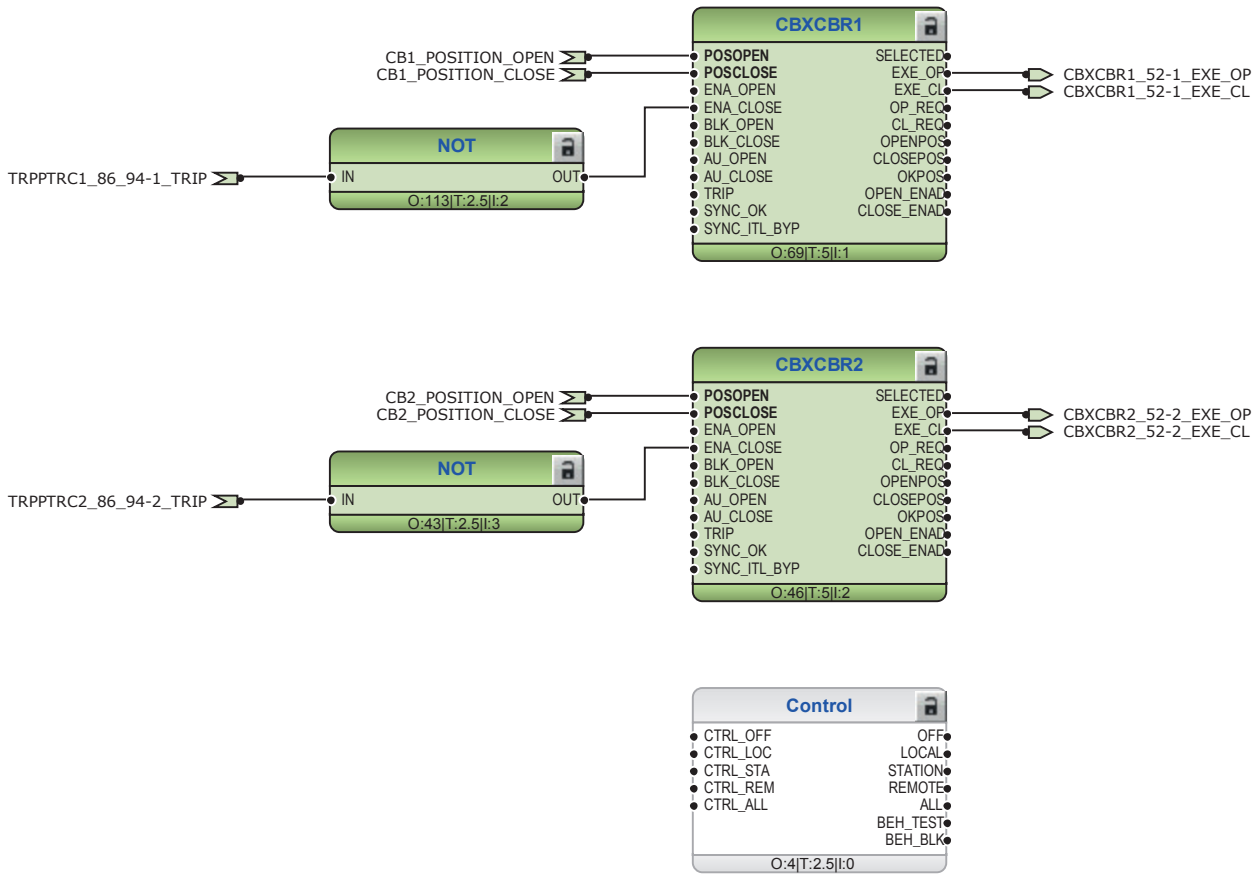


Figure 244: Circuit breaker control

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR_52 with PCM600, the function assumes that the breaker close commands are allowed continuously.

The sync check function SECRSYN1_25 is provided in this standard configuration. The main purpose of the synchronism and energizing check 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.

The sync check function 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 of the circuit breaker. The SYNC_OK output signal of SECRSYN1_25 is connected to ENA_CLOSE input of CBXCBR1_52-1.

By default, Bus 1 is designated as the bus side and Bus 2 as the line side. Thus, LLDB means that Bus 2 is live and Bus 1 is dead; similarly, LLLB means that both Bus 2 and 1

are live. When the fuse failure detection from either set of VTs is active, the sync check function will be blocked.

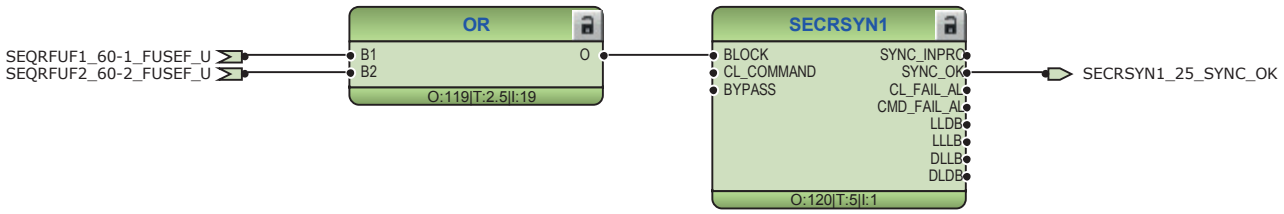


Figure 245: Sync check function

3.7.3.5 Functional diagrams for measurement functions

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

The three-phase source 1 (bus 1) voltages side phase voltage and the three-phase source 2 (bus 2) voltages side phase voltage inputs to the relay 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 and VSMSQI2 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.

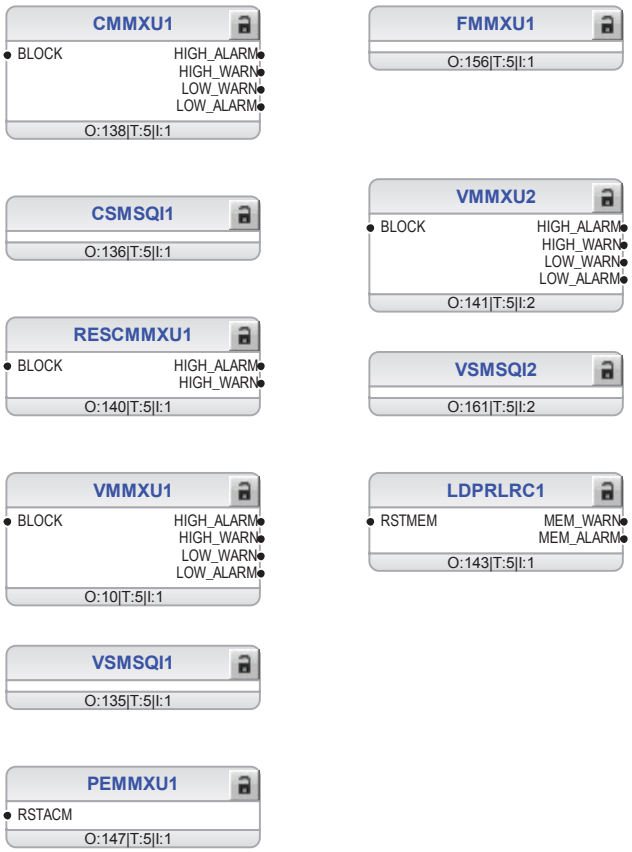


Figure 246: Measurements

Figure 247: Fault recorder

3.7.3.6 Functional diagrams for I/O and alarm LEDs

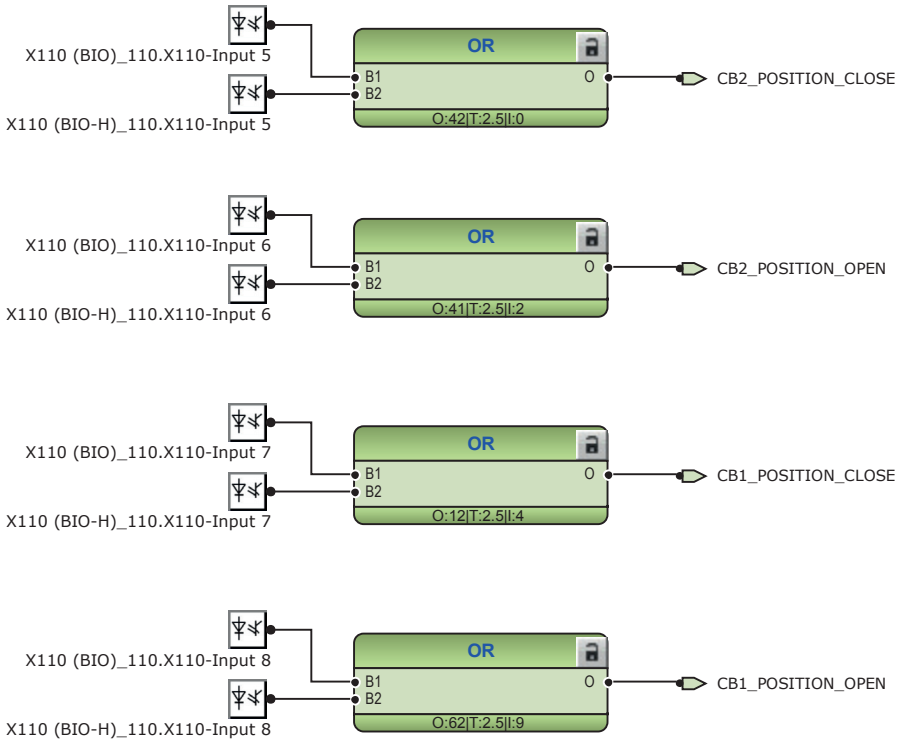


Figure 248: Default binary inputs - X110

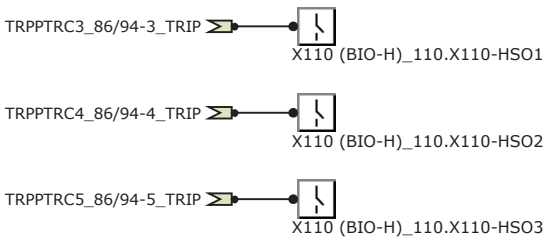


Figure 249: Default binary outputs - X110

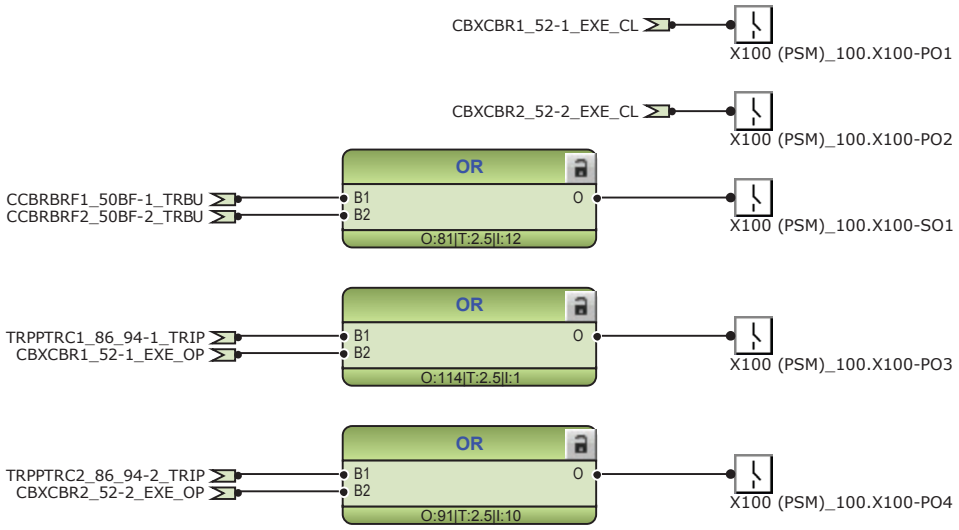
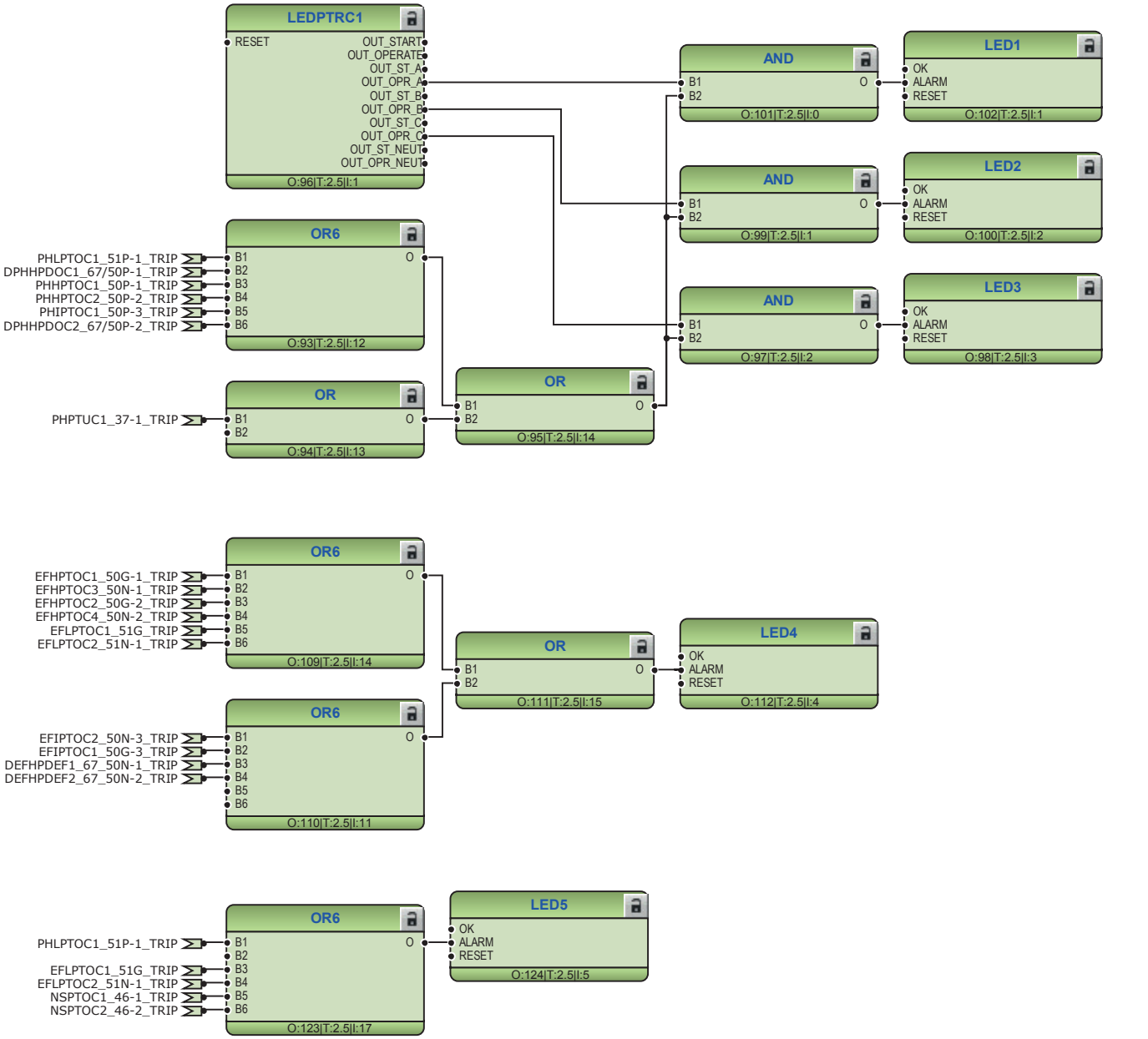
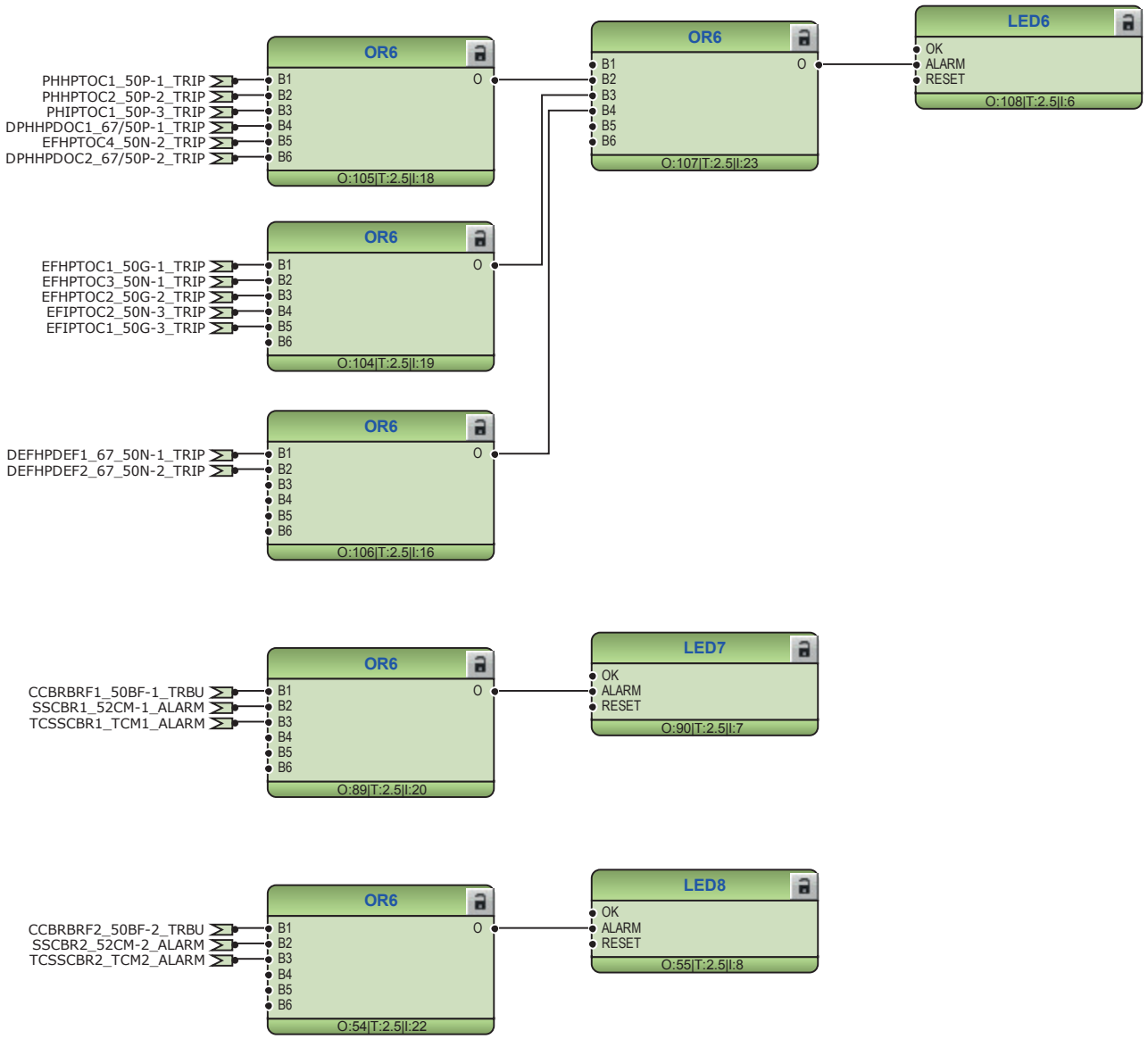


Figure 250: Default binary outputs - X100


LEDPTRC1
RESET
OUT_START
OUT_OPERATE
OUT_ST_A
OUT_OPR_A
OUT_ST_B
OUT_OPR_B
OUT_ST_C
OUT_OPR_C
OUT_ST_NEUT
OUT_OPR_NEUT
O:96|T:2.5|I:1
AND
B1
B2
O
O:101|T:2.5|I:0
LED1
OK
ALARM
RESET
O:102|T:2.5|I:1
AND
B1
B2
O
O:99|T:2.5|I:1
LED2
OK
ALARM
RESET
O:100|T:2.5|I:2
AND
B1
B2
O
O:97|T:2.5|I:2
LED3
OK
ALARM
RESET
O:98|T:2.5|I:3
OR6
PHLPTOC1_51P-1_TRIP
DPHHPDOC1_67/50P-1_TRIP
PHHPTOC1_50P-1_TRIP
PHHPTOC2_50P-2_TRIP
PHIPTOC1_50P-3_TRIP
DPHHPDOC2_67/50P-2_TRIP
B1
B2
B3
B4
B5
B6
O
O:93|T:2.5|I:12
OR
PHPTUC1_37-1_TRIP
B1
B2
O
O:94|T:2.5|I:13
OR
B1
B2
O
O:95|T:2.5|I:14
OR6
EFHPTOC1_50G-1_TRIP
EFHPTOC3_50N-1_TRIP
EFHPTOC2_50G-2_TRIP
EFHPTOC4_50N-2_TRIP
EFLPTOC1_51G_TRIP
EFLPTOC2_51N-1_TRIP
B1
B2
B3
B4
B5
B6
O
O:109|T:2.5|I:14
OR
B1
B2
O
O:111|T:2.5|I:15
LED4
OK
ALARM
RESET
O:112|T:2.5|I:4
OR6
EFIPTOC2_50N-3_TRIP
EFIPTOC1_50G-3_TRIP
DEFHPDEF1_67_50N-1_TRIP
DEFHPDEF2_67_50N-2_TRIP
B1
B2
B3
B4
B5
B6
O
O:110|T:2.5|I:11
OR6
PHLPTOC1_51P-1_TRIP
EFLPTOC1_51G_TRIP
EFLPTOC2_51N-1_TRIP
NSPTOC1_46-1_TRIP
NSPTOC2_46-2_TRIP
B1
B2
B3
B4
B5
B6
O
O:123|T:2.5|I:17
LED5
OK
ALARM
RESET
O:124|T:2.5|I:5


OR6
PHHPTOC1_50P-1_TRIP
PHHPTOC2_50P-2_TRIP
PHIPTOC1_50P-3_TRIP
DPHHPDOC1_67/50P-1_TRIP
EFHPTOC4_50N-2_TRIP
DPHHPDOC2_67/50P-2_TRIP
B1
B2
B3
B4
B5
B6
O
O:105|T:2.5|I:18
OR6
EFHPTOC1_50G-1_TRIP
EFHPTOC3_50N-1_TRIP
EFHPTOC2_50G-2_TRIP
EFIPTOC2_50N-3_TRIP
EFIPTOC1_50G-3_TRIP
O:104|T:2.5|I:19
OR6
DEFHPDEF1_67_50N-1_TRIP
DEFHPDEF2_67_50N-2_TRIP
O:106|T:2.5|I:16
OR6
B1
B2
B3
B4
B5
B6
O
O:107|T:2.5|I:23
LED6
OK
ALARM
RESET
O:108|T:2.5|I:6
OR6
CCBRBRF1_50BF-1_TRBU
SSCBR1_52CM-1_ALARM
TCSSCBR1_TCM1_ALARM
O:89|T:2.5|I:20
LED7
O:90|T:2.5|I:7
OR6
CCBRBRF2_50BF-2_TRBU
SSCBR2_52CM-2_ALARM
TCSSCBR2_TCM2_ALARM
O:54|T:2.5|I:22
LED8
O:55|T:2.5|I:8

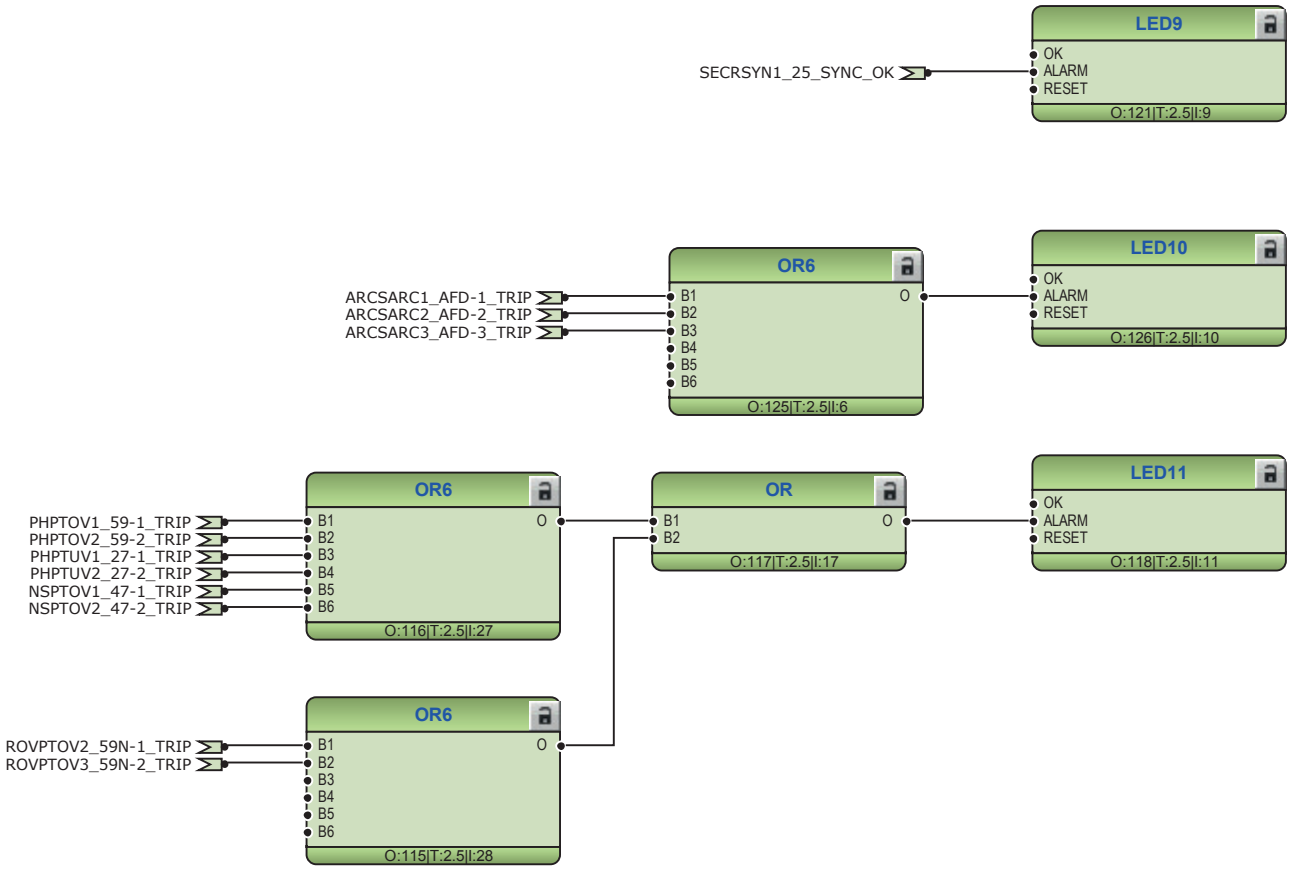


Figure 251: Default LED connection

3.7.3.7 Functional diagrams for other timer logics

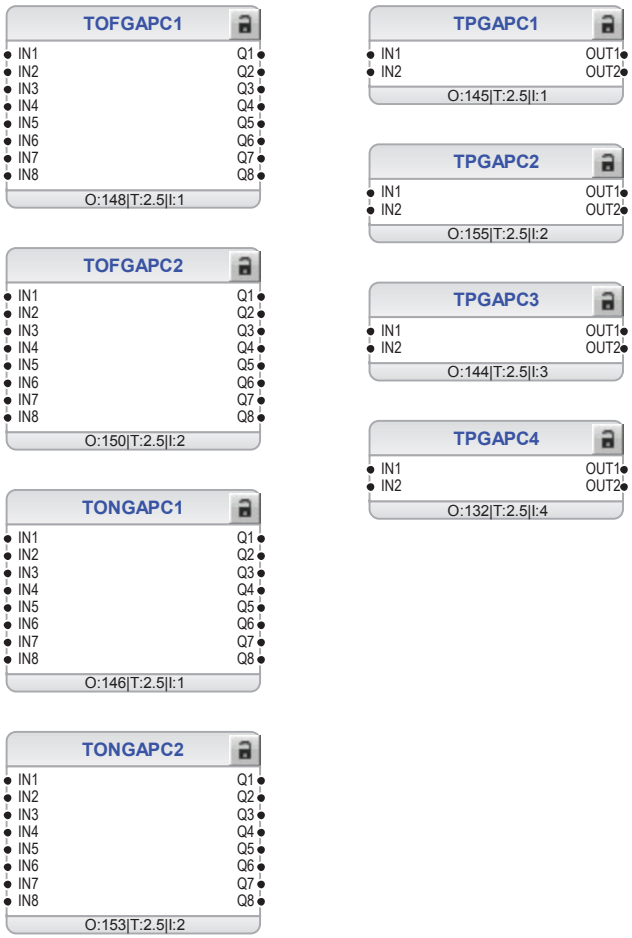


Figure 252: Programmable timers

3.7.3.8 Functional diagrams for communication

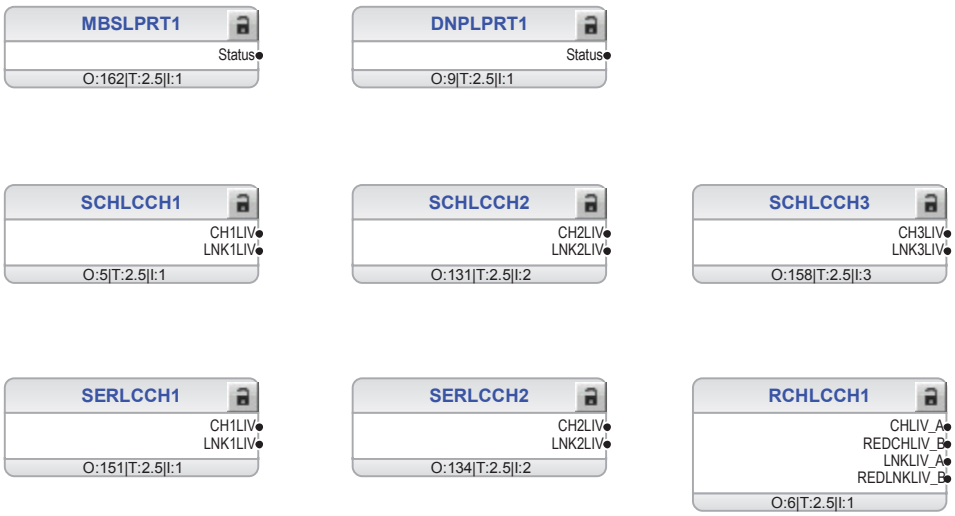


Figure 253: Default communication function connection

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for overcurrent protection

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

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

4.1.1.1 Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (F_n) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection).

Table 39: Limits of errors according to IEC 60044-1 for protective current transformers

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

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

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

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

The actual accuracy limit factor is calculated using the formula:

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

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

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

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

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

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

I_{kmax} is the highest fault current.

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

Recommended pickup current settings

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

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

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

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

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

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

4.1.1.3 Example for non-directional overcurrent protection

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

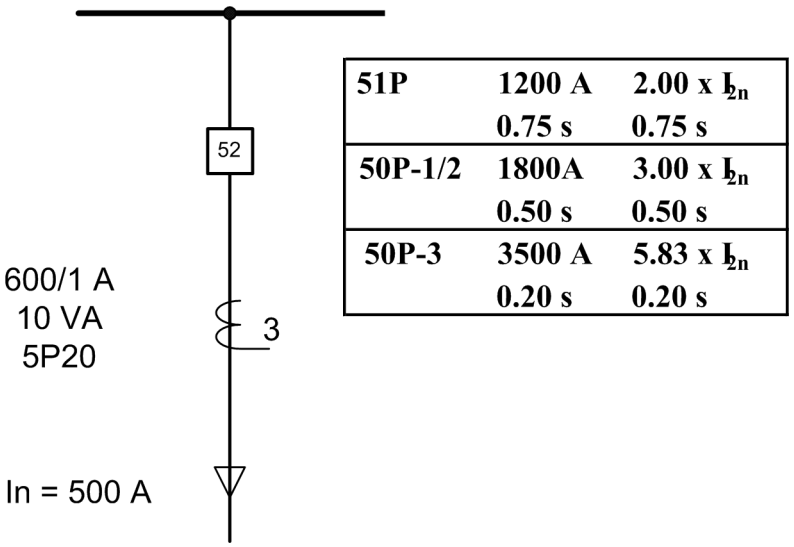


Figure 254: Example of three-stage overcurrent protection

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

The pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next protection relay (not visible in Figure 254). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the pickup current settings have to be defined so that the protection relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in Figure 254.

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

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

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

Table 40: Phase current inputs included in configurations D, F, N and P

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

5.1.1.2 Ground current

Table 41: Ground current input included in configurations D, F, N and P

Terminal	Description
X120:13-14	IG

5.1.1.3 Phase voltages

Table 42: Phase voltage inputs included in configurations F and N

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

Table 43: Phase voltage inputs included in configuration P

Terminal	Description
X130:7-8	VA(2)
X130:9-10	VB(2)
X130:11-12	VC(2)
X130:13-14	VA(1)
X130:15-16	VB(1)
X130:17-18	VC(1)

Table 44: Reference voltage input for SECRSYN1 included in configuration N

Terminal	Description
X130:9-10	V12B

5.1.1.4 Ground voltage

Table 45: Additional residual voltage input included in configurations F and N

Terminal	Description
X130:17-18	VG

5.1.1.5 Sensor inputs

Table 46: Combi sensor inputs included in configuration L

Terminal	Description
X131	IA VA
X132	IB VB
X133	IC VC

5.1.2 Auxiliary supply voltage input

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

Table 47: Auxiliary voltage supply

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

5.1.3 Binary inputs

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

Binary inputs of slot X110 are available with configurations D, F, L, N and P.

Table 48: Binary input terminals X110:1-13 with BIO0005 module

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

Table 49: Binary input terminals X110:1-10 with BIO0007 module

Terminal	Description
X110:1	BI1, +
X110:5	BI1, -
X110:2	BI2, +
X110:5	BI2, -

Table continues on next page

Terminal	Description
X110:3	BI3, +
X110:5	BI3, -
X110:4	BI4, +
X110:5	BI4, -
X110:6	BI5, +
X110:10	BI5, -
X110:7	BI6, +
X110:10	BI6, -
X110:8	BI7, +
X110:10	BI7, -
X110:9	BI8, +
X110:10	BI8, -

Binary inputs of slot X120 are available with configurations D, F, N and P.

Table 50: Binary input terminals X120-1...6

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

Binary inputs of slot X130 is optional for configuration D.

Table 51: Binary input terminals X130:1-9

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

Table continues on next page

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

Binary inputs of slot X130 are optional for configurations F and N.

Table 52: Binary input terminals X130:1-8 with AIM0006 module

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

Binary inputs of slot X130 are optional for configuration P.

Table 53: Binary input terminals X130:1-6 with AIM0007 module

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

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 flash detector.

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 flash detector option is selected when ordering a protection relay, the light sensor inputs are included in the communication module.

Table 54: 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 configuration D and with AIM0003 module in standard configurations F and N.

Table 55: Optional RTD/mA inputs with RTD0001 module

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

Table continues on next page

Terminal	Description
X130:16	RTD5 (AI7), -
X130:17	RTD6 (AI8), +
X130:18	RTD6 (AI8), -

1) Common ground for RTD channels 1-3
2) Common ground for RTD channels 4-6

Table 56: Optional RTD/mA inputs with AIM0003 module

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

5.2 Outputs

5.2.1 Outputs for tripping and controlling

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

Table 57: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCM resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCM1 input), NO
X100:19	PO3 (TCM1 input), NO

Table continues on next page

Terminal	Description
X100:20	PO4, NO (TCM resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCM2 input), NO
X100:24	PO4 (TCM2 input), NO

5.2.2 Outputs for signalling

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

Table 58: 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 D, F, L and N.

Output contacts of slot X110 are optional.

Table 59: Output contacts X110:14-24 with BIO0005

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

Table 60: Optional high-speed output contacts X110:15-24 with BIO0007

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

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

Output contacts of slot X130 are optional for configuration D.

Table 61: Output contacts X130:10-18

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

5.2.3 IRF

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

Table 62: IRF contact

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

Section 6 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
615 series	Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
AI	Analog input
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DFR	Digital fault recorder
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FTP	File transfer protocol
FTPS	FTP Secure

GOOSE	Generic Object-Oriented Substation Event
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 61850	International standard for substation communication and modeling
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IP	Internet protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
LLDB	Live line dead bus
MAC	Media access control
MCB	Miniature circuit breaker
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol

REF615	Feeder protection and control relay
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RS-232	Serial interface standard
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit
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
SNTP	Simple Network Time Protocol
SO	Signal output
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
UDP	User datagram protocol
UL	Underwriters Laboratories
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

ABB Distribution Solutions
Distribution Automation
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

ABB Inc.
655 Century Point
Lake Mary, FL 32746, USA
Phone +1-800-222 1946

www.abb.com/mediumvoltage
www.abb.com/relion
www.abb.com/substationautomation

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