RELION® 615 SERIES

Generator and Interconnection Protection
REG615
Application Manual

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Warranty

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Conformity

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

Table of contents

Section 1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

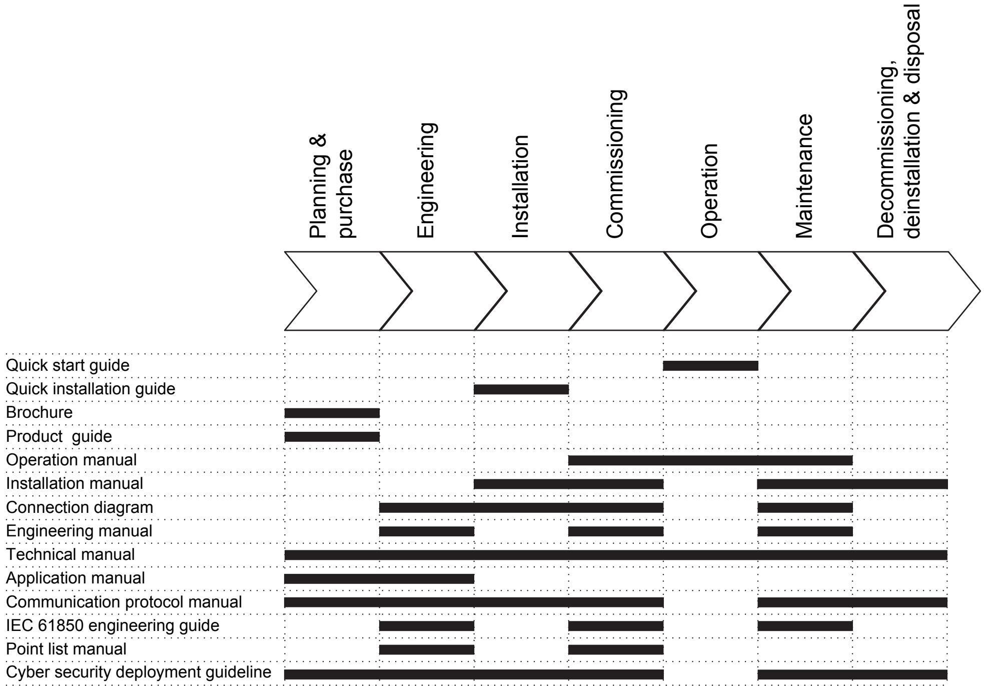


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2016-05-20	5.0 FP1	First release
B/2018-12-20	5.0 FP1	Content updated

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

1.3.3 Related documentation

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

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.
  To navigate between the options, use ↑ and ↓.
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile memory, select `Yes` and press ↵.
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67-1 (1)
	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67-2 (1)
Three-phase voltage-dependent overcurrent protection	PHPVOC1	3I(U)> (1)	51V (1)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Negative-sequence overcurrent protection for machines	MNSPTOC1	I2>M (1)	46M (1)
	MNSPTOC2	I2>M (2)	46M (2)
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U+ (1)
	PSPTUV2	U1< (2)	47U+ (2)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
	NSPTOV2	U2> (2)	47O- (2)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
	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)
Overexcitation protection	OEPVPH1	U/f> (1)	24 (1)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F (1)	49F (1)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T/G/C (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
Three-phase inrush detector	INRPHAR1	3I2f> (1)	68 (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
	TRPPTRC3	Master Trip (3)	94/86 (3)
	TRPPTRC4	Master Trip (4)	94/86 (4)
	TRPPTRC5	Master Trip (5)	94/86 (5)
	TRPPTRC6	Master Trip (6)	94/86 (6)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
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)
Stabilized and instantaneous differential protection for machines	MPDIF1	3dI>G/M (1)	87G/M (1)
Third harmonic-based stator earth-fault protection	H3EFPSEF1	dUo>/Uo3H (1)	27/59THD (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)
	DOPPDPR3	P>/Q> (3)	32R/32O (3)
Three-phase underexcitation protection	UEXPDIS1	X< (1)	40 (1)
Three-phase underimpedance protection	UZPDIS1	Z<G (1)	21G (1)
Out-of-step protection	OOSRPSB1	OOS (1)	78 (1)
Interconnection functions			
Directional reactive power undervoltage protection	DQPTUV1	Q> ->,3U< (1)	32Q,27 (1)
Low-voltage ride-through protection	LVRTPTUV1	U<RT (1)	27RT (1)
	LVRTPTUV2	U<RT (2)	27RT (2)
	LVRTPTUV3	U<RT (3)	27RT (3)
Voltage vector shift protection	VVSPPAM1	VS (1)	78V (1)
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQM3I (1)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQM3V (1)
Voltage variation	PHQVVR1	PQMU (1)	PQMV (1)
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC (1)	I <-> O ESC (1)
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (1)
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60 (1)
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM (1)
Measurement			
Disturbance recorder	RDRE1	DR (1)	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
	CMMXU2	3I (2)	3I (2)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
	VMMXU2	3U (2)	3V (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
	RESVMMXU2	Uo (2)	Vn (2)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (1)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f (1)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV	SMVRCV
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
Pulse timer (8 pcs), instance 2	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)
Time delay on (8 pcs)	TONGAPC1	TON (1)	TON (1)
	TONGAPC2	TON (2)	TON (2)
	TONGAPC3	TON (3)	TON (3)
	TONGAPC4	TON (4)	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)	SR (1)
	SRGAPC2	SR (2)	SR (2)
	SRGAPC3	SR (3)	SR (3)
	SRGAPC4	SR (4)	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)	MV (1)
	MVGAPC2	MV (2)	MV (2)
Generic control point (16 pcs)	SPCGAPC1	SPC (1)	SPC (1)
	SPCGAPC2	SPC (2)	SPC (2)
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4 (1)
	SCA4GAPC2	SCA4 (2)	SCA4 (2)
	SCA4GAPC3	SCA4 (3)	SCA4 (3)
	SCA4GAPC4	SCA4 (4)	SCA4 (4)
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4 (1)

Section 2 REG615 overview

2.1 Overview

REG615 is a dedicated generator and interconnection protection relay designed for the different power generation applications. REG615 is available in three standard configurations denoted A, C and D. Standard configuration A is intended for the interconnection protection, control, measurement and supervision of the common point of coupling distributed power generation into the utility network. Standard configurations C and D are designed for the protection, control, measurement and supervision of small or medium size generators used in diesel, gas, hydroelectric, combined heat and power (CHP), and steam power plants. REG615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series protection 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. Once the standard configuration relay has been given the application-specific settings, it can directly be put into service.

The generator protection relay provides main protection for small size power generators. The generator protection relay is also used as back-up protection for medium size generators in power applications, where an independent and redundant protection system is required. The interconnection protection relay provides main protection fulfilling the grid codes to connect distributed generation with the power grid.

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302.

2.1.1 Product version history

Product version	Product history
5.0 FP1	Product released

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- REG615 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
- 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 functions

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Power quality functions
- RTD/mA measurement
- IEC 61850-9-2 LE
- 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	Slot ID	Content options	
Plug-in unit	-	HMI	Small (5 lines, 20 characters) Large (10 lines, 20 characters) with SLD
			Small Chinese (3 lines, 8 or more characters) Large Chinese (7 lines, 8 or more characters) with SLD
	X100	Auxiliary power/BO module	48...250V 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	BIO module	8 binary inputs 4 SO contacts
			8 binary inputs 3 HSO contacts
	X120	AI/BI module	Only with configurations A and C: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1] 4 binary inputs
			Only with configuration D: 6 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1]
Case	X130	AI/BI module	3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs Additionally with configurations A and D: 1 reference voltage input for SECRSYN1 (60...210 V) Additionally with configuration C: 1 residual voltage input for H3EFPSEF1 (60...210 V)
		AI/RTD/mA module	3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA inputs 2 RTD sensor inputs Additionally with configurations A and D: 1 reference voltage input for SECRSYN1 (60...210 V) Additionally with configuration C: 1 residual voltage input for H3EFPSEF1 (60...210 V)
	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.

Rated values of the current and voltage inputs are basic setting parameters of the protection relay. The binary input thresholds are selectable within the range 16…176 V DC by adjusting the binary input setting parameters.

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

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

Table 3: Input/output overview

Std. conf.	Order code digit		Analog channels		Binary channels			
	5-6	7-8	CT	VT	BI	BO	RTD	mA
A	AE / AF	AG	4	5	16	4 PO + 6 SO	-	-
		FC	4	5	16	4 PO + 2 SO + 3 HSO	-	-
	FE / FF	AD	4	5	12	4 PO + 6 SO	2	1
		FE	4	5	12	4 PO + 2 SO + 3 HSO	2	1
C	AE / AF	AG	4	5	16	4 PO + 6 SO	-	-
		FC	4	5	16	4 PO + 2 SO + 3 HSO	-	-
	FE / FF	AD	4	5	12	4 PO + 6 SO	2	1
		FE	4	5	12	4 PO + 2 SO + 3 HSO	2	1
D	BC / BD	AD	7	5	12	4 PO + 6 SO	-	-
		FE	7	5	12	4 PO + 2 SO + 3 HSO	-	-
	BE / BF	BA	7	5	8	4 PO + 6 SO	2	1
		FD	7	5	8	4 PO + 2 SO + 3 HSO	2	1

2.4 Local HMI

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

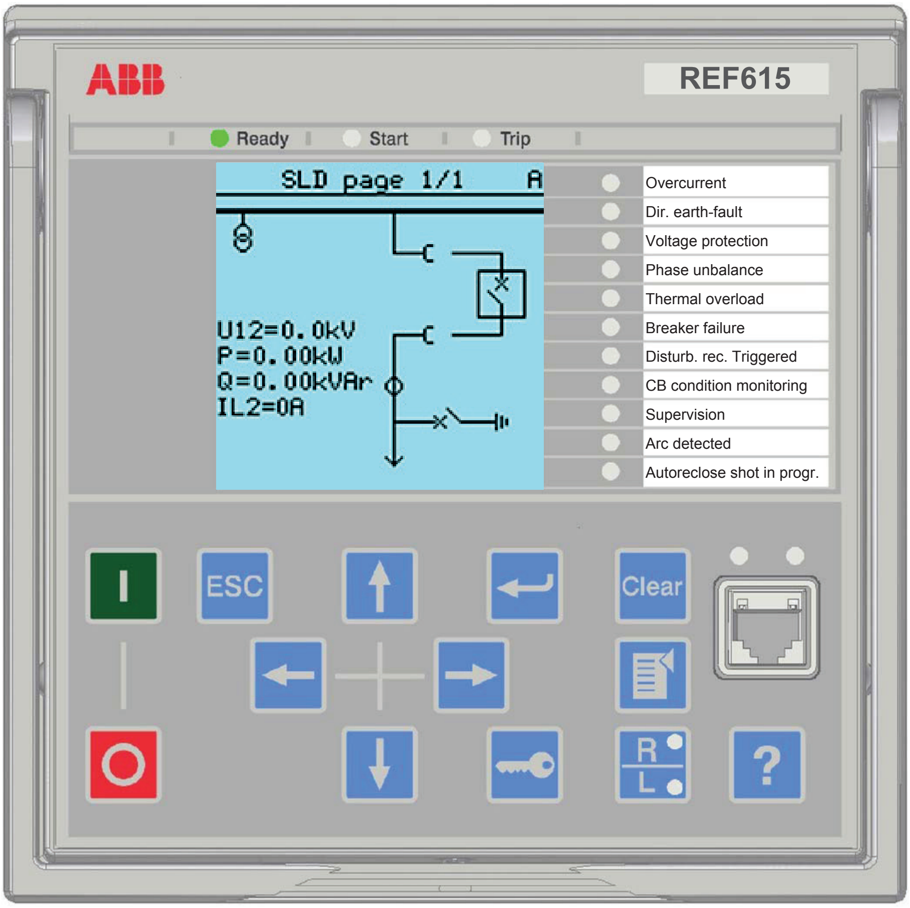


Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Small display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

1) Depending on the selected language

Table 5: Large display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20
Large, variable width (13 × 14 pixels)	7	8 or more

1) Depending on the selected language

The display view is divided into four basic areas.

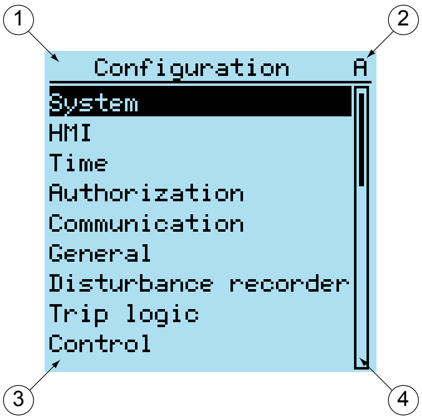


Figure 3: Display layout

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: Ready, Start and Trip.

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

2.4.3 Keypad

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

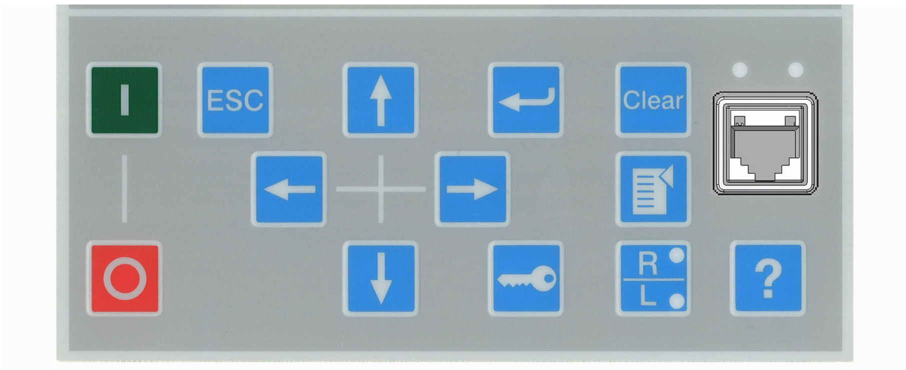


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

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

WHMI is disabled by default.

WHMI offers several functions.

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

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

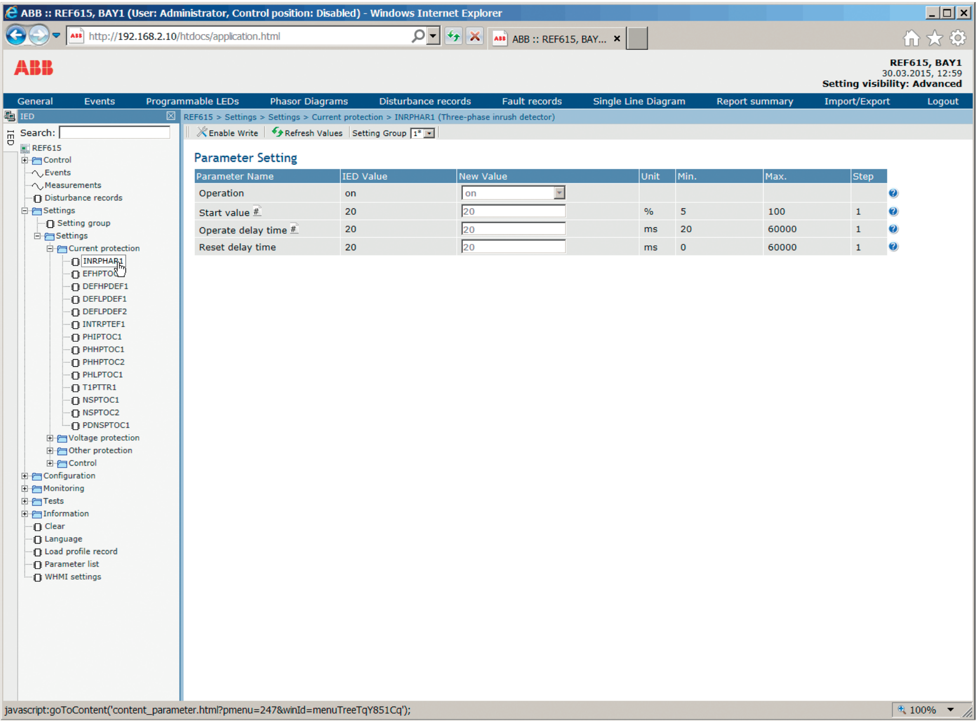


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

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

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

Table 6: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.6.1 Audit trail

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

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

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

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

Table 7: Audit trail events

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

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

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

Table 8: Comparison of authority logging levels

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

2.7 Communication

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

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices (so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Furthermore, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard.

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

All communication connectors, except for the front port connector, are placed on integrated optional communication modules.

2.7.1 Self-healing Ethernet ring

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

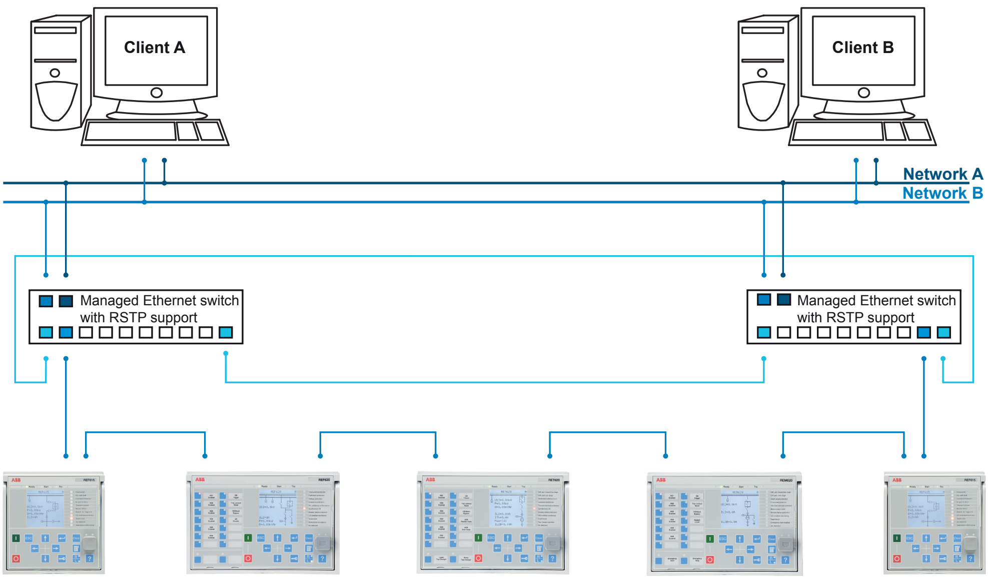


Figure 6: Self-healing Ethernet ring solution

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

2.7.2 Ethernet redundancy

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

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

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

PRP

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

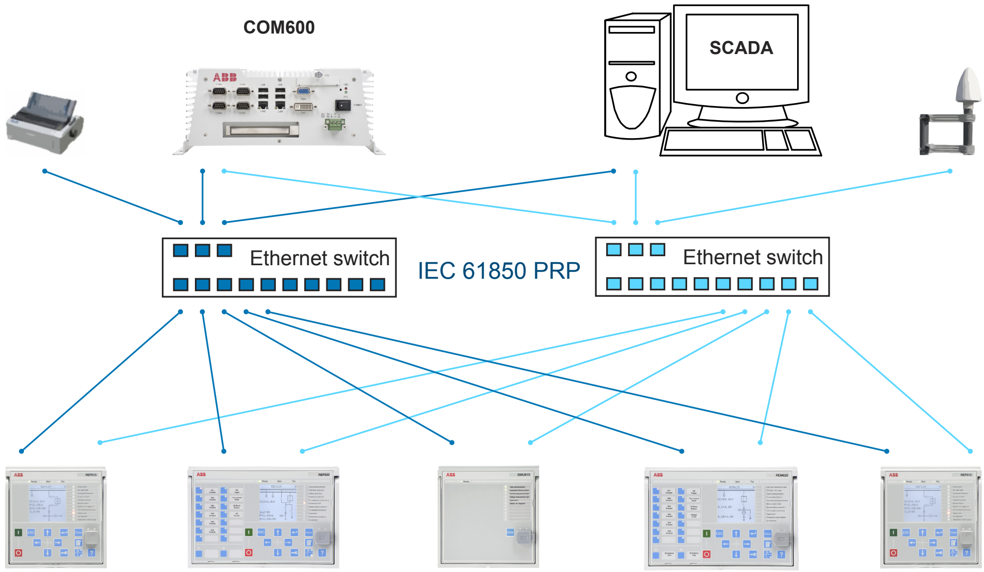


Figure 7: PRP solution

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

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

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

HSR

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

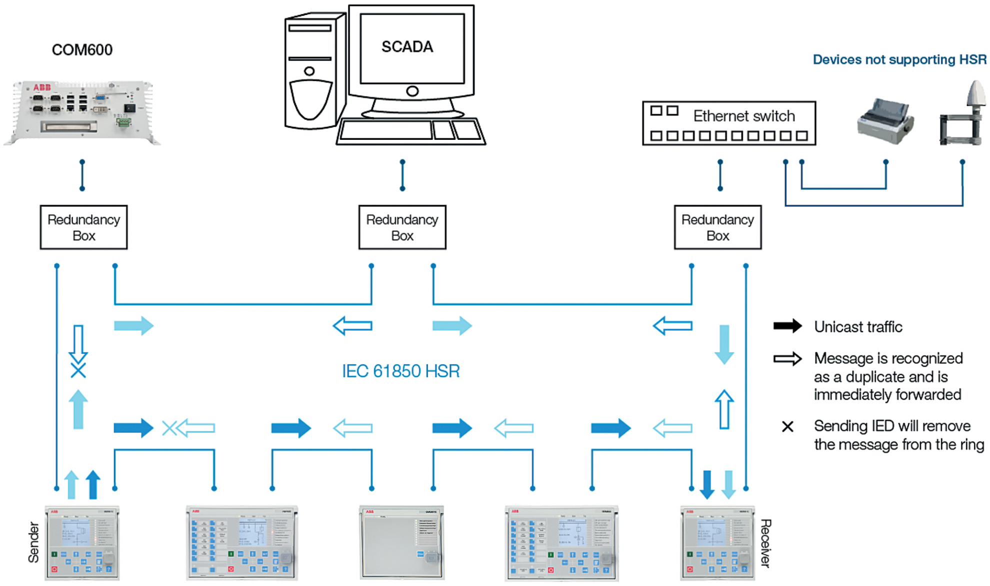


Figure 8: HSR solution

2.7.3 Process bus

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

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

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

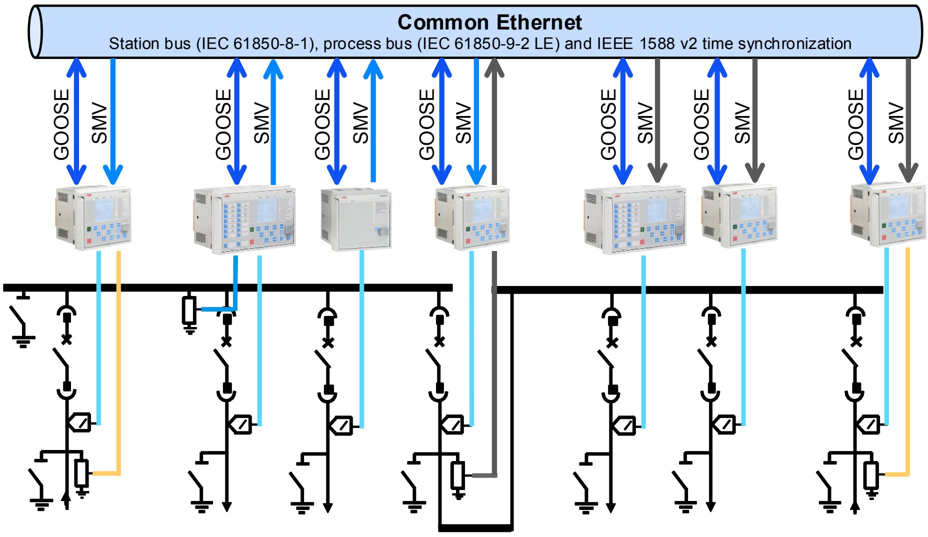


Figure 9: Process bus application of voltage sharing and synchrocheck

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

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

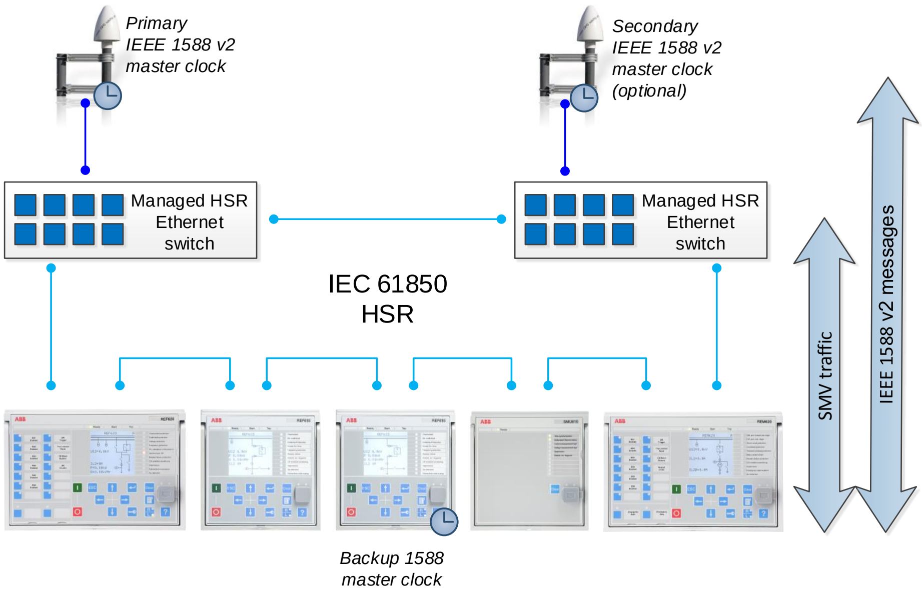


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

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

2.7.4 Secure communication

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

Section 3 REG615 standard configurations

3.1 Standard configurations

REG615 is available with three 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 protection 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 REG615 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 busbar.

Table 9: Standard configurations

Description	Std. conf.
Interconnection protection for distributed power generation	A
Generator protection with 100% stator earth-fault protection	C
Generator protection with generator differential and directional overcurrent protection and synchro-check	D

Table 10: Supported functions

Function	IEC 61850	A	C	D
Protection				
Three-phase non-directional overcurrent protection, low stage	PHLPTOC		1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC		1	1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	2		1 TR
Three-phase directional overcurrent protection, high stage	DPHHPDOC	1		1 TR
Three-phase voltage-dependent overcurrent protection	PHPVOC		1	1
Non-directional earth-fault protection, high stage	EFHPTOC	1	1	1
Directional earth-fault protection, low stage	DEFLPDEF	2	2	2
Directional earth-fault protection, high stage	DEFHPDEF	1	1	1
Transient/intermittent earth-fault protection	INTRPTEF	1 [1)]		
Negative-sequence overcurrent protection	NSPTOC	2		
Negative-sequence overcurrent protection for machines	MNSPTOC		2	2
Residual overvoltage protection	ROVPTOV	2	2	2

Table continues on next page

Function	IEC 61850	A	C	D
Three-phase undervoltage protection	PHPTUV	2	2	2
Three-phase overvoltage protection	PHPTOV	2	2	2
Positive-sequence undervoltage protection	PSPTUV	2	2	2
Negative-sequence overvoltage protection	NSPTOV	2	2	2
Frequency protection	FRPFRQ	6	6	4
Overexcitation protection	OEPVPH		1	1
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	1		
Three-phase thermal overload protection, two time constants	T2PTTR		1	1
Circuit breaker failure protection	CCBRBRF	1	1 [2)]	1 [2)]
Three-phase inrush detector	INRPHAR	1	1	1
Master trip	TRPPTRC	2 (3) [3)]	3 (3) [3)]	3 (3) [3)]
Arc protection	ARCSARC	(3)	(3) [2)]	(3) [2)]
Multipurpose protection	MAPGAPC	18	18	18
Stabilized and instantaneous differential protection for machines	MPDIF			1
Third harmonic-based stator earth-fault protection	H3EFPSEF		1	
Underpower protection	DUPPDPR		2	2
Reverse power/directional overpower protection	DOPPDPR	2	3	2
Three-phase underexcitation protection	UEXPDIS		1	1
Three-phase underimpedance protection	UZPDIS		1	
Out-of-step protection	OOSRPSB		1	1
Interconnection functions				
Directional reactive power undervoltage protection	DQPTUV	1		
Low-voltage ride-through protection	LVRTPTUV	3		
Voltage vector shift protection	VVSPPAM	1		
Power quality				
Current total demand distortion	CMHAI	(1) [4)]	(1) [4)]	(1) [4)]
Voltage total harmonic distortion	VMHAI	(1) [4)]	(1) [4)]	(1) [4)]
Voltage variation	PHQVVR	(1) [4)]	(1) [4)]	(1) [4)]
Voltage unbalance	VSQVUB	(1) [4)]	(1) [4)]	(1) [4)]
Control				
Circuit-breaker control	CBXCBR	1	1	1
Disconnector control	DCXSWI	2	2	2
Earthing switch control	ESXSWI	1	1	1
Disconnector position indication	DCSXSWI	3	3	3
Earthing switch indication	ESSXSWI	2	2	2
Synchronism and energizing check	SECRSYN	1		1
Condition monitoring and supervision				
Circuit-breaker condition monitoring	SSCBR	1	1	1
Trip circuit supervision	TCSSCBR	2	2	2
Current circuit supervision	CCSPVC	1		
Fuse failure supervision	SEQSPVC	1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1
Measurement				
Disturbance recorder	RDRE	1	1	1
Load profile record	LDPRLRC	1	1	1
Fault record	FLTRFRC	1	1	1
Three-phase current measurement	CMMXU	1	1	2
Sequence current measurement	CSMSQI	1	1	1
Residual current measurement	RESCMMXU	1	1	1
Three-phase voltage measurement	VMMXU	2	1	2
Residual voltage measurement	RESVMMXU	1	2	1

Table continues on next page

Function	IEC 61850	A	C	D
Sequence voltage measurement	VSMSQI	1	1	1
Three-phase power and energy measurement	PEMMXU	1	1	1
RTD/mA measurement	XRGGIO130	(1)	(1)	(1)
Frequency measurement	FMMXU	1	1	1
IEC 61850-9-2 LE sampled value sending 5)6)	SMVSENDER	(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) 5)6)	SMVRCV	(1)	(1)	(1)
Other				
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4
Move (8 pcs)	MVGAPC	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1	1
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = optional TR = The function block is to be used on the terminal side in the application.				

1) "Io measured" is always used.
2) "Io calculated" is always used.
3) Master trip is included and connected to the corresponding HSO in the configuration only when the BIO0007 module is used. If additionally the ARC option is selected, ARCSARC is connected in the configuration to the corresponding master trip input.
4) Power quality option includes current total demand distortion, voltage total harmonic distortion, voltage variation and voltage unbalance.
5) Available only with IEC 61850-9-2
6) Available only 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

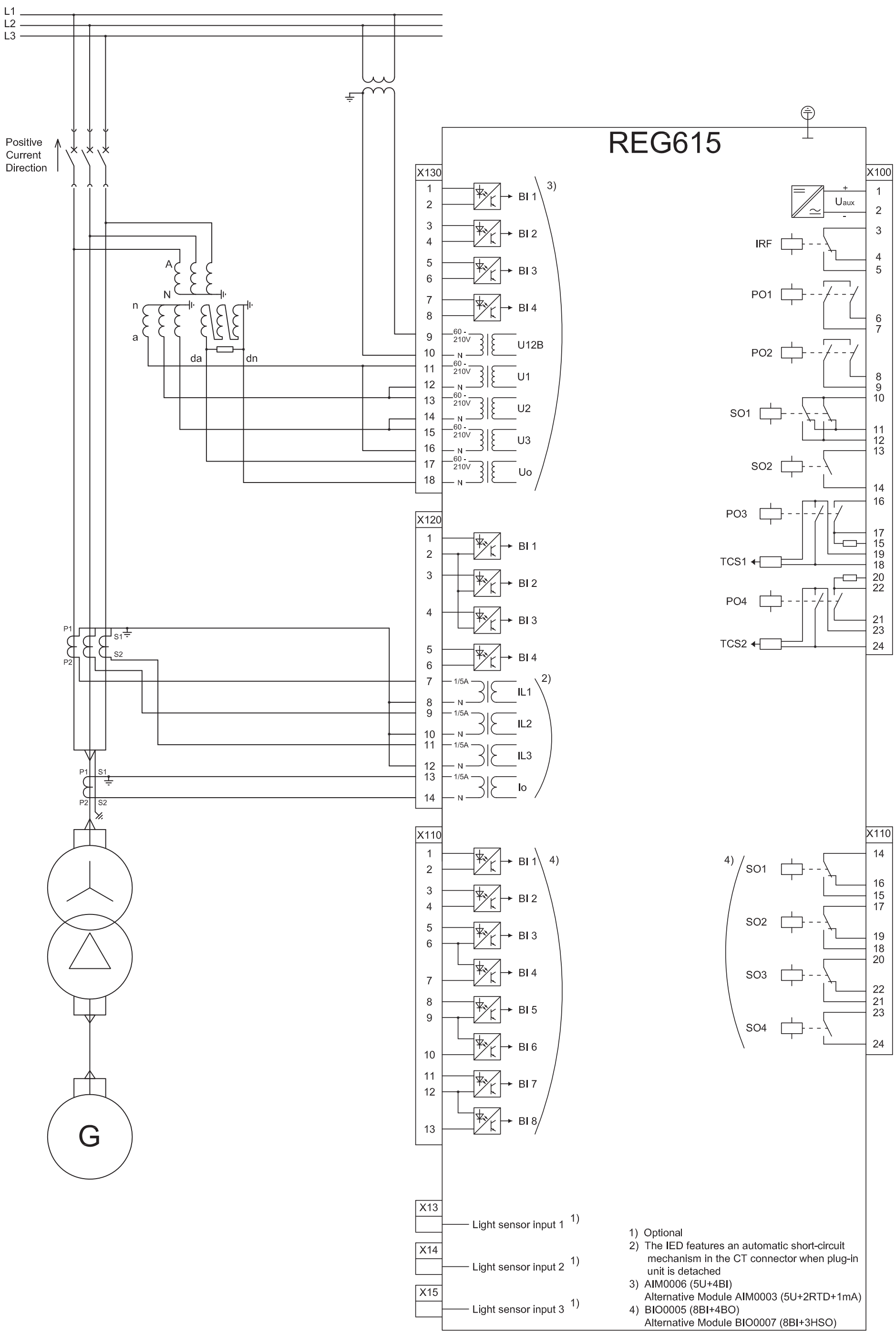


Figure 11: Connection diagram for the A configuration

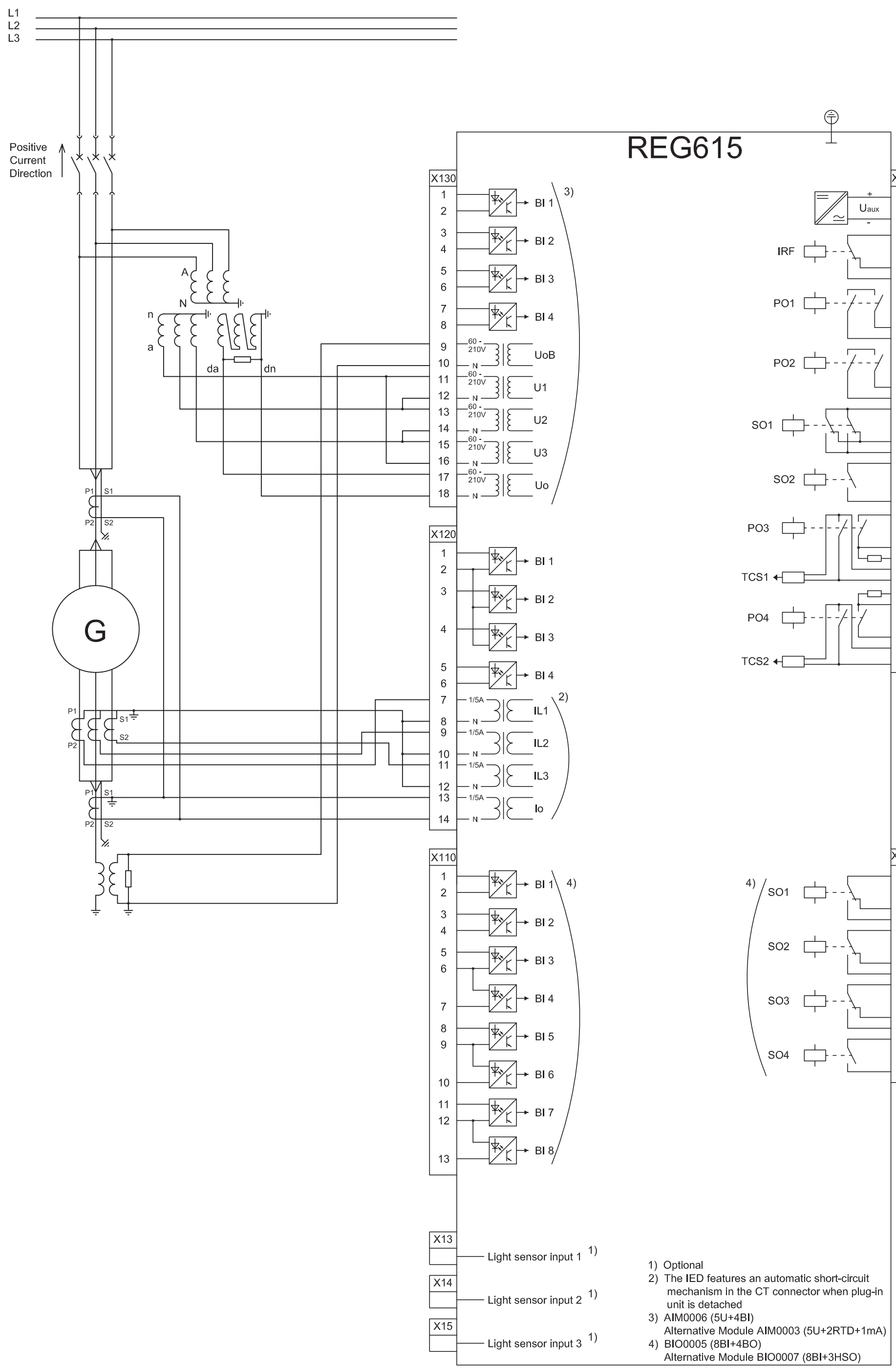


Figure 12: Connection diagram for the C configuration

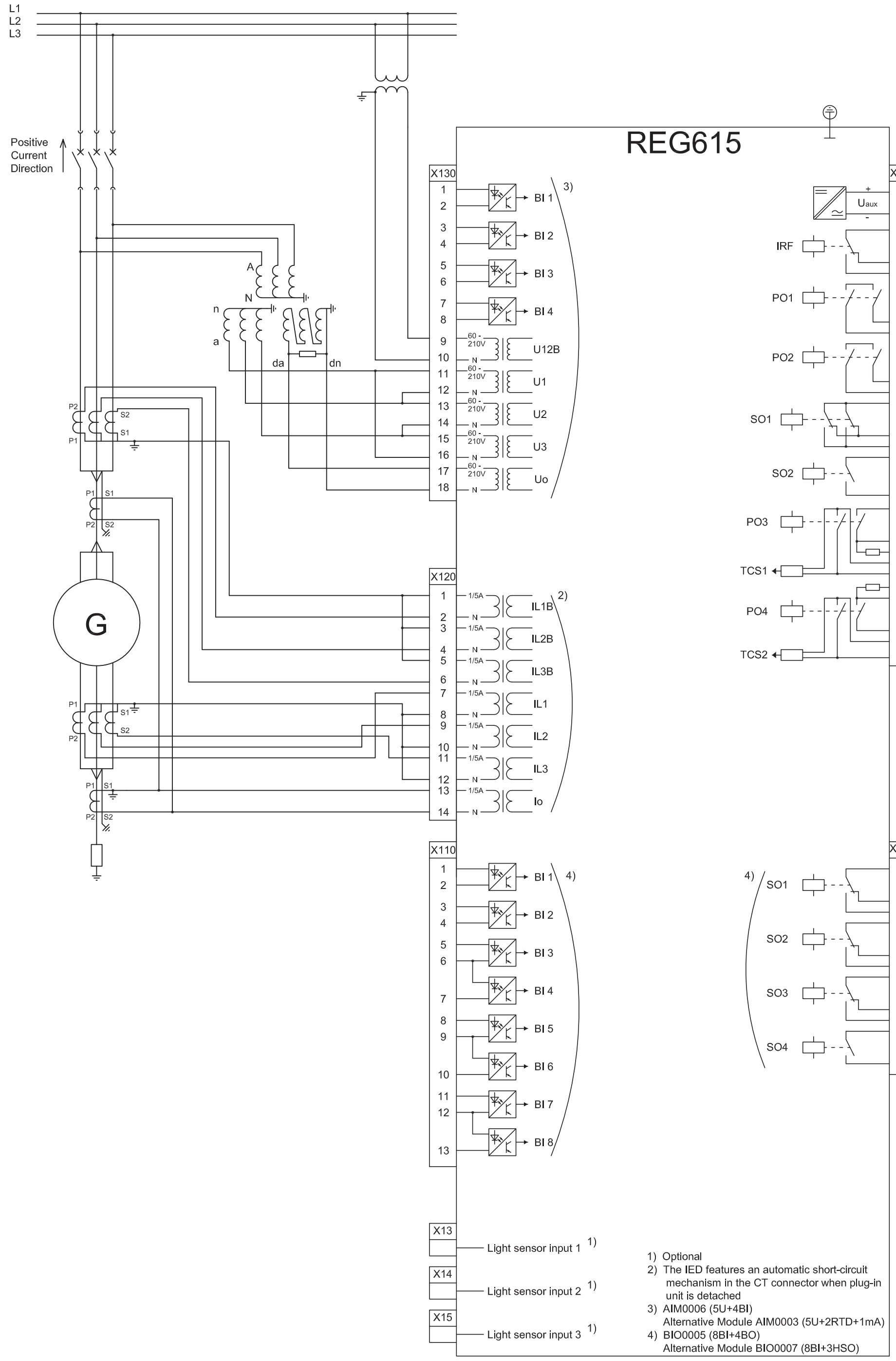


Figure 13: Connection diagram for the D configuration

3.3 Standard configuration A

3.3.1 Applications

The standard configuration with directional reactive power undervoltage and low-voltage ride-through protection, voltage vector shift and frequency-based protection is intended as interconnection protection for common point of coupling distributed power generation into the utility network.

Standard configuration A is not designed for using all the available functionality content in one relay at the same time. Directional earth-fault protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user specific configuration load is verified with the Application Configuration tool in PCM600.

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

3.3.2 Functions

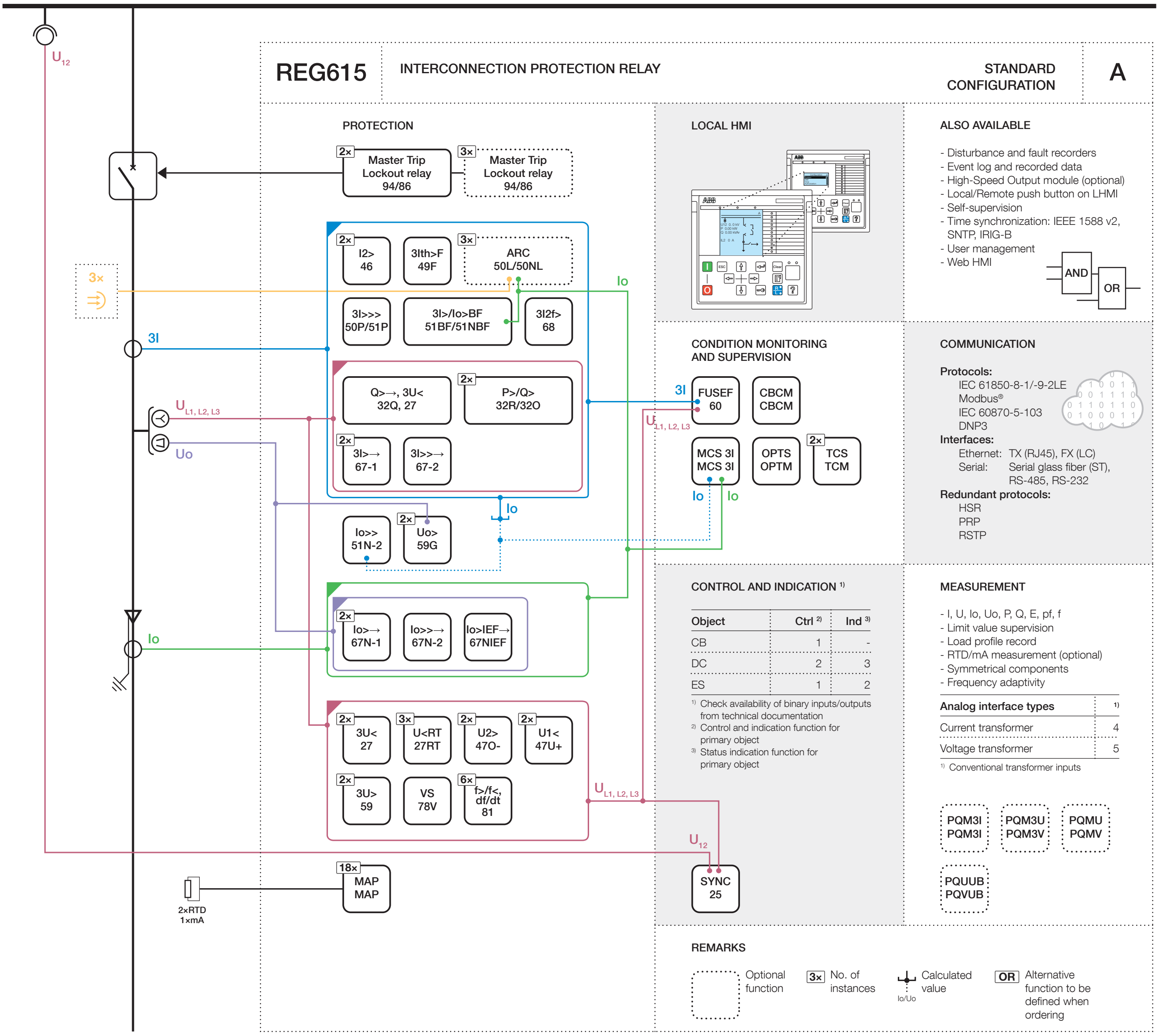


Figure 14: Functionality overview for standard configuration A

3.3.2.1 Default I/O connections

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

Table 11: Default connections for binary inputs

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

Table 12: Default connections for binary outputs

Binary output	Description
X100-PO1	Circuit breaker close command
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General protection start indication
X100-SO2	General protection operate indication
X100-PO3	Circuit breaker open command/trip 1
X100-PO4	Circuit breaker open command/trip 2
X110-SO1	Overcurrent protection operated
X110-SO2	Earth fault protection operated
X110-SO3	Voltage or frequency protection operated
X110-SO4	Interconnection protection operated
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 13: Default connections for LEDs

LED	Description
1	Interconnection protection operated
2	Power protection operated
3	Overcurrent protection operated
4	Earth-fault protection operated
5	Synchronism or energizing check ok
6	Voltage or frequency protection operated
Table continues on next page	

LED	Description
7	Thermal overload of NPS protection operated
8	Disturbance recorder triggered
9	Supervision alarms
10	Arc fault detected
11	Circuit breaker failure protection operated

3.3.2.2 Default disturbance recorder settings

Table 14: Default disturbance recorder analog channels

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

Table 15: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	DPHLPDOC1 - start	Positive or Rising
3	DPHLPDOC2 - start	Positive or Rising
4	DPHHPDOC1 - start	Positive or Rising
5	EFHPTOC1 - start	Positive or Rising
6	NSPTOC1 - start	Positive or Rising
7	NSPTOC2 - start	Positive or Rising
8	PHPTOV1 - start	Positive or Rising
9	PHPTOV2 - start	Positive or Rising
10	PHPTUV1 - start	Positive or Rising
11	PHPTUV2 - start	Positive or Rising
12	ROVPTOV1 - start	Positive or Rising
13	ROVPTOV2 - start	Positive or Rising
14	NSPTOV1 - start	Positive or Rising
Table continues on next page		

Channel	ID text	Level trigger mode
15	NSPTOV2 - start	Positive or Rising
16	PSPTUV1 - start	Positive or Rising
17	PSPTUV2 - start	Positive or Rising
18	FRPFRQ1 - start	Positive or Rising
19	FRPFRQ2 - start	Positive or Rising
20	FRPFRQ3 - start	Positive or Rising
21	FRPFRQ4 - start	Positive or Rising
22	T1PTTR1 - start	Positive or Rising
23	DOPPDPR1 - start	Positive or Rising
24	DOPPDPR2 - start	Positive or Rising
25	DQPTUV1 - start	Positive or Rising
26	LVRTPTUV1 - start	Positive or Rising
27	LVRTPTUV2 - start	Positive or Rising
28	LVRTPTUV3 - start	Positive or Rising
29	PHIPTOV1 - operate	Level trigger off
	DPHLPDOC1 - operate	
	DPHLPDOC2 - operate	
	DPHHPDOC1 - operate	
30	EFHPTOC1 - operate	Level trigger off
31	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
32	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
33	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
34	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	NSPTOV1 - operate	
	NSPTOV2 - operate	
	PSPTUV1 - operate	
	PSPTUV2 - operate	
35	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
	FRPFRQ4 - operate	
36	T1PTTR1 - operate	Level trigger off
37	DOPPDPR1 - operate	Level trigger off
	DOPPDPR2 - operate	
38	DQPTUV1 - operate	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
39	LVRTPTUV1 - operate	Level trigger off
	LVRTPTUV2 - operate	
	LVRTPTUV3 - operate	
40	VVSPPAM1 - operate	Positive or Rising
41	ARCSARC1 - operate	Positive or Rising
42	ARCSARC2 - operate	Positive or Rising
43	ARCSARC3 - operate	Positive or Rising
44	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
45	SEQSPVC1 - fusef 3ph	Level trigger off
46	CCSPVC1 - fail	Level trigger off
47	INRPHAR1 - blk2h	Level trigger off
48	VVSPPAM1 - int blkd	Level trigger off
49	CCBRBRF1 - trret	Level trigger off
50	CCBRBRF1 - trbu	Level trigger off
51	X110BI1 - CB closed	Level trigger off
52	X110BI2 - CB open	Level trigger off

3.3.3 Functional diagrams

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

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

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

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. The Application Configuration tool also includes fixed Boolean signals TRUE and FALSE which can be used according to the application needs.

3.3.3.1 Functional diagrams for protection

The functional diagrams describe the relay 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. Three-phase non-directional overcurrent protection, instantaneous stage, PHIPTOC1 can be blocked by activation of inrush protection.

Figure 15: Overcurrent protection function

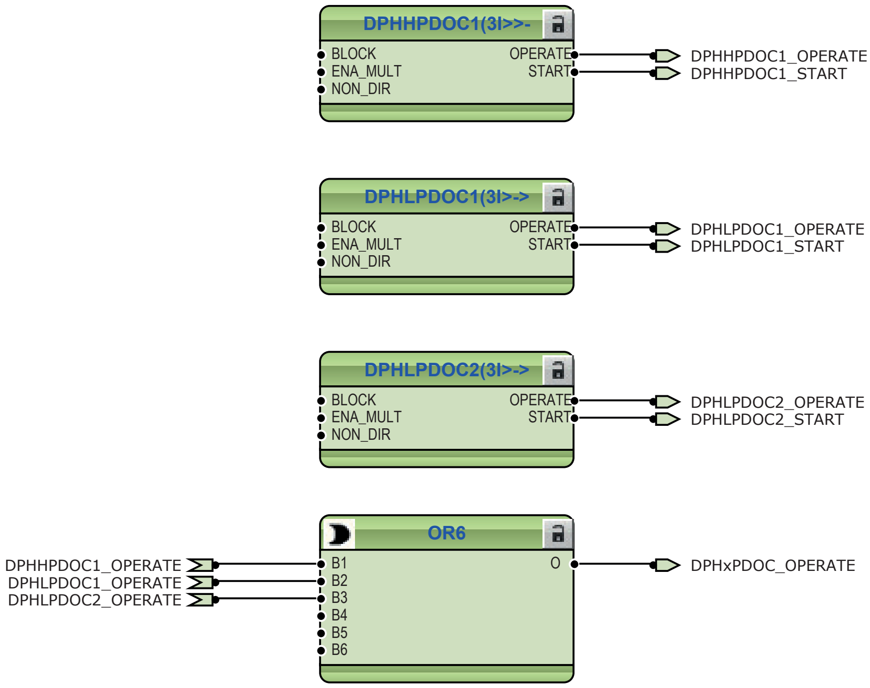


Figure 16: Directional overcurrent protection function

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

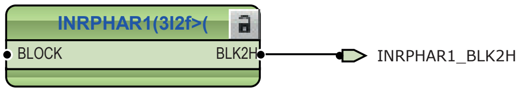


Figure 17: Inrush detector function

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

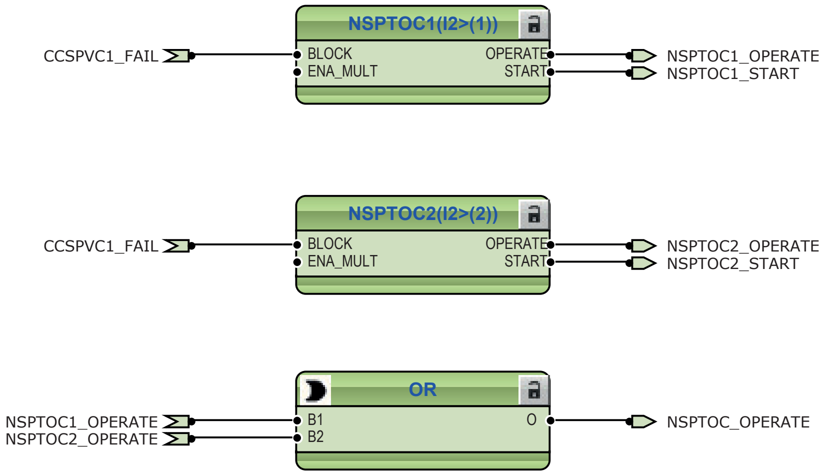


Figure 18: Negative sequence overcurrent protection function

One non-directional sensitive earth-fault stage EFHPTOC1 is offered for earth-fault protection.

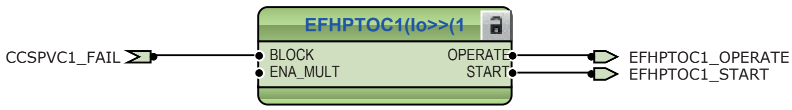


Figure 19: Earth-fault protection function

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

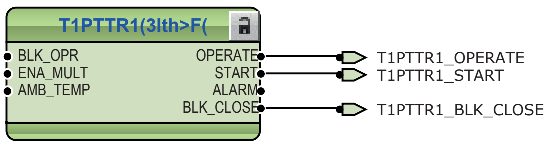


Figure 20: Thermal overcurrent protection function

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

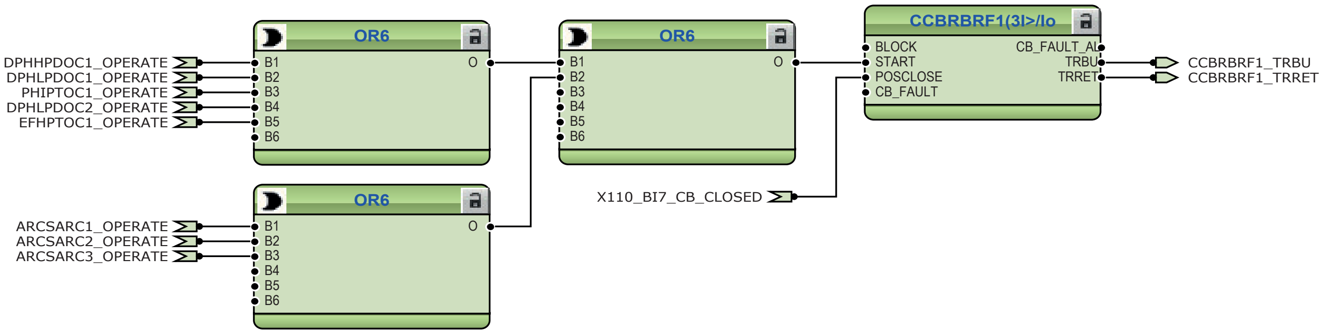


Figure 21: Circuit breaker failure protection function

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

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

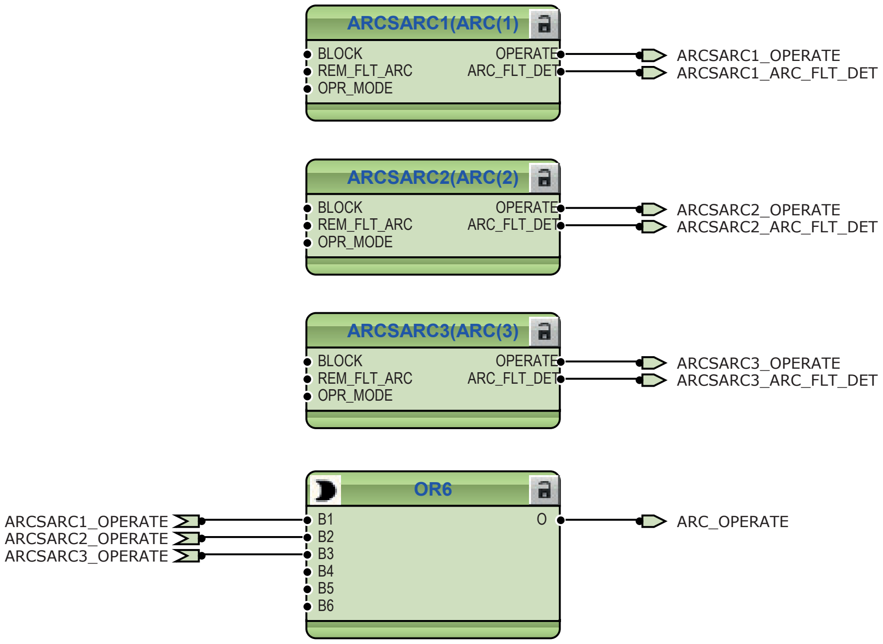


Figure 22: Arc protection function

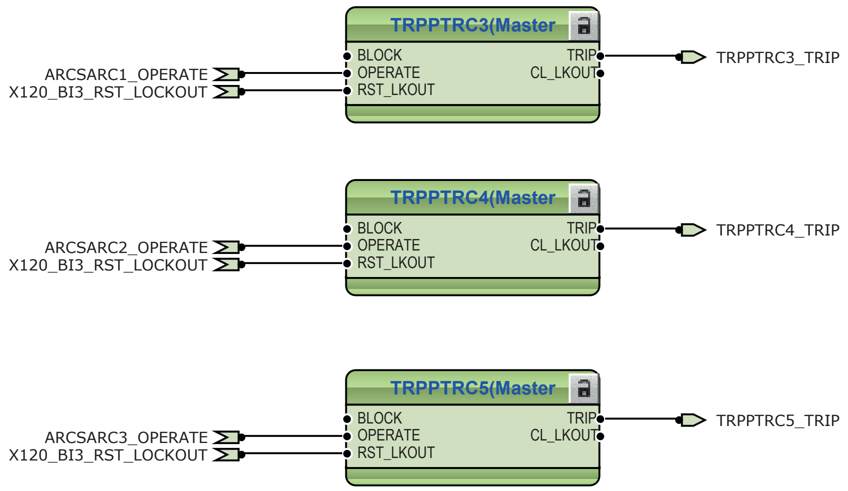


Figure 23: Arc protection with dedicated HSO

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

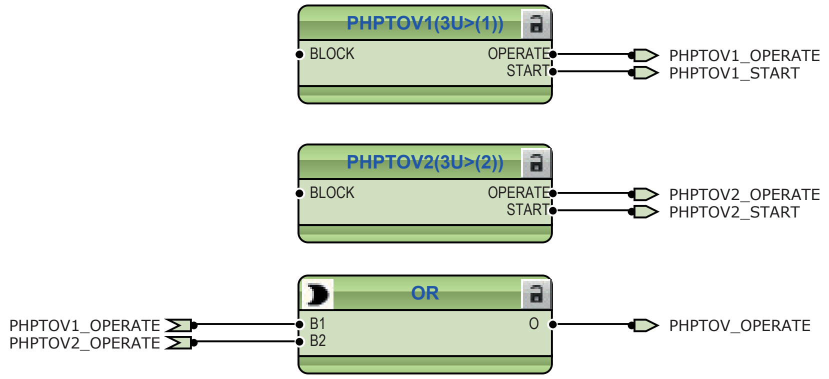


Figure 24: Overvoltage protection function

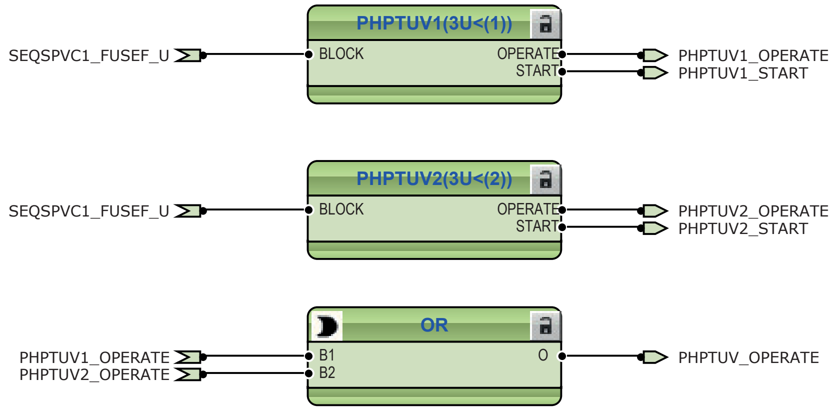


Figure 25: Undervoltage protection function

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

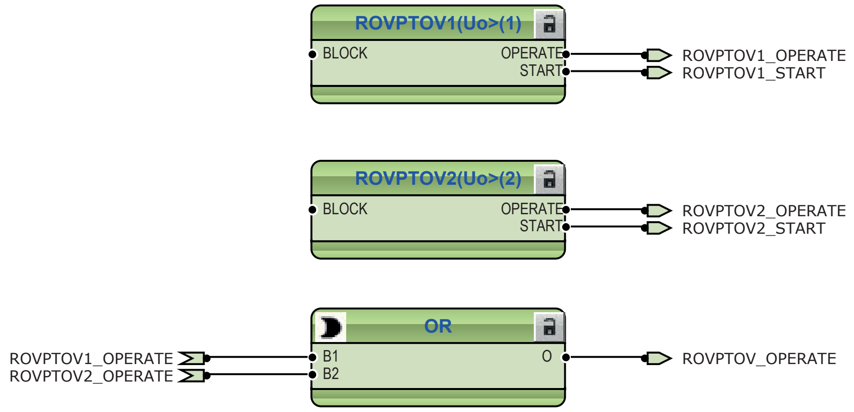


Figure 26: Residual overvoltage protection function

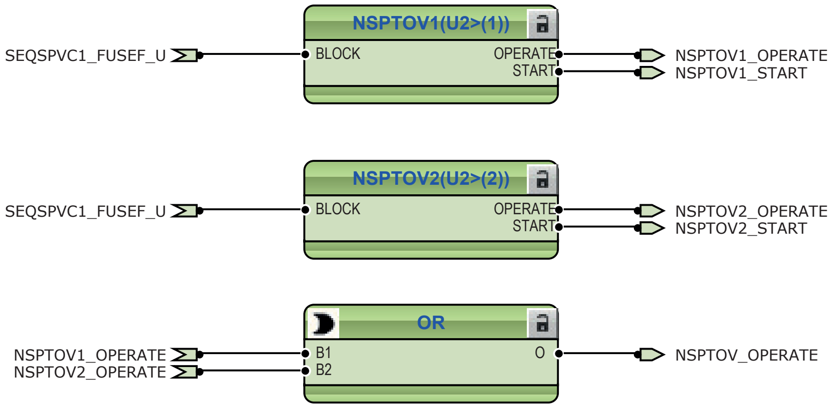


Figure 27: Negative sequence overvoltage protection function

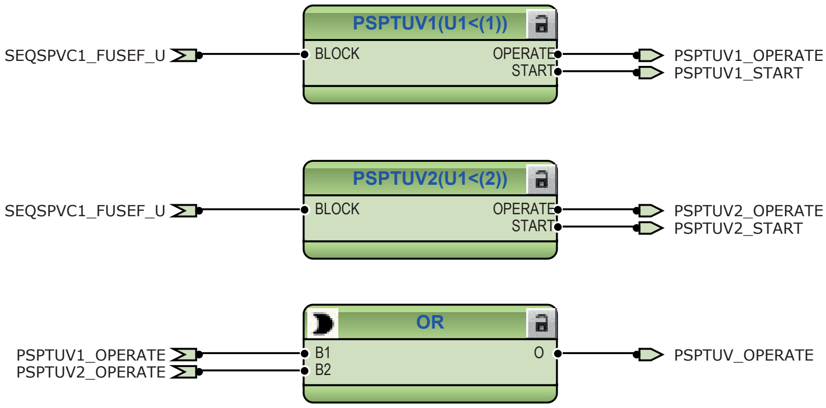


Figure 28: Positive sequence undervoltage protection function

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

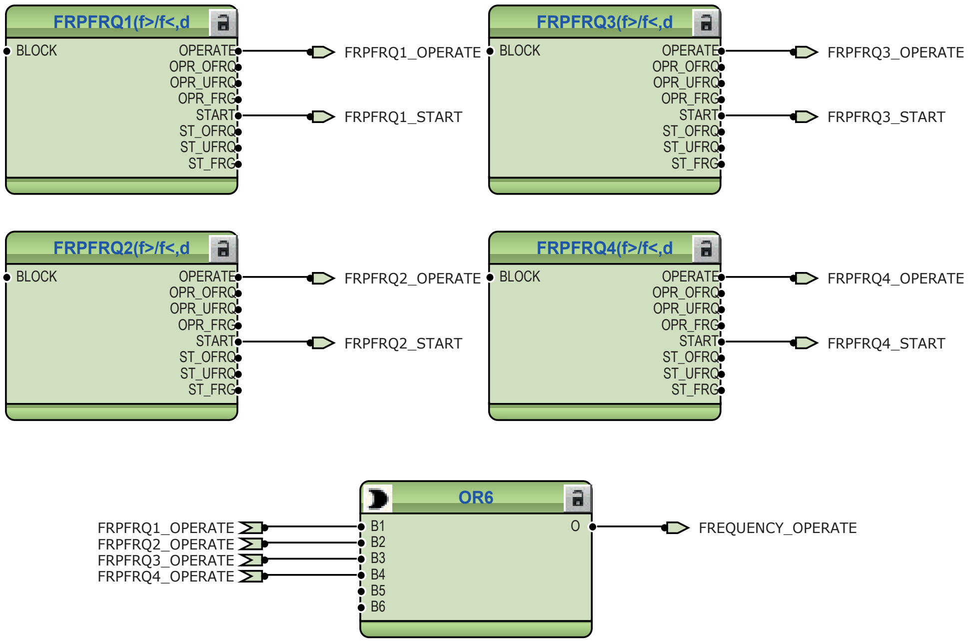


Figure 29: Frequency protection function

Two instances of directional overpower protection are provided for indicating overload on the system, which can be used for protecting the transformer from delivering excessive load or to indicate that a customer is supplying power into the grid.

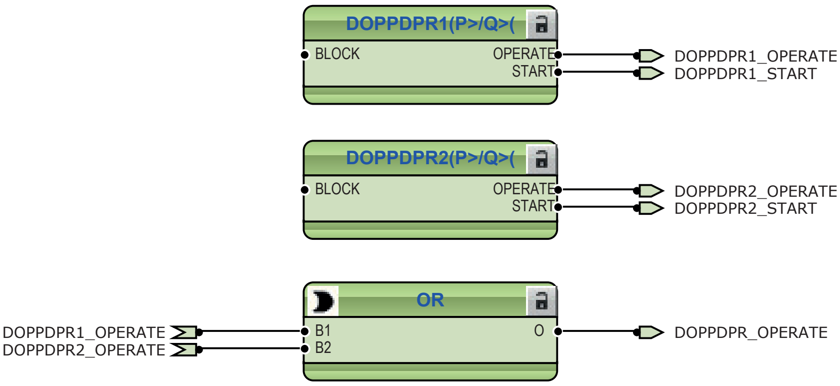


Figure 30: Directional overpower protection function

Configuration includes interconnection protection functions directional reactive power undervoltage protection DQPTUV1, voltage vector shift protection VVSPPAM1 and three stages of low-voltage ride-through protection LVRTPTUV. These functions can be used in the common point of coupling, depending on the selected setting to disconnect the distributed power generation to support utility grid stability and to detect islanding. They can also be used to disconnect the distributed generator from common point of coupling. A failure in the voltage measuring circuit detected by the fuse failure function is used to block LVRTPTUV and DQPTUV1 protection functions.

Figure 31: Reactive power undervoltage protection function

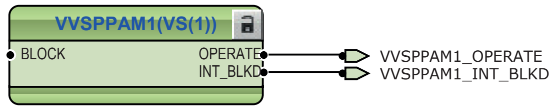


Figure 32: Vector shift protection function

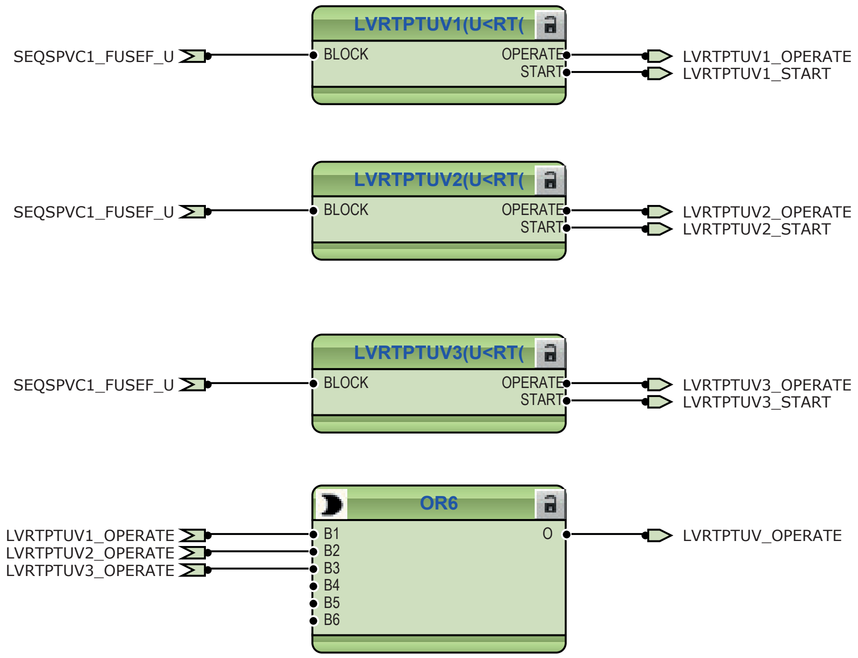


Figure 33: Low voltage ride through protection function

General start and operate signals from all 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.

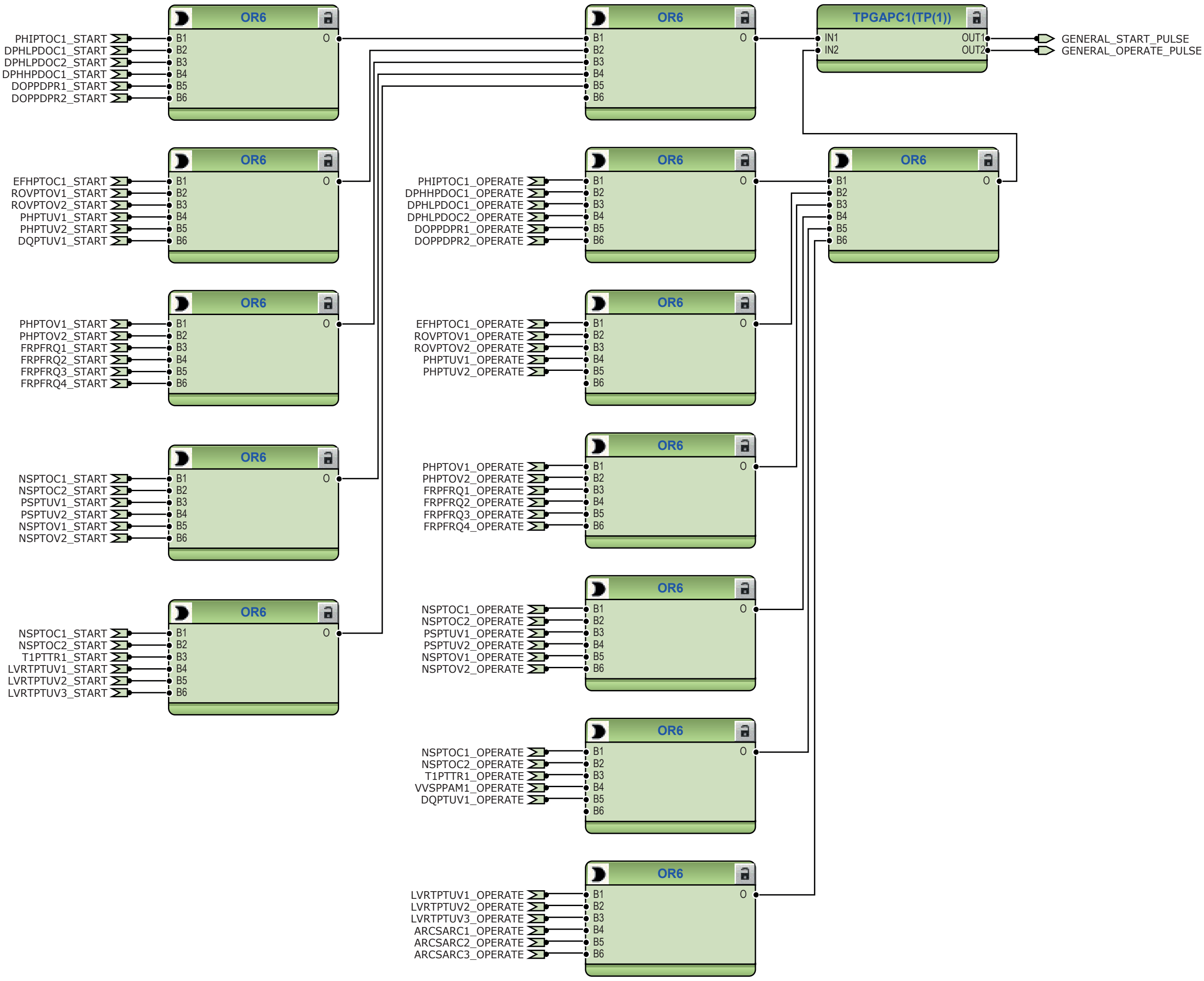


Figure 34: General start and operate signal

The operating signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO4. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X120:BI3 is assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

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

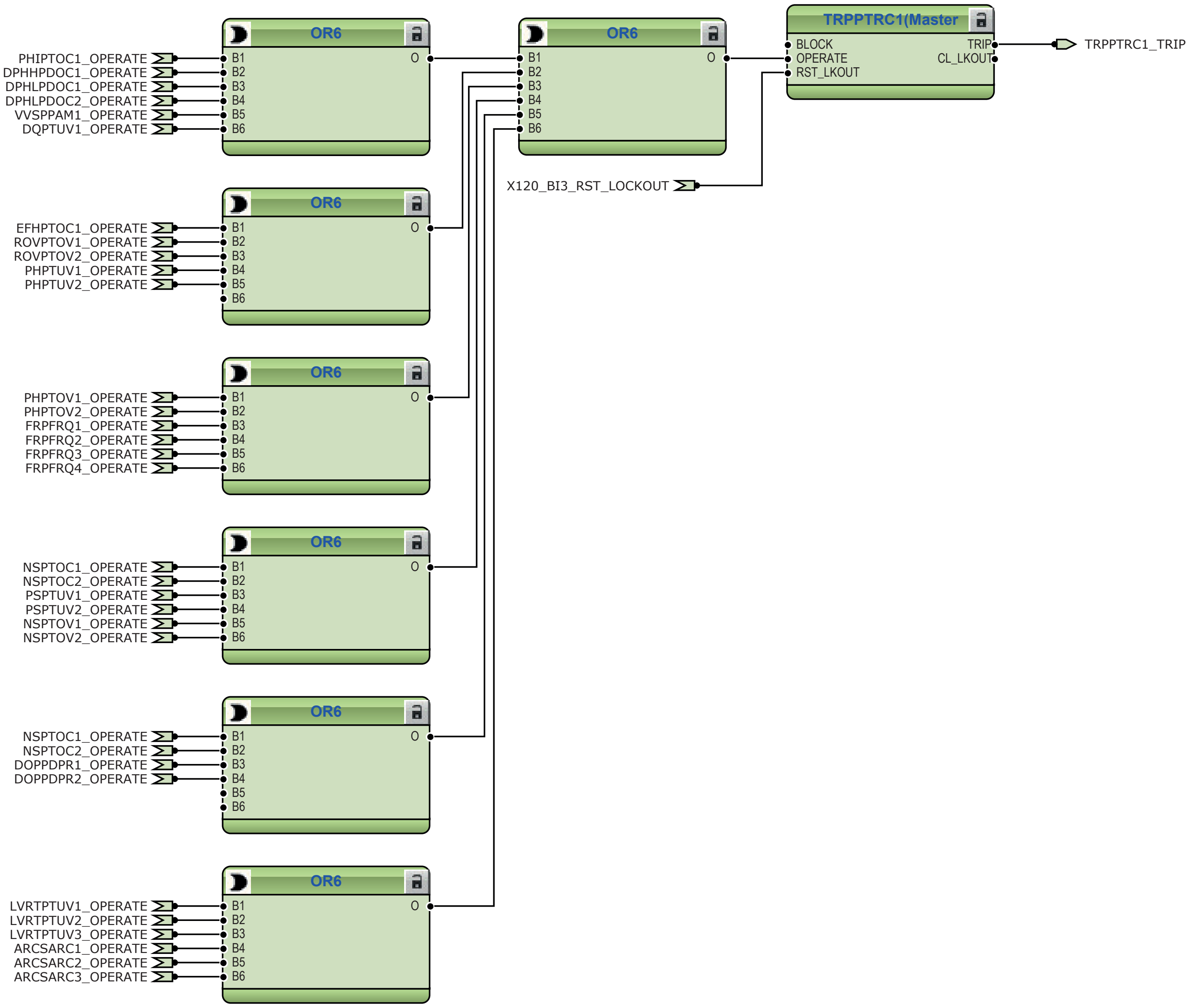


Figure 35: Trip logic TRPPTRC1

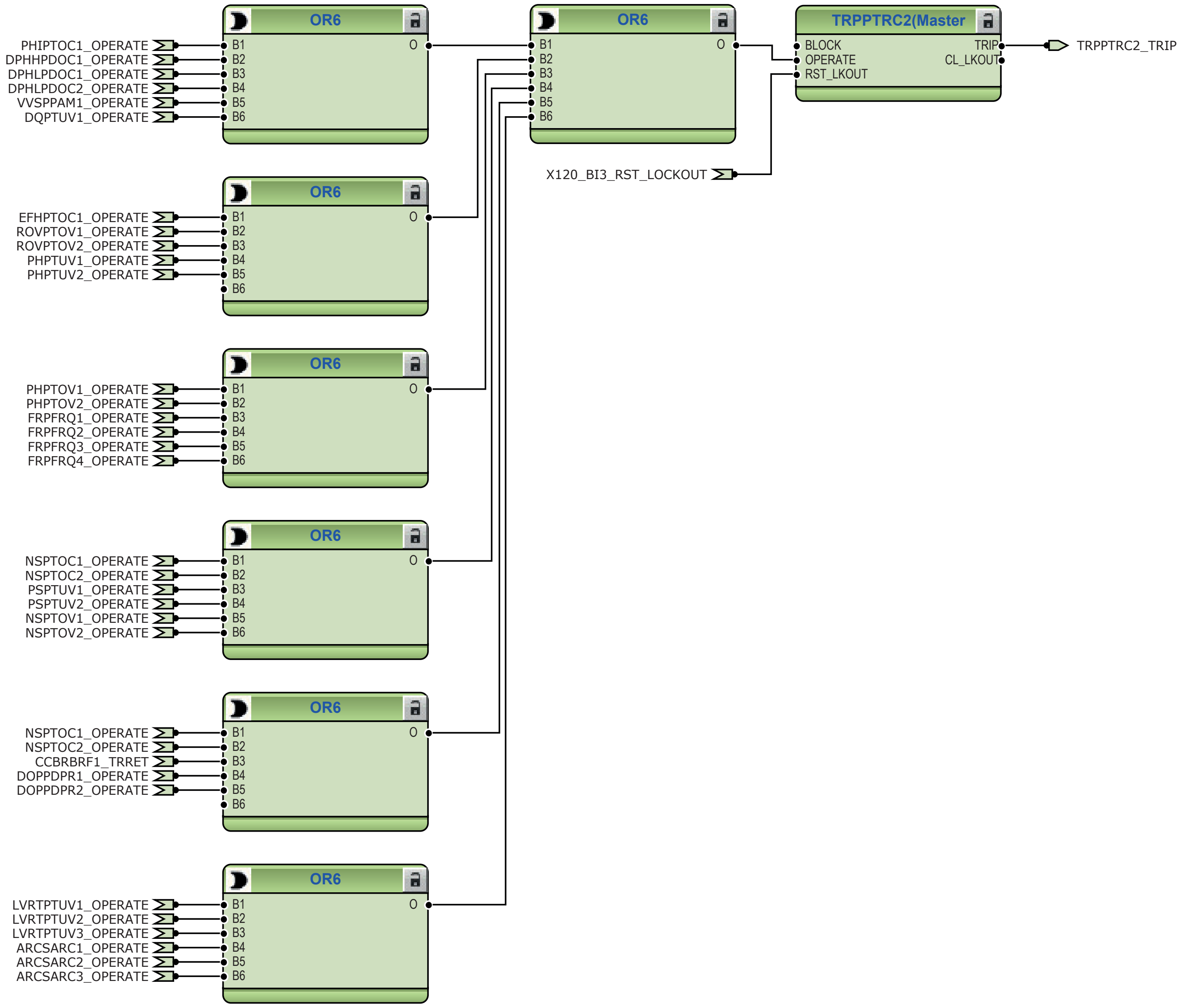


Figure 36: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

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

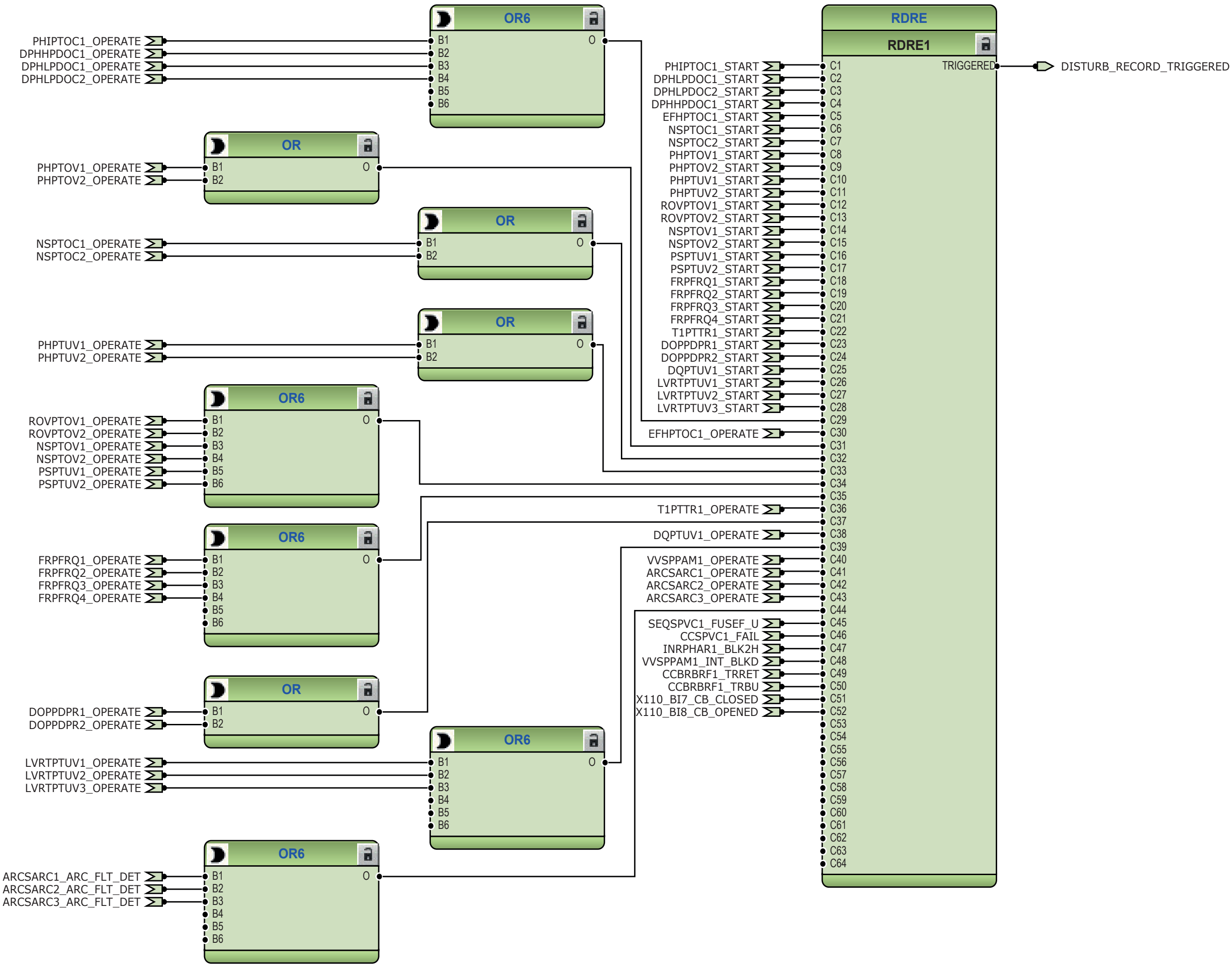


Figure 37: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

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

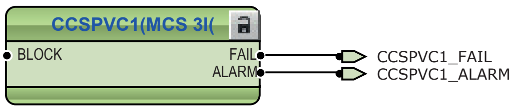


Figure 38: Current circuit supervision function

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

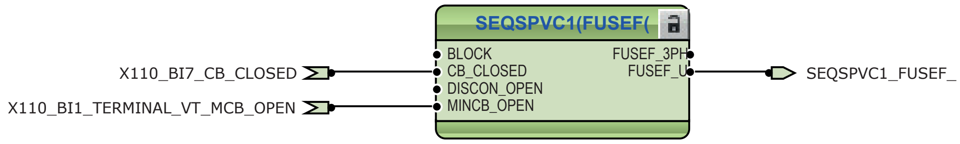


Figure 39: Fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

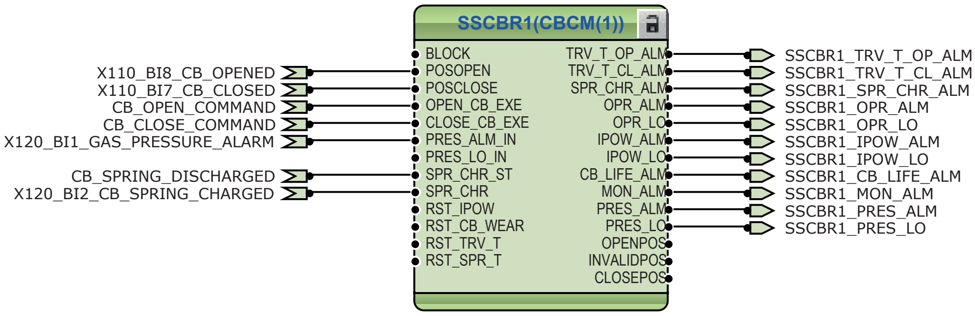


Figure 40: Circuit breaker condition monitoring function

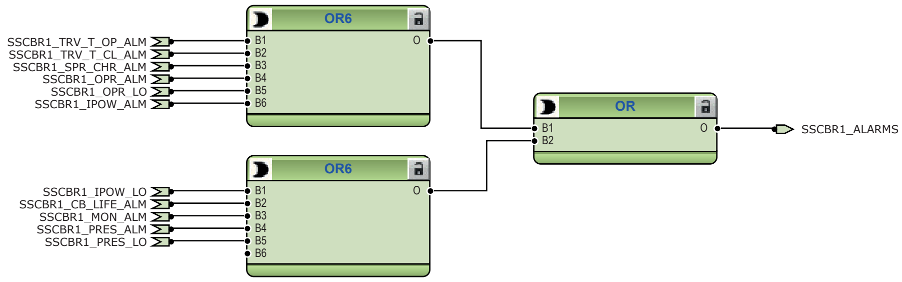


Figure 41: Logic for circuit breaker monitoring alarm

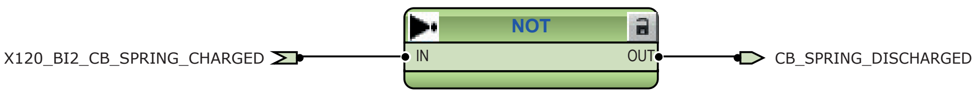


Figure 42: Logic for start of circuit breaker spring charging

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

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

Set the parameters for TCSSCBR1 properly.

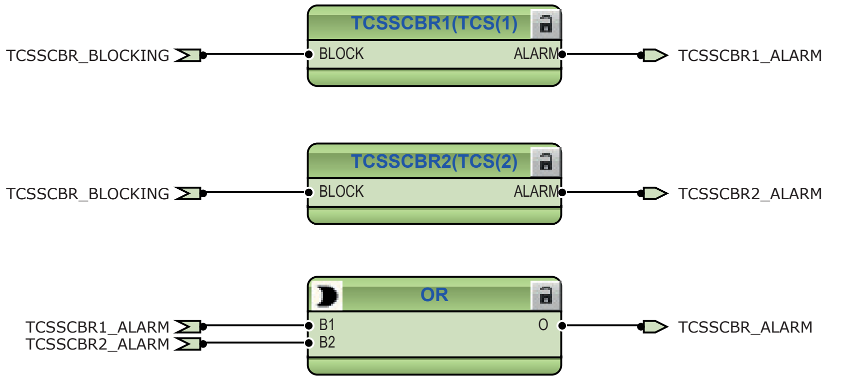


Figure 43: Trip circuit supervision function

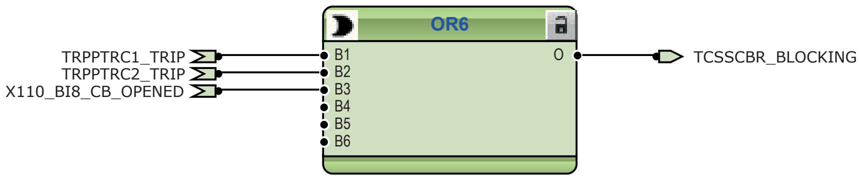


Figure 44: Logic for blocking of trip circuit supervision

3.3.3.4 Functional diagrams for control and interlocking

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

SECRSYN measures the bus and line voltages and compares them to set the conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for allowing closing or closing the circuit breaker. The `SECRSYN1_SYNC_OK` output signal of SECRSYN is connected to `SYNC_OK` input of CBXCBR through control logic. The function is blocked in case of terminal side or bus side MCB is open.

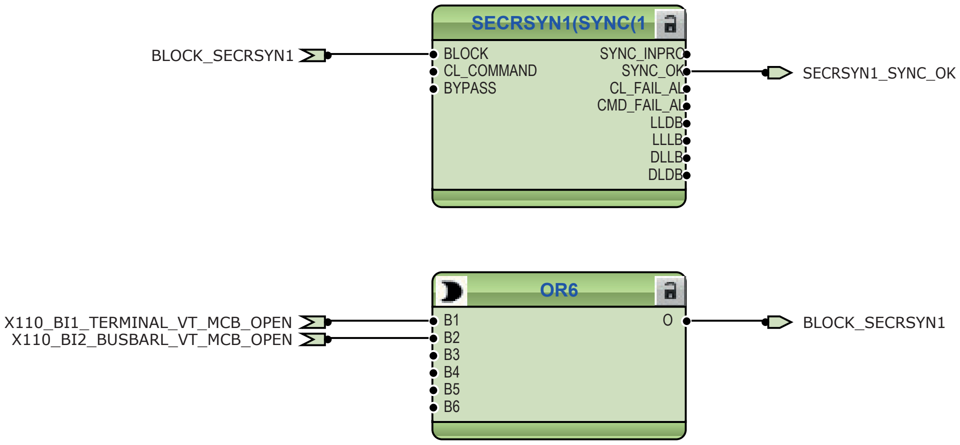


Figure 45: Synchrocheck function

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

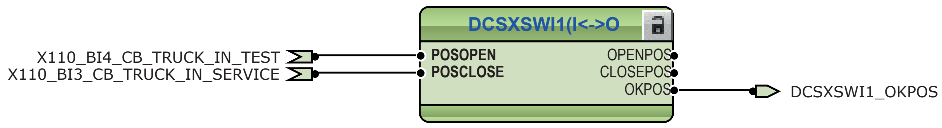


Figure 46: Disconnector control logic

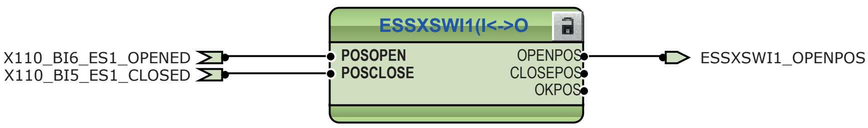


Figure 47: Earth switch control logic

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

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

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

SYNC_ITL_BYP overrides, for example, active interlocking conditions when the circuit breaker truck is closed in service position.

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

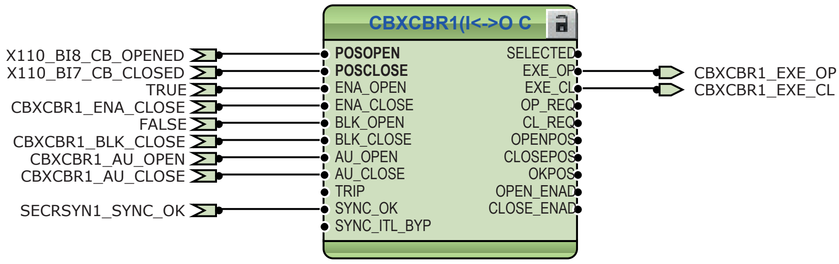


Figure 48: Circuit breaker 1 control logic

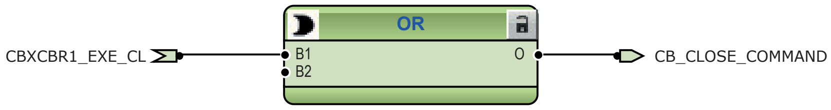


Figure 49: Signal for closing coil of circuit breaker 1

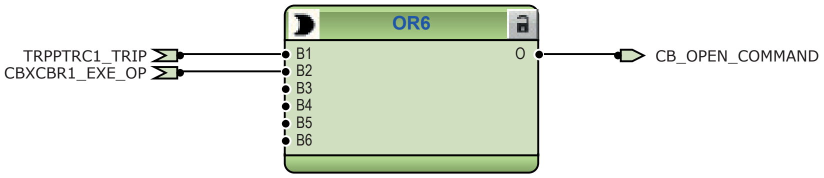


Figure 50: Signal for opening coil of circuit breaker 1

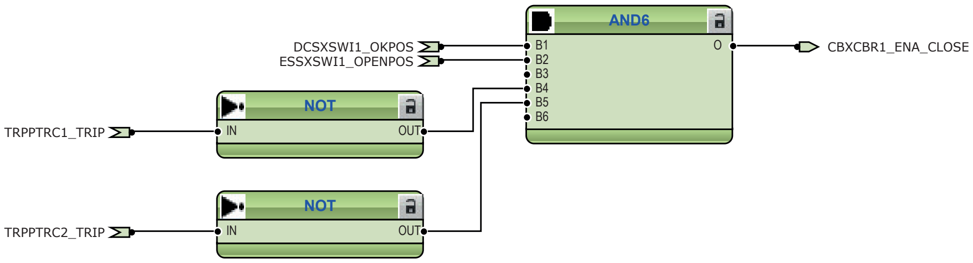


Figure 51: Circuit breaker 1 close enable logic

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

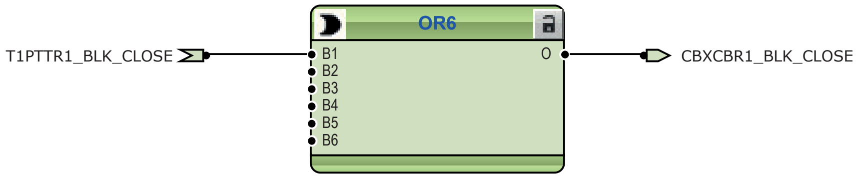


Figure 52: Circuit breaker 1 close blocking logic

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

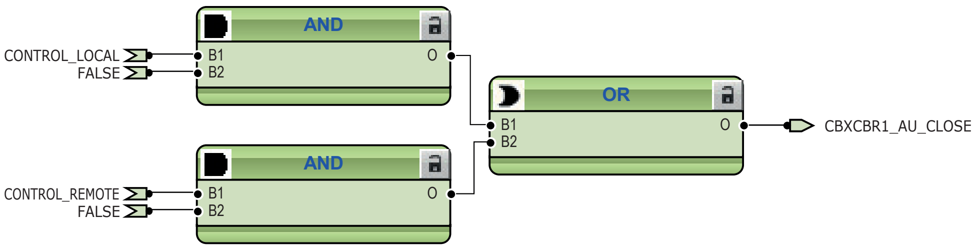


Figure 53: External closing command for circuit breaker 1

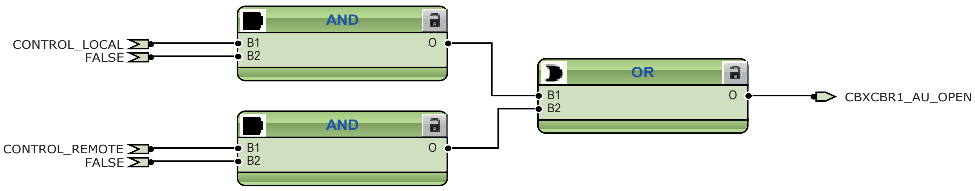


Figure 54: External opening command for circuit breaker 1

3.3.3.5 Functional diagram 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. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase line side phase voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1 whereas the bus side voltage input to the relay is measured by the three-phase voltage measurement function VMMXU2. The three-phase 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 on the line side.

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 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.

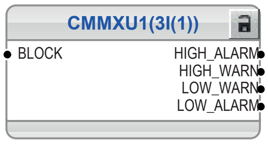


Figure 55: Current measurement: Three-phase current measurement

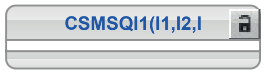


Figure 56: Current measurement: Sequence current measurement

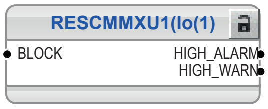


Figure 57: Current measurement: Residual current measurement

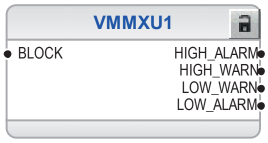


Figure 58: Voltage measurement: Three-phase voltage measurement (Terminal side)

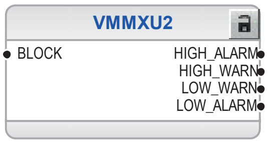


Figure 59: Voltage measurement: Three-phase voltage measurement (Bus side)

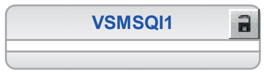


Figure 60: Voltage measurement: Sequence voltage measurement

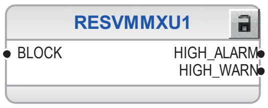


Figure 61: Voltage measurement: Residual voltage measurement

Figure 62: Other measurement: Frequency measurement

Figure 63: Other measurement: Three phase power and energy measurement

Figure 64: Other measurement: Data monitoring

Figure 65: Other measurement: Load profile record

3.3.3.6 Functional diagrams for IOs and alarm LEDs

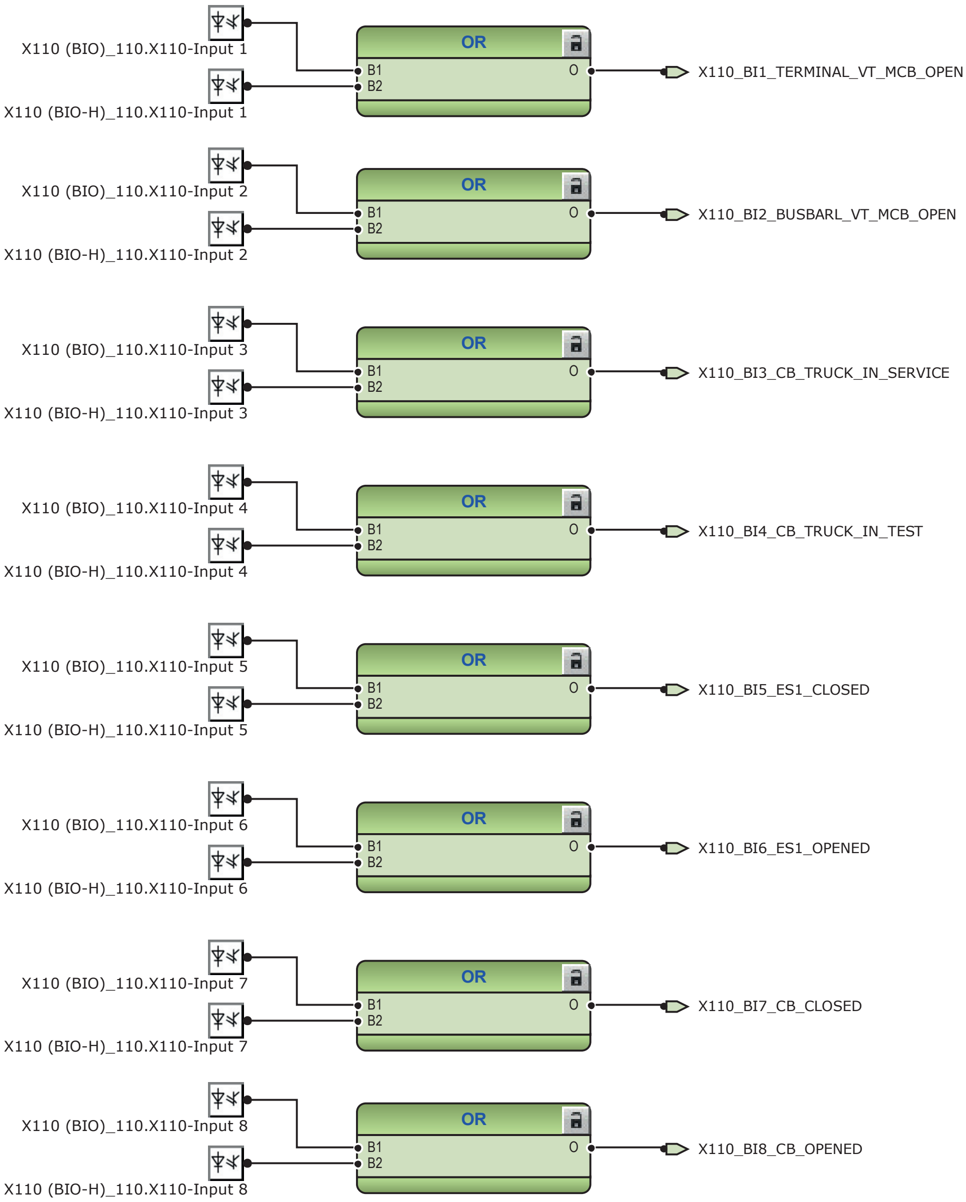


Figure 66: Default binary input - X110

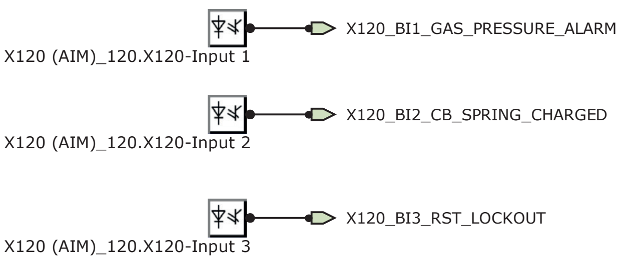


Figure 67: Default binary input - X120

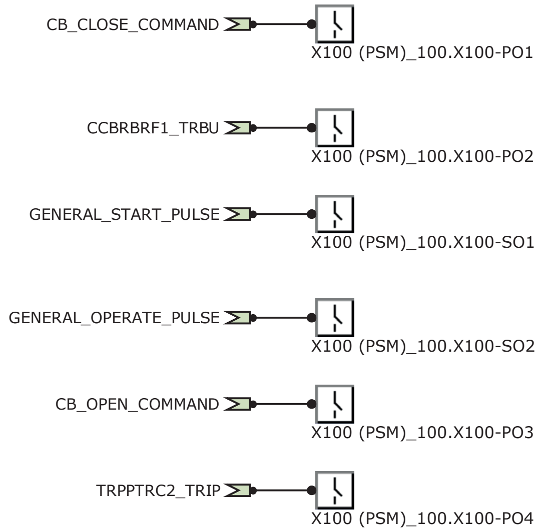


Figure 68: Default binary output - X100

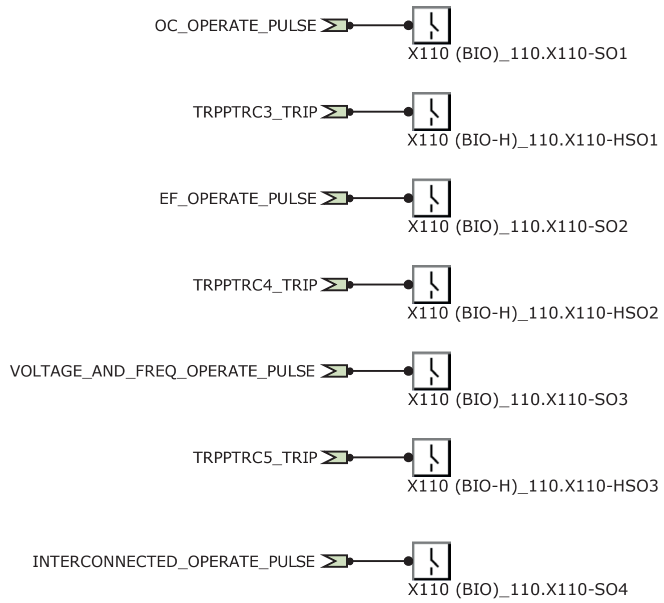
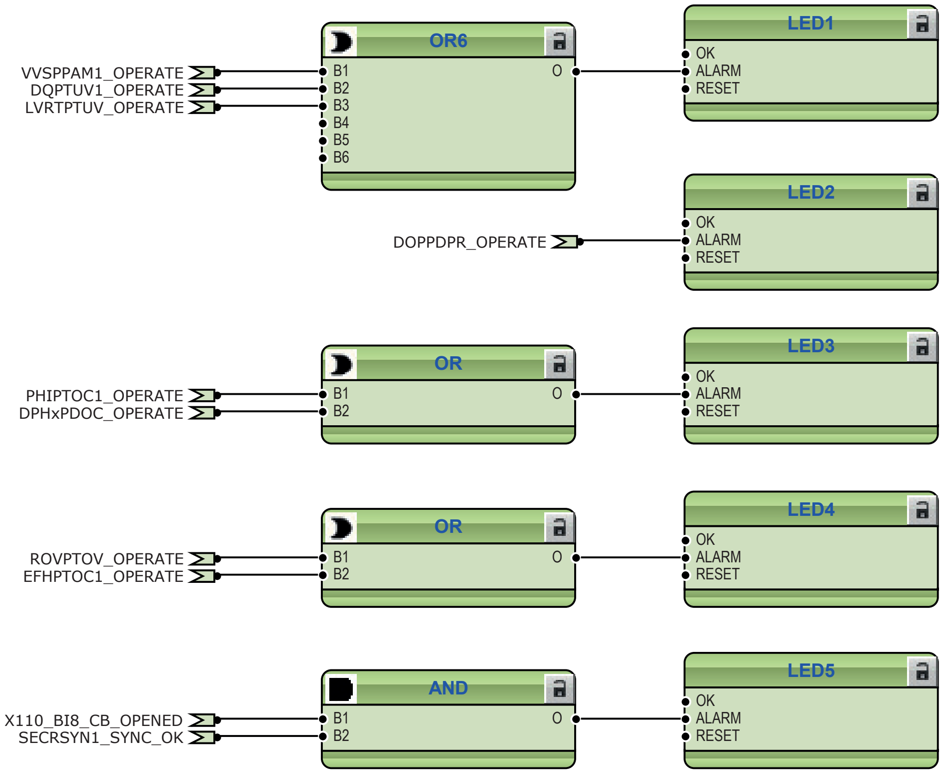


Figure 69: Default binary output - X110


VVSPPAM1_OPERATE
DQPTUV1_OPERATE
LVRTPTUV_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED1
OK
ALARM
RESET
DOPPDPR_OPERATE
LED2
OK
ALARM
RESET
PHIPTOC1_OPERATE
DPHxPDOC_OPERATE
OR
B1
B2
O
LED3
OK
ALARM
RESET
ROVPTOV_OPERATE
EFHPTOC1_OPERATE
OR
B1
B2
O
LED4
OK
ALARM
RESET
X110_BI8_CB_OPENED
SECRSYN1_SYNC_OK
AND
B1
B2
O
LED5
OK
ALARM
RESET

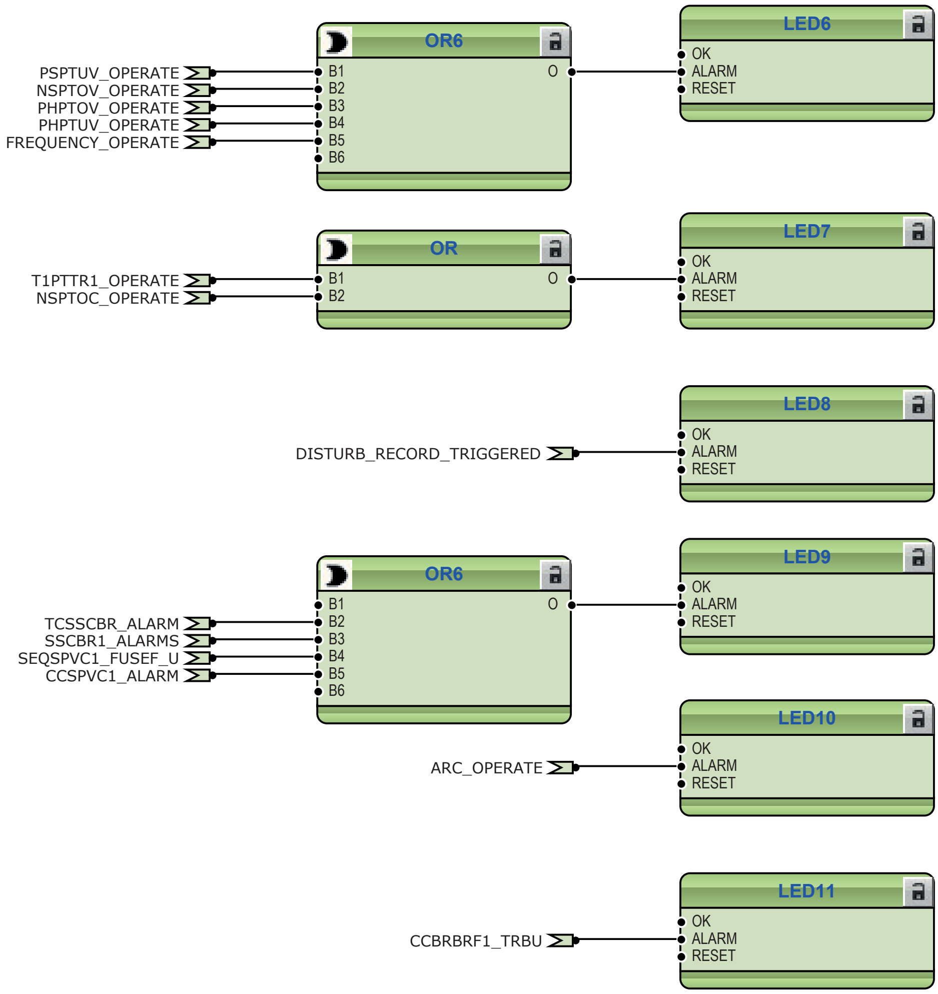


Figure 70: Default LED connection

3.3.3.7 Functional diagram for other timer logics

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

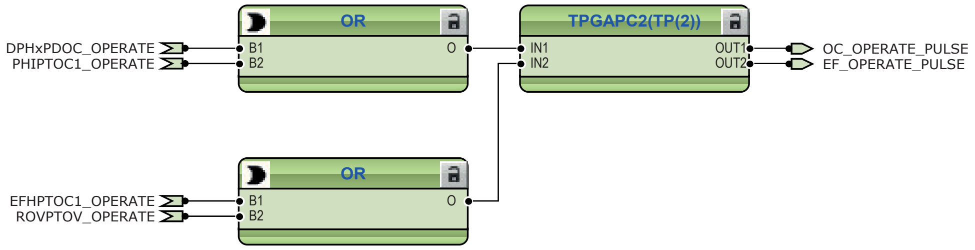


Figure 71: Timer logic for overcurrent and earth-fault operate pulse

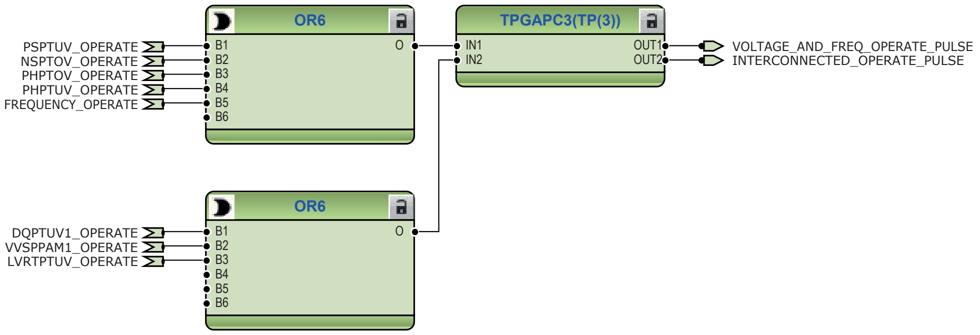


Figure 72: Timer logic for voltage/frequency and interconnected protection operate pulse

3.3.3.8 Other functions

The configuration includes three instances of directional earth-fault protection, transient/intermittent earth-fault protection, 18 instances of multipurpose protection MAPGAPC, power quality function, two more instances of frequency protection and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.4 Standard configuration C

3.4.1 Applications

The standard configuration with power protection, 100% stator earth-fault protection with third harmonic-based stator earth-fault protection, overcurrent and directional earth-fault protection, voltage and frequency based protection, underexcitation, underimpedance and out-of-step protection is mainly intended for the main protection of a small size synchronous power generator or as backup protection for a medium size synchronous power generator.

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

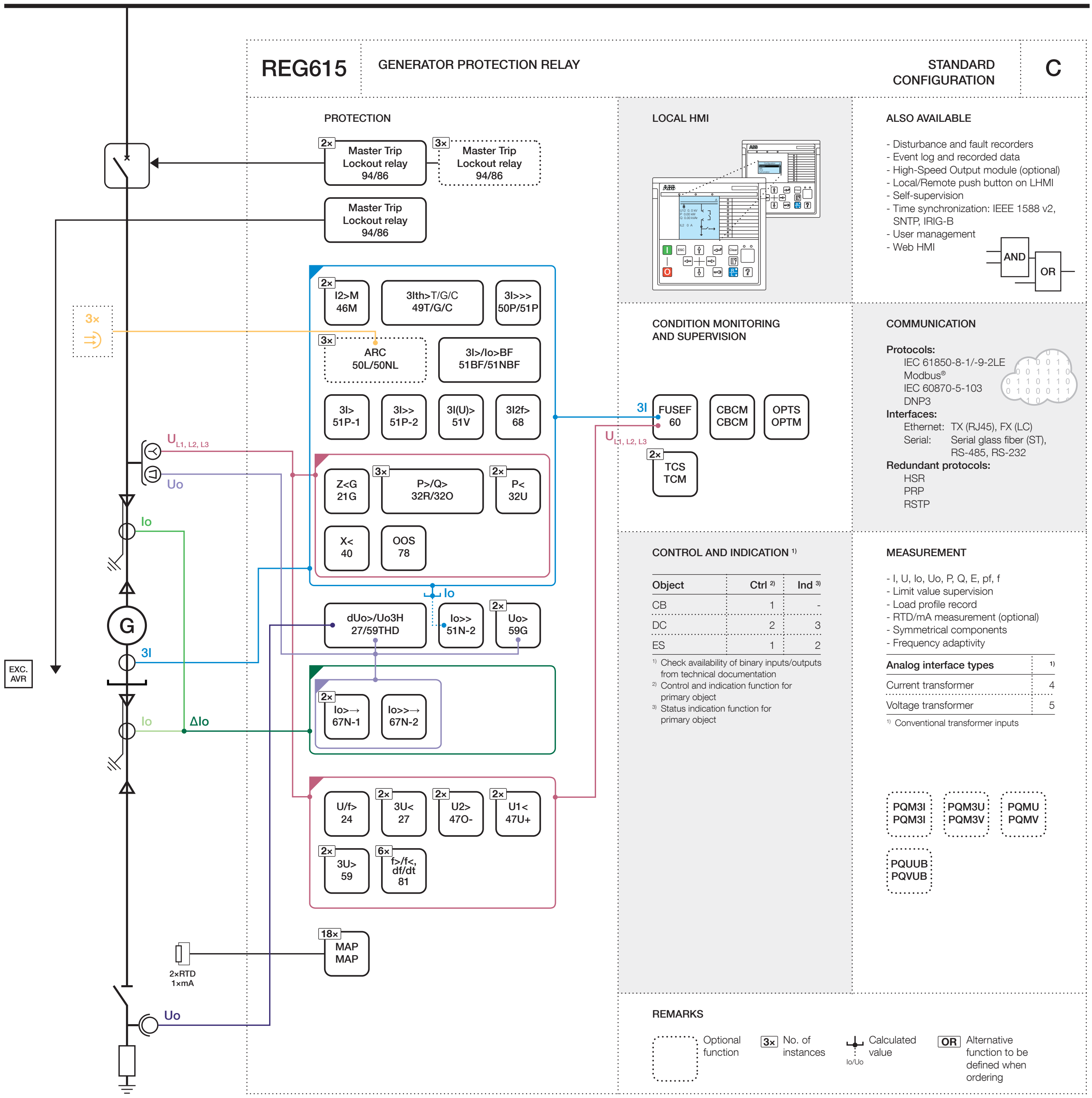


Figure 73: Functionality overview for standard configuration C

3.4.2.1 Default I/O connections

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

Table 16: Default connections for binary inputs

Binary input	Description
X110-BI1	Terminal VT secondary MCB open
X110-BI2	Neutral VT secondary MCB open
X110-BI3	Circuit breaker truck in (service position) indication
X110-BI4	Circuit breaker truck out (test position) indication
X110-BI5	Earthing switch closed indication
X110-BI6	Earthing switch open indication
X110-BI7	Circuit breaker closed indication
X110-BI8	Circuit breaker open indication
X120-BI1	Circuit breaker low gas pressure indication
X120-BI2	Circuit breaker spring charged indication
X120-BI3	-
X120-BI4	-
X130-BI1	External trip 1
X130-BI2	External trip 2
X130-BI3	Lockout reset
X130-BI4	Field excitation open indication

Table 17: Default connections for binary outputs

Binary output	Description
X100-PO1	Generator circuit breaker open command/trip 2
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Prime mover shutdown
X100-SO2	General protection operate indication
X100-PO3	Generator circuit breaker open command/trip 1
X100-PO4	Field excitation circuit breaker open command
X110-SO1	Overcurrent protection operated
X110-SO2	Earth fault protection operated
X110-SO3	Voltage or frequency protection operated
X110-SO4	Thermal overload of NPS protection operated
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 18: Default connections for LEDs

LED	Description
1	Under impedance protection operated
2	Power protection operated
3	Overcurrent protection operated
4	Earth-fault protection operated
5	Under excitation protection operated
6	Voltage or frequency protection operated
7	Thermal overload of NPS protection operated
8	Disturbance recorder triggered
9	Supervision alarms
10	Arc fault detected
11	Circuit breaker failure protection operated

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	UoB
10	-
11	-
12	-

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHIPTOC2 - start	Positive or Rising
4	PHPVOC1 - start	Positive or Rising
5	DEFLPDEF1 - start	Positive or Rising
6	DEFLPDEF2 - start	Positive or Rising
7	DEFHPDEF1 - start	Positive or Rising
Table continues on next page		

Channel	ID text	Level trigger mode
8	EFHPTOC1 - start	Positive or Rising
9	MNSPTOC1 - start	Positive or Rising
10	MNSPTOC2 - start	Positive or Rising
11	PHPTUV1 - start	Positive or Rising
12	PHPTUV2 - start	Positive or Rising
13	H3EFPSEF1 - start	Positive or Rising
14	PHPTOV1 - start	Positive or Rising
15	PHPTOV2 - start	Positive or Rising
16	FRPFRQ1 - start	Positive or Rising
17	FRPFRQ2 - start	Positive or Rising
18	FRPFRQ3 - start	Positive or Rising
19	FRPFRQ4 - start	Positive or Rising
20	OEPVPH1 - start	Positive or Rising
21	UZPDIS1 - start	Positive or Rising
22	UEXPDIS1 - start	Positive or Rising
23	ROVPTOV1 - start	Positive or Rising
24	ROVPTOV2 - start	Positive or Rising
25	NSPTOV1 - start	Positive or Rising
26	NSPTOV2 - start	Positive or Rising
27	PSPTUV1 - start	Positive or Rising
28	PSPTUV2 - start	Positive or Rising
29	DUPPDPR1 - start	Positive or Rising
30	DUPPDPR2 - start	Positive or Rising
31	DOPPDPR1 - start	Positive or Rising
32	DOPPDPR2 - start	Positive or Rising
33	DOPPDPR3 - start	Positive or Rising
34	T2PTTR1 - start	Positive or Rising
35	CCBRBRF1 - trret	Level trigger off
36	CCBRBRF1 - trbu	Level trigger off
37	PHLPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHIPTOC2 - operate	
	PHPVOC1 - operate	
38	EFHPTOC1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	DEFHPDEF1 - operate	
39	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
Table continues on next page		

Channel	ID text	Level trigger mode
40	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
41	H3EFPSEF1 - operate	Level trigger off
42	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
43	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
	FRPFRQ4 - operate	
44	OEPVPH1 - operate	Level trigger off
45	UZPDIS1 - operate	Level trigger off
46	UEXPDIS1 - operate	Level trigger off
47	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
	NSPTOV1 - operate	
	NSPTOV2 - operate	
	PSPTUV1 - operate	
	PSPTUV2 - operate	
48	INRPHAR1 - blk2h	Level trigger off
49	DUPPDPR1 - operate	Level trigger off
	DUPPDPR2 - operate	
	DOPPDPR1 - operate	
	DOPPDPR2 - operate	
	DOPPDPR2 - operate	
50	T2PTTR1 - operate	Level trigger off
51	SEQSPVC1- fusef 3ph	Level trigger off
52	SEQSPVC1- fusef u	Level trigger off
53	X130BI2 - Ext trip1	Positive or Rising
54	X130BI2 - Ext trip2	Positive or Rising
55	X110BI4 - Field Excitation open	Positive or Rising
56	X110BI7 - CB closed	Level trigger off
57	X110BI8 - CB open	Level trigger off
58	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
59	ARCSARC1 - operate	Positive or Rising
60	ARCSARC2 - operate	Positive or Rising
61	ARCSARC3 - operate	Positive or Rising

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. It is assumed that the core balance CT is provided both on line and neutral side of the generator and are connected such that the differential residual current is fed to the protection relay.

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

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. The Application Configuration tool also includes fixed Boolean signals TRUE and FALSE which can be used according to the application needs.

3.4.3.1 Functional diagrams for protection

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

Three non-directional overcurrent stages are offered for detecting phase faults in generators. In addition to overcurrent stages, one instance of voltage dependent overcurrent protection is also provided which can be used as a backup protection against phase faults. During certain conditions, fault current for three phase faults may be less than full load current of the generator. This may not get noticed by phase overcurrent protection, but the fault will cause generator terminal voltage to drop. Voltage dependent overcurrent protection can be used to detect and operate such faults.

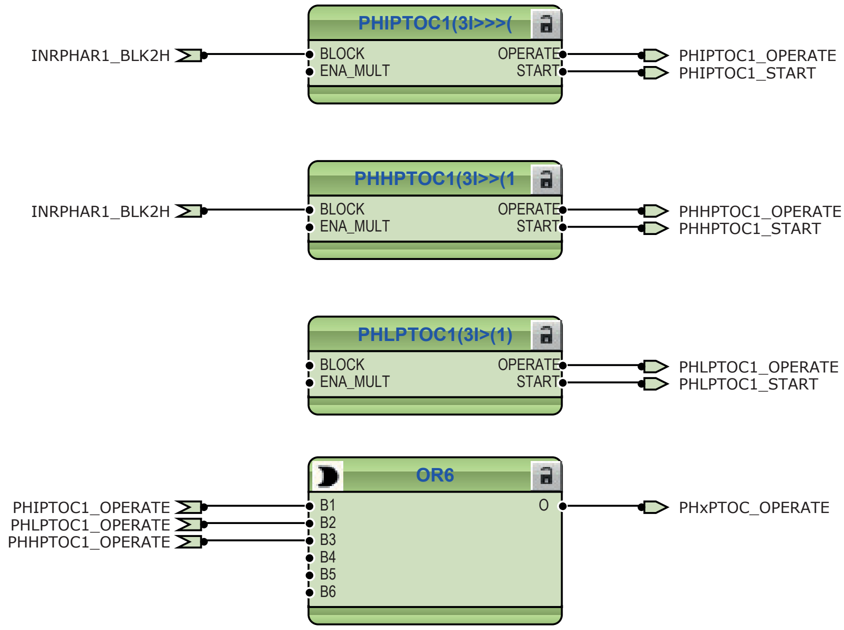


Figure 74: Overcurrent protection function

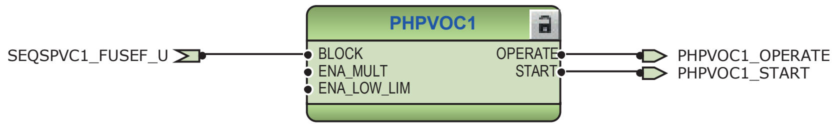


Figure 75: Voltage dependent overcurrent protection function

The output `BLK2H` of three-phase inrush detector INRPHAR1 either blocks the function or multiplies the active settings for any of the available overcurrent or earth-fault function blocks. In the configuration, INRPHAR1 blocks the high and instantaneous stage of non-directional overcurrent protection.

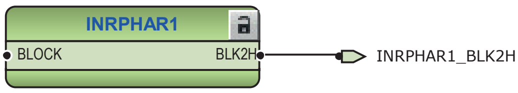


Figure 76: Inrush detector function

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 are provided for phase unbalance protection. These functions are used to protect against unbalance conditions due to unbalance load or unsymmetrical faults.

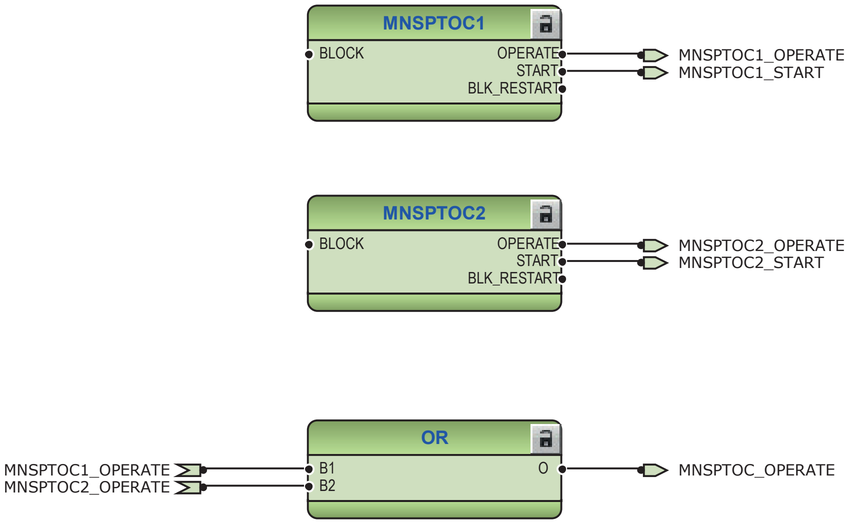


Figure 77: Negative sequence overcurrent protection function

One non-directional sensitive earth-fault stage EFHPTOC1 and three directional earth-fault stages DEFxPDEF are offered for providing primary and backup protection for generator earth-fault protection. Transient/intermittent earth-fault protection INTRPTEF is used for transient based earth-fault protection.

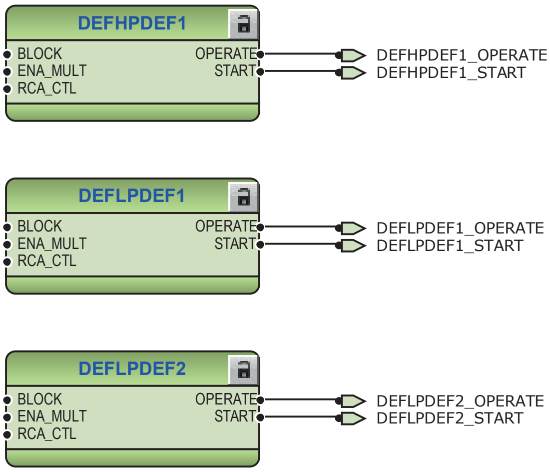


Figure 78: Directional earth-fault protection function

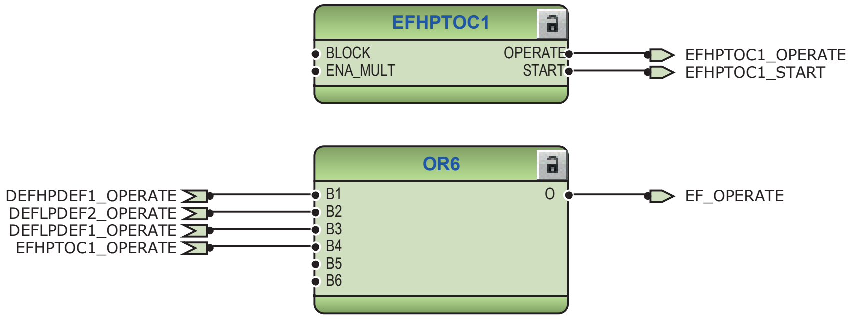


Figure 79: Earth-fault protection function

Third harmonic-based stator earth-fault protection is provided to give 100% stator winding protection. The protection is blocked by MCB open from neutral side VT.

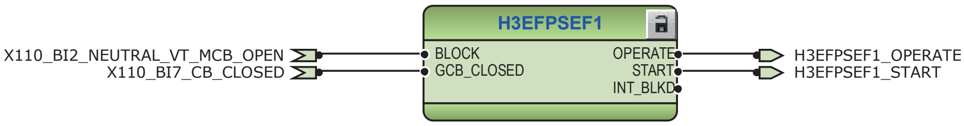


Figure 80: Third harmonic-based stator earth-fault protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects continuous overloading conditions preventing excessive insulation damage in the long run.

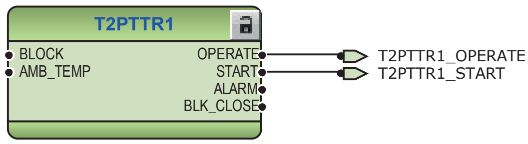


Figure 81: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` input by a number of different protection functions available in the 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` operating output is used for retripping its own breaker through TRPPTRC2_TRIP. The `TRBU` output gives a backup trip to the breaker feeding upstream. For this purpose, the `TRBU` operating output signal is connected to the binary output X100:PO2. In addition, `TRBU` operating output is also used to trip field excitation circuit breaker through TRPPTRC6_TRIP_FIELD EXCITATION.

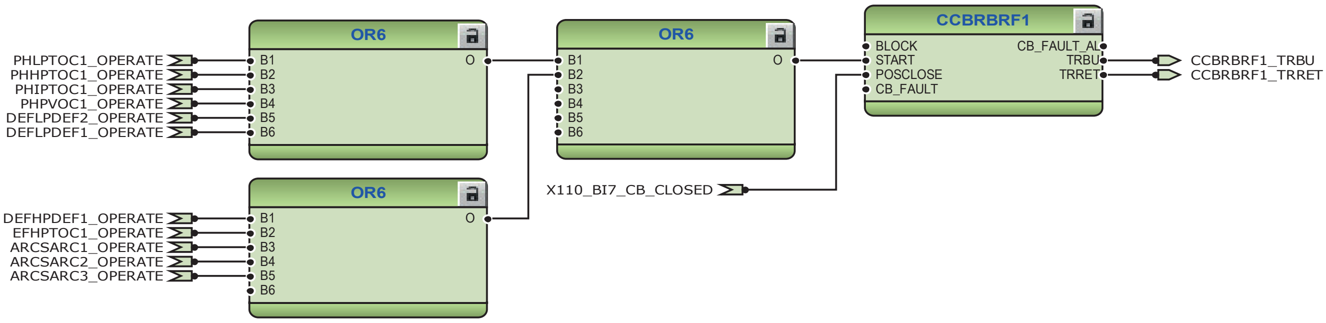


Figure 82: Circuit breaker failure protection function

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

The operating signals from ARCSARC1...3 are connected to both generator circuit breaker trip logic TRPPTRC1 and TRPPTRC2 and also to field excitation circuit breaker trip logic TRPPTRC6. If the relay has been ordered with high speed binary outputs, the individual operating signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

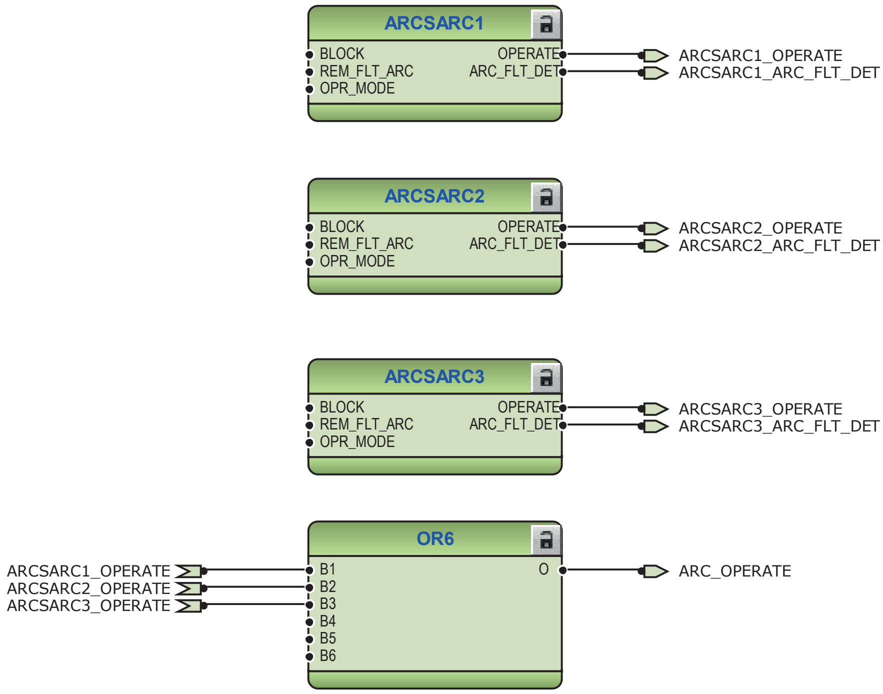


Figure 83: Arc protection function

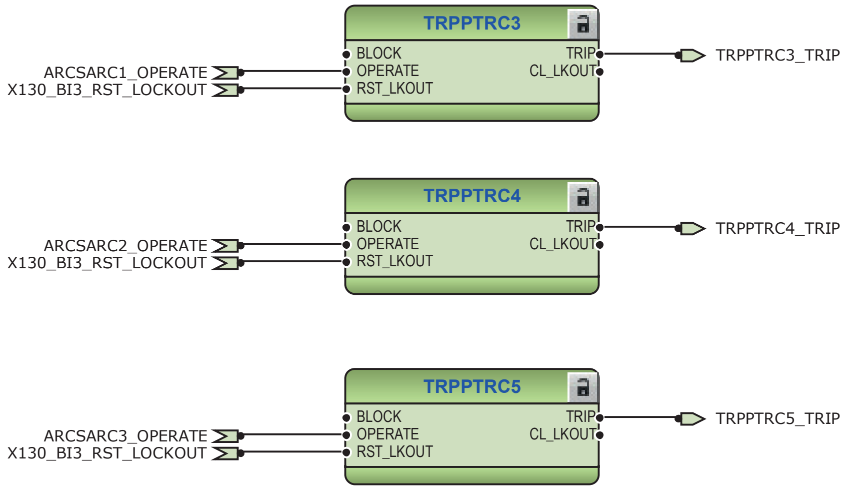


Figure 84: Arc protection with dedicated HSO

Two three-phase overvoltage protection stages PHPTOV offer protection against abnormal overvoltage conditions that arise due to load rejection or transient surges in the network or when a generator is running but not connected to a system due to a fault with AVR. Similarly, two three-phase undervoltage protection stages PHPTUV offer protection against undervoltage conditions or are used as a backup against underimpedance protection.

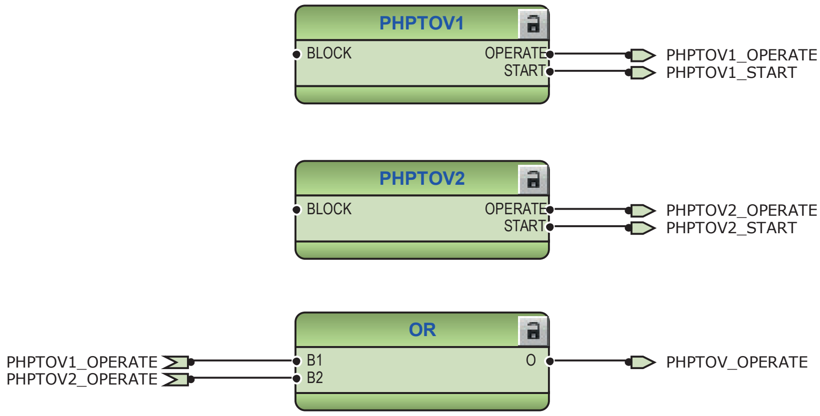


Figure 85: Overvoltage protection function

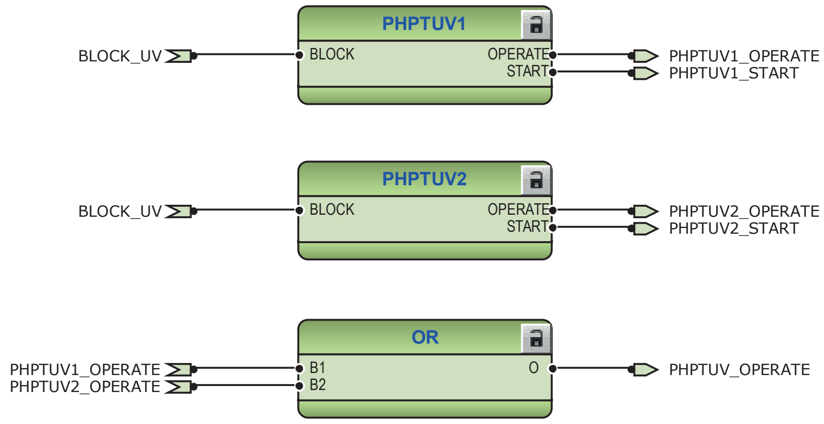


Figure 86: Undervoltage protection function

Two stages of each positive-sequence undervoltage PSPTUV and negative-sequence overvoltage NSPTOV protection functions are also provided. A failure in the voltage measuring circuit is detected by the fuse failure function. The fuse failure activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping. In addition, undervoltage protection is also blocked when a generator circuit breaker is in open position.

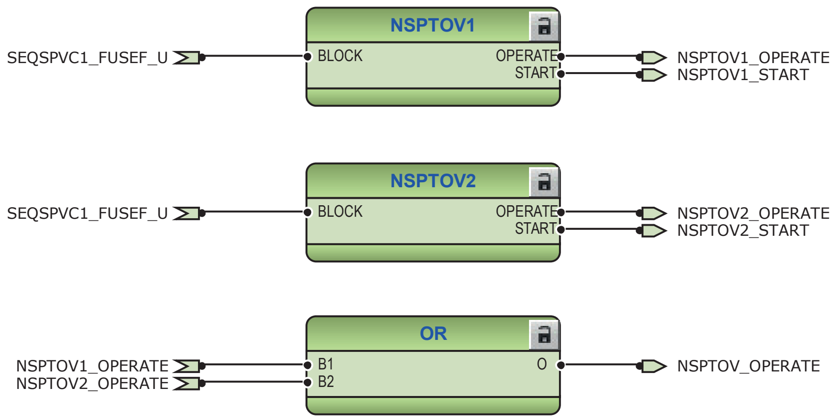


Figure 87: Negative sequence overvoltage protection function

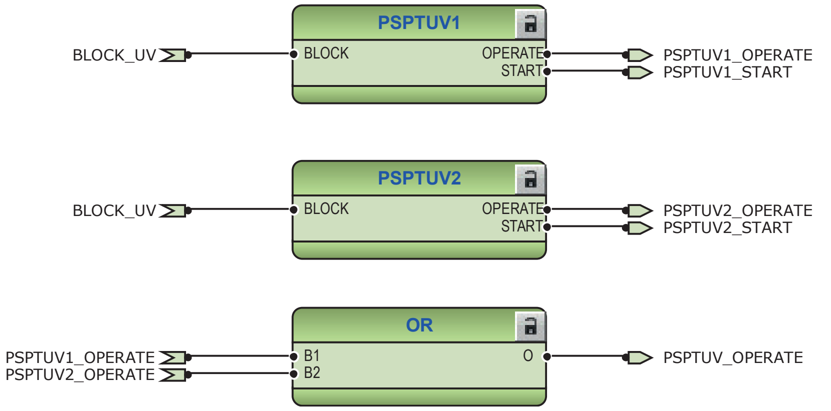


Figure 88: Positive sequence undervoltage protection function

Residual overvoltage protection ROVPTOV provides protection against stator earth faults from 5% to 100% of winding from neutral. Two instances of ROVPTOV are provided.

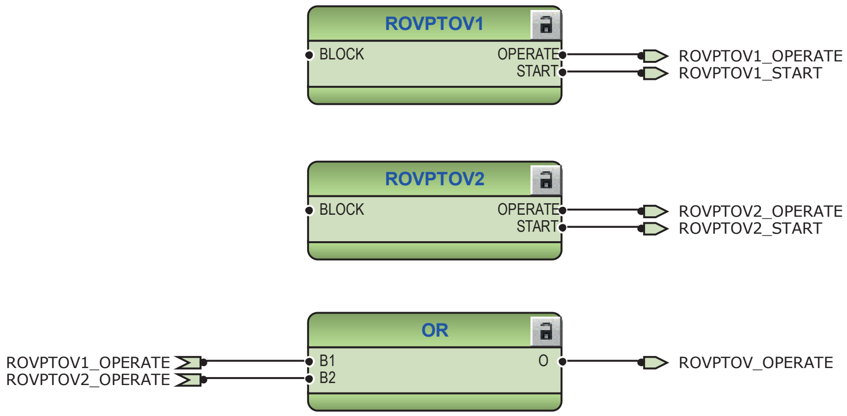


Figure 89: Residual overvoltage protection function

The selectable underfrequency or overfrequency or rate of change of frequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. Configuration offers six instances of frequency protection, these instances can be configured to operate as underfrequency or overfrequency or rate of change of frequency according to the system requirement. The frequency protection is blocked when generator CB is in open position.

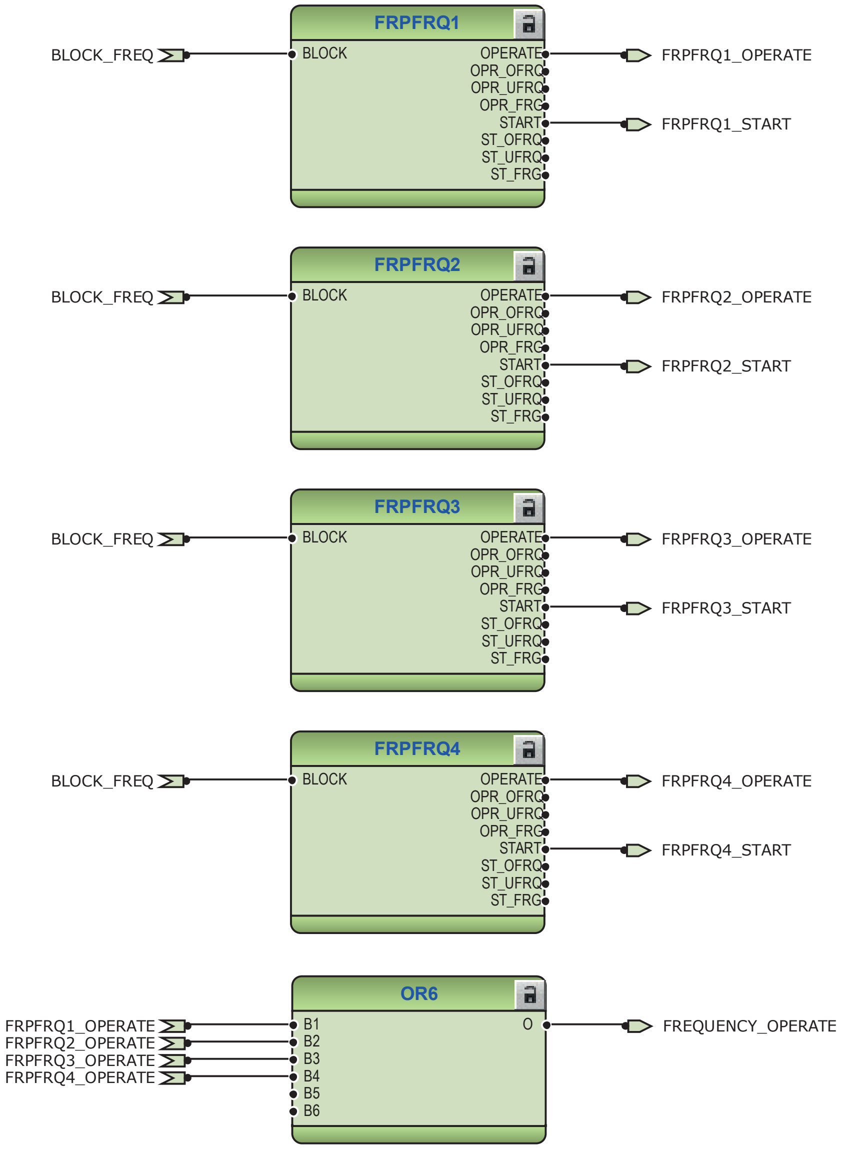


Figure 90: Frequency protection function

Three instances of reverse power/directional overpower protection DOPPDPR are provided to detect either loss of prime mover or detecting motoring action or detecting any abnormal high reactive power being absorbed by the generator.

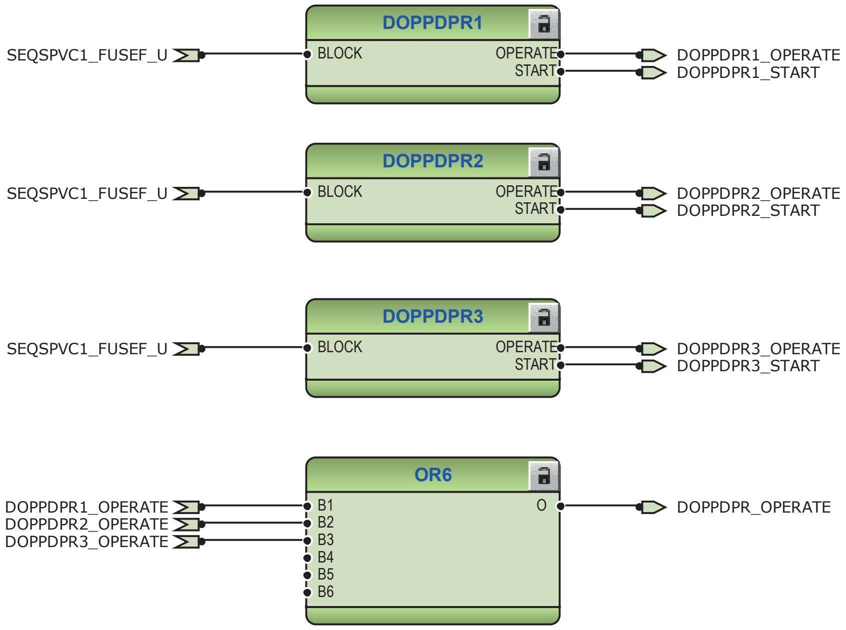


Figure 91: Directional overpower protection function

Two instances of underpower protection DUPPDPR are provided. Normally these are used in coordination with reverse active power protection.

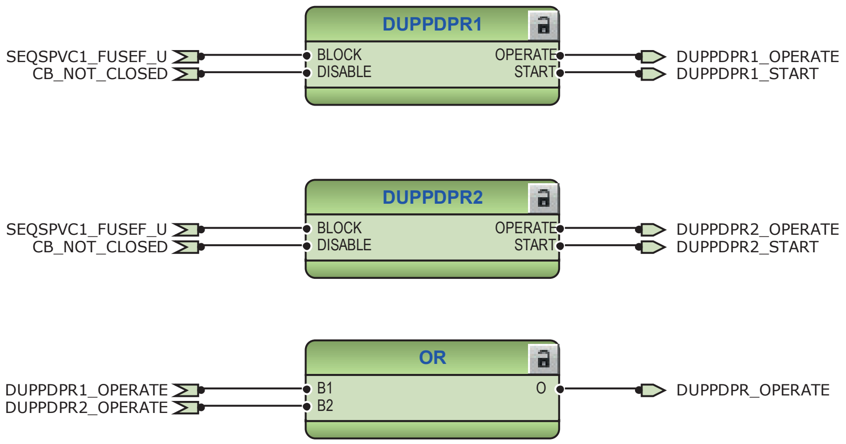


Figure 92: Directional underpower protection function

On losing excitation, generator may over speed and operate as an induction generator taking reactive power from the system which may reduce system voltages, three-phase underexcitation protection UEXPDIS is provided to detect such conditions. Directional underpower protection is disabled when the generator circuit breaker is in open position.

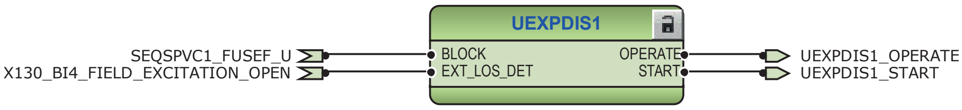


Figure 93: Underexcitation protection function

Three-phase underimpedance protection UZPDIS can be used as a backup protection against phase faults by calculating impedance at the generator terminals.

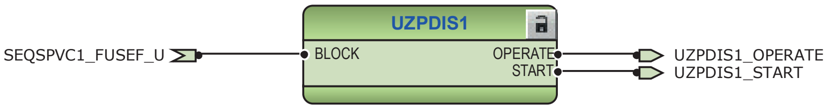


Figure 94: Underimpedance protection function

Overexcitation protection OEPVPH is provided to protect the generator against overexcitation. Due to overexciation, saturation of the magnetic core of generator and connected transformer may occur, and stray flux may be induced in nonlaminated components that are not designed to carry flux. Excessive flux also causes excessive eddy currents resulting into excessive voltage between laminations causing overheating and damage to insulation.

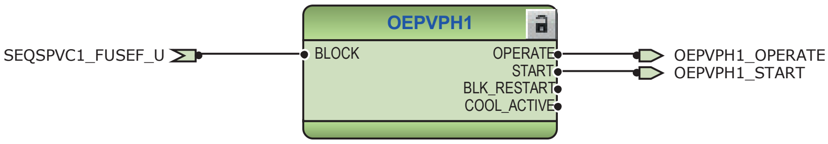


Figure 95: Overexcitation protection function

General start and operate signals from all 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 output.

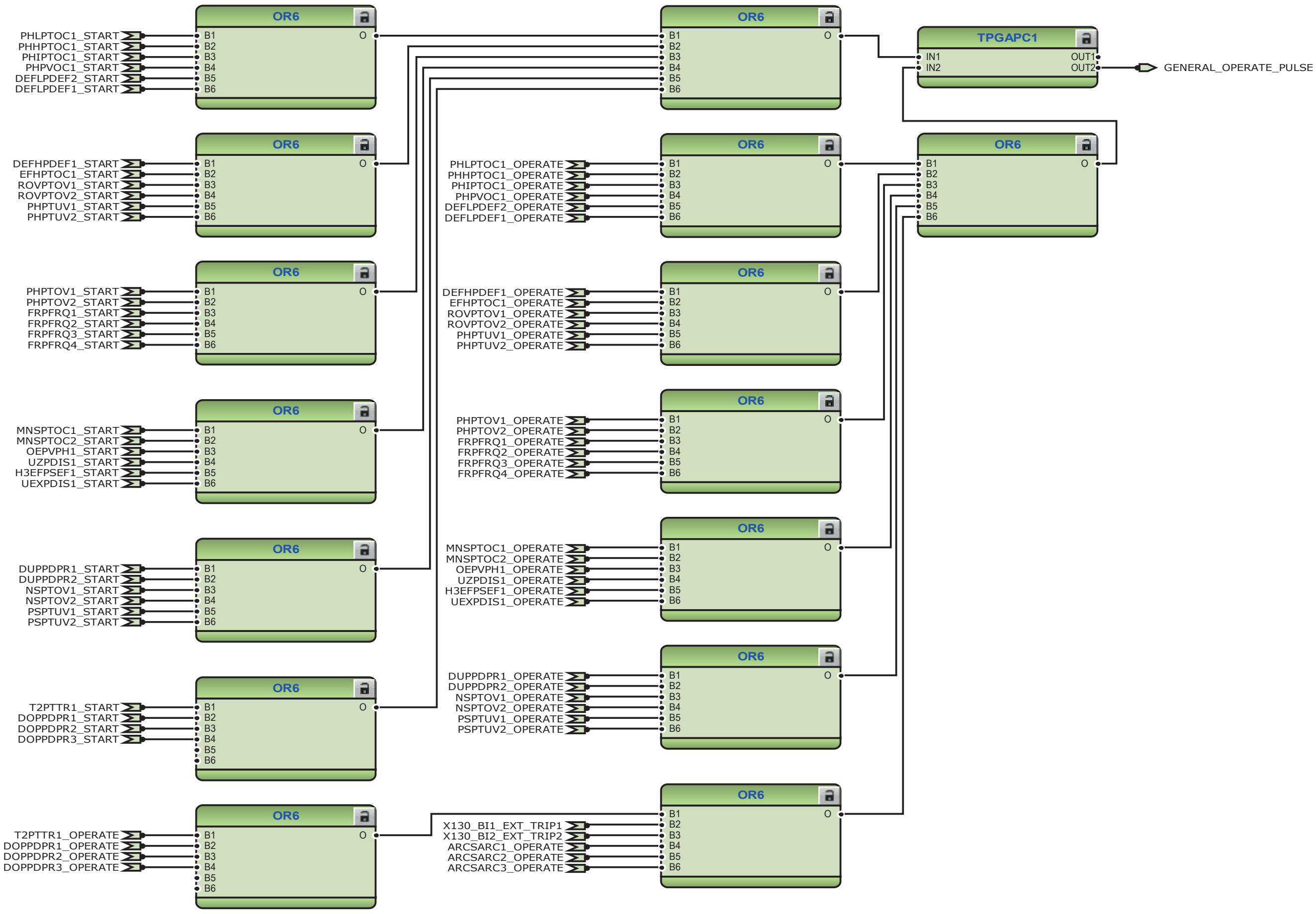


Figure 96: *General start and operate signal*

The operating signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X130:BI3 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

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

In addition, trip logic TRPPTRC6 is available to trip the circuit breaker of filed excitation. The protection function which should trip the field excitations are connected to TRPPTRC6.

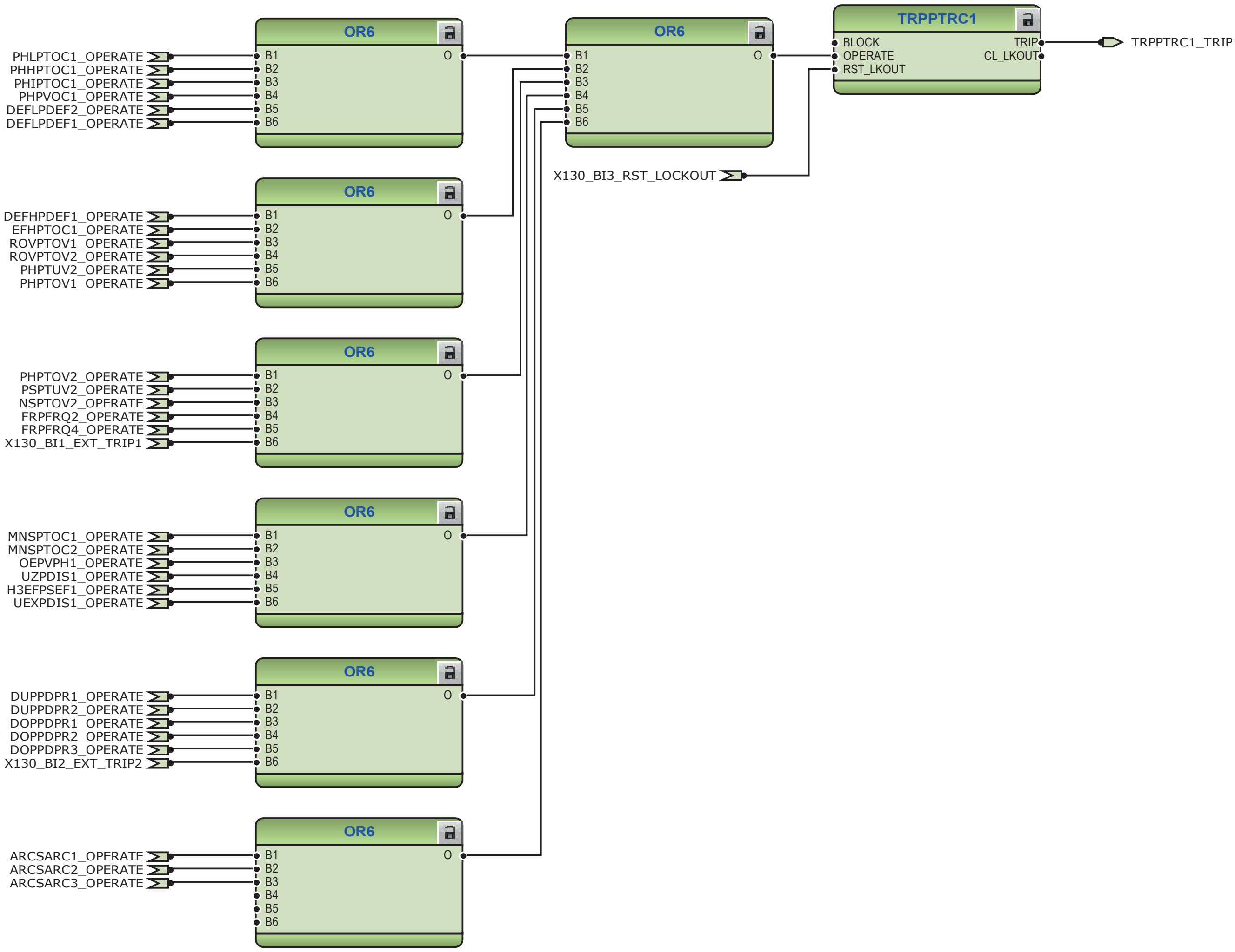


Figure 97: Trip logic TRPPTRC1

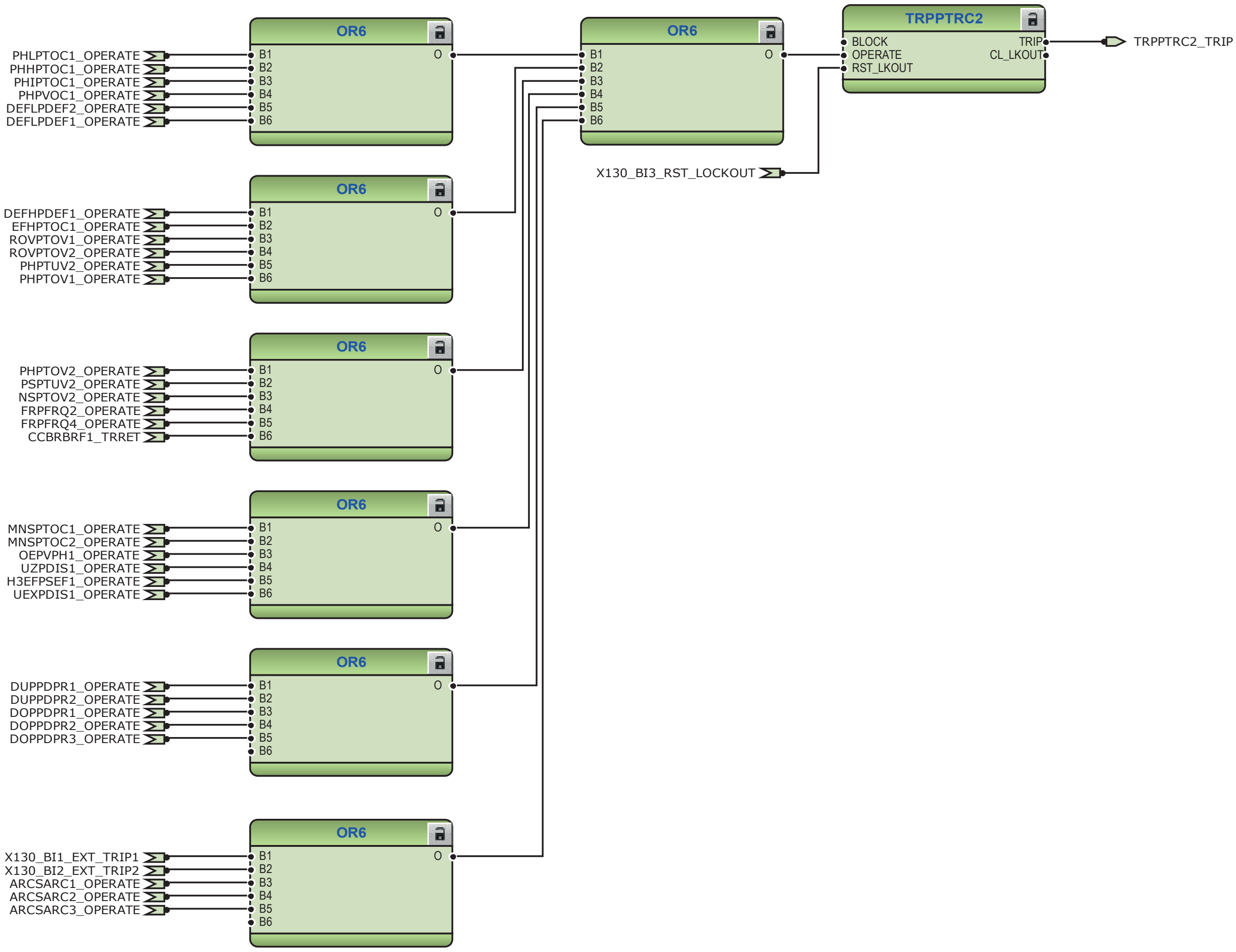


Figure 98: Trip logic TRPPTRC2

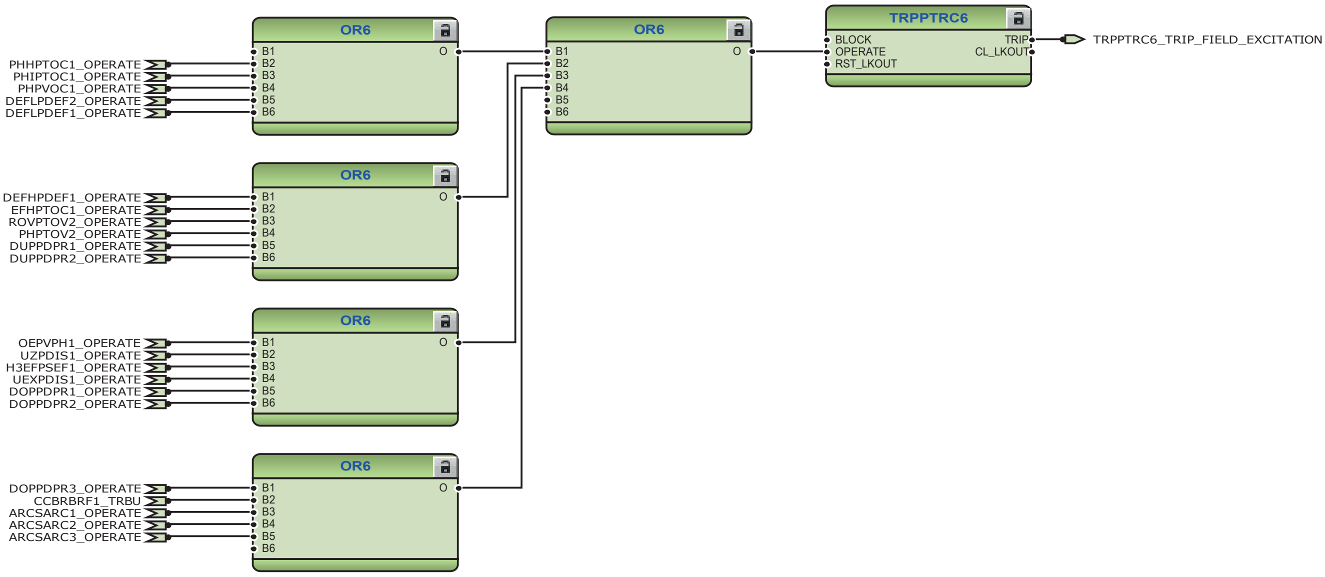


Figure 99: Trip logic TRPPTRC6 (Field excitation)

3.4.3.2 Functional diagrams for disturbance recorder

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

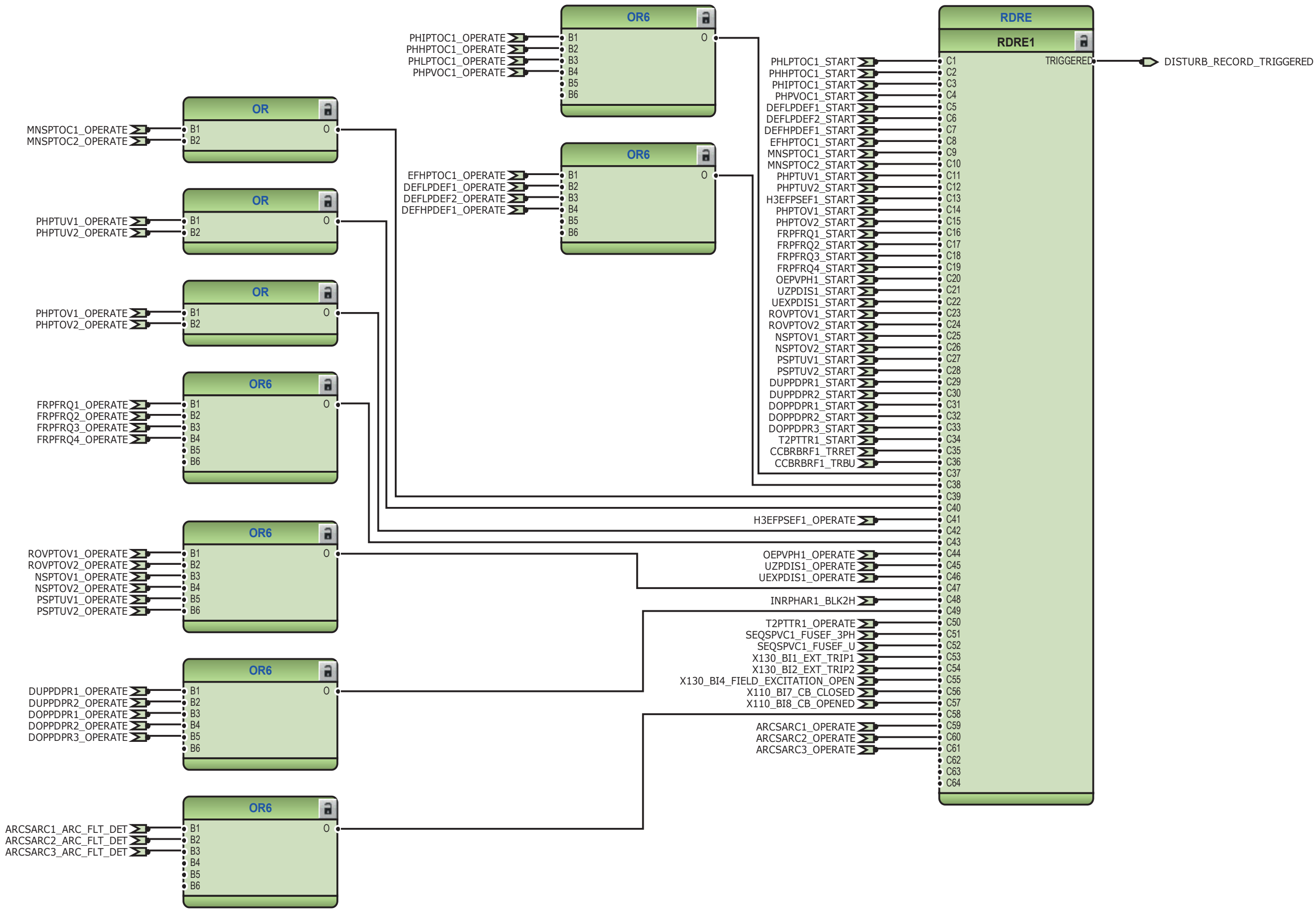


Figure 100: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

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

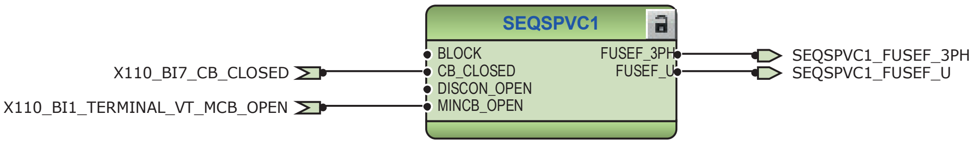


Figure 101: Fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

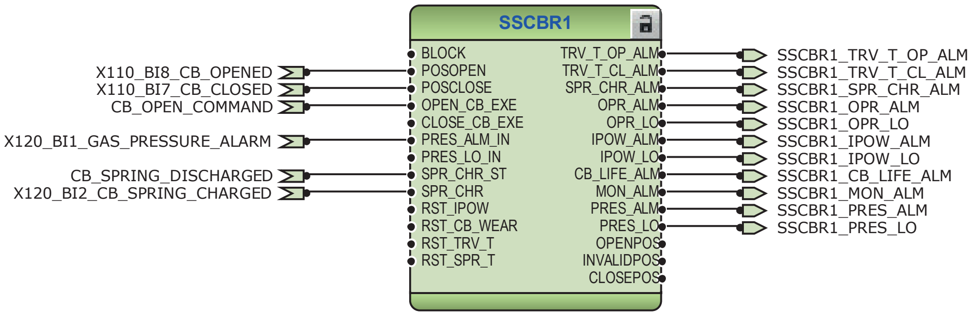


Figure 102: Circuit breaker condition monitoring function

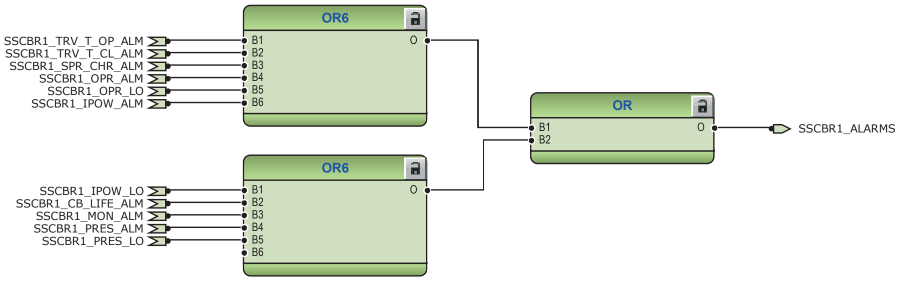


Figure 103: Logic for circuit breaker monitoring alarm

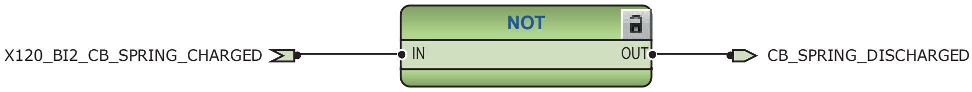


Figure 104: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 function is blocked by the master trip TRPPTRC1 and TRPPTRC2 and the generator circuit breaker open signal, whereas TCSSCBR2 function is blocked by the master trip TRPPTRC6 and the field excitation 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's normally open auxiliary contact.

Set the parameters for TCSSCBR1 properly.

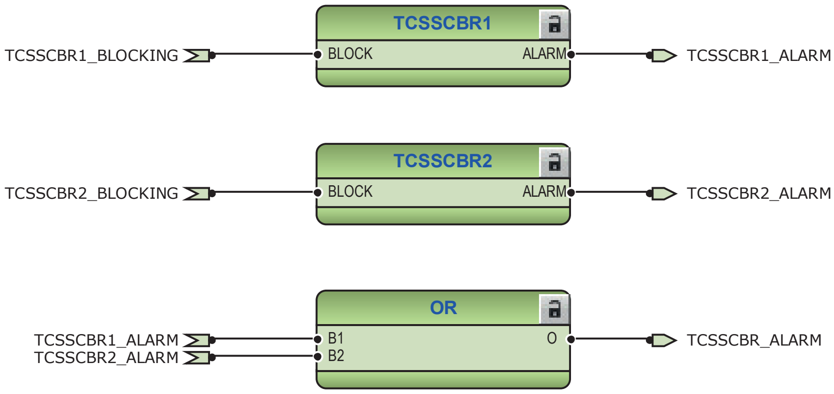


Figure 105: Trip circuit supervision function

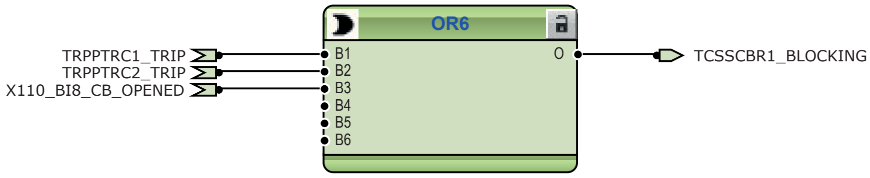


Figure 106: Logic for blocking of trip circuit supervision

Runtime counter for machines and devices MDSOPT provides history data since the last commissioning. The counter counts the total number of generator running hours and is incremented when the energizing circuit breaker is closed.

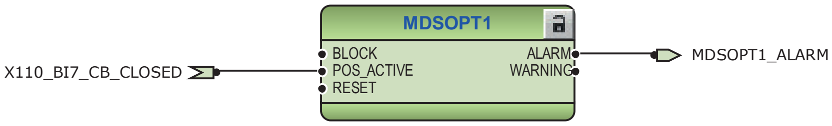


Figure 107: Generator runtime counter

3.4.3.4 Functional diagrams for control and interlocking

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

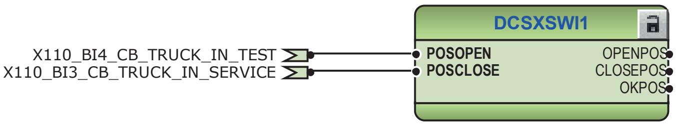


Figure 108: Disconnector control logic

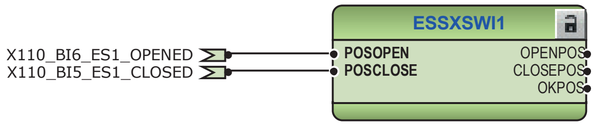


Figure 109: Earth switch control logic

The circuit breaker closing is disabled by default, as in case of generator, the closing of the circuit breaker is done by a special synchronizer device.

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

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

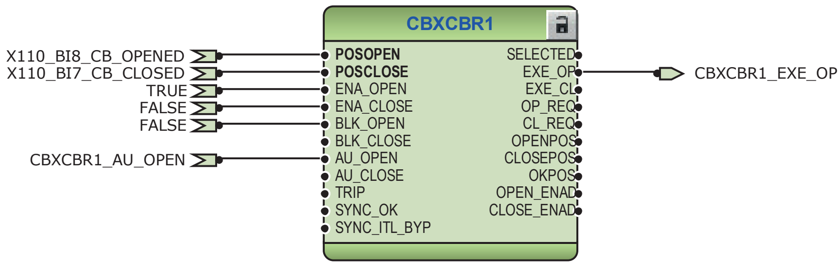


Figure 110: Circuit breaker 1 control logic

Figure 111: Signal for opening coil of circuit breaker 1

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

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

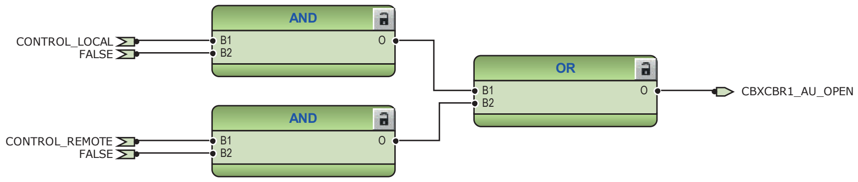


Figure 112: External opening command for circuit breaker 1

3.4.3.5 Functional diagram 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 X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase terminal side voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1. In addition to phase voltage, terminal side and neutral side residual voltage are measured by residual voltage measurement RESVMMXU1 and RESVMMXU2. The three-phase voltage input as well as residual voltages are connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

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

The frequency measurement FMMXU1 of the power system and 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.

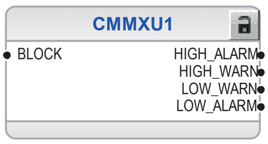


Figure 113: Current measurement: Three-phase current measurement

Figure 114: Current measurement: Sequence current measurement

Figure 115: Current measurement: Residual current measurement

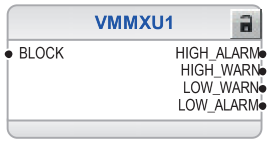


Figure 116: Voltage measurement: Three-phase voltage measurement

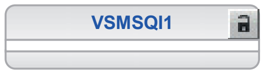


Figure 117: Voltage measurement: Sequence voltage measurement

Figure 118: Voltage measurement: Residual voltage measurement (Terminal side)

Figure 119: Voltage measurement: Residual voltage measurement (Neutral side)

Figure 120: Other measurement: Frequency measurement

Figure 121: Other measurement: Three phase power and energy measurement

Figure 122: Other measurement: Data monitoring

Figure 123: Other measurement: Load profile record

3.4.3.6 Functional diagrams for IOs and alarm LEDs

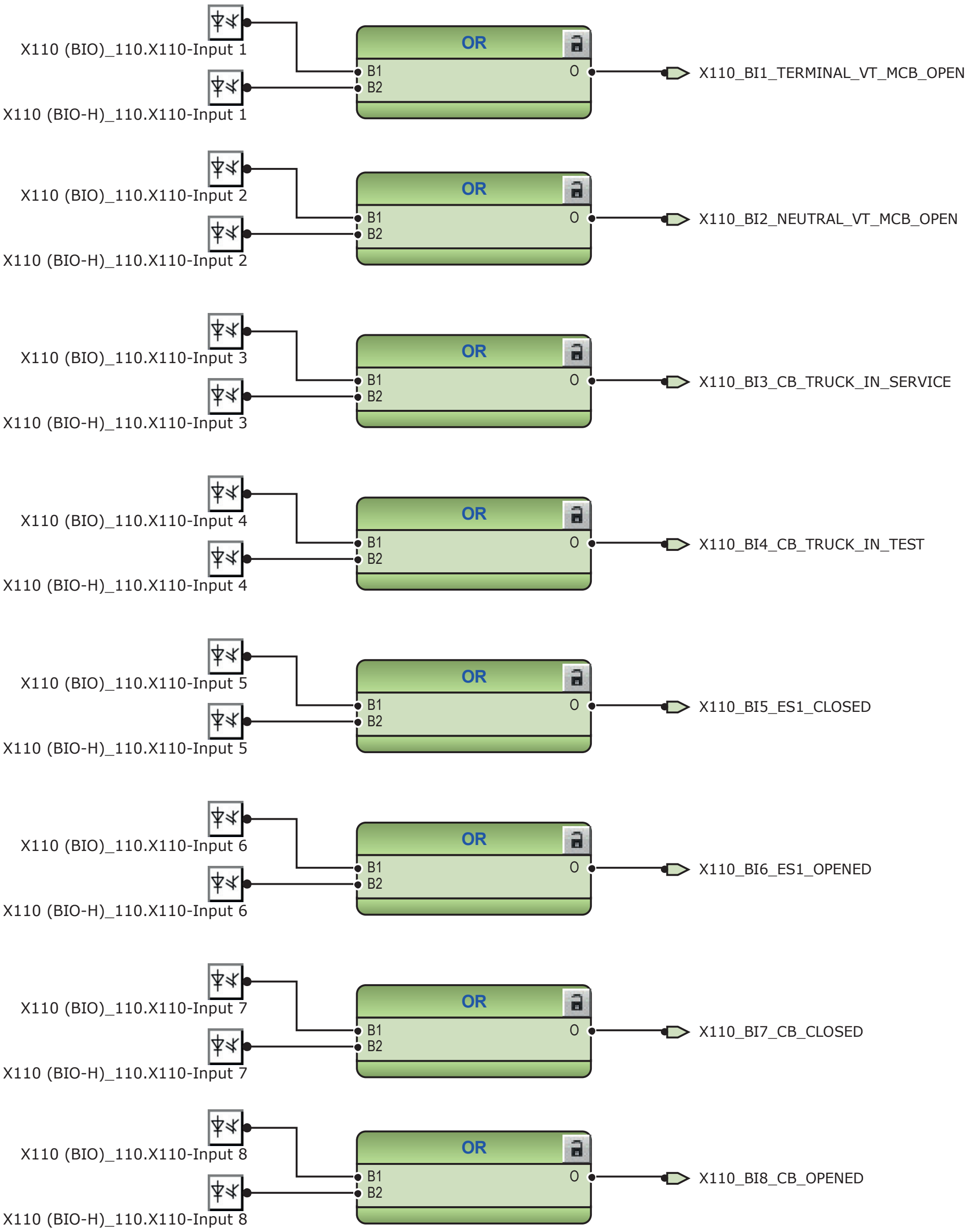


Figure 124: Default binary input - X110

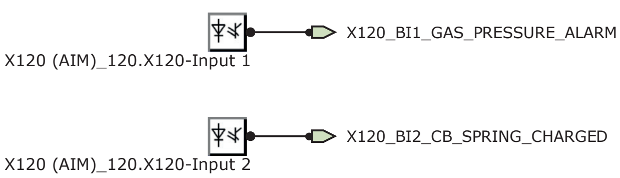


Figure 125: Default binary input - X120

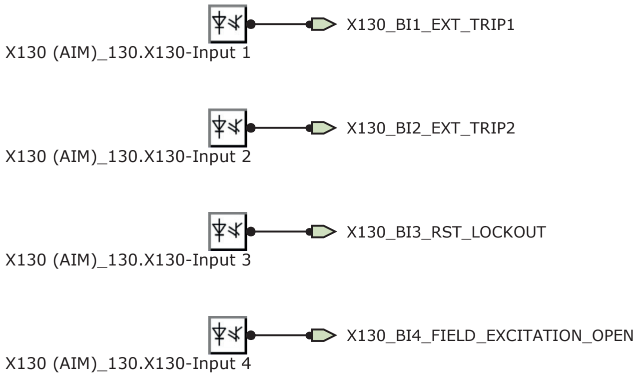


Figure 126: Default binary input - X130

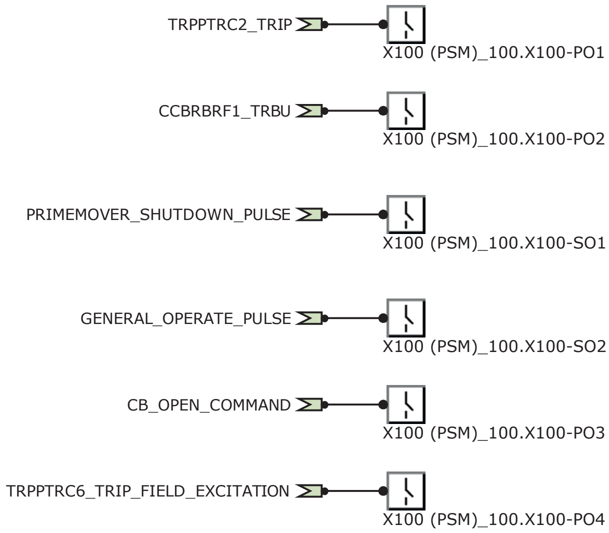


Figure 127: Default binary output - X100

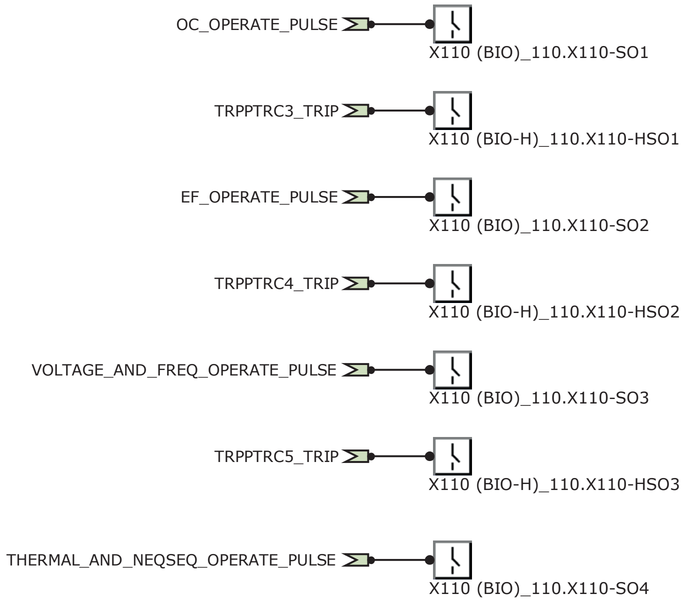
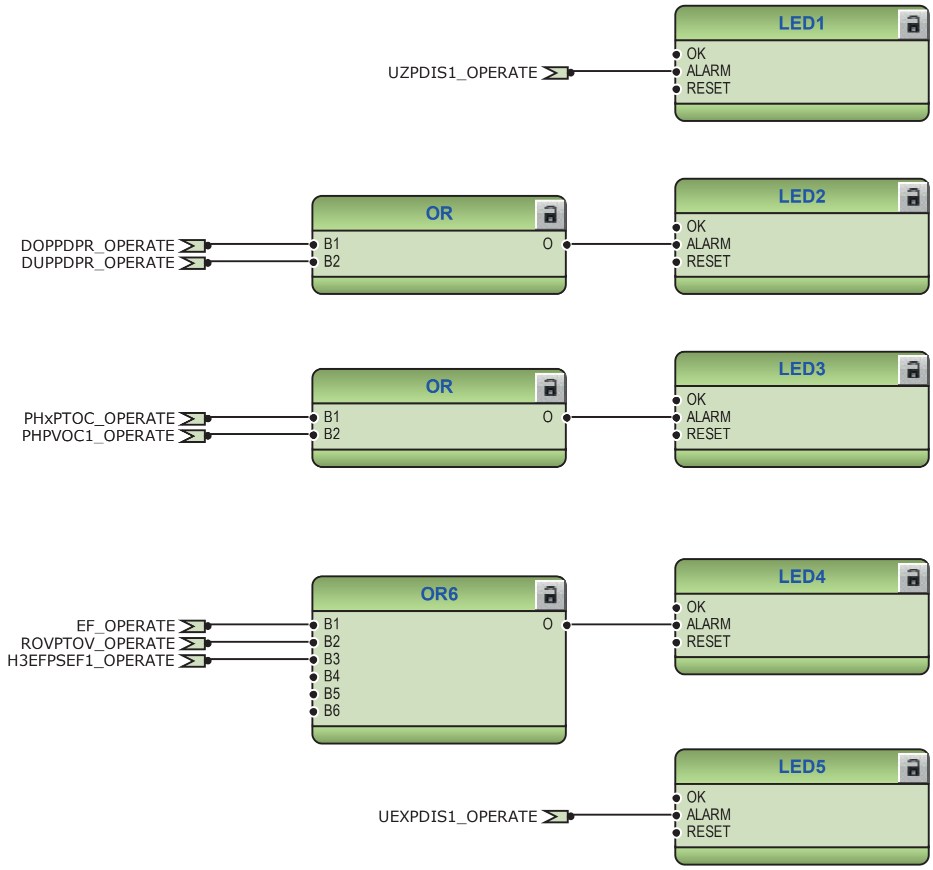


Figure 128: Default binary output - X110


UZPDIS1_OPERATE
LED1
OK
ALARM
RESET
DOPPDPR_OPERATE
DUPPDPR_OPERATE
OR
B1
B2
O
LED2
OK
ALARM
RESET
PHxPTOC_OPERATE
PHPVOC1_OPERATE
OR
B1
B2
O
LED3
OK
ALARM
RESET
EF_OPERATE
ROVPTOV_OPERATE
H3EFPSEF1_OPERATE
OR6
B1
B2
B3
B4
B5
B6
O
LED4
OK
ALARM
RESET
UEXPDIS1_OPERATE
LED5
OK
ALARM
RESET

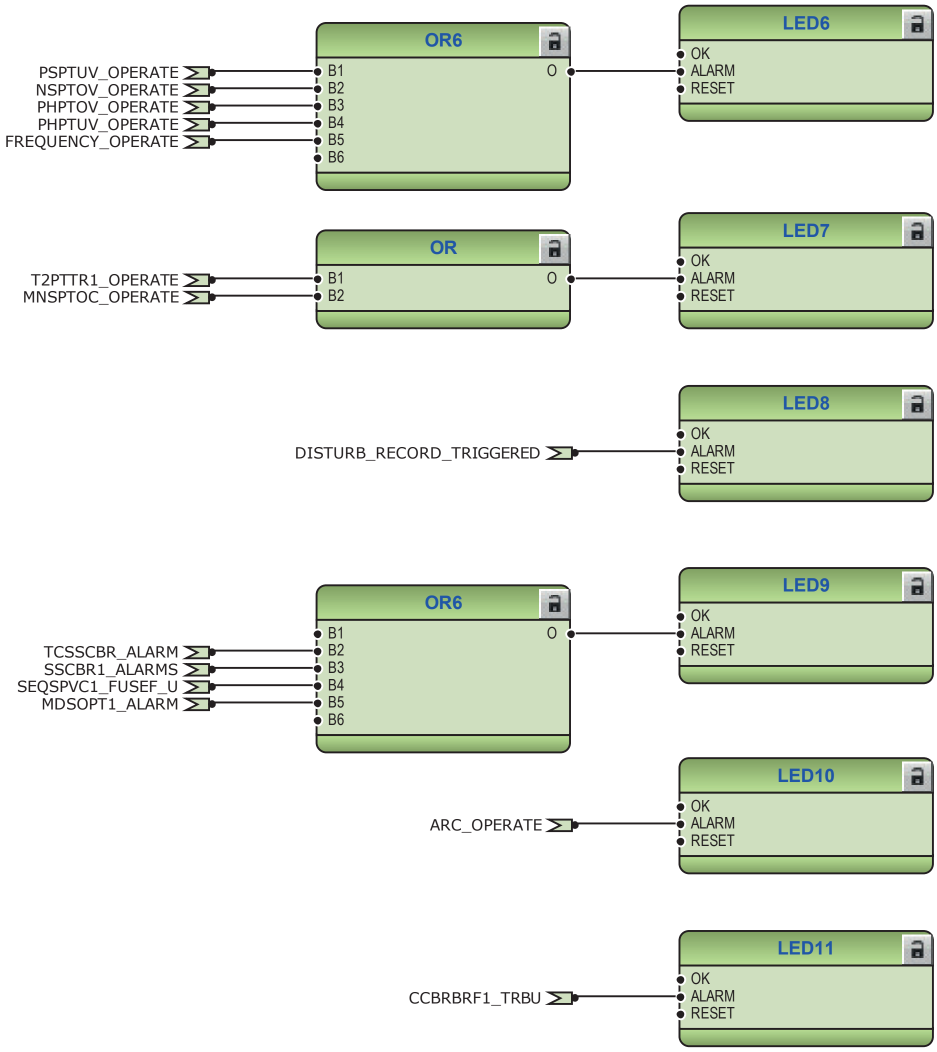


Figure 129: Default LED connection

3.4.3.7 Functional diagram for other timer logics

The configuration includes overcurrent operate, earth-fault operate, voltage and frequency operate, interconnected protection operate, prime mover shutdown logic, blocking logic for undervoltage protection and frequency protection and logic to disable directional underpower protection. The operate logics are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

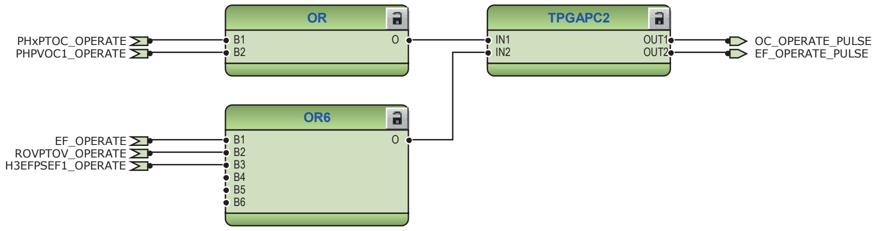


Figure 130: Timer logic for overcurrent and earth-fault operate pulse

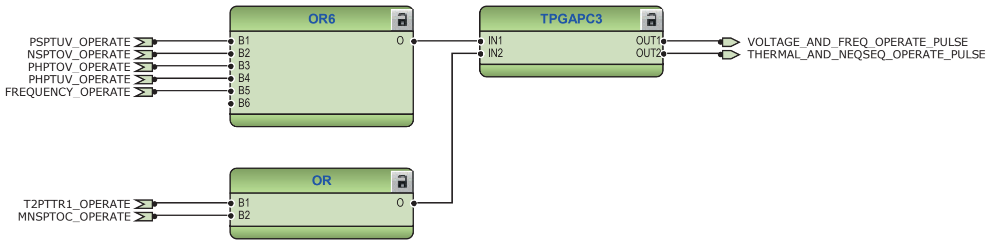


Figure 131: Timer logic for voltage/frequency and interconnected protection operate pulse

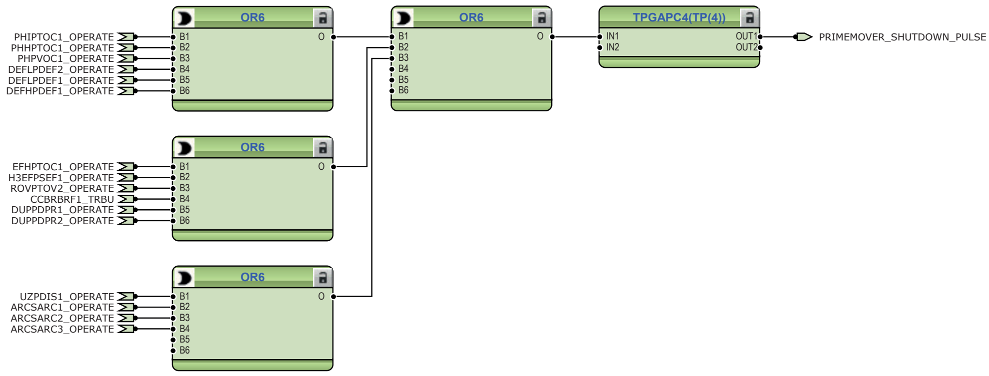


Figure 132: Timer logic for primemover shutdown pulse

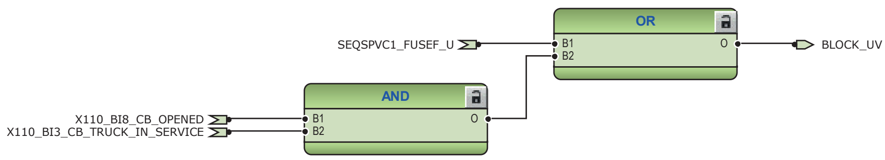


Figure 133: Blocking logic for undervoltage protection

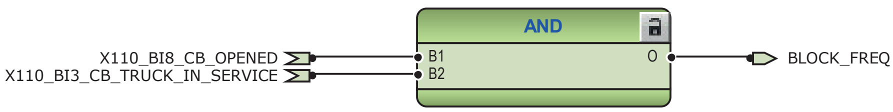


Figure 134: Blocking logic for frequency protection

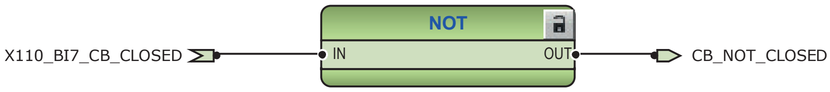


Figure 135: Disable logic for directional underpower protection

3.4.3.8 Other functions

The configuration includes 18 instances of multipurpose protection MAPGAPC, power quality functions, two more instances of frequency protection and different types of timers and control functions. These functions are not included in the application configuration but they can be added based on the system requirements.

3.5 Standard configuration D

3.5.1 Applications

The standard configuration with differential protection for machines, power protection, overcurrent protection, voltage and frequency based protection, underexcitation and out-of-step protection is mainly intended for the main protection for a small size synchronous power generator or as backup protection for a medium size synchronous power generator.

Standard configuration D is not designed for using all the available functionality content in one relay at the same time. Three-phase directional overcurrent protection, three-phase voltage protection, positive-sequence and negative-sequence voltage protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user-specific configuration load is verified with the Application Configuration tool in PCM600.

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

3.5.2 Functions

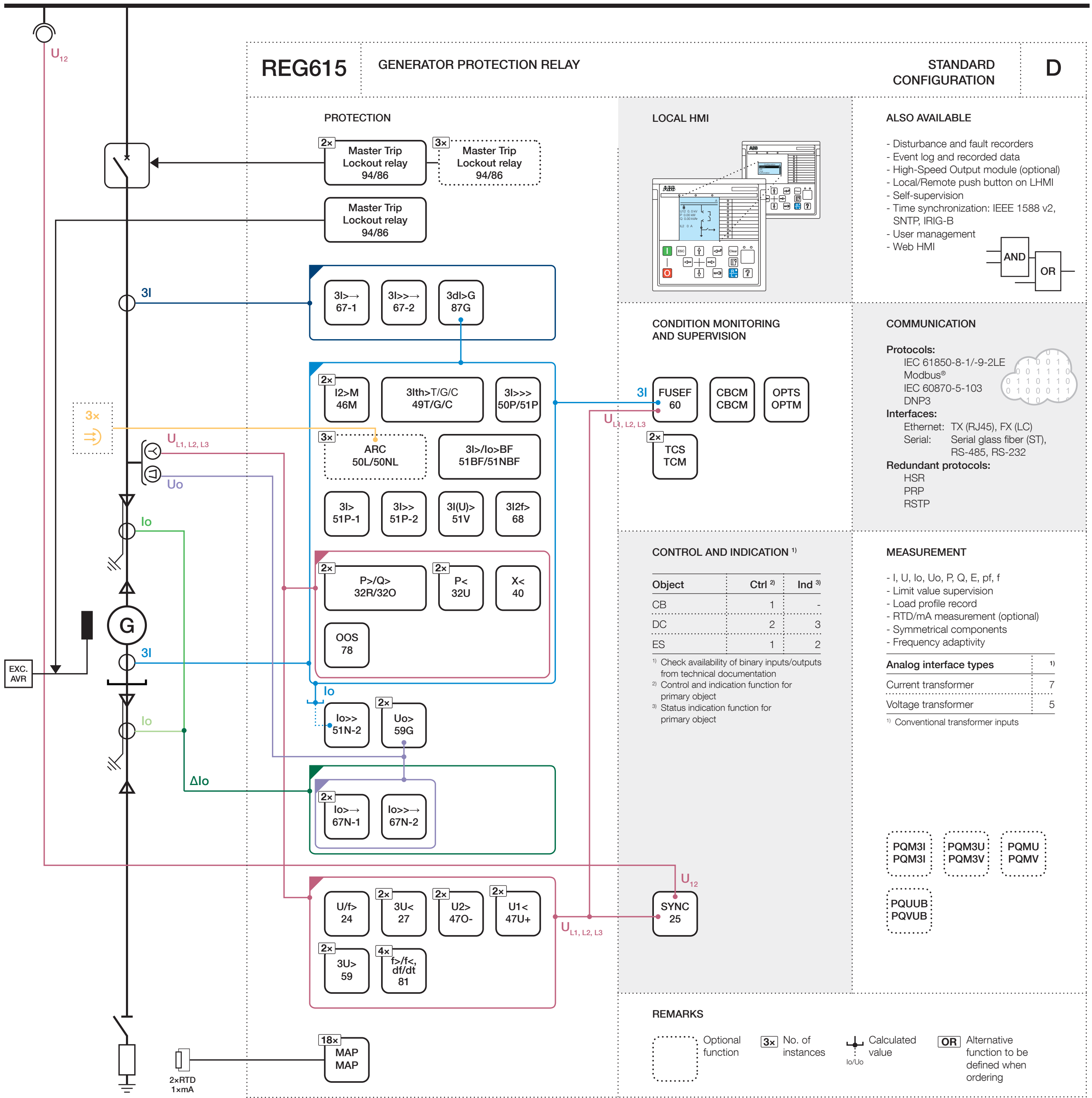


Figure 136: Functionality overview for standard configuration D

3.5.2.1 Default I/O connections

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

Table 21: Default connections for binary inputs

Binary input	Description
X110-BI1	Terminal VT secondary MCB open
X110-BI2	Neutral VT secondary MCB open
X110-BI3	Circuit breaker truck in (service position) indication
X110-BI4	Circuit breaker truck out (test position) indication
X110-BI5	Earthing switch closed indication
X110-BI6	Earthing switch open indication
X110-BI7	Circuit breaker closed indication
X110-BI8	Circuit breaker open indication
X130-BI1	External trip 1
X130-BI2	External trip 2
X130-BI3	Lockout reset
X130-BI4	Field excitation open indication

Table 22: Default connections for binary outputs

Binary output	Description
X100-PO1	Generator circuit breaker open command/trip 2
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Prime mover shutdown
X100-SO2	General protection operate indication
X100-PO3	Generator circuit breaker open command/trip 1
X100-PO4	Field excitation circuit breaker open command
X110-SO1	In synchronism for closing
X110-SO2	Differential protection operated
X110-SO3	Frequency protection operated
X110-SO4	Thermal overload of NPS protection operated
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 23: Default connections for LEDs

LED	Description
1	Differential protection operated
2	Power protection operated
3	Overcurrent protection operated
4	Earth-fault protection operated
5	Synchronism or energization check OK
6	Frequency protection operated
Table continues on next page	

LED	Description
7	Thermal overload of NPS protection operated
8	Disturbance recorder triggered
9	Supervision alarms
10	Arc fault detected
11	Circuit breaker failure protection operated

3.5.2.2 Default disturbance recorder settings

Table 24: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8	Uo
9	U1
10	U2
11	U3
12	U1B

Table 25: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHIPTOC2 - start	Positive or Rising
4	PHPVOC1 - start	Positive or Rising
8	DEFLPDEF1 - start	Positive or Rising
9	DEFLPDEF2 - start	Positive or Rising
10	DEFHPDEF1 - start	Positive or Rising
11	EFHPTOC1 - start	Positive or Rising
12	MNSPTOC1 - start	Positive or Rising
13	MNSPTOC2 - start	Positive or Rising
18	DOPPDPR1 - start	Positive or Rising
19	DOPPDPR2 - start	Positive or Rising
21	DUPPDPR1 - start	Positive or Rising
22	DUPPDPR2 - start	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
23	OEPVPH1 - start	Positive or Rising
25	UEXPDIS1 - start	Positive or Rising
26	ROVPTOV1 - start	Positive or Rising
27	ROVPTOV2 - start	Positive or Rising
32	FRPFRQ1 - start	Positive or Rising
33	FRPFRQ2 - start	Positive or Rising
34	FRPFRQ3 - start	Positive or Rising
35	FRPFRQ4 - start	Positive or Rising
36	T2PTTR1 - start	Positive or Rising
37	PHLPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHIPTOC2 - operate	
	PHPVOC1 - operate	
39	EFHPTOC1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	DEFHPDEF1 - operate	
40	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
42	DUPPDPR1 - operate	Level trigger off
	DUPPDPR2 - operate	
	DOPPDPR1 - operate	
	DOPPDPR2 - operate	
43	OEPVPH1 - operate	Level trigger off
45	UEXPDIS1 - operate	Level trigger off
46	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
47	FRPFRQ1 - operate	Level trigger off
	FRPFRQ2 - operate	
	FRPFRQ3 - operate	
	FRPFRQ4 - operate	
48	MPDIF1 - opr ls	Positive or Rising
49	MPDIF1 - opr hs	Positive or Rising
50	MPDIF1 - int blkd	Level trigger off
51	T2PTTR1 - operate	Level trigger off
52	CCBRBRF1 - trret	Level trigger off
53	CCBRBRF1 - trbu	Level trigger off
54	INRPHAR1 - blk2h	Level trigger off
55	SEQSPVC1 - fusef u	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
56	X130BI1 - Ext trip1	Positive or Rising
57	X130BI2 - Ext trip2	Positive or Rising
58	X130BI4 - Field excitation open	Positive or Rising
59	X110BI7 - CB closed	Level trigger off
60	X110BI8 - CB open	Level trigger off
61	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
62	ARCSARC1 - operate	Positive or Rising
63	ARCSARC2 - operate	Positive or Rising
64	ARCSARC3 - operate	Positive or Rising

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 analog channels are assigned to different functions. The phase currents to the protection relay are fed from a current transformer. The common signal marked with 3I represents the three phase currents of the neutral side of the generator and 3IB represents the three phase currents of the terminal side of the generator. It is assumed that the core balance CT is provided both on line and neutral side of the generator and are connected such that the differential residual current is fed to the protection relay.

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

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. The Application Configuration tool also includes fixed Boolean signals TRUE and FALSE which can be used according to the application needs.

3.5.3.1 Functional diagrams for protection

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

Three non-directional and two directional overcurrent stages are offered for detecting phase faults in generators. In addition, one instance of voltage-dependent overcurrent protection is also provided which can be used as a backup protection against phase faults. During certain conditions, the fault current for three-phase faults may be less than full load current of the generator. This may not get noticed by phase overcurrent protection, but the fault causes generator terminal voltage to drop. Voltage dependent overcurrent protection can be used to detect and operate such faults.

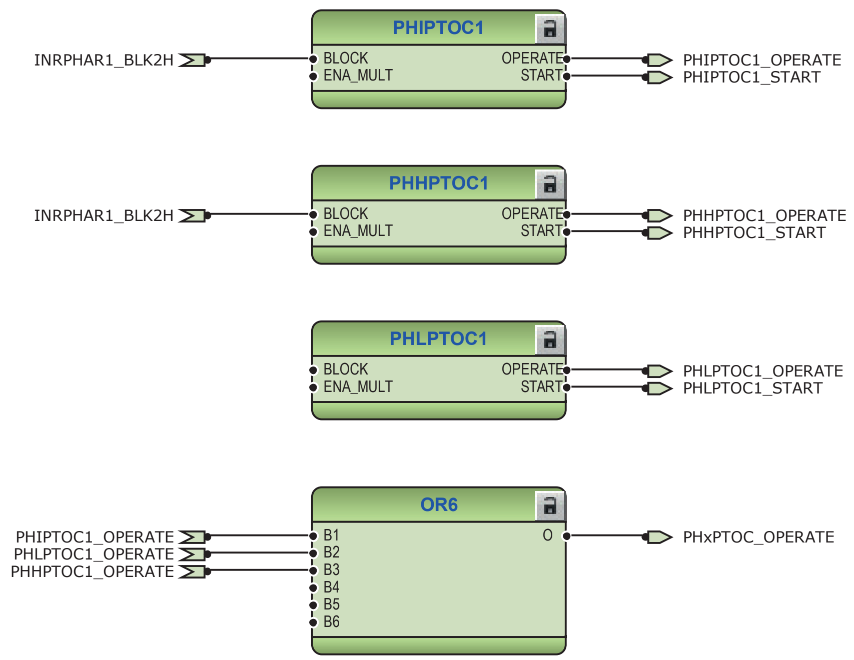


Figure 137: Non directional overcurrent protection function

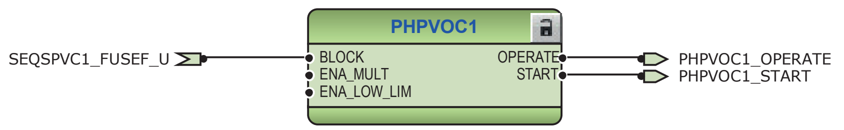


Figure 138: Voltage dependent overcurrent protection function

The output `BLK2H` of three-phase inrush detector INRPHAR1 either blocks the function or multiplies the active settings for any of the available overcurrent or earth-fault function blocks. In the configuration, INRPHAR1 blocks the high and instantaneous stage of non-directional overcurrent protection.

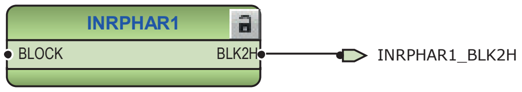


Figure 139: Inrush detector function

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 are provided for phase unbalance protection. These functions are used to protect against unbalance conditions due to unbalance load or unsymmetrical faults.

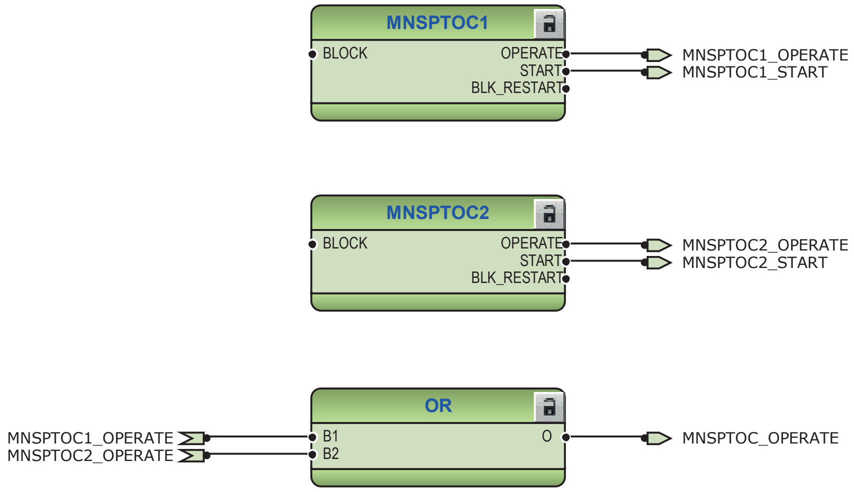


Figure 140: Negative sequence overcurrent protection function

One non-directional sensitive earth-fault stage EFHPTOC1 and three directional earth-fault stages DEFxPDEF are offered for providing primary and backup protection for generator earth-fault protection. Transient/intermittent earth-fault protection INTRPTEF is used for transient-based earth-fault protection.

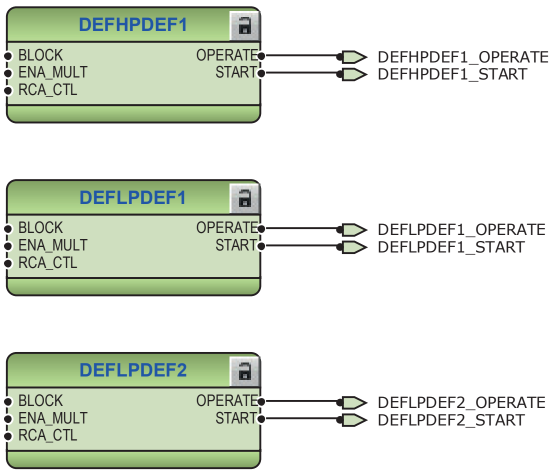


Figure 141: Directional earth-fault protection function

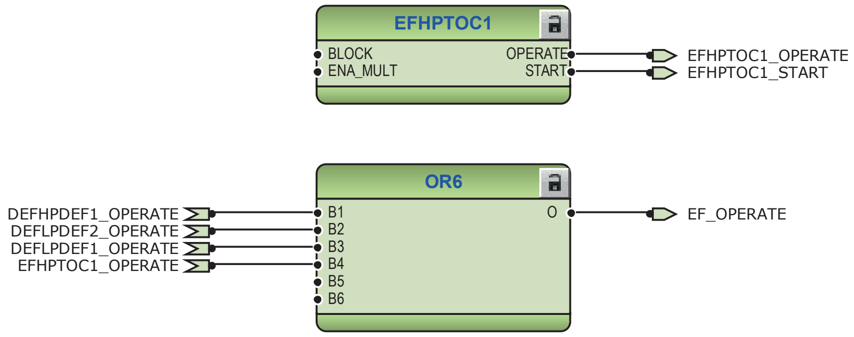


Figure 142: Earth-fault protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects continuous overloading conditions preventing excessive insulation damage in the long run.

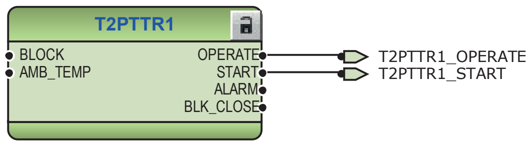


Figure 143: Thermal overcurrent protection function

The stabilized and instantaneous differential protection for machines MPDIF1 provides protection against internal failures. The relay compares the phase currents on both sides of the generator to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operating signal. The operating signal is connected to the master trip 1 and 2, trip of field excitation and also to the alarm LED 1.

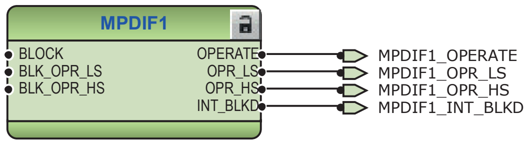


Figure 144: Differential protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the `START` 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` operating output is used for retripping its own breaker through TRPPTRC2_TRIP. The `TRBU` output gives a backup trip to the breaker feeding upstream. For this purpose, the `TRBU` operating output signal is connected to the binary output X100:PO2. In addition, `TRBU` operating output is also used to trip field excitation circuit breaker through TRPPTRC6_TRIP_FIELD EXCITATION.

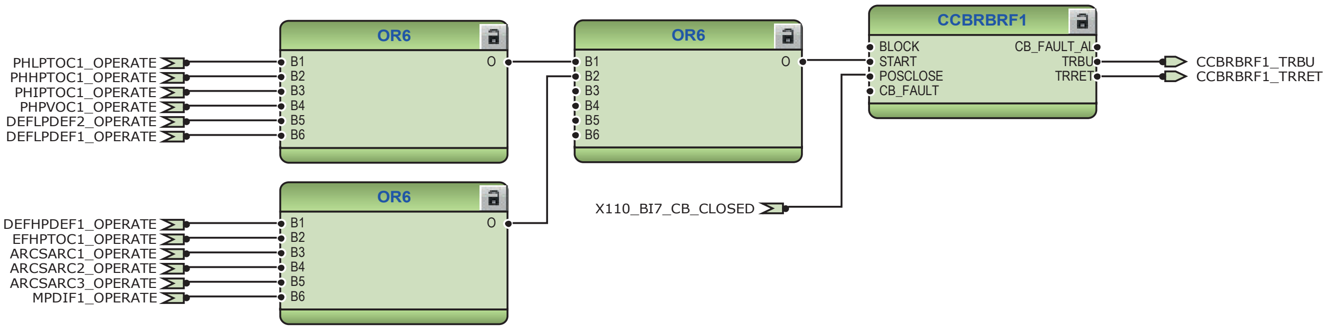


Figure 145: Circuit breaker failure protection function

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

The operating signals from ARCSARC1...3 are connected to both generator circuit breaker trip logic TRPPTRC1 and TRPPTRC2 and also to field excitation circuit breaker trip logic TRPPTRC6. If the relay has been ordered with high speed binary outputs, the individual operating signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

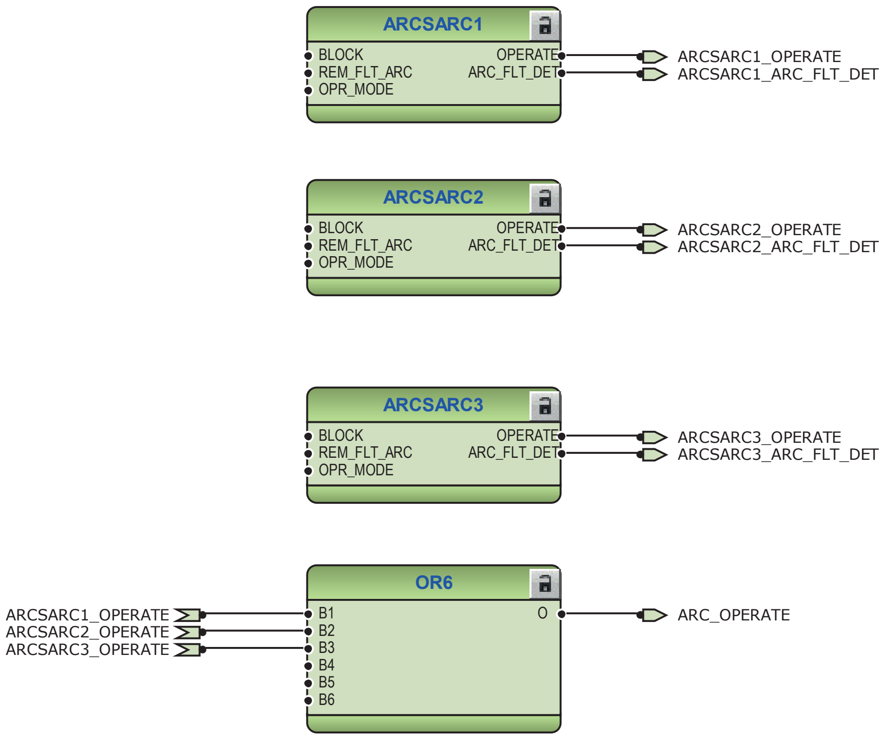


Figure 146: Arc protection function

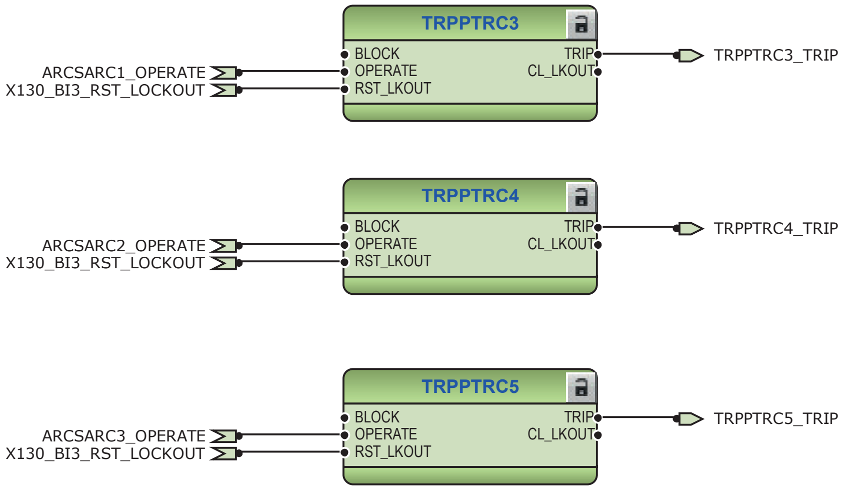


Figure 147: Arc protection with dedicated HSO

Residual overvoltage protection ROVPTOV provides protection against stator earth faults from 5% to 100% of winding from neutral. Two instances of ROVPTOV are provided.

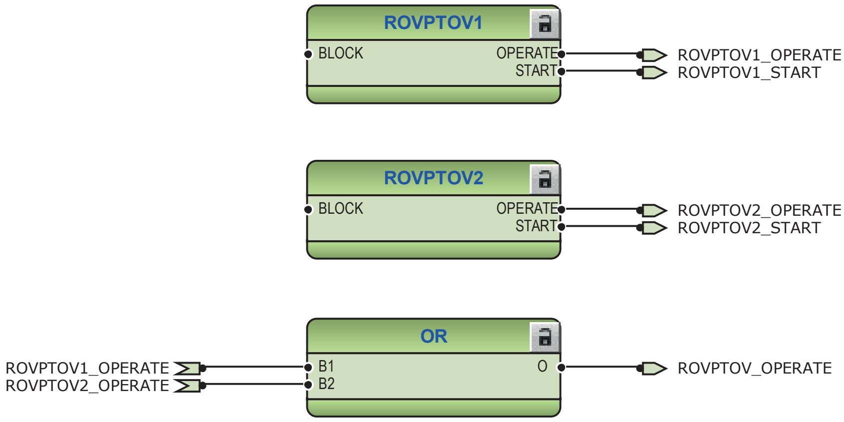


Figure 148: Residual overvoltage protection function

The selectable underfrequency or overfrequency or rate of change of frequency protection FRPFRQ prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. Configuration offers four instances of frequency protection, these instances can be configured to operate as underfrequency or overfrequency or rate of change of frequency according to the system requirement. The frequency protection is blocked when generator CB is in open position.

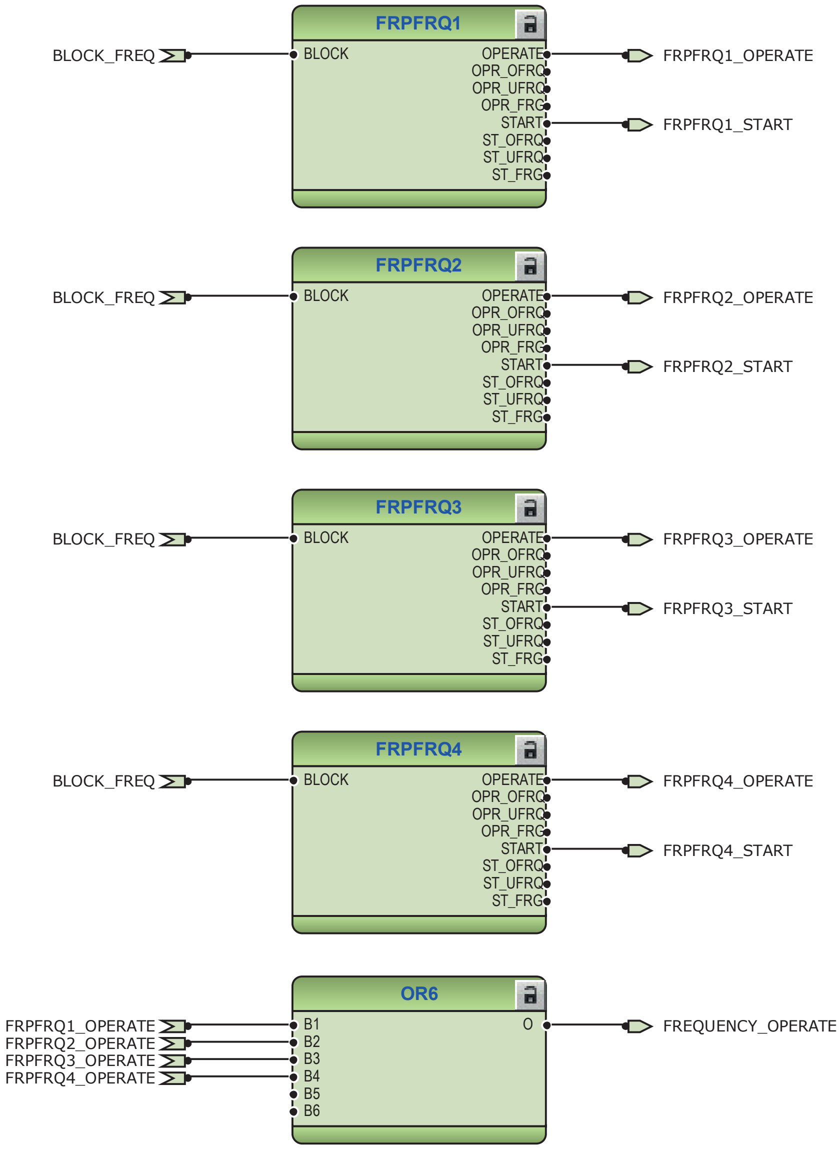


Figure 149: Frequency protection function

Two instances of reverse power/directional overpower protection DOPPDPR are provided to detect either loss of prime mover or detecting motoring action or detecting any abnormal high reactive power being absorbed by the generator.

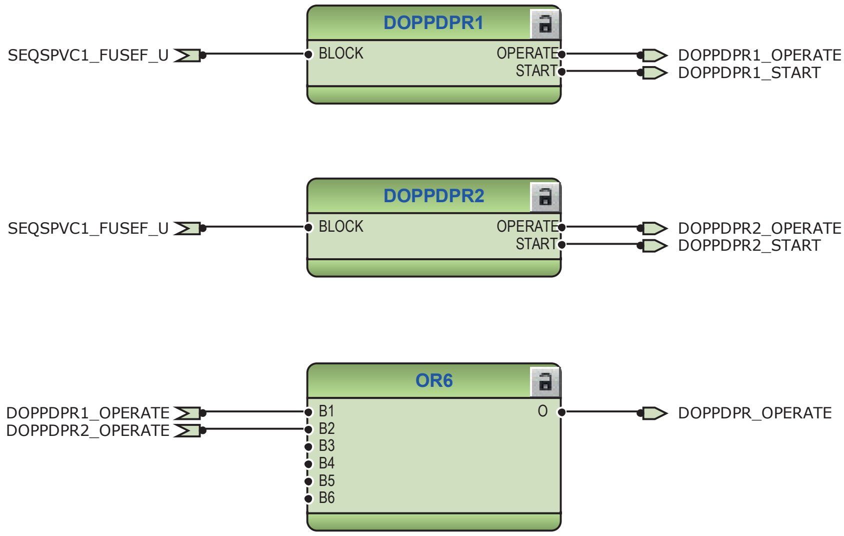


Figure 150: Directional overpower protection function

Two instances of underpower protection DUPPDPR are provided. Normally these are used in coordination with reverse active power protection.

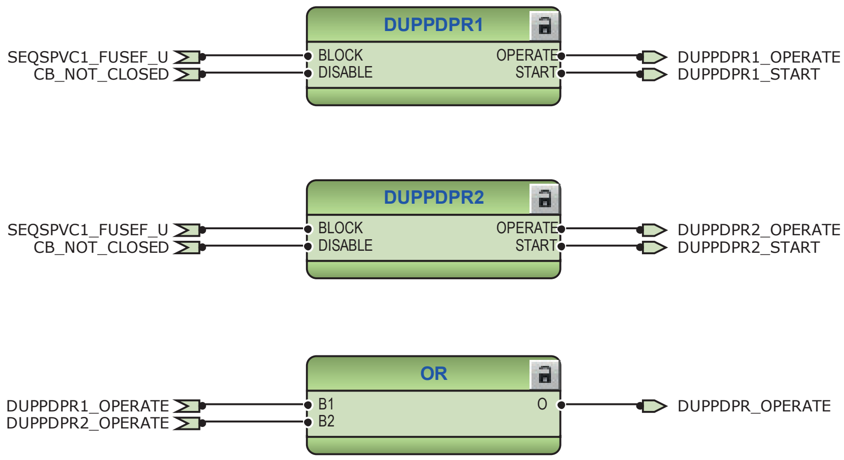


Figure 151: Directional underpower protection function

On losing excitation, generator may over speed and operate as an induction generator taking reactive power from the system which may reduce system voltages. Three-phase underexcitation protection UEXPDIS is provided to detect such conditions. Directional underpower protection is disabled when the generator circuit breaker is in open position.

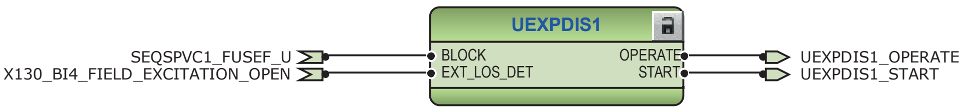


Figure 152: Underexcitation protection function

Overexcitation protection OEPVPH is provided to protect the generator against overexcitation. Due to overexcitation, saturation of the magnetic core of generator and connected transformer may occur, and stray flux may be induced in nonlaminated components that are not designed to carry flux. Excessive flux also causes excessive eddy currents resulting into excessive voltage between laminations causing overheating and damage to insulation.

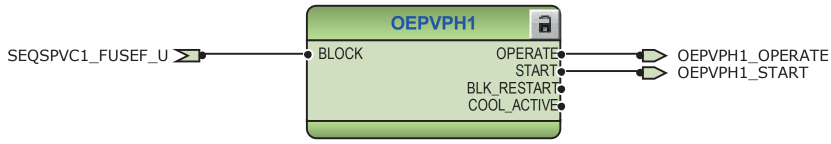


Figure 153: Overexcitation protection function

General start and operate signals from all 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 output.

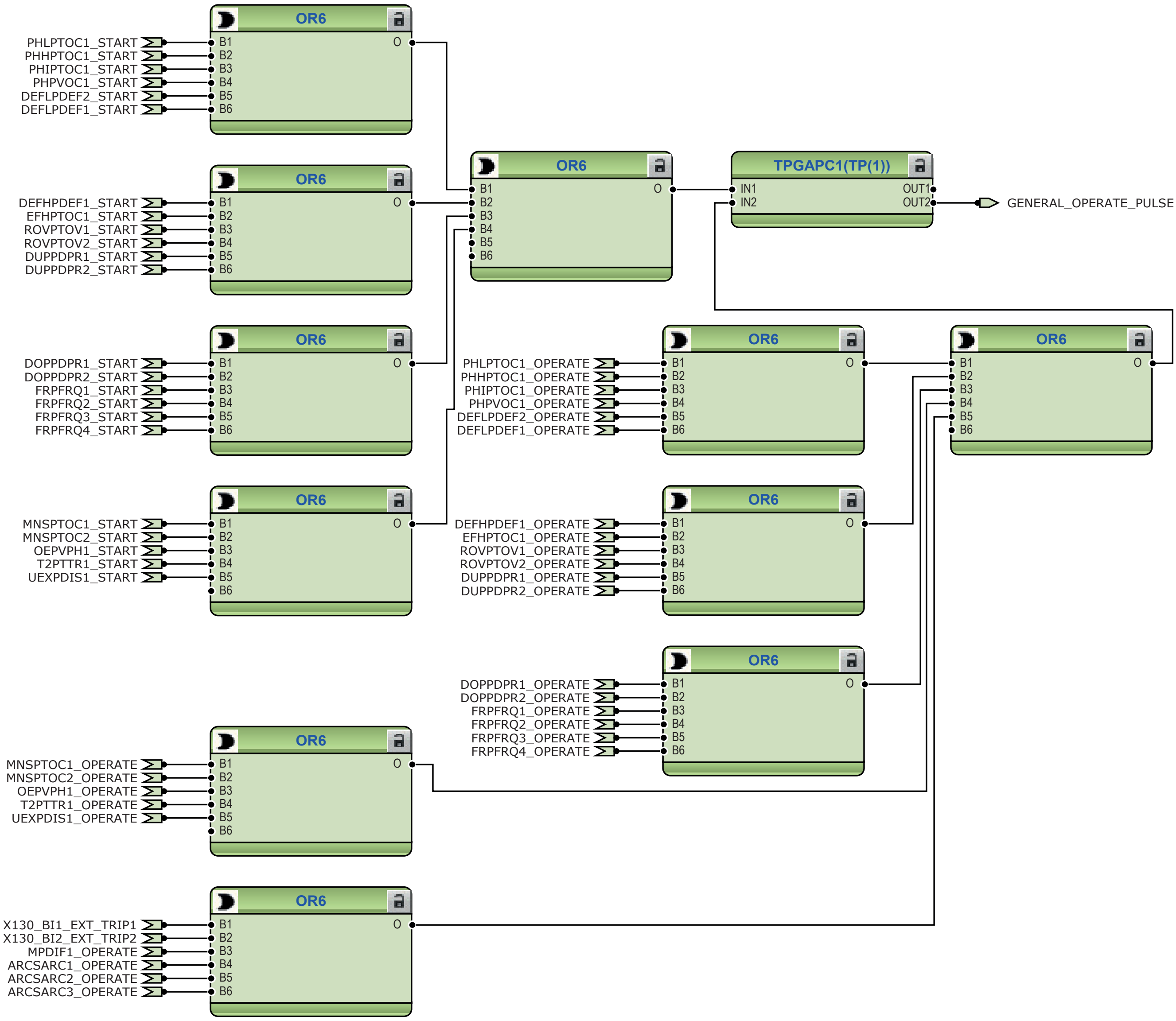


Figure 154: General start and operate signal

The operating signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X130:BI3 has been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

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

In addition, trip logic TRPPTRC6 is available to trip the circuit breaker of filed excitation. The protection function which should trip the field excitations are connected to TRPPTRC6.

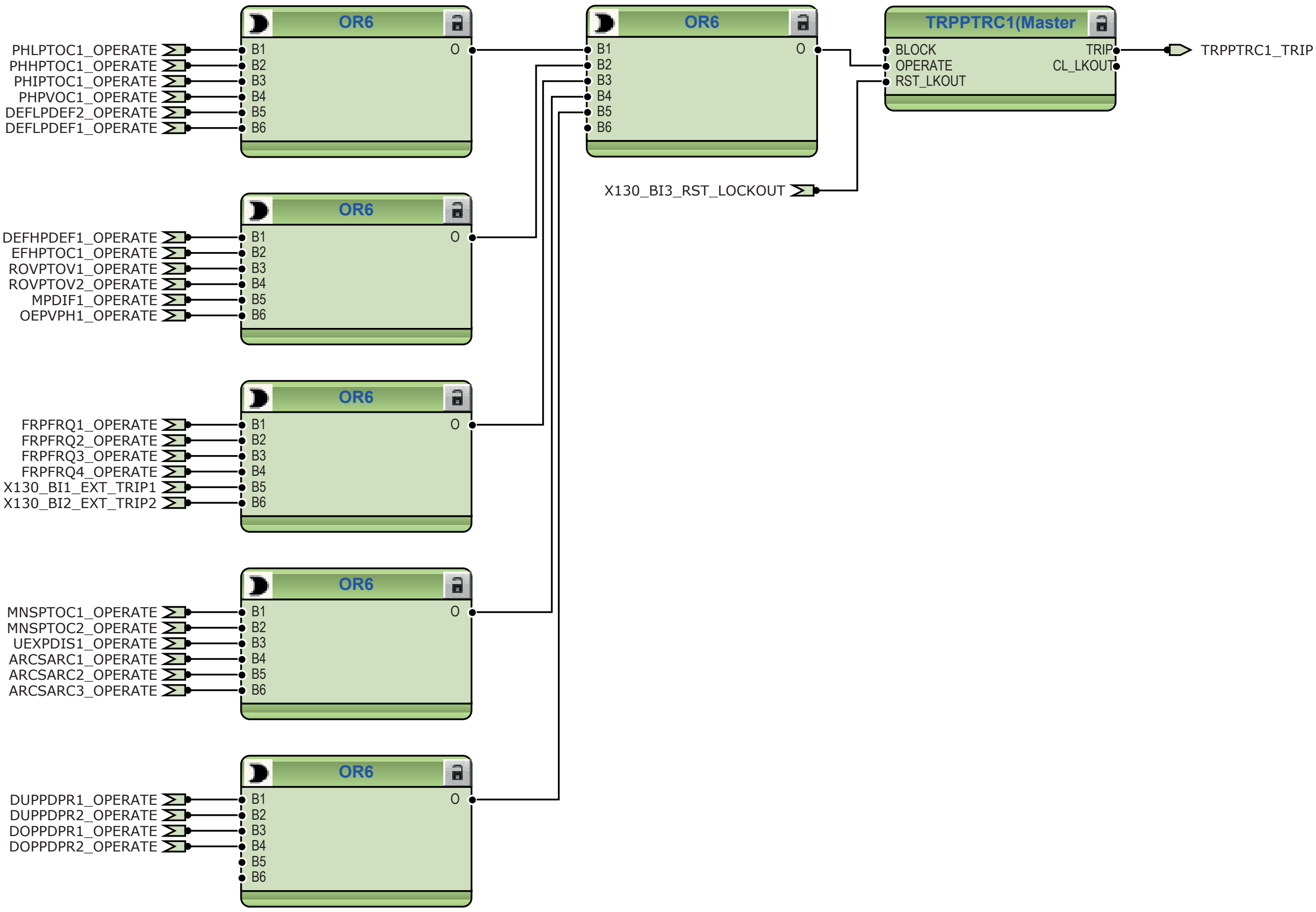


Figure 155: *Trip logic TRPPTRC1*

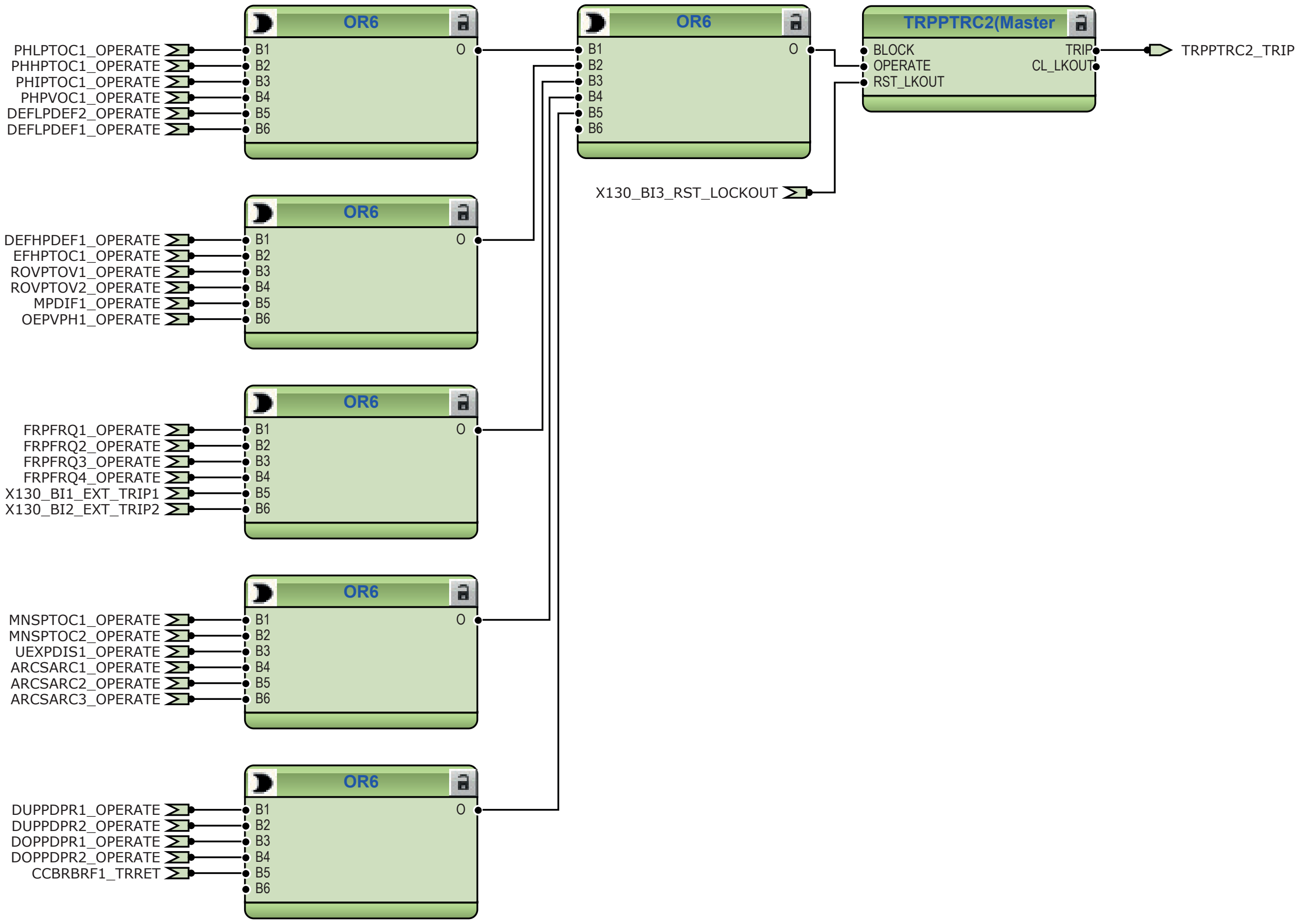


Figure 156: Trip logic TRPPTRC2

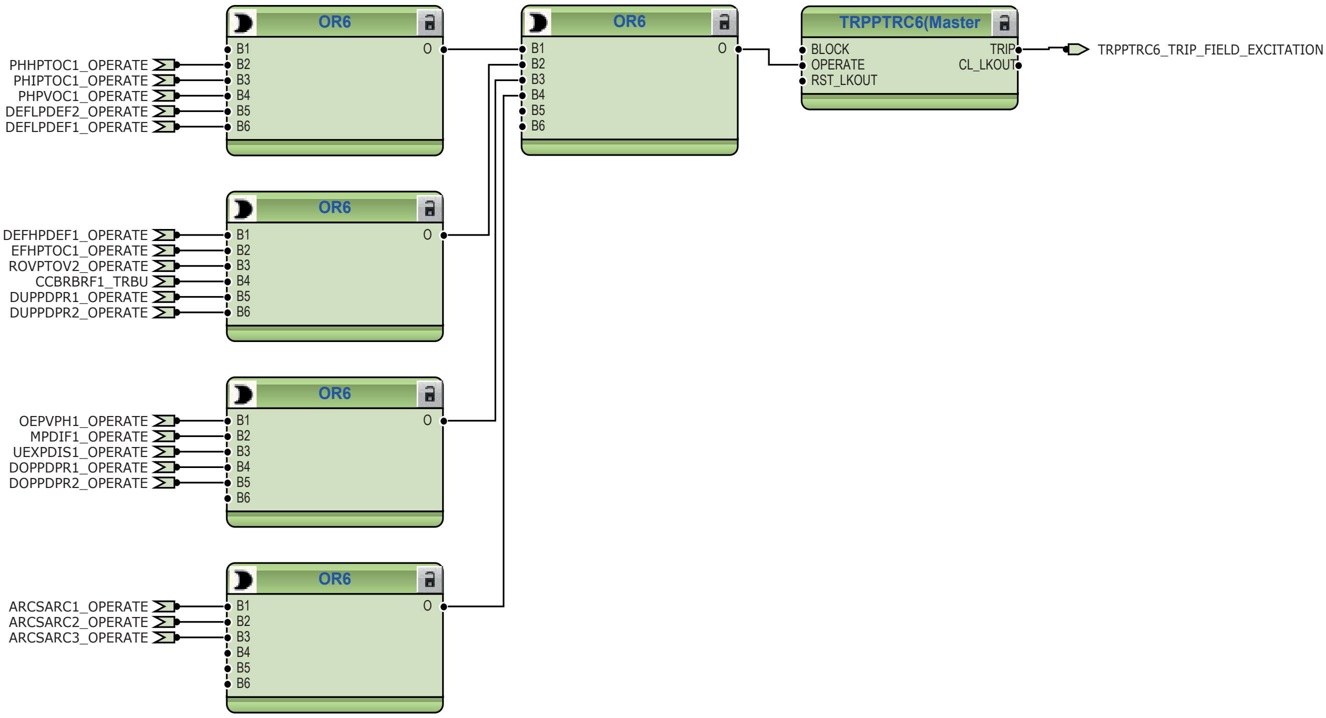


Figure 157: Trip logic TRPPTRC6 (Field excitation)

3.5.3.2 Functional diagrams for disturbance recorder

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

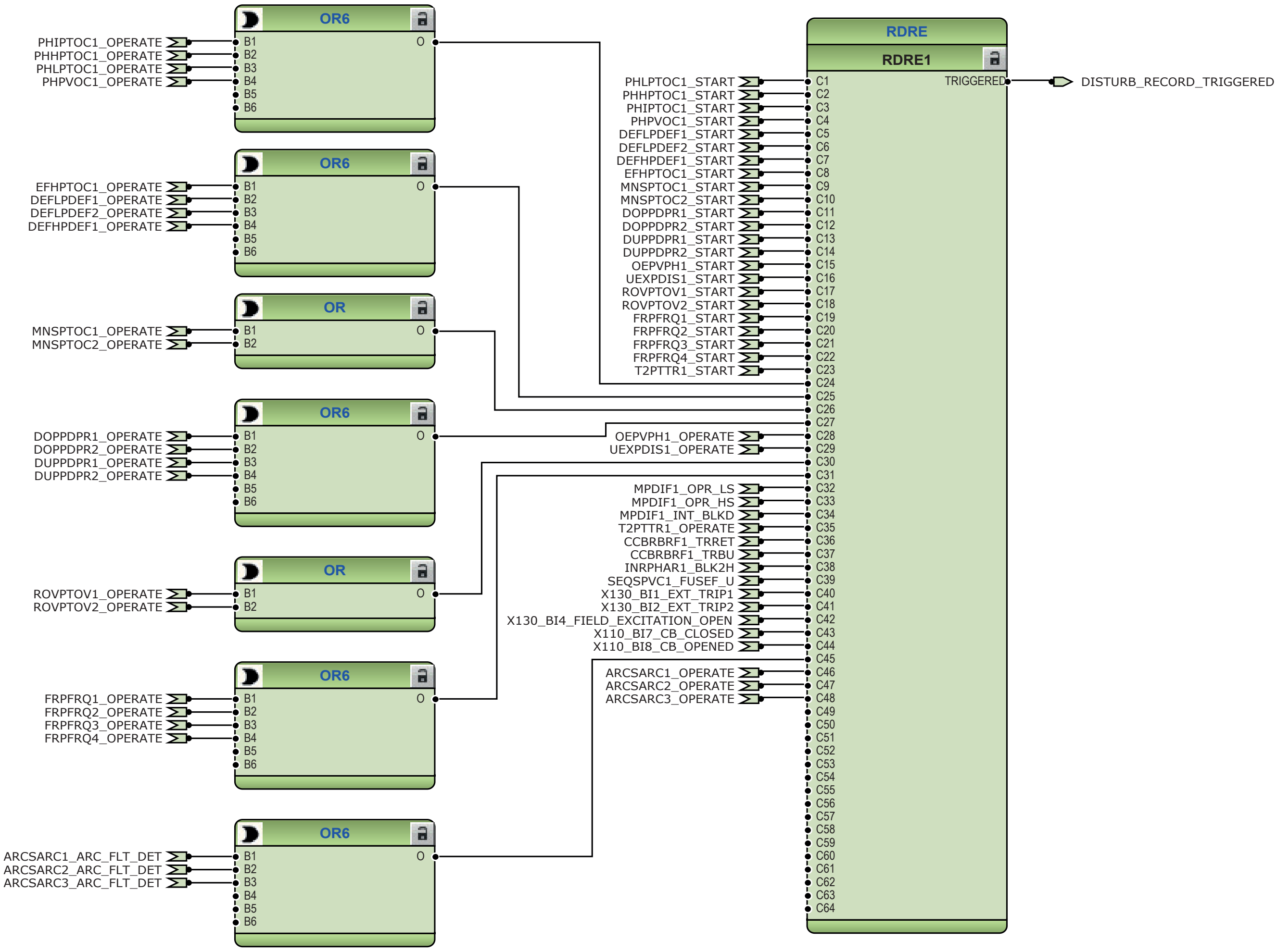


Figure 158: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

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

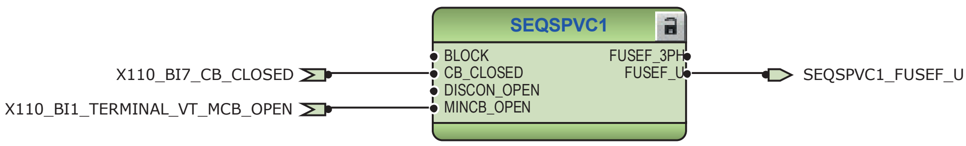


Figure 159: Fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

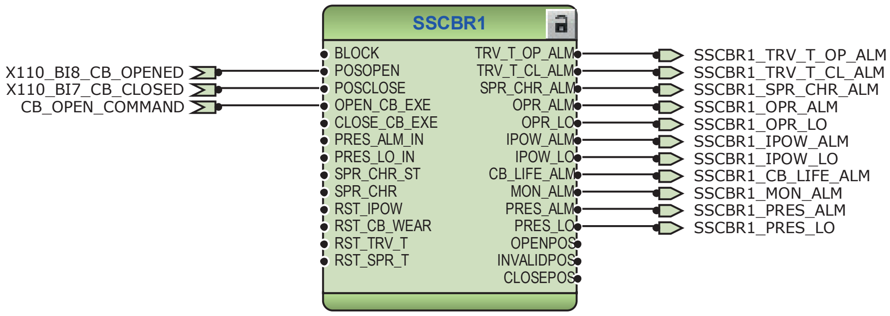


Figure 160: Circuit breaker condition monitoring function

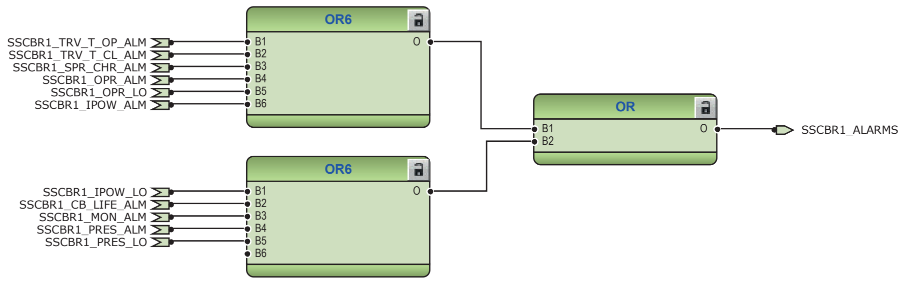


Figure 161: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 function is blocked by the master trip TRPPTRC1 and TRPPTRC2 and the generator circuit breaker open signal, whereas TCSSCBR2 function is blocked by the master trip TRPPTRC6 and the field excitation 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's normally open auxiliary contact.

Set the parameters for TCSSCBR1 properly.

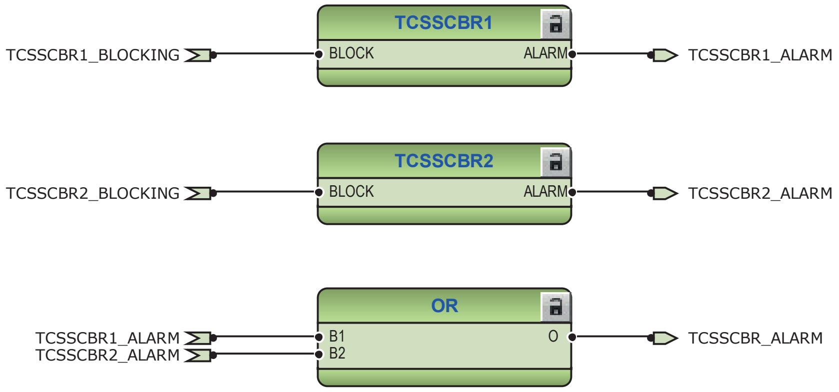


Figure 162: Trip circuit supervision function

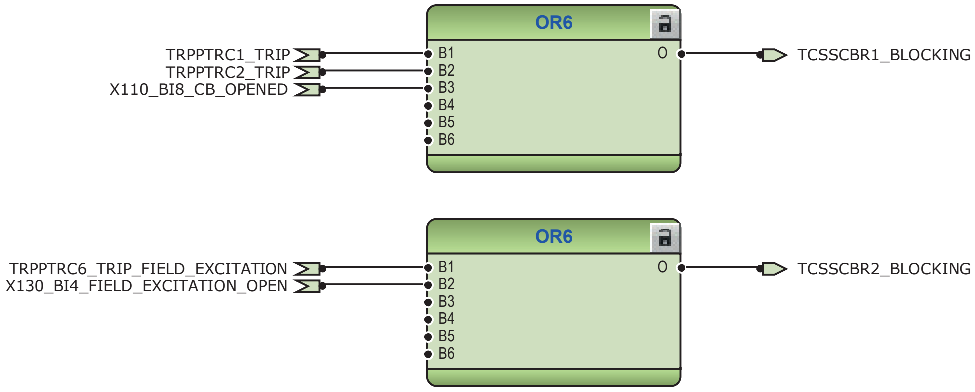


Figure 163: Logic for blocking of trip circuit supervision

Runtime counter for machines and devices MDSOPT provides history data since the last commissioning. The counter counts the total number of generator running hours and is incremented when the energizing circuit breaker is closed.

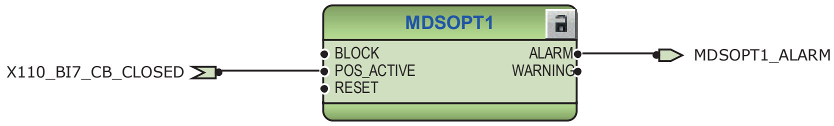


Figure 164: Generator runtime counter

3.5.3.4 Functional diagrams for control and interlocking

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

SECRSYN measures the bus and line voltages and compares them to set conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for closing the circuit breaker or allowing the closing. The SECRSYN1_SYNC_OK output signal of SECRSYN is connected to SYNC_OK input of CBXCBR through control logic. The function is blocked in case of terminal side or bus side MCB is open.

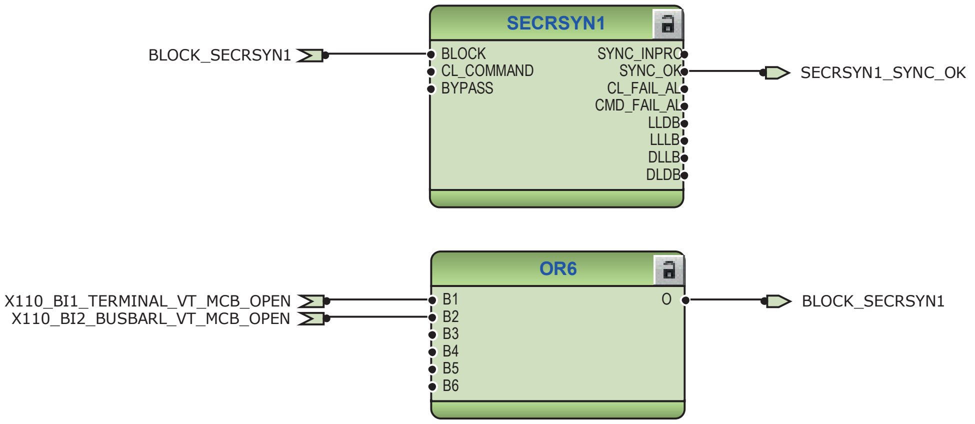


Figure 165: Synchrocheck function

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

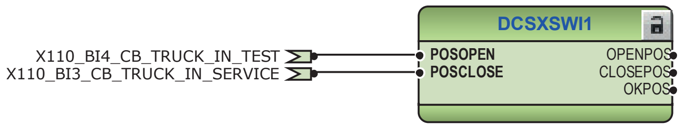


Figure 166: Disconnector control logic

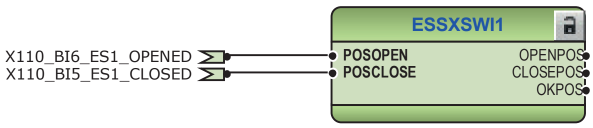


Figure 167: Earth switch control logic

The circuit breaker closing is disabled by default, as in case of generator, the closing of the circuit breaker is done by a special synchronizer device.

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

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

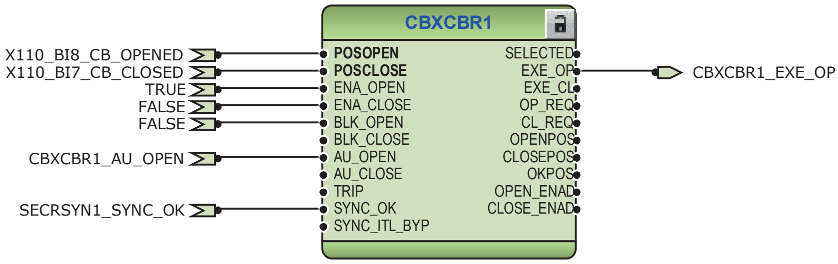


Figure 168: Circuit breaker 1 control logic

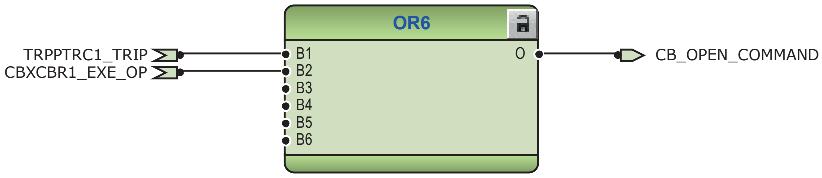


Figure 169: Signal for opening coil of circuit breaker 1

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

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

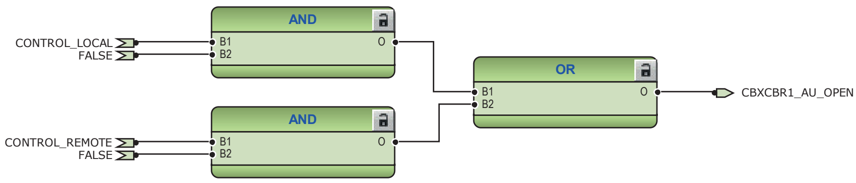


Figure 170: External opening command for circuit breaker 1

3.5.3.5 Functional diagram for measurement functions

The neutral side and terminal side phase current inputs to the relay are measured by the three-phase current measurement CMMXU1 and CMMXU2. The three-phase current input is connected to the X120 card in the back panel. The neutral side sequence current measurement is measured by CSMSQI1 and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase terminal side voltage inputs to the relay are measured by three-phase voltage measurement VMMXU1 whereas the bus side voltage input to the relay is measured by three-phase voltage measurement VMMXU2. In addition to phase voltage, terminal side residual voltage is measured by residual voltage measurement RESVMMXU1. The three-phase voltage inputs as well as residual voltages are connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

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

The frequency measurement FMMXU1 of the power system and 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.

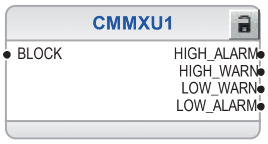


Figure 171: Current measurement: Three-phase current measurement (neutral side)

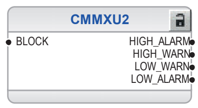


Figure 172: Current measurement: Three-phase current measurement (terminal side)

Figure 173: Current measurement: Sequence current measurement

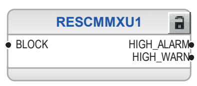


Figure 174: Current measurement: Residual current measurement

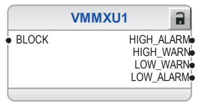


Figure 175: Voltage measurement: Three-phase voltage measurement (terminal side)

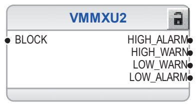


Figure 176: Voltage measurement: Three-phase voltage measurement (bus side)

Figure 177: Voltage measurement: Sequence voltage measurement

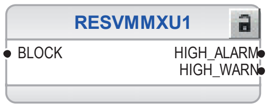


Figure 178: Voltage measurement: Residual voltage measurement

Figure 179: Other measurement: Frequency measurement

Figure 180: Other measurement: Three phase power and energy measurement

Figure 181: Other measurement: Data monitoring

Figure 182: Other measurement: Load profile record

3.5.3.6 Functional diagrams for IOs and alarm LEDs

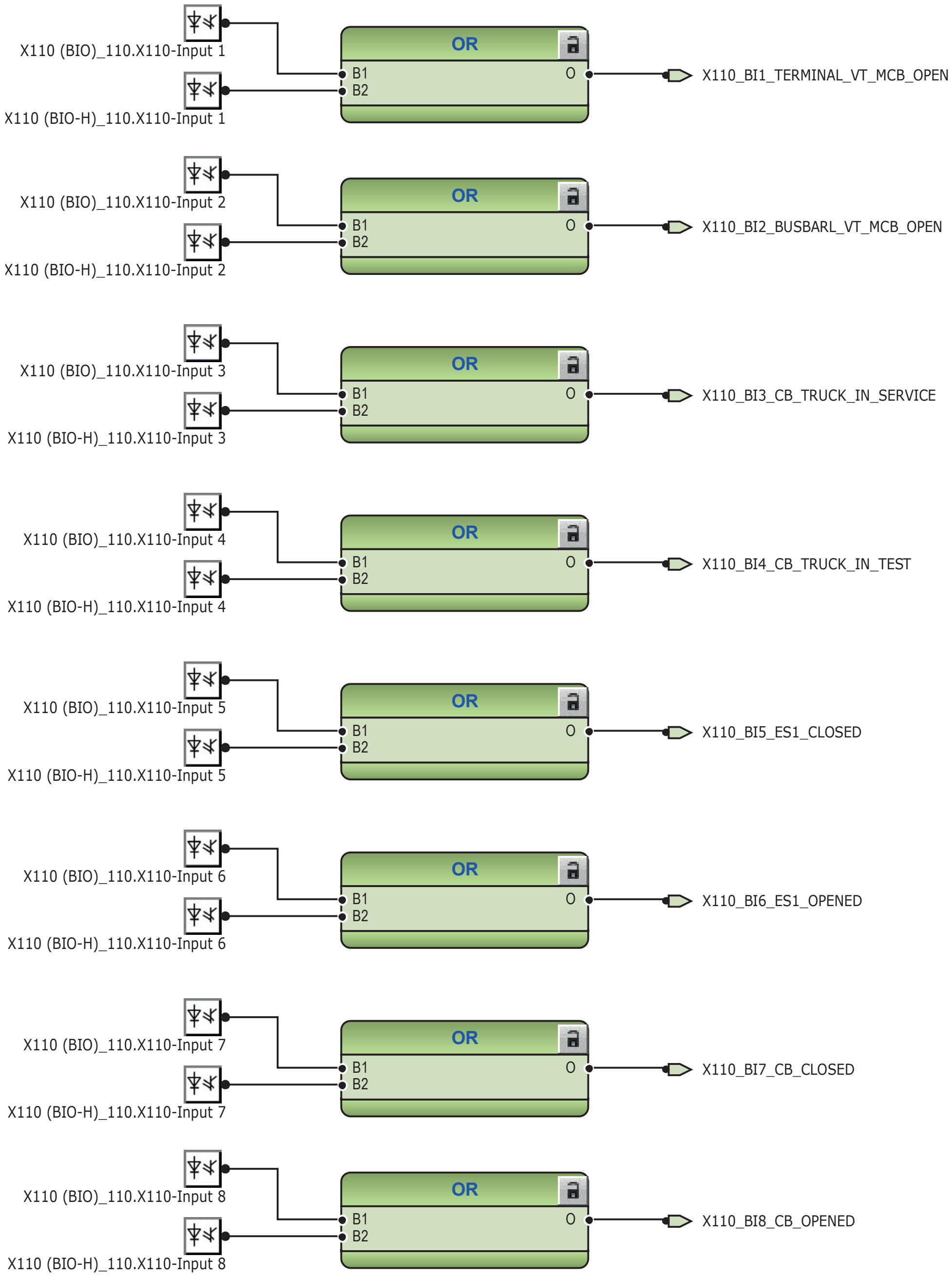


Figure 183: Default binary input - X110

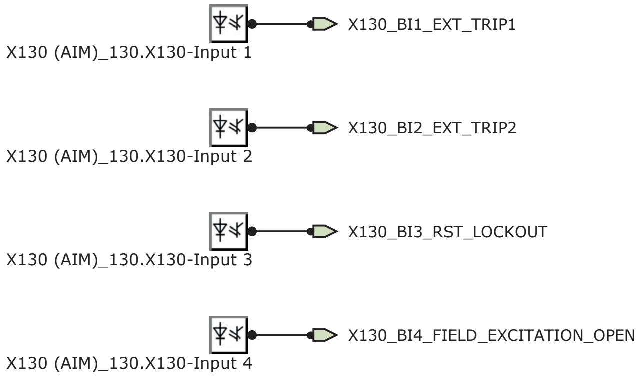


Figure 184: Default binary input - X130

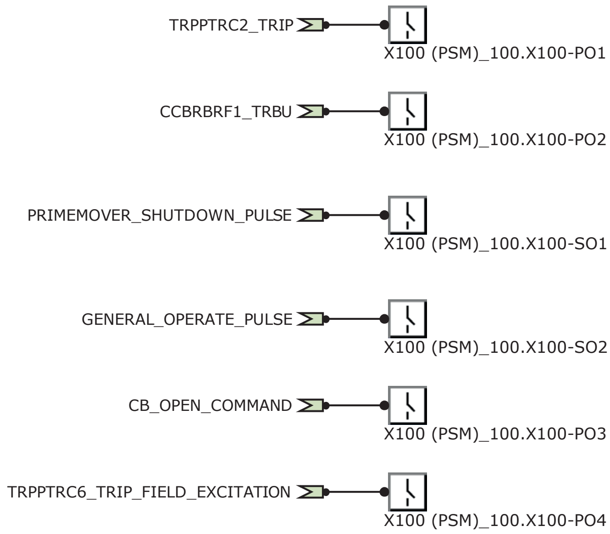


Figure 185: Default binary output - X100

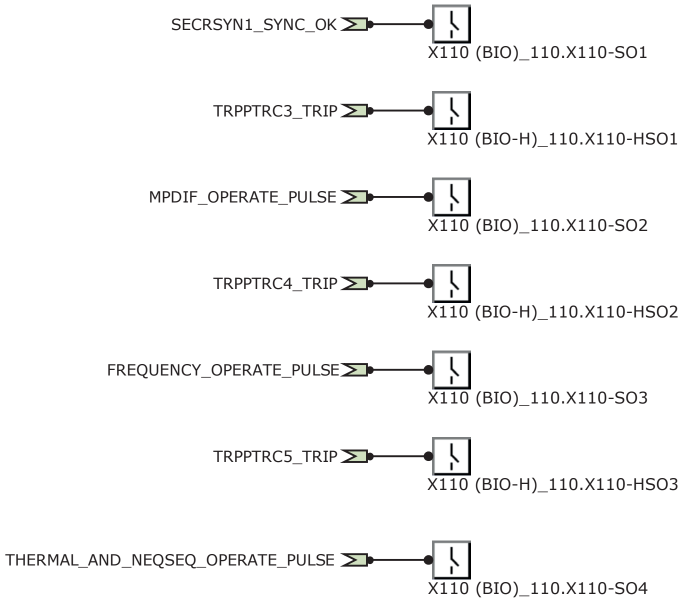
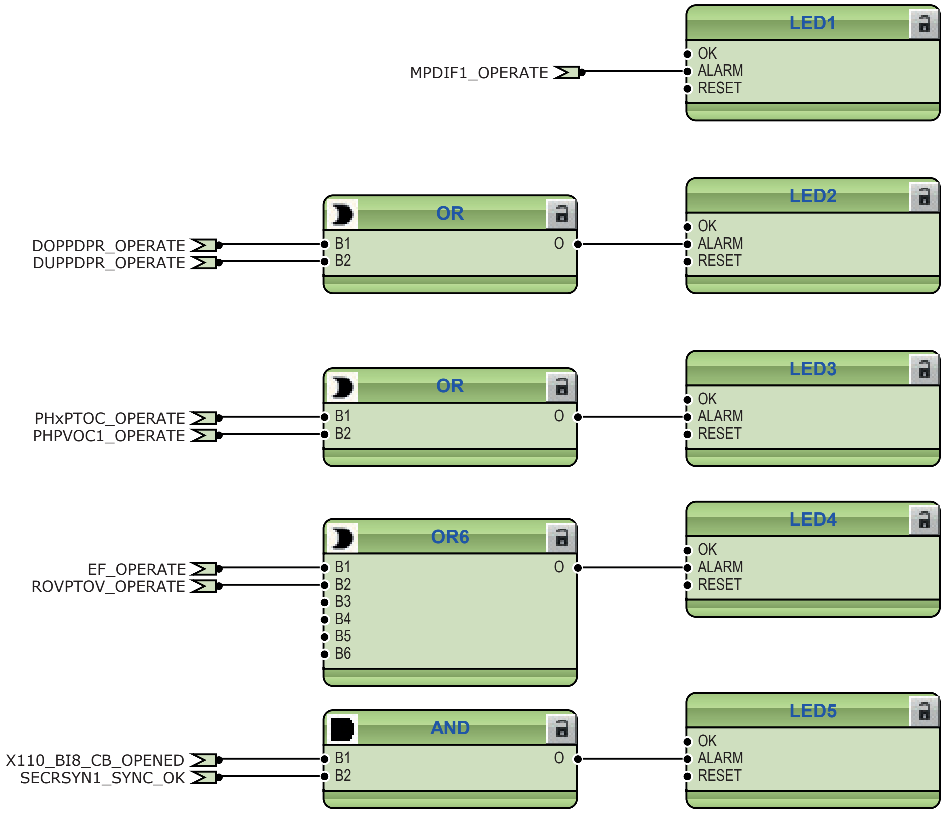


Figure 186: Default binary output - X110


LED1
OK
ALARM
RESET
MPDIF1_OPERATE
OR
B1
B2
O
DOPPDPR_OPERATE
DUPPDPR_OPERATE
LED2
OK
ALARM
RESET
OR
B1
B2
O
PHxPTOC_OPERATE
PHPVOC1_OPERATE
LED3
OK
ALARM
RESET
OR6
B1
B2
B3
B4
B5
B6
O
EF_OPERATE
ROVPTOV_OPERATE
LED4
OK
ALARM
RESET
AND
B1
B2
O
X110_BI8_CB_OPENED
SECRSYN1_SYNC_OK
LED5
OK
ALARM
RESET

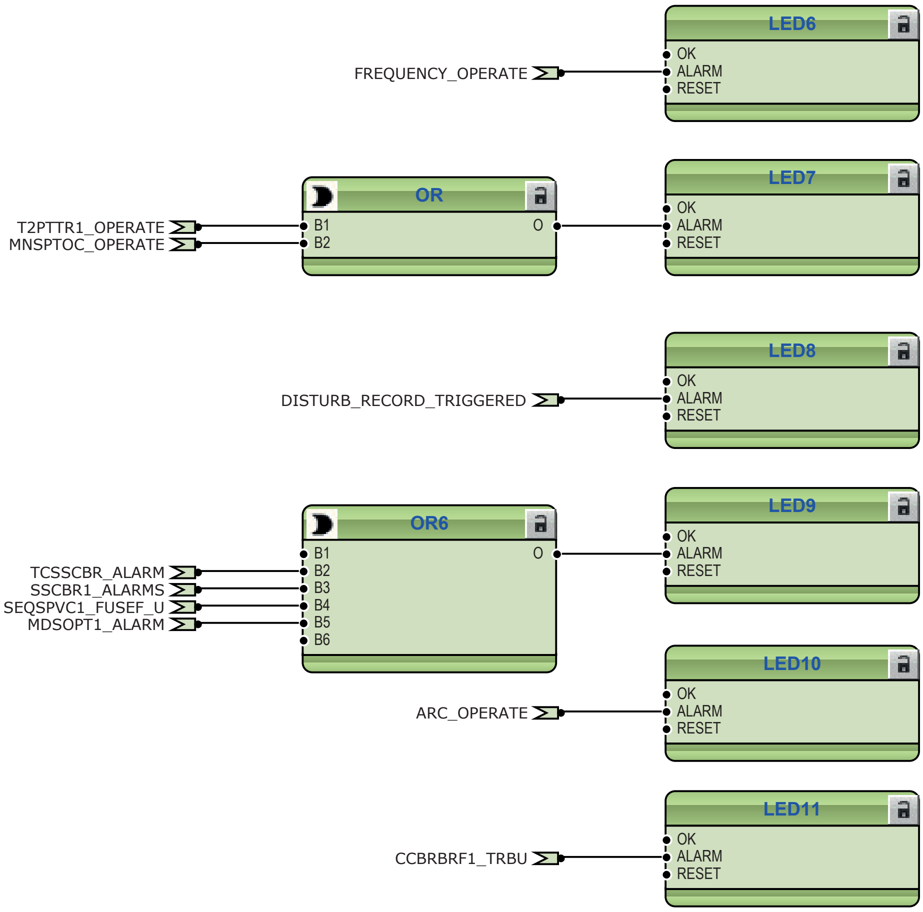


Figure 187: Default LED connection

3.5.3.7 Functional diagram for other timer logics

The configuration includes differential operate, frequency operate, thermal and negative-sequence protection operate, prime mover shutdown logic, blocking logic for frequency protection and logic to disable directional underpower protection. The operate logics are connected to the minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to the binary outputs.

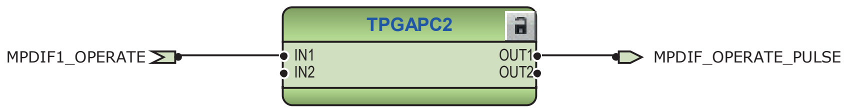


Figure 188: Timer logic for differential protection operate pulse

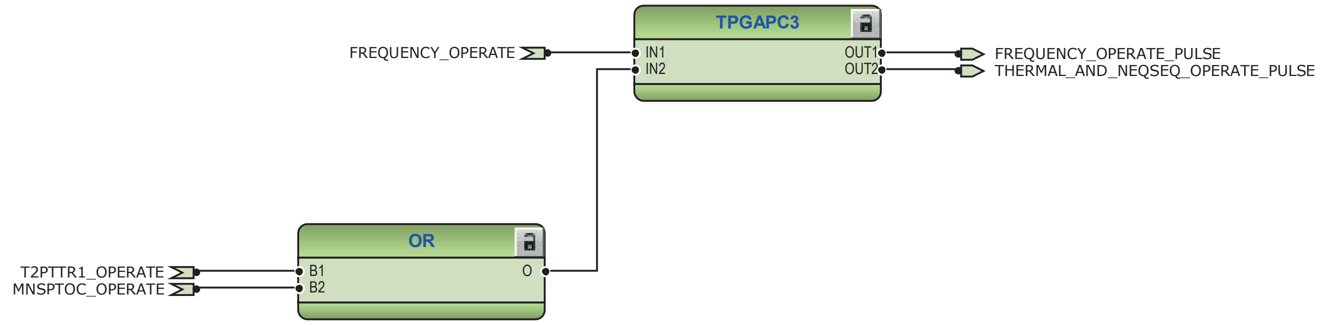


Figure 189: Timer logic for voltage/frequency and thermal/negative sequence protection operate pulse

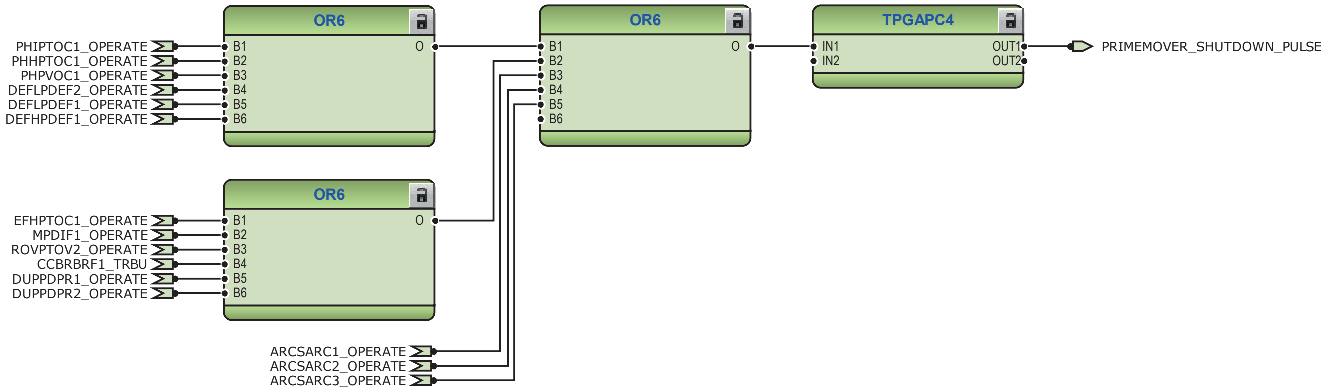


Figure 190: Timer logic for primemover shutdown pulse

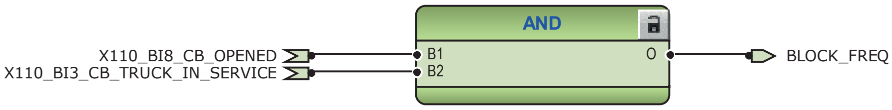


Figure 191: Blocking logic for frequency protection

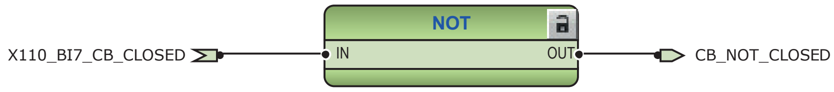


Figure 192: Disable logic for directional underpower protection

3.5.3.8 Other functions

The configuration includes two instances of three-phase directional overcurrent protection, two instances of three-phase undervoltage and overvoltage protection, two instances of negative-sequence overvoltage and positive-sequence undervoltage protection, 18 instances of multipurpose protection MAPGAPC, power quality function and different types of timers and control functions. These functions are not included in the application configuration but they can be added based on the system requirements.

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 26: 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 start current settings

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

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

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

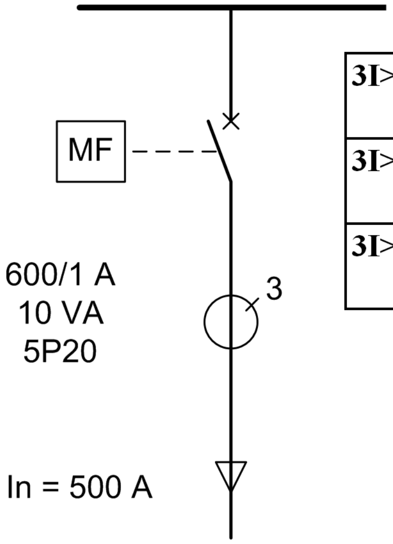
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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

4.1.1.3 Example for non-directional overcurrent protection

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



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

Figure 193: Example of three-stage overcurrent protection

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 193). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 193.

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

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

Table 27: Phase current inputs included in configurations A and C

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

Table 28: Phase current inputs included in configuration D

Terminal	Description
X120:1-2	IL1B
X120:3-4	IL2B
X120:5-6	IL3B
X120:7-8	IL1
X120:9-10	IL2
X120:11-12	IL3

5.1.1.2 Residual current

Table 29: Residual current input included in configurations A, C and D

Terminal	Description
X120:13-14	Io

5.1.1.3 Phase voltages

Table 30: Phase voltage inputs included in configurations A, C and D

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

Table 31: Reference voltage input for SECRSYN1 included in configurations A and D

Terminal	Description
X130:9-10	U12B

5.1.1.4 Residual voltage

Table 32: Additional residual voltage input included in configurations A, C and D

Terminal	Description
X130:9-10	UoB 1)
X130:17-18	Uo

1) Used only for H3EFPSEF1 in configuration C

5.1.2 Auxiliary supply voltage input

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

Table 33: Auxiliary voltage supply

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

5.1.3 Binary inputs

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

Binary inputs of slot X110 are available with configurations A, C and D.

Table 34: Binary input terminals X110:1-13 with BIO0005 module

Terminal	Description
X110:1 X110:2	BI1, + BI1, -
X110:3 X110:4	BI2, + BI2, -
X110:5 X110:6	BI3, + BI3, -
X110:6 X110:7	BI4, - BI4, +
Table continues on next page	

Terminal	Description
X110:8 X110:9	BI5, + BI5, -
X110:9 X110:10	BI6, - BI6, +
X110:11 X110:12	BI7, + BI7, -
X110:12 X110:13	BI8, - BI8, +

Table 35: Binary input terminals X110:1-10 with BIO0007 module

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

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

Table 36: Binary input terminals X120-1...6

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

Table 37:

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

5.1.4 Optional light sensor inputs

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

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

Table 38: Light sensor input connectors

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

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 39: Output contacts

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

5.2.2 Outputs for signalling

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

Table 40: Output contacts X100:10-14

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

Output contacts of slot X110 are optional for configurations A, C and D.

Table 41: 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
Table continues on next page	

Terminal	Description
X110:20	SO3, common
X110:21	SO3, NO
X110:22	SO3, NC
X110:23	SO4, common
X110:24	SO4, NO

Table 42: 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

Table 43: 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 44: IRF contact

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

Section 6 Glossary

615 series	Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
AC	Alternating current
AI	Analog input
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
I/O	Input/output
IEC	International Electrotechnical Commission

IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol

PTP	Precision Time Protocol
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit
SAN	Single attached node
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SMV	Sampled measured values
SNTP	Simple Network Time Protocol
SO	Signal output
TCS	Trip-circuit supervision
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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