RELION® 620 SERIES

Motor Protection and Control REM620

Application Manual

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2014/30/EU) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2014/35/EU). 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.

Contents

1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

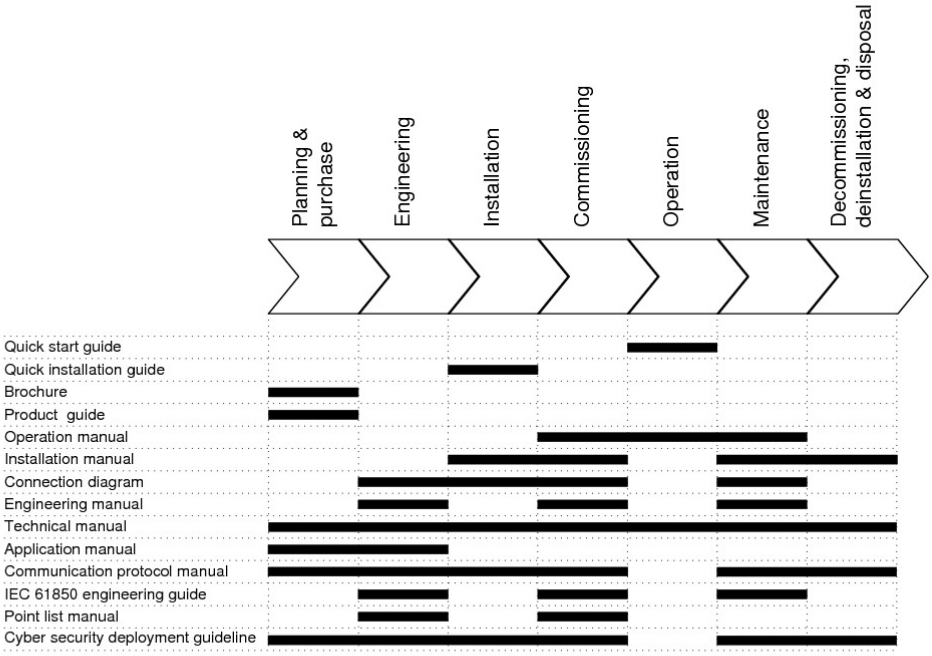


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2013-05-07	2.0	First release
B/2013-07-01	2.0	Content updated
C/2015-12-11	2.0 FP1	Content updated to correspond to the product version
D/2019-06-19	2.0 FP1	Content updated
E/2021-12-16	2.0 FP1	Content updated

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS757645
DNP3 Communication Protocol Manual	1MRS757646
IEC 60870-5-103 Communication Protocol Manual	1MRS757647
IEC 61850 Engineering Guide	1MRS757650
Engineering Manual	1MRS757642
Installation Manual	1MRS757641
Operation Manual	1MRS757643
Technical Manual	1MRS757644

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	ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67-1 (1)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67-2 (1)
	DPHHPDOC2	3I>> -> (2)	67-2 (2)
Three-phase voltage-dependent overcurrent protection	PHPVOC1	3I(U)> (1)	51V (1)
	PHPVOC2	3I(U)> (2)	51V (2)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
	PHPTUV3	3U< (3)	27 (3)
	PHPTUV4	3U< (4)	27 (4)
Single-phase undervoltage protection, secondary side	PHAPTUV1	U_A< (1)	27_A (1)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)
	PHPTOV3	3U> (3)	59 (3)
Single-phase overvoltage protection, secondary side	PHAPTOV1	U_A> (1)	59_A (1)
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)
Negative-sequence overcurrent protection for machines	MNSPTOC1	I2>M (1)	46M (1)
	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I< (1)	37 (1)
	LOFLPTUC2	3I< (2)	37 (2)
Motor load jam protection	JAMPTOC1	Ist> (1)	51LR (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
Motor start-up supervision	STTPMSU1	Is2t n< (1)	49,66,48,51LR (1)
Phase reversal protection	PREVPTOC1	I2>> (1)	46R (1)
Thermal overload protection for motors	MPTTR1	3Ith>M (1)	49M (1)
Stabilized and instantaneous differential protection for machines	MPDIF1	3dI>M/G (1)	87M/G (1)
High-impedance/flux-balance based differential protection for motors	MHZPDIF1	3dIHi>M (1)	87MH (1)
High-impedance based restricted earth-fault protection	HREFPDIF1	dIoHi> (1)	87NH (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
	CCBRBRF2	3I>/Io>BF (2)	51BF/51NBF (2)
	CCBRBRF3	3I>/Io>BF (3)	51BF/51NBF (3)
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)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Multipurpose protection	MAPGAPC1	MAP (1)	MAP (1)
	MAPGAPC2	MAP (2)	MAP (2)
	MAPGAPC3	MAP (3)	MAP (3)
	MAPGAPC4	MAP (4)	MAP (4)
	MAPGAPC5	MAP (5)	MAP (5)
	MAPGAPC6	MAP (6)	MAP (6)
	MAPGAPC7	MAP (7)	MAP (7)
	MAPGAPC8	MAP (8)	MAP (8)
	MAPGAPC9	MAP (9)	MAP (9)
	MAPGAPC10	MAP (10)	MAP (10)
	MAPGAPC11	MAP (11)	MAP (11)
	MAPGAPC12	MAP (12)	MAP (12)
	MAPGAPC13	MAP (13)	MAP (13)
	MAPGAPC14	MAP (14)	MAP (14)
	MAPGAPC15	MAP (15)	MAP (15)
	MAPGAPC16	MAP (16)	MAP (16)
	MAPGAPC17	MAP (17)	MAP (17)
	MAPGAPC18	MAP (18)	MAP (18)
Automatic switch-onto-fault logic (SOF)	CVPSOF1	CVPSOF (1)	SOFT/21/50 (1)
Directional reactive power undervoltage protection	DQPTUV1	Q> -> ,3U< (1)	32Q,27 (1)
	DQPTUV2	Q> -> ,3U< (2)	32Q,27 (2)
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)
	UEXPDIS2	X< (2)	40 (2)
Low-voltage ride-through protection	LVRTPTUV1	U<RT (1)	27RT (1)
	LVRTPTUV2	U<RT (2)	27RT (2)
	LVRTPTUV3	U<RT (3)	27RT (3)
Rotor earth-fault protection	MREFPTOC1	Io>R (1)	64R (1)
Control			

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)
	CBXCBR2	I <-> O CB (2)	I <-> O CB (2)
	CBXCBR3	I <-> O CB (3)	I <-> O CB (3)
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
	DCXSWI3	I <-> O DCC (3)	I <-> O DCC (3)
	DCXSWI4	I <-> O DCC (4)	I <-> O DCC (4)
Earthing switch control	ESXSWI1	I <-> O ESC (1)	I <-> O ESC (1)
	ESXSWI2	I <-> O ESC (2)	I <-> O ESC (2)
	ESXSWI3	I <-> O ESC (3)	I <-> O ESC (3)
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)
	DCSXSWI4	I <-> O DC (4)	I <-> O DC (4)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
	ESSXSWI3	I <-> O ES (3)	I <-> O ES (3)
Emergency start-up	ESMGAPC1	ESTART (1)	ESTART (1)
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (1)
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
	SSCBR2	CBCM (2)	CBCM (2)
	SSCBR3	CBCM (3)	CBCM (3)
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)
	MDSOPT2	OPTS (2)	OPTM (2)
Measurement			
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)
	CSMSQI2	I1, I2, I0 (B) (1)	I1, I2, I0 (B) (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
Single-phase voltage measurement	VAMMXU2	U_A (2)	V_A (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Frequency measurement	FMMXU1	f (1)	f (1)
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQM3I (1)
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQM3V (1)
Voltage variation	PHQVVR1	PQMU (1)	PQMV (1)
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB (1)
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
	TPSGAPC2	TPS (2)	TPS (2)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
	TPMGAPC2	TPM (2)	TPM (2)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)
Time delay on (8 pcs)	TONGAPC1	TON (1)	TON (1)
	TONGAPC2	TON (2)	TON (2)
	TONGAPC3	TON (3)	TON (3)
	TONGAPC4	TON (4)	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)	SR (1)
	SRGAPC2	SR (2)	SR (2)
	SRGAPC3	SR (3)	SR (3)
	SRGAPC4	SR (4)	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)	MV (1)
	MVGAPC2	MV (2)	MV (2)
	MVGAPC3	MV (3)	MV (3)
	MVGAPC4	MV (4)	MV (4)
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4 (1)
	MVI4GAPC2	MVI4 (2)	MVI4 (2)
	MVI4GAPC3	MVI4 (3)	MVI4 (3)
	MVI4GAPC4	MVI4 (4)	MVI4 (4)
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4 (1)
	SCA4GAPC2	SCA4 (2)	SCA4 (2)
	SCA4GAPC3	SCA4 (3)	SCA4 (3)
	SCA4GAPC4	SCA4 (4)	SCA4 (4)
Generic control point (16 pcs)	SPCGAPC1	SPC (1)	SPC (1)
	SPCGAPC2	SPC (2)	SPC (2)
	SPCGAPC3	SPC (3)	SPC (3)
Remote generic control points	SPCRGAPC1	SPCR (1)	SPCR (1)
Local generic control points	SPCLGAPC1	SPCL (1)	SPCL (1)
Generic up-down counters	UDFCNT1	UDCNT (1)	UDCNT (1)
	UDFCNT2	UDCNT (2)	UDCNT (2)
	UDFCNT3	UDCNT (3)	UDCNT (3)
	UDFCNT4	UDCNT (4)	UDCNT (4)
	UDFCNT5	UDCNT (5)	UDCNT (5)
	UDFCNT6	UDCNT (6)	UDCNT (6)
	UDFCNT7	UDCNT (7)	UDCNT (7)
	UDFCNT8	UDCNT (8)	UDCNT (8)
	UDFCNT9	UDCNT (9)	UDCNT (9)
	UDFCNT10	UDCNT (10)	UDCNT (10)
	UDFCNT11	UDCNT (11)	UDCNT (11)
	UDFCNT12	UDCNT (12)	UDCNT (12)
Programmable buttons (16 buttons)	FKEYGGIO1	FKEY (1)	FKEY (1)
Logging functions			
Disturbance recorder	RDRE1	DR (1)	DFR (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
Fault recorder	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Sequence event recorder	SER1	SER (1)	SER (1)

2 REM620 overview

2.1 Overview

REM620 is a dedicated motor management relay perfectly aligned for the protection, control, measurement and supervision of medium-sized and large asynchronous and synchronous motors requiring also differential protection in the manufacturing and process industry.

REM620 is a member of ABB's Relion® protection and control product family and its 620 series. The 620 series relays are characterized by their functional scalability and withdrawable-unit design.

The 620 series has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability of substation automation devices.

The 620 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
2.0	Product released
2.0 FP1	• New configuration B • IEC 61850 Edition 2 • Support for IEC 61850-9-2 LE • Synchronism and energizing check support with IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • Configuration migration support • Software closable Ethernet ports • Report summary via WHMI • Multifrequency admittance-based E/F • Fault locator • Profibus adapter support • Setting usability improvements

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- REM620 Connectivity Package Ver.2.1 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
- Differential Characteristics Tool
- Lifecycle Traceability
- Configuration Wizard
- AR Sequence Visualizer
- Label Printing
- IEC 61850 Configuration
- IED Configuration Migration

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

2.2 Operation functionality

2.2.1 Optional functions

- IEC 61850
- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- RTD/mA measurement
- IEC 61850-9-2 LE
- IEEE 1588 v2 time synchronization
- Arc protection
- Synchronous machines protection package

2.3 Physical hardware

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

Table 2: Plug-in unit and case

Main unit	Slot ID	Content	Module ID	Details
Plug- in unit	-	HMI	DIS0009	Large (8 lines, 16 characters)
	X100	Auxiliary power/BO module	PSM0003 or PSM0004	48...250 V DC/100...240 V AC or 24...60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X105	Empty		Not equipped by default, but alternatively may be equipped as indicated below
		Optional BI/O module	BIO0005	Optional for configurations A and B 8 binary inputs 4 SO contacts
			BIO0007	Optional for configurations A and B 8 binary inputs 3 high speed SO contacts
		Optional RTD/mA module	RTD0003	Optional for configurations A and B 2 generic mA inputs 6 RTD sensor inputs
	X110	Alternative with BI/O or RTD/mA module	BIO0005	With configuration A 8 binary inputs 4 SO contacts
			RTD0003	With configuration A 2 generic mA inputs 6 RTD sensor inputs
		BI/O module	BIO0005	With configuration B 8 binary inputs 4 SO contacts
	X115	BI/O module	BIO0005	With configurations A and B 8 binary inputs 4 SO contacts

Table continues on the next page

Main unit	Slot ID	Content	Module ID	Details
	X120	AI module	AIM0005 or AIM0015	With configuration A 3 phase current inputs (1/5A) 3 phase current inputs (1/5A) 1 residual current input (1/5 A or 0.2/1 A)[1]
Case	X130	AI/BI module	AIM0006	With configuration A 5 voltage inputs 4 binary inputs
		Sensor input module	SIM0002 or SIM0005	With configuration B 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)[1]
	X000	Optional communication module		See the technical manual for details about the different types of communication modules

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

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

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

Table 3: Input/output overview

Default conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
A	AA/AB	AA	7	5	-	20	4 PO + 10 SO	6	2
		AB				12	4 PO + 6SO	12	4
		AC				20	4 PO + 6 SO + 3 HSO	6	2
		NN				12	4 PO + 6 SO	6	2
	AC/AD	AA	7	5	-	28	4 PO + 14 SO	-	-
		AB				20	4 PO + 10 SO	6	2
		AC				28	4 PO + 10 SO + 3 HSO	-	-
		NN				20	4 PO + 10 SO	-	-
B	DA/DB	AA	1	-	3	24	4 PO + 14 SO	-	-
		AB				16	4 PO + 10 SO	6	2

Table continues on the next page

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

Default conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
		AC				24	4 PO + 10 SO + 3 HSO	-	-
		NN				16	4 PO + 10 SO	-	-

2.4 Local HMI

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

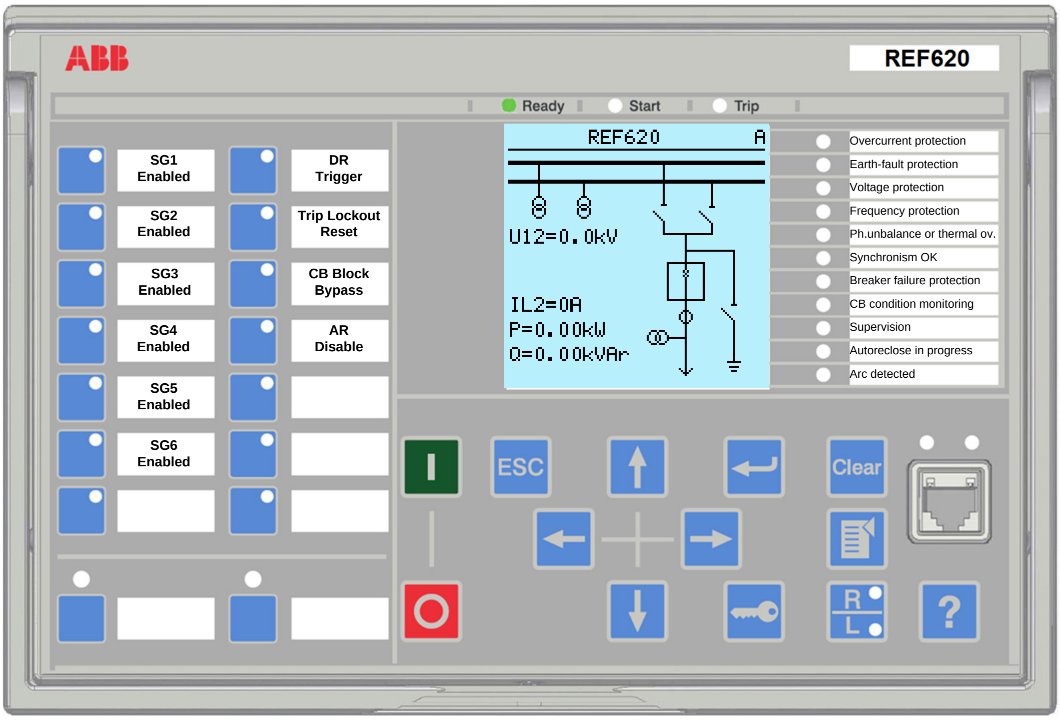


Figure 2: Example of the LHMI

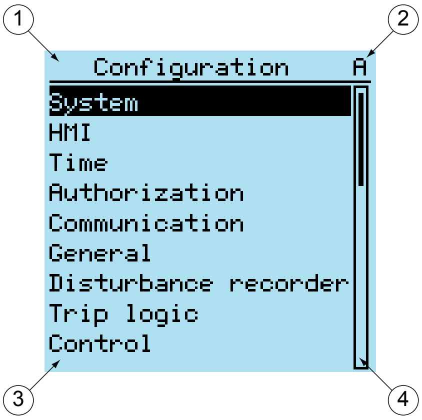
2.4.1 Display

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

Table 4: Display

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

The display view is divided into four basic areas.



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

Figure 3: Display layout

2.4.2 LEDs

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

There are 11 matrix programmable LEDs and 16 programmable push buttons with LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

2.4.3 Keypad

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

[1] Depending on the selected language

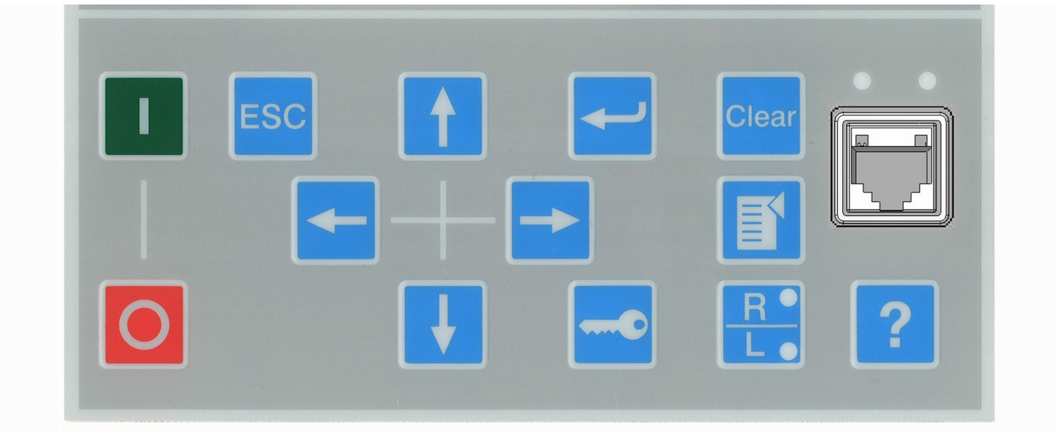


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.4.3.1 Programmable push buttons with LEDs

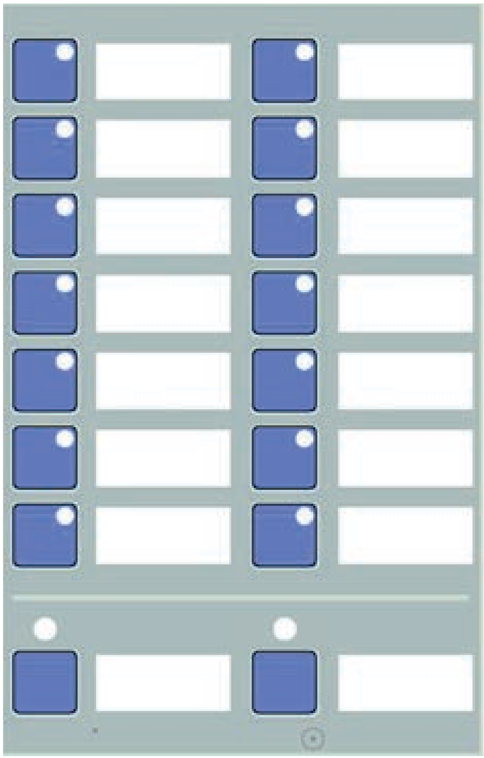


Figure 5: Programmable push buttons with LEDs

The LHMI keypad on the left side of the protection relay contains 16 programmable push buttons with red LEDs.

The buttons and LEDs are freely programmable, and they can be configured both for operation and acknowledgement purposes. That way, it is possible to get acknowledgements of the executed actions associated with the buttons. This combination can be useful, for example, for quickly selecting or changing a setting group, selecting or operating equipment, indicating field contact status or indicating or acknowledging individual alarms.

The LEDs can also be independently configured to bring general indications or important alarms to the operator's attention.

To provide a description of the button function, it is possible to insert a paper sheet behind the transparent film next to the button.

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.

Control operations are not allowed by WHMI.

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.

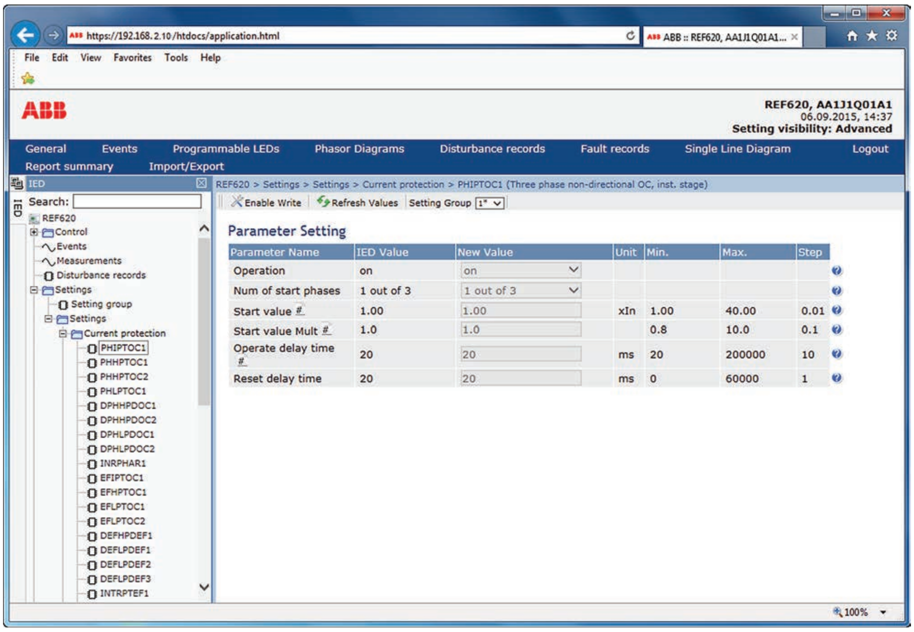


Figure 6: Example view of the WHMI

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.

If the relay-specific Administrator password is forgotten, ABB can provide a one-time reliable key to access the protection relay. For support, contact ABB. The recovery of the Administrator password takes a few days.

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

Table 5: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with (only locally) • Changing setting groups • Controlling • Clearing indications
ENGINEER	• Changing settings • Clearing event list • Clearing 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 6: Audit trail events

Audit trail event	Description
Configuration change	Configuration files changed
Firmware change	Firmware changed
Firmware change fail	Firmware change failed
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 7: Comparison of authority logging levels

Audit trail event	Authority logging level					
	None	Configuration change	Setting group	Setting group, control	Settings edit	All
Configuration change		•	•	•	•	•

Table continues on the next page

Audit trail event	Authority logging level					
Firmware change		●	●	●	●	●
Firmware change fail		●	●	●	●	●
Setting group re-mote			●	●	●	●
Setting group local			●	●	●	●
Control remote				●	●	●
Control local				●	●	●
Test on				●	●	●
Test off				●	●	●
Reset trips				●	●	●
Setting commit					●	●
Time change						●
View audit log						●
Login						●
Logout						●
Password change						●
Firmware reset						●
Violation local						●
Violation remote						●

2.7 Communication

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

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

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

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

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.

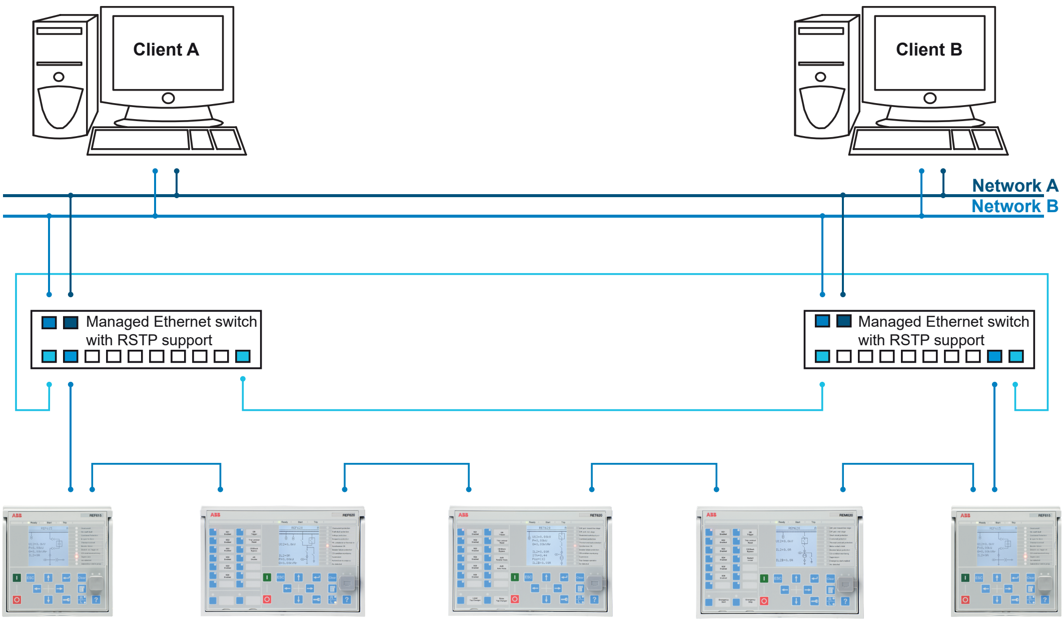


Figure 7: Self-healing Ethernet ring solution

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 620 series protection relays.

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.

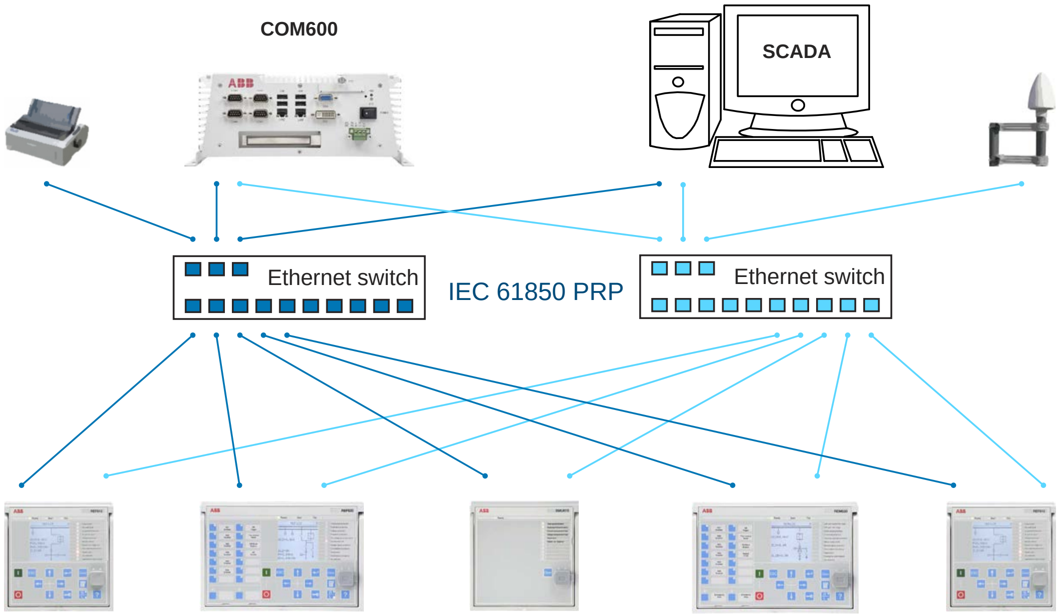


Figure 8: PRP solution

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.

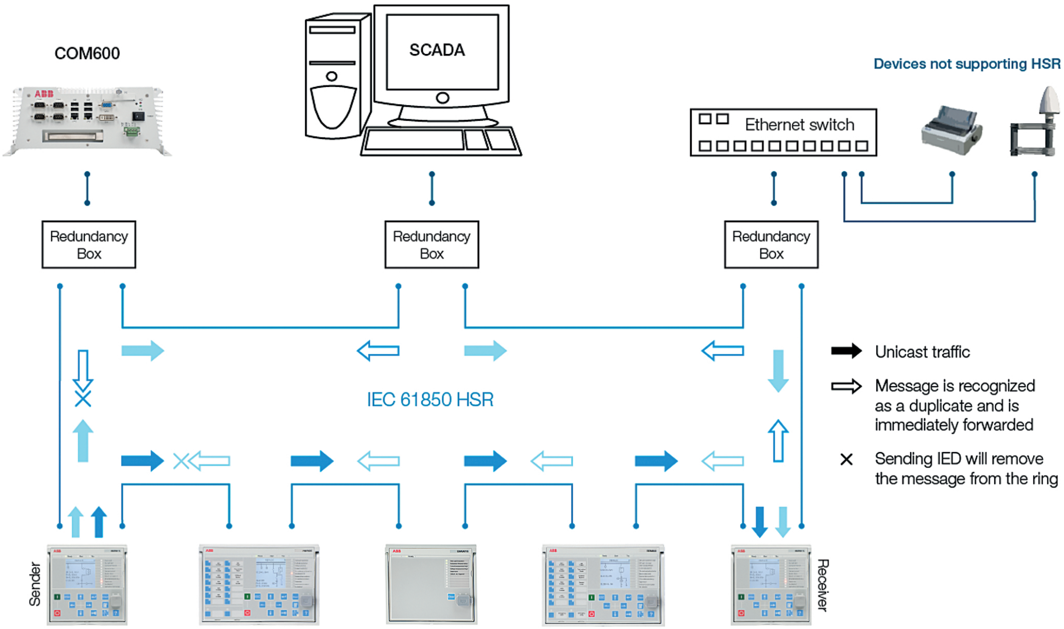


Figure 9: HSR solution

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.

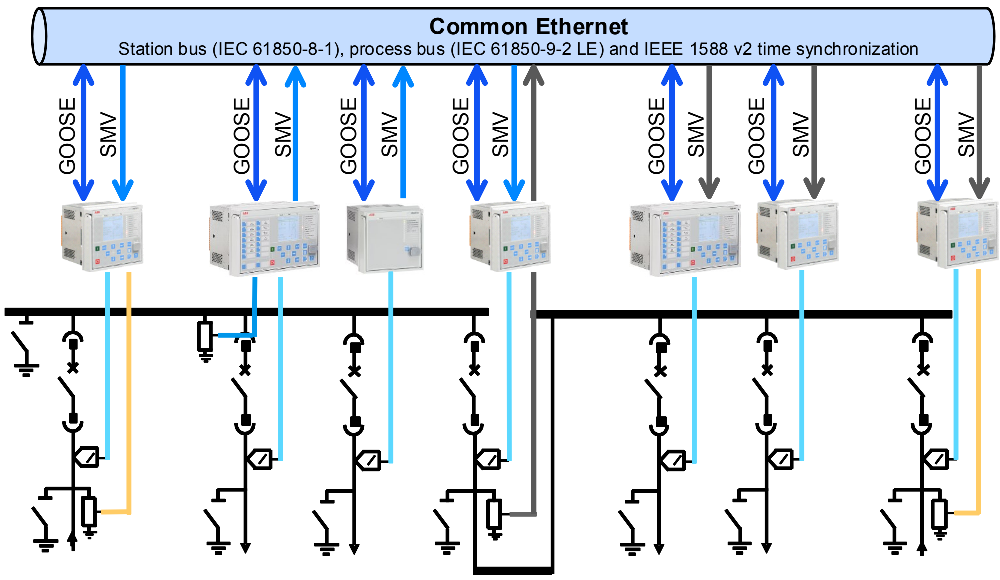


Figure 10: Process bus application of voltage sharing and synchrocheck

The 620 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 620 series protection relay to other devices with phase voltage based functions and 9-2 support.

The 620 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.

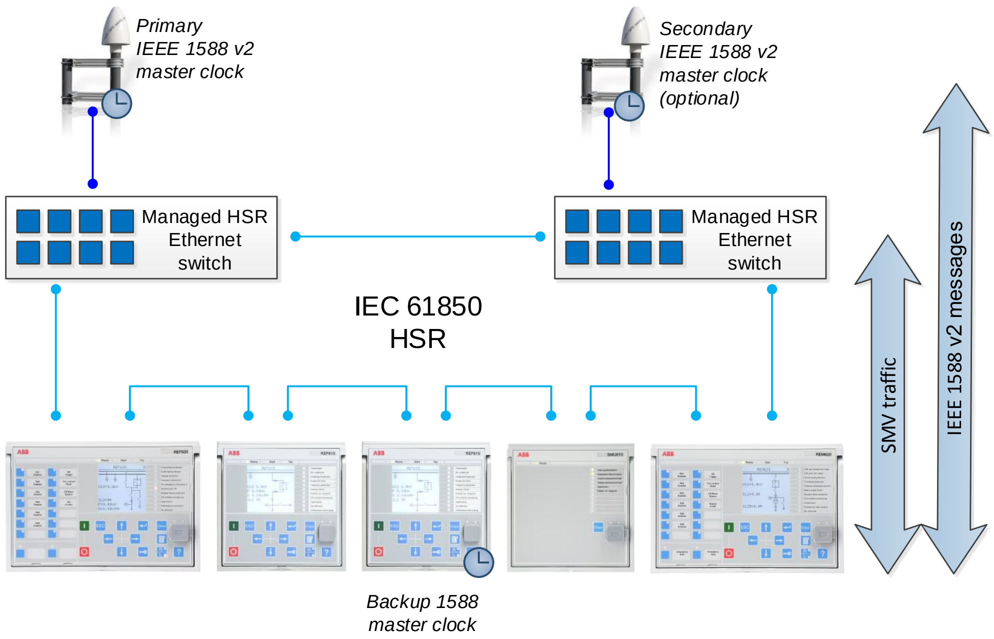


Figure 11: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

The process bus option is available for all 620 series protection relays equipped with phase voltage inputs. Another requirement is a communication card with IEEE 1588 v2 support (COM0031...COM0034 or COM0037). See the IEC 61850 engineering guide for detailed system requirements and configuration details.

2.7.4 Secure communication

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

3 REM620 default configurations

3.1 Default configuration

The 620 series relays are configured with default configurations, which can be used as examples of the 620 series engineering with different function blocks. The default configurations are not aimed to be used as real end-user applications. The end-users always need to create their own application configuration with the configuration tool. However, the default configuration can be used as a starting point by modifying it according to the requirements.

REM620 is available in two alternative default configurations: configuration A with traditional current and voltage measurement transducers and configuration B with current and voltage sensors. The default configuration can be altered by means of the graphical signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Furthermore, the application configuration functionality of the 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.

3.1.1 Supported functions in REM620

Table 8: Supported functions

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	1	1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	2	2
Three-phase voltage-dependent overcurrent protection	PHPVOC	2	2
Non-directional earth-fault protection, low stage	EFLPTOC	1 [1] [2]	1 [2]

Table continues on the next page

1 Function uses calculated value when the high-impedance based restricted earth-fault protection is used
2 Function uses calculated value when the rotor earth-fault protection is used

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
Non-directional earth-fault protection, high stage	EFHPTOC	1 [1,2]	1 [2]
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	1 [1,2]	1 [2]
Directional earth-fault protection, low stage	DEFLPDEF	1 [1,2]	1 [2,3]
Directional earth-fault protection, high stage	DEFHPDEF	1 [1,2]	1 [2,3]
Residual overvoltage protection	ROVPTOV	3	3 [3]
Three-phase undervoltage protection	PHPTUV	4	4
Single-phase undervoltage protection, secondary side	PHAPTUV	1	
Three-phase overvoltage protection	PHPTOV	3	3
Single-phase overvoltage protection, secondary side	PHAPTOV	1	
Positive-sequence undervoltage protection	PSPTUV	2	2
Negative-sequence overvoltage protection	NSPTOV	2	2
Frequency protection	FRPFRQ	6	6
Negative-sequence overcurrent protection for machines	MNSPTOC	2	2
Loss of load supervision	LOFLPTUC	2	2
Motor load jam protection	JAMPTOC	1	1
Motor start-up supervision	STTPMSU	1	1
Phase reversal protection	PREVPTOC	1	1
Thermal overload protection for motors	MPTTR	1	1
Stabilized and instantaneous differential protection for machines	MPDIF	1	
High-impedance/flux-balance based differential protection for motors	MHZPDIF	1	
High-impedance based restricted earth-fault protection	HREFPDIF	1	
Circuit breaker failure protection	CCBRBRF	3	3
Master trip	TRPPTRC	4	4
Arc protection	ARCSARC	(3) [4]	(3) [4]
Multipurpose protection	MAPGAPC	18	18
Automatic switch-onto-fault logic (SOF)	CVPSOF	1	1
Directional reactive power undervoltage protection	DQPTUV	(2)	(2)
Underpower protection	DUPPDPR	(2)	(2)
Reverse power/directional overpower protection	DOPPDPR	(3)	(3)
Three-phase underexcitation protection	UEXPDIS	(2)	(2)

Table continues on the next page

3 Uo is calculated from the measured phase voltages
4 Io is calculated from the measured phase currents

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
Low-voltage ride-through protection	LVRTPTUV	(3)	(3)
Rotor earth-fault protection	MREFPTOC	1	1
Control			
Circuit-breaker control	CBXCBR	3	3
Disconnector control	DCXSWI	4	4
Earthing switch control	ESXSWI	3	3
Disconnector position indication	DCSXSWI	4	4
Earthing switch indication	ESSXSWI	3	3
Emergency start-up	ESMGAPC	1	1
Synchronism and energizing check	SECRSYN	1	(1) [5]
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR	3	3
Trip circuit supervision	TCSSCBR	2	2
Current circuit supervision	CCSPVC	1	1
Fuse failure supervision	SEQSPVC	1	1
Runtime counter for machines and devices	MDSOPT	2	2
Measurement			
Three-phase current measurement	CMMXU	2	1
Sequence current measurement	CSMSQI	2	1
Residual current measurement	RESCMMXU	1	1
Three-phase voltage measurement	VMMXU	1	1
Single-phase voltage measurement	VAMMXU	1	(1) [5]
Residual voltage measurement	RESVMMXU	1	
Sequence voltage measurement	VSMSQI	1	1
Three-phase power and energy measurement	PEMMXU	1	1
Load profile record	LDPRLRC	1	1
Frequency measurement	FMMXU	1	1
Power quality			
Current total demand distortion	CMHAI	1	1
Voltage total harmonic distortion	VMHAI	1	1
Voltage variation	PHQVVR	1	1
Voltage unbalance	VSQVUB	1	1
Other			
Minimum pulse timer (2 pcs)	TPGAPC	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	2	2
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	2	2
Pulse timer (8 pcs)	PTGAPC	2	2
Time delay off (8 pcs)	TOFGAPC	4	4

Table continues on the next page

[5] Available only with IEC 61850-9-2 LE

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
Time delay on (8 pcs)	TONGAPC	4	4
Set-reset (8 pcs)	SRGAPC	4	4
Move (8 pcs)	MVGAPC	4	4
Integer value move	MVI4GAPC	4	4
Analog value scaling	SCA4GAPC	4	4
Generic control point (16 pcs)	SPCGAPC	3	3
Remote generic control points	SPCRGAPC	1	1
Local generic control points	SPCLGAPC	1	1
Generic up-down counters	UDFCNT	12	12
Programmable buttons (16 buttons)	FKEYGGIO	1	1
Logging functions			
Disturbance recorder	RDRE	1	1
Fault recorder	FLTRFRC	1	1
Sequence event recorder	SER	1	1
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = optional			

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

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

If the number of inputs and/or outputs in a default configuration is not sufficient, it is possible either to modify the chosen default configuration in order to release some binary inputs or binary outputs which have originally been configured for other purposes, or to connect 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 default 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.

3.1.3 LED functionality

The protection relay has dynamic programmable LEDs. The presentation of the LEDs in this manual differs from the actual function blocks in the configurations.

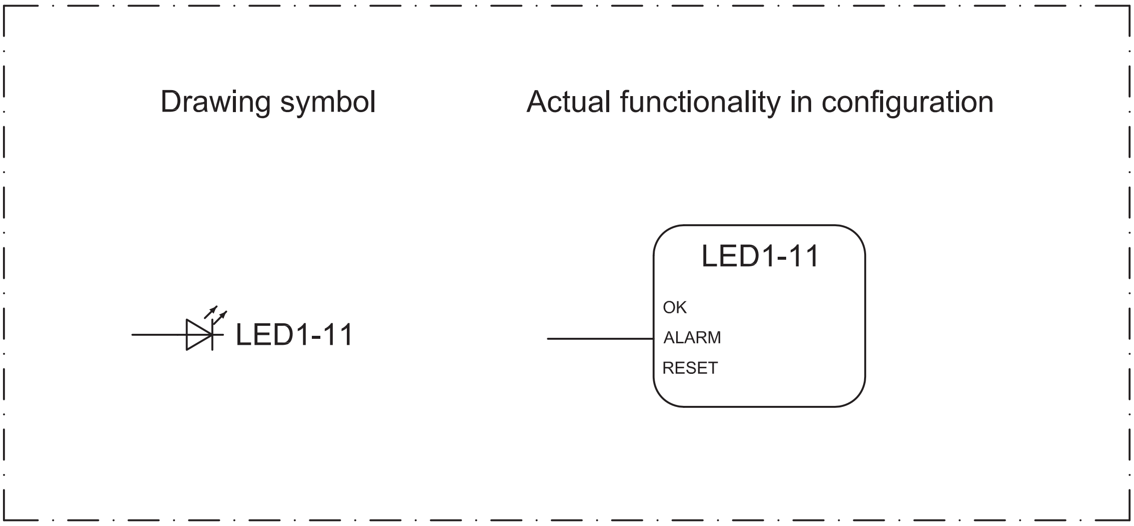


Figure 12: Drawing symbol used in the manual and the default connection of the LED function blocks in the configurations

3.2 Connection diagrams

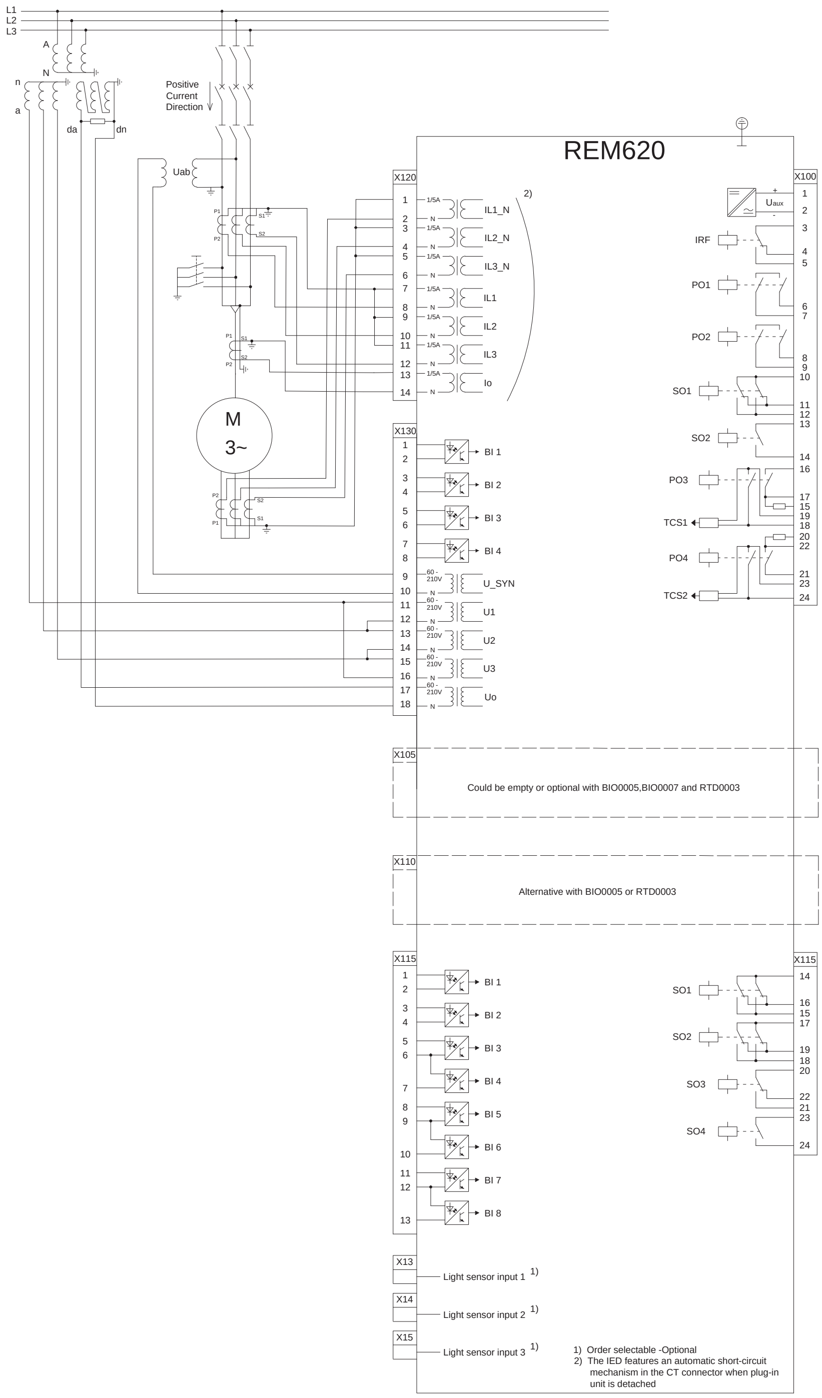


Figure 13: Connection diagram for the A configuration

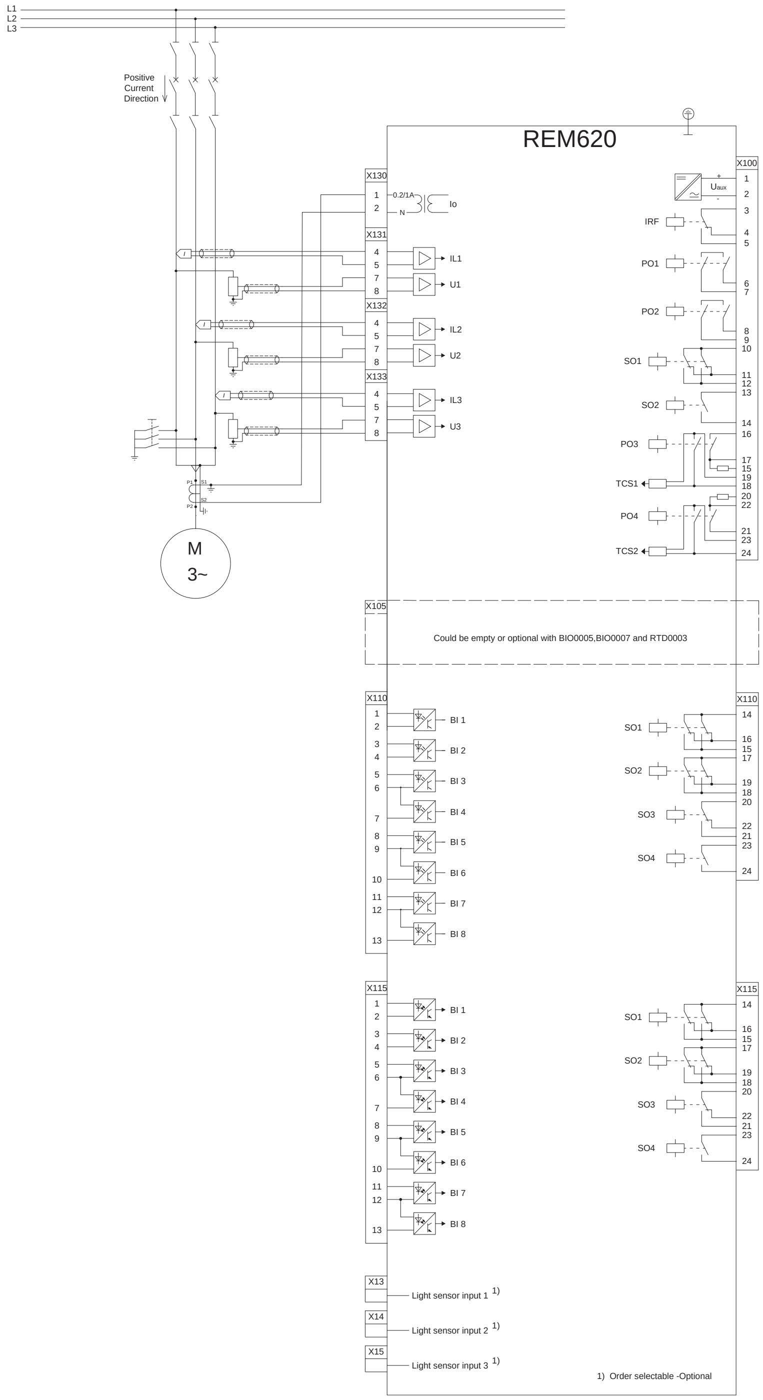


Figure 14: Connection diagram for the configuration with SIM0002 module

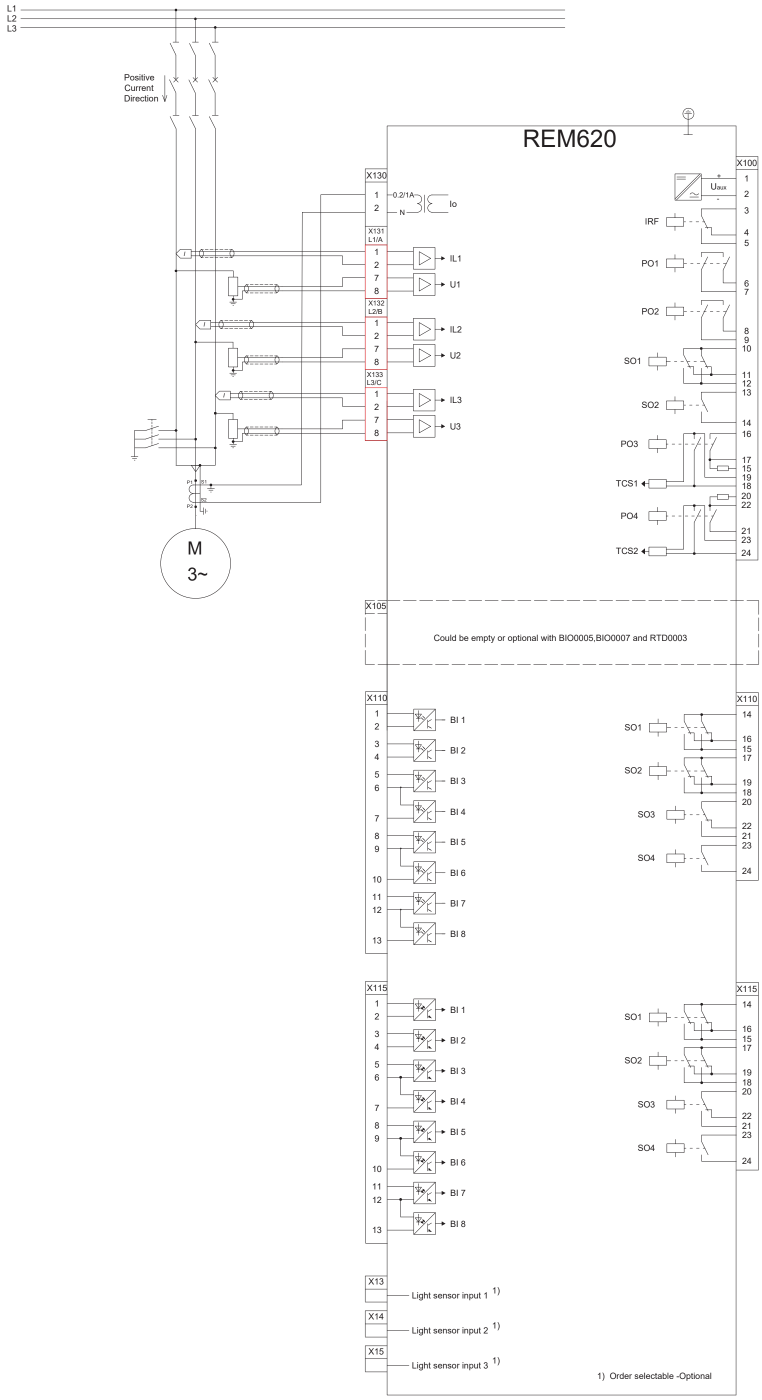


Figure 15: Connection diagram for the configuration with SIM0005 module

3.3 Optional modules

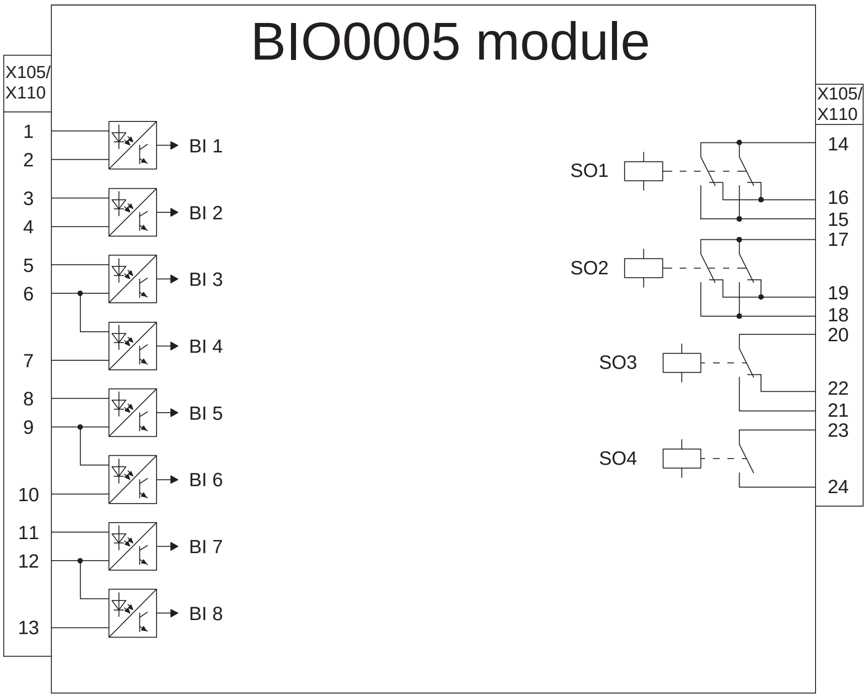


Figure 16: Optional BIO0005 module (slot X105)

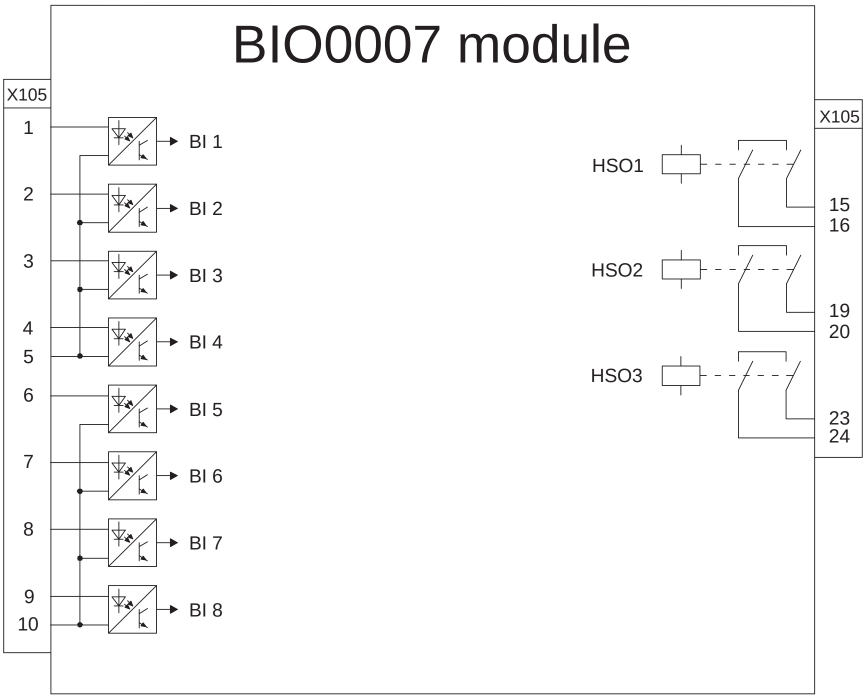


Figure 17: Optional BIO0007 module for fast outputs (slot X105)

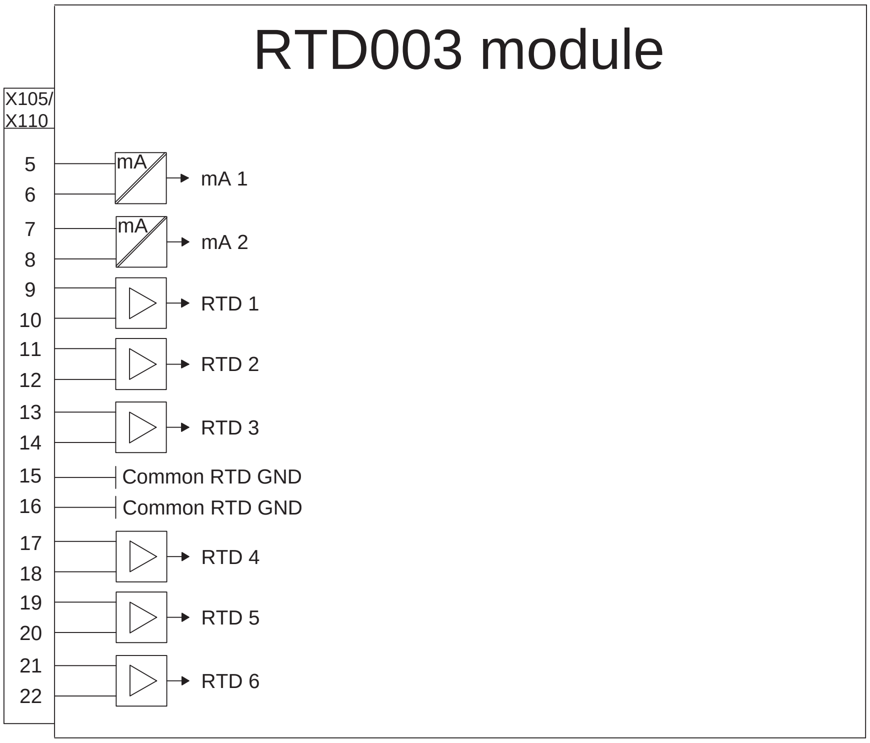


Figure 18: Optional RTD0003 module (slot X105)

3.4 Presentation of default configurations

Functional diagrams

The functional diagrams describe the IED's functionality from the protection, measuring, condition monitoring, disturbance recording, control and interlocking perspective. Diagrams show the default functionality with simple symbol logics forming principle diagrams. The external connections to primary devices are also shown, stating the default connections to measuring transformers.The positive measuring direction of directional protection functions is towards the outgoing feeder.

The functional diagrams are divided into sections with each section constituting one functional entity. The external connections are also divided into sections. Only the relevant connections for a particular functional entity are presented in each section.

Protection function blocks are part of the functional diagram. They are identified based on their IEC 61850 name but the IEC based symbol and the ANSI function number are also included. Some function blocks, such as PHHPTOC, are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name, IEC symbol and ANSI function number are appended with a running number, that is an instance number, from one upwards.

Signal Matrix and Application Configuration

With Signal Matrix and Application Configuration in PCM600, it is possible to modify the default configuration according to the actual needs. The IED 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. The Signal Matrix tool is used for GOOSE signal input engineering and for making cross-references between the physical I/O signals and the function blocks. The Signal Matrix tool cannot be used for adding or removing function blocks, for example, GOOSE receiving function blocks. The Application Configuration tool is used for these kind of operations. If a function block is removed with Application Configuration, the function-related data disappears from the menus as well as from the 61850 data model, with the exception of some basic functions (61850 logical nodes), which are mandatory and thus cannot be removed from the IED configuration by removing them from Application Configuration.

3.5 Default configuration A

3.5.1 Applications

The default configuration is designed for differential protection and mainly intended for comprehensive protection and control functionality of circuit breaker controlled asynchronous motors. With minor modifications this default configuration can be applied also for contactor controlled motors.

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

The default configuration can also be used with double bus arrangements. If the voltages are measured from the bus side in a double busbar configuration, an external voltage switch is needed to bring the right voltage set to the IED.

The configuration can also be modified to be used with several different start connection schemes by utilizing the available controllable blocks.

3.5.2 Functions

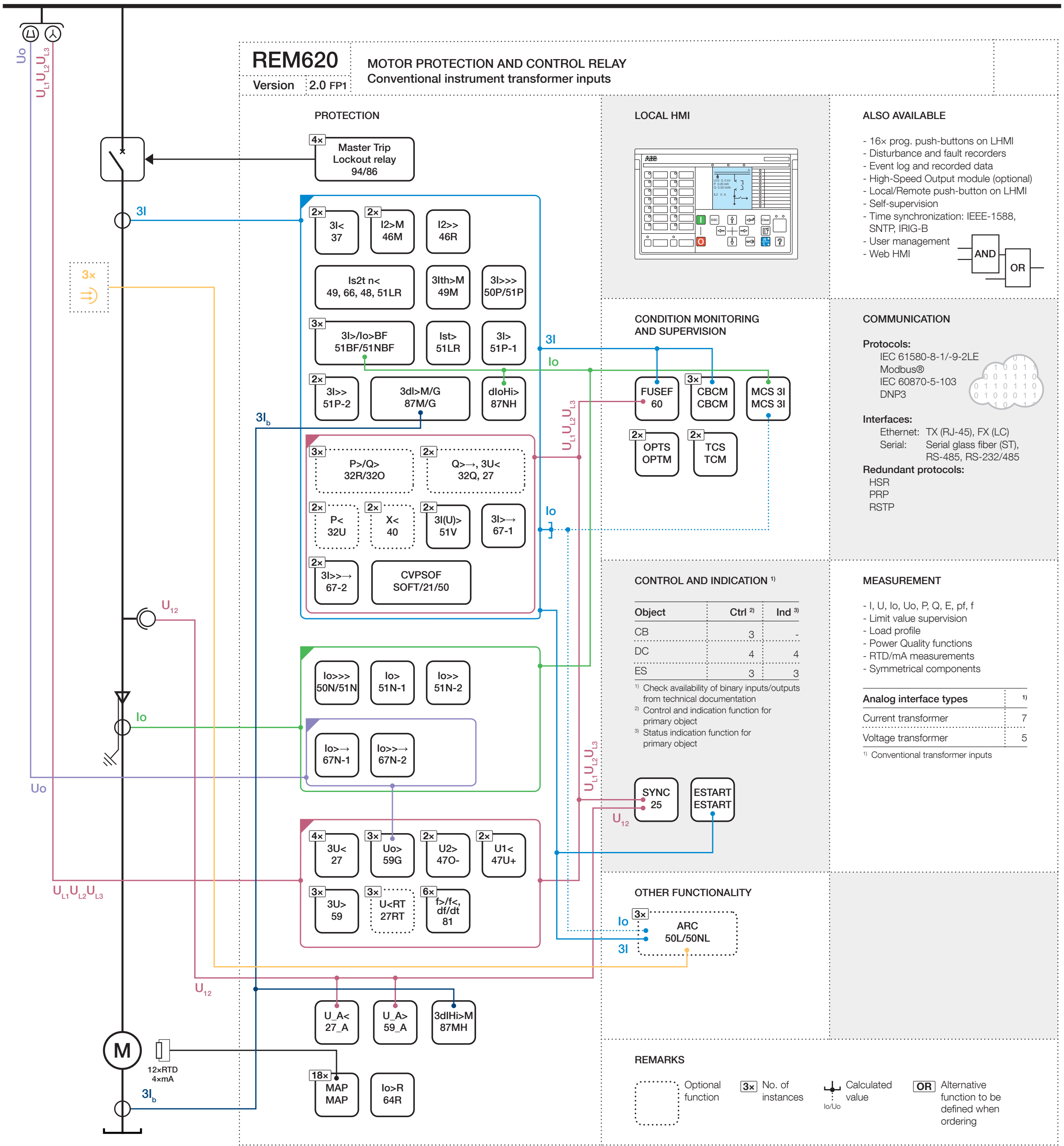


Figure 19: Functionality overview of default configuration with conventional instrument transformer inputs

3.5.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Default usage	Connector pins
IL1_N	Phase A current, neutral side	X120:1,2
IL2_N	Phase B current, neutral side	X120:3,4
IL3_N	Phase C current, neutral side	X120:5,6
IL1	Phase A current, terminal side	X120:7,8
IL2	Phase B current, terminal side	X120:9,10
IL3	Phase C current, terminal side	X120:11,12
Io	Residual current	X120:13,14
U_SYN	Phase-to-phase voltage U12, terminal side	X130:9,10
U1	Phase-to-phase voltage U12, bus side	X130:11,12
U2	Phase-to-phase voltage U23, bus side	X130:13,14
U3	Phase-to-phase voltage U31, bus side	X130:15,16
Uo	Residual voltage, bus side	X130:17,18
RTD1	Motor winding U temperature	X110:9,10
RTD2	Motor winding V temperature	X110:11,12
RTD3	Motor winding W temperature	X110:13,14
RTD4	Motor cooling air temperature	X110:17,18
RTD5	Motor bearing temperature	X110:19,20
RTD6	Motor ambient temperature	X110:21,22

Table 10: Default connections for binary inputs

Binary input	Default usage	Connector pins
X105-BI1	Rotation direction	X105:1,2
X105-BI2	Emergency start enable	X105:3,4
X105-BI3	External restart inhibit	X105:5,6
X105-BI4	External trip	X105:7,6
X105-BI5	Emergency start	X105:8,9
X105-BI6	Emergency stop	X105:10,9
X105-BI7	Line MCB open position indication	X105:11,12
X105-BI8	-	X105:13,12
X115-BI1	Circuit breaker closed position indication	X115:1,2
X115-BI2	Circuit breaker open position indication	X115:3,4
X115-BI3	Circuit breaker low gas pressure alarm	X115:5,6
X115-BI4	Circuit breaker spring charged indication	X115:7,6
X115-BI5	Earthing switch 1 closed position indication	X115:8,9
X115-BI6	Earthing switch 1 open position indication	X115:10,9
X115-BI7	Speed switch (motor running)	X115:11,12
X115-BI8	Bus MCB open position indication	X115:13,12

Table continues on the next page

Binary input	Default usage	Connector pins
X130-BI1	Disconnector 1 closed position indication	X130:1,2
X130-BI2	Disconnector 1 open position indication	X130:3,4
X130-BI3	Disconnector 2 closed position indication	X130:5,6
X130-BI4	Disconnector 2 open position indication	X130:7,8

Table 11: Default connections for binary outputs

Binary input	Default usage	Connector pins
X100-PO1	Restart enable	X100:6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8,9
X100-SO1	General start indication	X100:10,11,(12)
X100-SO2	General operate indication	X100:13,14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X115-SO1	Motor startup indication	X115:14-16
X115-SO2	Open command (for contactor applications)	X115:17-19
X115-SO3	Thermal overload alarm	X115:20-22
X115-SO4	Motor differential protection operate alarm	X115:23,24

Table 12: Default connections for LEDs

LED	Default usage	Label description
1	Motor differential protection biased stage operate	Diff. prot. biased low stage
2	Motor differential protection instantaneous stage operate	Diff. prot. inst. stage
3	Short circuit protection operate	Short circuit protection
4	Combined protection indication of the other protection functions	Combined Protection
5	Thermal overload protection operate	Thermal Overload for Motors
6	Motor restart inhibit	Motor restart inhibit
7	Circuit breaker failure protection backup protection operate	Breaker failure protection
8	Circuit breaker condition monitoring alarm	CB condition monitoring
9	Supervision alarm	Supervision
10	Emergency start enabled	Emergency start enabled
11	Arc fault detected	Arc detected

Table 13: Default connections for function keys

FK/ SPCGAPC number	Default usage	Operation mode	Pulsed length
1	Setting Group 1 Enabled	Pulsed	150 ms
2	Setting Group 2 Enabled	Pulsed	150 ms

Table continues on the next page

FK/ SPCGAPC number	Default usage	Operation mode	Pulsed length
3	Setting Group 3 Enabled	Pulsed	150 ms
4	Setting Group 4 Enabled	Pulsed	150 ms
5	Setting Group 5 Enabled	Pulsed	150 ms
6	Setting Group 6 Enabled	Pulsed	150 ms
7	-	Off	1000 ms
8	Emergency Start	Pulsed	150 ms
9	Disturbance Recorder Manual Trigger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms
11	Circuit Breaker Block Bypass	Toggle	1000 ms
12	Restart Inhibit	Toggle	1000 ms
13	-	Off	1000 ms
14	-	Off	1000 ms
15	-	Off	1000 ms
16	-	Off	1000 ms

3.5.2.2 Default disturbance recorder settings

Table 14: Default disturbance recorder settings binary channels

Channel	Id text	Level trigger mode
1	PHLPTOC1_START	Positive or Rising
2	PHHPTOC1_START	Positive or Rising
3	PHHPTOC2_START	Positive or Rising
4	PHIPTOC1_START	Positive or Rising
5	DPHLPDOC1_START	Positive or Rising
6	DPHHPDOC1_START	Positive or Rising
7	DPHHPDOC2_START	Positive or Rising
8	PHxPTOC or DPHxPDOC_OPERATE	Level trigger off
9	EFLPTOC1_START	Positive or Rising
10	EFHPTOC1_START	Positive or Rising
11	EFIPTOC1_START	Positive or Rising
12	DEFLPDEF1_START	Positive or Rising
13	DEFHPDEF1_START	Positive or Rising
14	EFxPTOC or DEFxPDEF_OPERATE	Level trigger off
15	ROVPTOV1/2/3_START	Positive or Rising
16	ROVPTOV1/2/3_OPERATE	Level trigger off
17	PHPTUV or PHPTOV or PSPTUV or NSPTOV_START	Positive or Rising
18	PHPTUV or PHPTOV or PSPTUV or NSPTOV_OPERATE	Level trigger off

Table continues on the next page

Channel	Id text	Level trigger mode
19	FRPFRQ_START	Positive or Rising
20	FRPFRQ_OPERATE	Level trigger off
21	MNSPTOC1_START	Positive or Rising
22	MNSPTOC2_START	Positive or Rising
23	MNSPTOC1/2_BLK_RESTART	Level trigger off
24	MNSPTOC1/2_OPERATE	Level trigger off
25	LOFLPTUC1_START	Positive or Rising
26	LOFLPTUC2_START	Positive or Rising
27	LOFPTUC1/2_OPERATE	Level trigger off
28	MPTTR1_ALARM	Level trigger off
29	MPTTR1_BLK_RESTART	Level trigger off
30	MPTTR1_OPERATE	Level trigger off
31	PREVPTOC1_START	Positive or Rising
32	PREVPTOC1_OPERATE	Level trigger off
33	ESMGAPC_ST_EMERG_ENA	Level trigger off
34	MPDIF1_OPERATE	Positive or Rising
35	MPDIF1_OPR_LS	Level trigger off
36	MPDIF1_OPR_HS	Level trigger off
37	MPDIF1_INT_BLKD	Level trigger off
38	JAMPTOC1_OPERATE	Positive or Rising
39	STTPMSU1_MOT_START	Positive or Rising
40	STTPMSU1_LOCK_START	Level trigger off
41	STTPMSU1_OPR_IIT	Positive or Rising
42	STTPMSU1_OPR_STALL	Positive or Rising
43	ARCSARC1/2/3_ARC_FLT_DET	Level trigger off
44	ARCSARC1_OPERATE	Positive or Rising
45	ARCSARC2_OPERATE	Positive or Rising
46	ARCSARC3_OPERATE	Positive or Rising
47	SEQSPVC1_FUSEF_3PH	Level trigger off
48	SEQSPVC1_FUSEF_U	Level trigger off
49	CCSPVC1_FAIL	Level trigger off
50	CCBRBRF1_TRRET	Level trigger off
51	CCBRBRF1_TRBU	Level trigger off
52	CB Closed	Level trigger off
53	CB Open	Level trigger off
54	Emergency Start Enable	Level trigger off
55	Bus MCB Open	Level trigger off
56	Line MCB Open	Level trigger off
57	External Restart Inhibit	Level trigger off
58	Speed Switch	Level trigger off
59	MDSOPT1_ALARM	Level trigger off

Table continues on the next page

Channel	Id text	Level trigger mode
60	MAPGAPC1_START	Positive or Rising
61	MAPGAPC2_START	Positive or Rising
62	MAPGAPC3_START	Positive or Rising
63	MAPGAPC1/2/3_OPERATE	Level trigger off
64	FKEY K9_DR Manual Trigger	Positive or Rising

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

Table 15: Default analog channel selection and text settings

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

3.5.2.3 Default operation mode for generic control point

Table 16: Default operation modes

Channel	Signal name	Value	Pulse length
1	SG1 Enabled	Pulsed	150 ms
2	SG2 Enabled	Pulsed	150 ms
3	SG3 Enabled	Pulsed	150 ms
4	SG4 Enabled	Pulsed	150 ms
5	SG5 Enabled	Pulsed	150 ms
6	SG6 Enabled	Pulsed	150 ms
7		Off	1000 ms
8	Emergency Start	Pulsed	150 ms
9	DR Trigger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms

Table continues on the next page

[1] ILxB in this table refers to ILx_N in the connection diagrams.

Channel	Signal name	Value	Pulse length
11	CB Block Bypass	Toggle	1000 ms
12	Restart Inhibit	Toggle	1000 ms
13		Off	1000 ms
14		Off	1000 ms
15		Off	1000 ms
16	Emergency Stop	Pulsed	150 ms
Grey cells indicate different default settings.			

3.5.2.4 Physical analog channels

There are seven current channels and five voltage channels in this configuration.

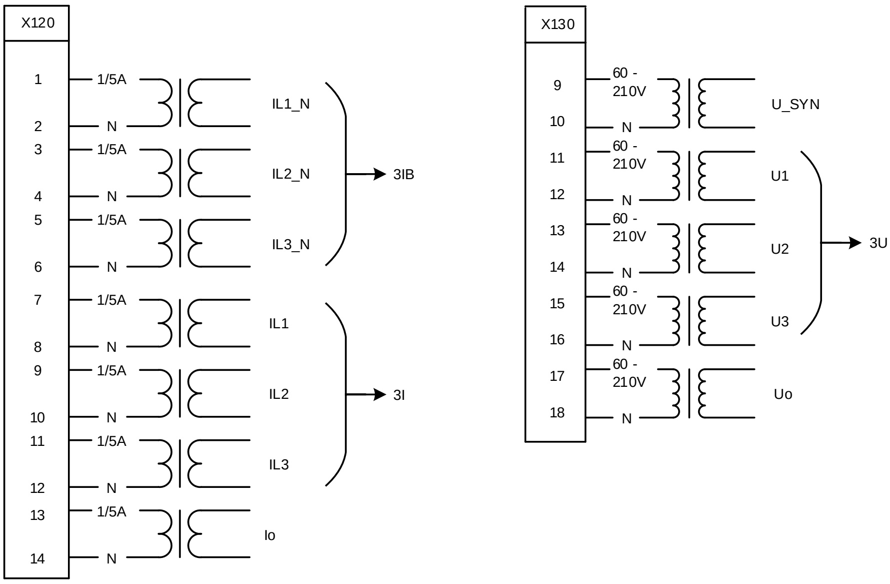


Figure 20: Physical analog channels in default configuration A

The physical analog channels of all functions which require current or voltage inputs in this configuration are listed in *Table 18*. Meaning of the symbols is explained in *Table 17*.

Table 17: Explanations of symbols in the physical analog channel table

Symbol	Description
x	The analog channel is assigned to the function by default.
C	The function can be set to use residual voltage or current calculated based on the three-phase input. Only applicable for functions which need residual voltage or current as input.
D	The analog channel is dedicated to the function. When the corresponding function is taken into use, other functions cannot use this analog channel any more. The other functions can be set to use calculated values instead of physical measured value or select an alternative operation mode not requiring this physical measured channel. However, some functions might not have such operation modes and might become unusable in the configuration. All functions marked to use the same HW channel under the same column should be checked to make sure the functions work.

Table 18: Physical analog channels of functions

IEC61850	3I	3U	Io	Uo	3IB	U_SYN
Protection						
PHLPTOC1	x					
PHHPTOC1	x					
PHHPTOC2	x					
PHIPTOC1	x					
DPHLPDOC1	x	x				
DPHHPDOC1	x	x				
DPHHPDOC2	x	x				
PHPVOC1	x	x				
PHPVOC2	x	x				
EFLPTOC1	C		x			
EFHPTOC1	C		x			
EFIPTOC1	C		x			
DEFLPDEF1	C	C	x	x		
DEFHPDEF1	C	C	x	x		
ROVPTOV1		C		x		
ROVPTOV2		C		x		
ROVPTOV3		C		x		
PHPTUV1		x				
PHPTUV2		x				
PHPTUV3		x				
PHPTUV4		x				
PHAPTUV1						x
PHPTOV1		x				
PHPTOV2		x				
PHPTOV3		x				
PHAPTOV1						x

Table continues on the next page

IEC61850	3I	3U	Io	Uo	3IB	U_SYN
PSPTUV1		x				
PSPTUV2		x				
NSPTOV1		x				
NSPTOV2		x				
FRPFRQ1		x				
FRPFRQ2		x				
FRPFRQ3		x				
FRPFRQ4		x				
FRPFRQ5		x				
FRPFRQ6		x				
MNSPTOC1	x					
MNSPTOC2	x					
LOFLPTUC1	x					
LOFLPTUC2	x					
JAMPTOC1	x					
STTPMSU1	x					
PREVPTOC1	x					
MPTTR1	x					
MPDIF1	x				x	
MHZPDIF1					D	
HREFPDIF1			D			
CCBRBRF1	x		x			
CCBRBRF2	x		x			
CCBRBRF3	x		x			
ARCSARC1	x					
ARCSARC2	x					
ARCSARC3	x					
CVPSOF1	x	x				
DQPTUV1	x	x				
DQPTUV2	x	x				
DUPPDPR1	x	x				
DUPPDPR2	x	x				
DOPPDPR1	x	x				
DOPPDPR2	x	x				
DOPPDPR3	x	x				
UEXPDIS1	x	x				
UEXPDIS2	x	x				
LVRTPTUV1		x				
LVRTPTUV2		x				
LVRTPTUV3		x				
MREFPTOC1			D			

Table continues on the next page

IEC61850	3I	3U	Io	Uo	3IB	U_SYN
Control						
ESMGAPC1	x					
SECRSYN1		x				x
Condition monitoring						
SSCBR1	x					
SSCBR2	x					
SSCBR3	x					
CCSPVC1	x		x			
SEQSPVC1	x	x				
Measurement						
CMMXU1	x					
CMMXU2					x	
CSMSQI1	x					
CSMSQI2					x	
RESCMMXU1			x			
VMMXU1		x				
VAMMXU2						x
RESVMMXU1				x		
VSMSQI1		x				
PEMMXU1	x	x				
FMMXU1		x				
Power quality						
CMHAI1	x					
VMHAI1		x				
PHQVVR1	x	x				
VSQVUB1		x				

3.5.3 Functional diagrams

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

The analog channels, measurements from CTs and VTs have fixed connections to the different function blocks inside the relay. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The signal marked with `3I` represents the three phase currents from the terminal side of the motor. The signal marked with `3IB` represents the three phase currents from the neutral side of the motor. The signal `Io` represents the measured residual current, fed from either residually connected CTs or an external core balance CT or neutral CT, depending on application.

The signal marked with `3U` represents the three phase system voltages on the bus. These inputs are connected in Delta, which are typically fed from open-delta (V connected) VTs from the system. When star connected VT is available in the system, the VT inputs in the IED are star connected and configuration setting is suitably changed. In addition, the signal marked with `Uo` represents the measured residual voltage via open-delta connected VTs.

The signal marked `Usyn` is measured from the VT on the terminal side of the motor. This signal is used to check synchronizing.

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

There are 16 programmable push buttons offered in the front panel of the unit. The relay offers six different settings groups which can be set based on individual needs.

Each group can then, be activated or deactivated by using a programmable button. In addition to this, the programmable button can be also used for emergency start and emergency stop, manual trigger of disturbance recorder, master trip lockout reset, circuit breaker control interlocking bypass, restart inhibit, and so on.

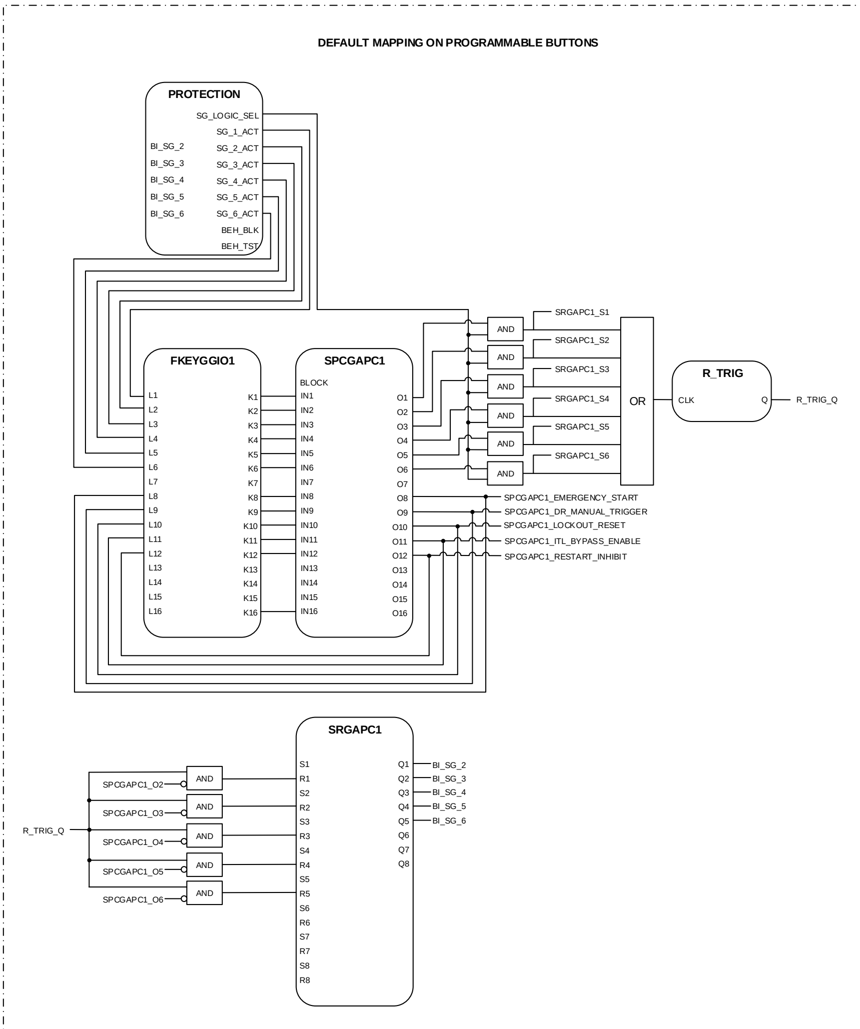


Figure 21: Default mapping on programmable buttons

3.5.3.1 Functional diagrams for protection

The functional diagrams describe the relay's protection functionality in detail and picture the default connections.

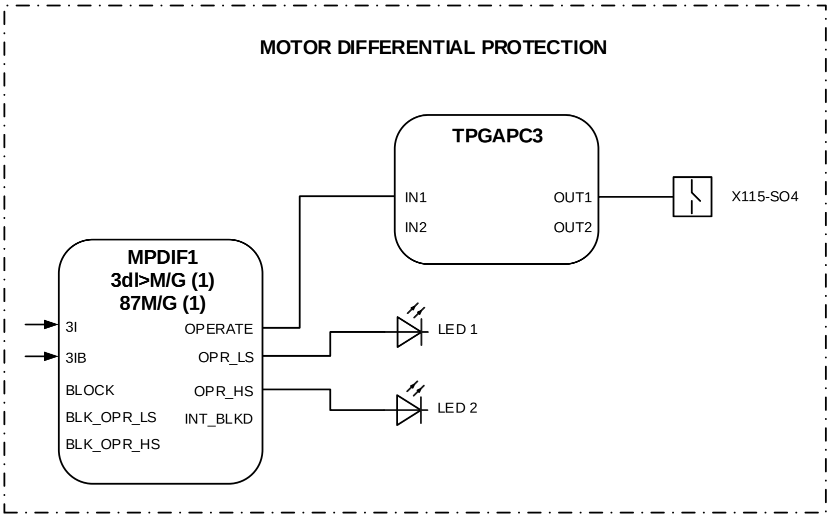


Figure 22: Motor differential protection

The motor differential protection MPDIF1 is used to detect motor internal winding faults. The `OPERATE` output is connected to the Master Trip and also connected to signal output X110-SO4 via generic timer TPGAPC3 .The `OPR_LS` output is connected to alarm LED 1 and the `OPR_HS` output is connected to alarm LED 2.

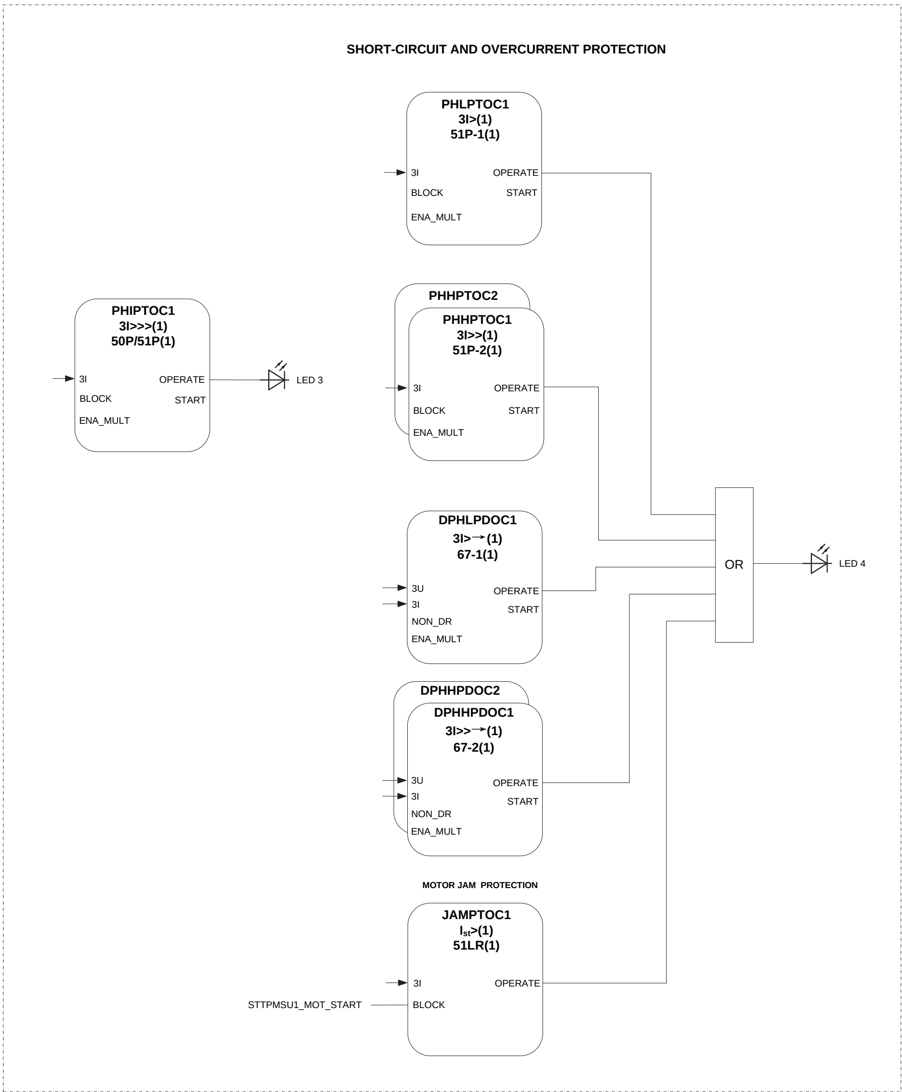


Figure 23: Overcurrent and motor jam protection

Seven overcurrent stages in total are offered for overcurrent and short-circuit protection. Three stages are for directional functionality DPHxPDOC, while the others are only for non-directional overcurrent protection PHxPTOC.

PHLPTOC1 can be used for overcurrent protection, and PHIPTOC1 for the short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation.

The motor load jam protection JAMPTOC1 is used for protecting the motor in stall or mechanical jam situations during the running state. The motor jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

The `OPERATE` outputs are connected to the Master Trip. The `OPERATE` outputs are also connected to the alarm LED 4, except for PHIPTOC1, which is connected to the alarm LED 3. LED 3 is used for short-circuit protection alarm indication; LED 4 is used for combined protection alarm indication, including overcurrent protection, earth-fault protection, phase unbalance protection, voltage protection, motor jam protection, loss of load protection and frequency protection.

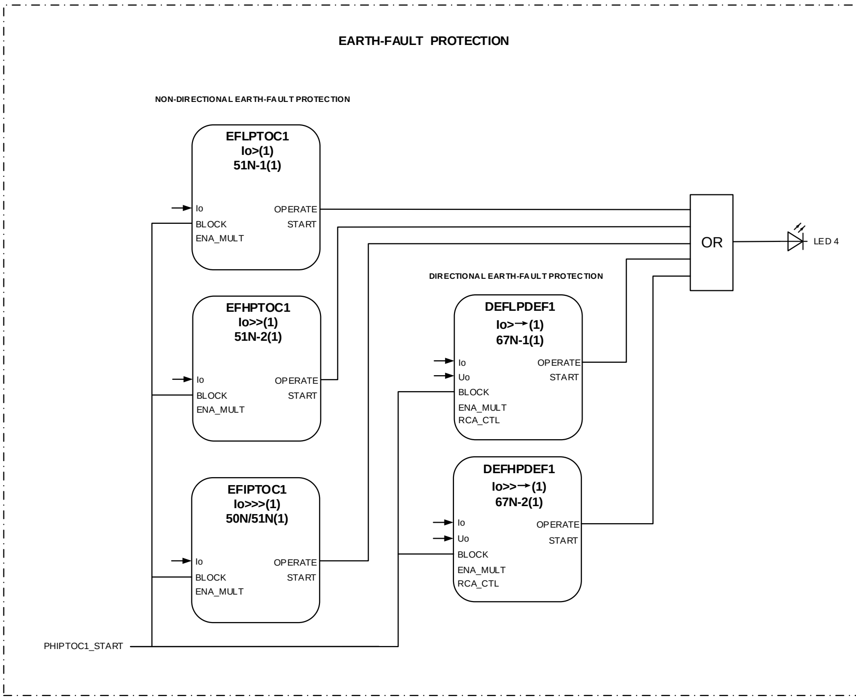


Figure 24: Earth-fault protection

Three stage non-directional earth-fault protection EFxPTOC is offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing. In addition, there are two directional protection stages DEFxPDEF which can also be used as non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor start-up.

The earth-fault protection is blocked when the short-circuit protection PHIPTOC1 is started. The `OPERATE` outputs of the earth-fault protection functions are connected to the Master Trip and alarm LED 4.

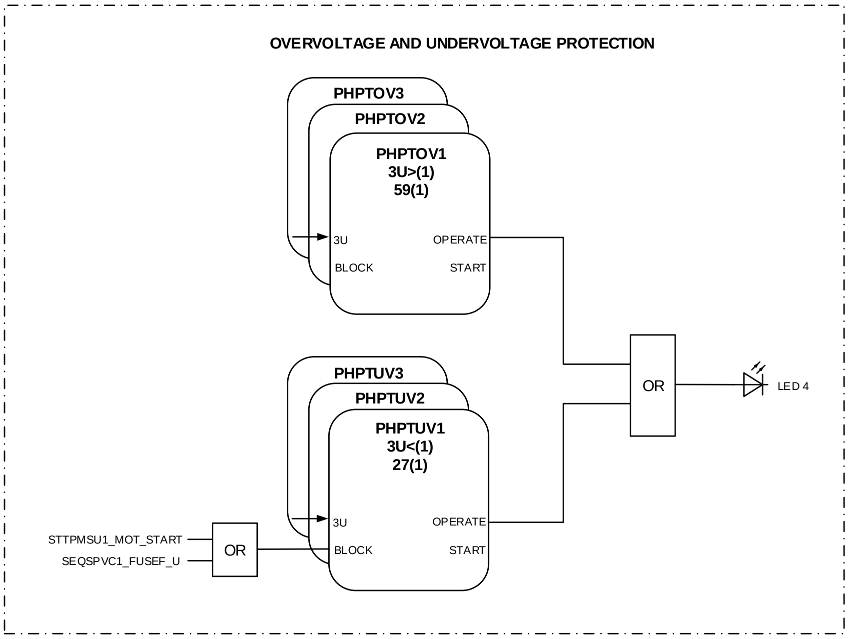


Figure 25: Overvoltage and undervoltage protection

Three instances of overvoltage protection PHPTOV1…3 and undervoltage protection PHPTUV1…3 offer protection against abnormal phase voltage conditions. The three-phase undervoltage protection is blocked during motor start-up to prevent unwanted operation, in case there is a short voltage drop. Also if the fuse failure is detected, the undervoltage function is blocked.

The `OPERATE` outputs of voltage functions are connected to the Master Trip and alarm LED 4.

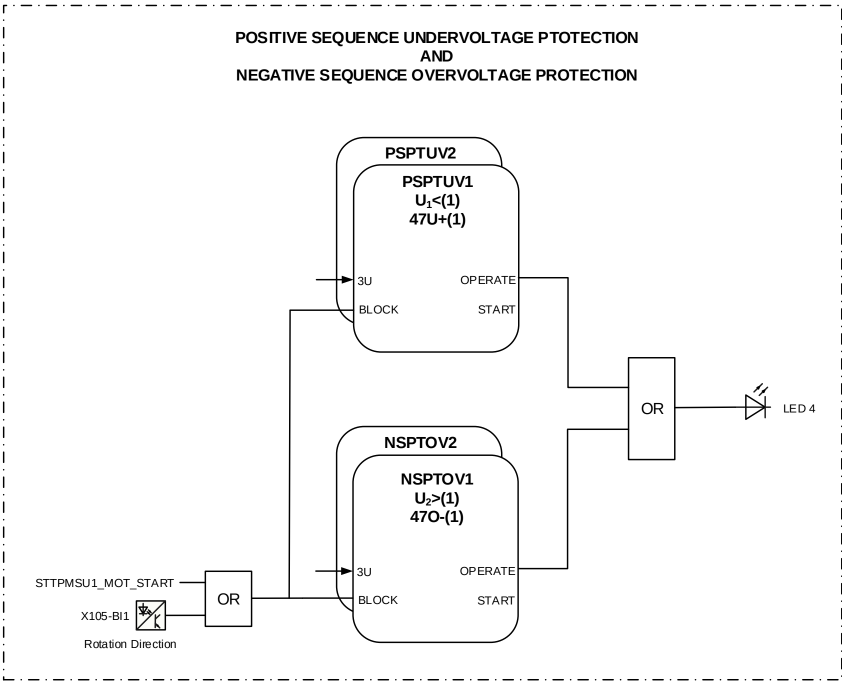


Figure 26: Positive-sequence undervoltage and negative-sequence overvoltage protection

The positive-sequence undervoltage PSPTUV1/2 and negative-sequence overvoltage NSPTOV1/2 protections are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order. The positive-sequence undervoltage and negative-sequence overvoltage functions are blocked during motor start-up to prevent unwanted operation, in case there is a short voltage drop. Also the binary input X105-BI1, which indicates the motor rotation direction, is used to block these functions by default.

The `OPERATE` outputs of voltage-sequence functions are connected to the Master Trip and alarm LED 4.

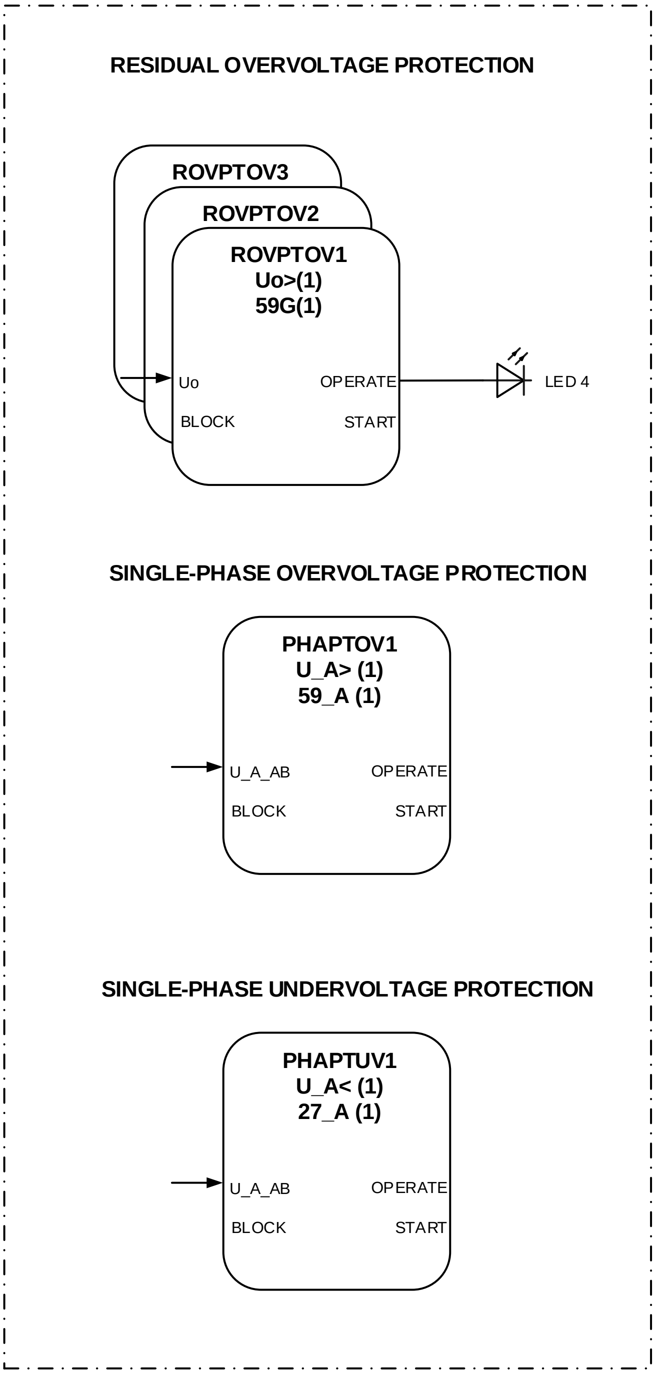


Figure 27: Residual overvoltage protection

The residual overvoltage protection ROVPTOV1...3 provides earth-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The `OPERATE` outputs are connected to the Master Trip and alarm LED 4.

The single-phase overvoltage protection PHAPTOV1 and single-phase undervoltage protection PHAPTUV1 are used for voltage protection by using the same extra single voltage input for terminal of the motor. These functions are not connected to disturbance recorder and not configured to trip the circuit breaker by default.

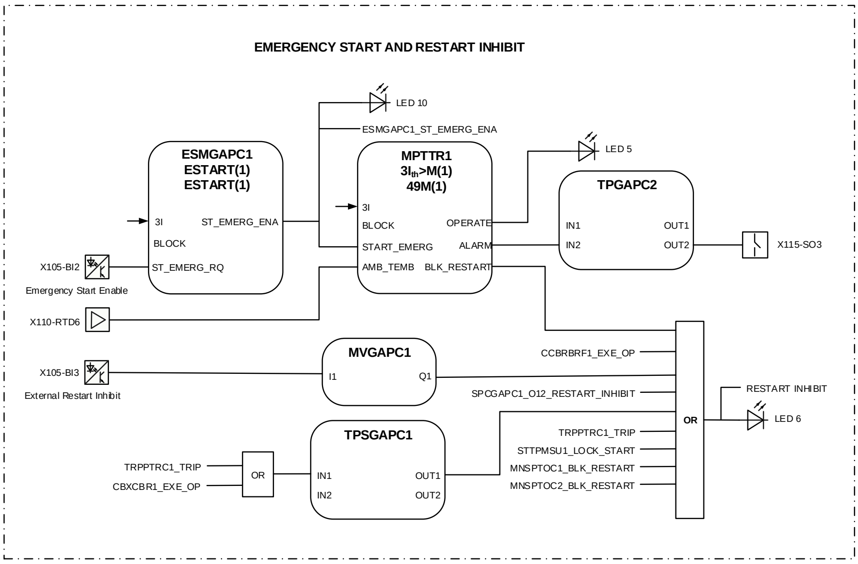


Figure 28: Emergency start and restart inhibit

The emergency start function ESMGAPC1 allows motor start-ups, although the calculated thermal level or cumulative start-up time counter is blocking the restart. The emergency start is enabled for ten minutes after the selected binary input X105- BI2 is energized. On the rising edge of the emergency start signal, various events occur.

- The calculated thermal level in MPTTR1 is set slightly below the restart inhibit level to allow at least one motor start-up
- The value of the cumulative start-up time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor start-up
- Set start value of the MAPGAPC1 function is increased (or decreased) depending on the *Start value Add* setting
- Alarm LED 10 is activated

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time of ten minutes has expired.

The thermal overload protection function MPTTR1 detects short- and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor. The `OPERATE` output of MPTTR1 is connected to alarm LED 5, which is used for thermal overload protection alarm indication. The `ALARM` output of MPTTR1 is connected to output X115-SO3 via generic timer TPGAPC2.

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection, where the motor has damping remanence voltage after circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1. The alarm LED 6 is used for restart inhibit alarm indication.

The restart inhibit is also activated when one of the conditions is met.

- An active trip command
- Motor start-up supervision has issued lockout
- Motor unbalance function has issued restart blocking
- An external restart inhibit is activated by one push button through `SPCGAPC1_O12` or by a binary input X105-BI3 via MVGAPC1

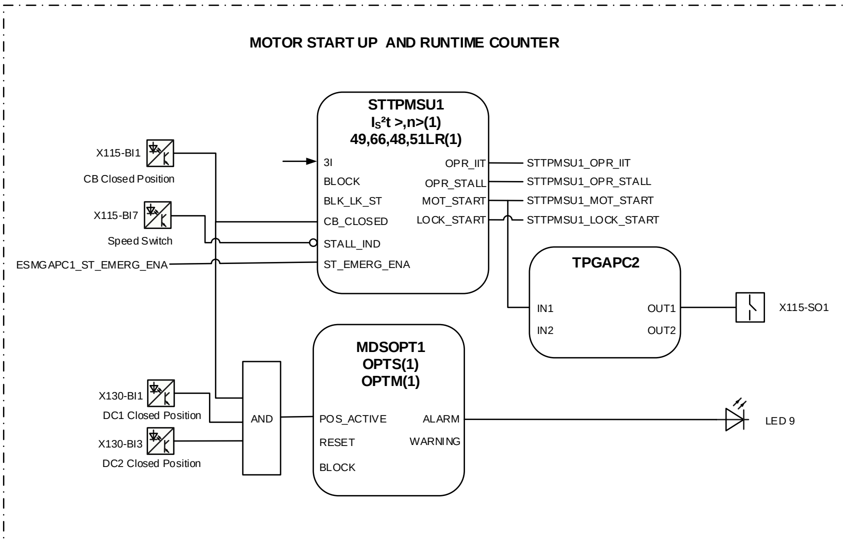


Figure 29: Motor startup supervision

With the motor start-up supervision function STTPMSU1, the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor.

When the emergency start request is activated by ESMGAPC1 and STTPMSU1 is in lockout state, the lockout `LOCK_START` is deactivated and emergency start is available. The `MOT_START` output of STTPMSU1 is connected to output X115-SO1 via generic timer TPGAPC2.

The motor running time counter MDSOPT1 provides history data since last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 9. LED 9 is used for general supervision of trip circuit, current measurement circuit, voltage measurement circuit and motor operation time.

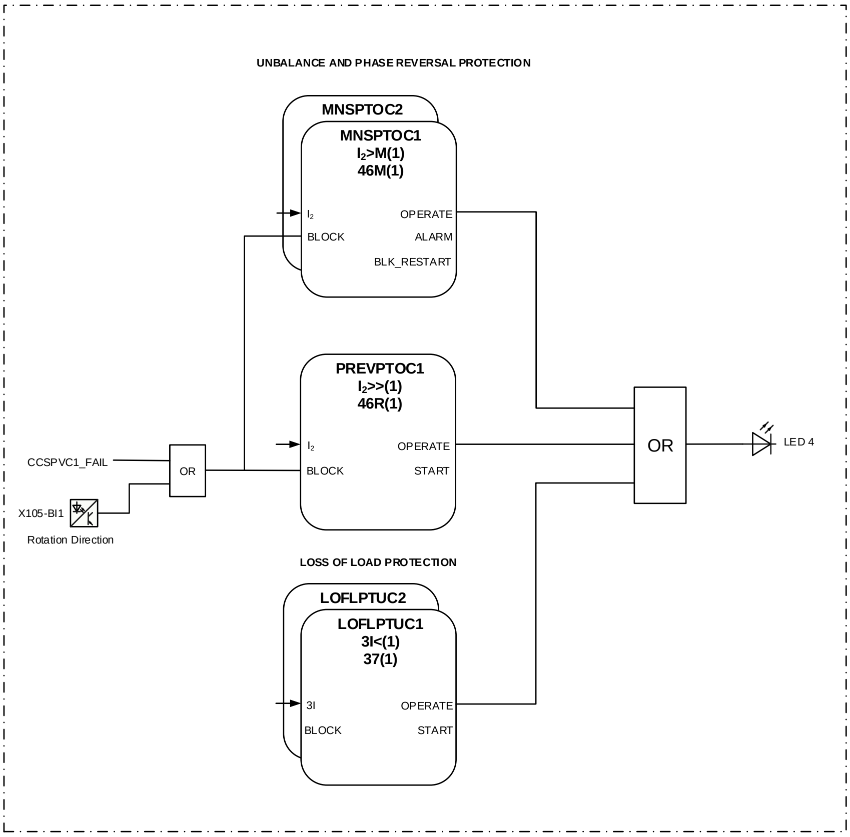


Figure 30: Phase unbalance and loss of load protection

Two negative-sequence overcurrent stages MNSPTOC1 and MNSPTOC2 are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The phase reversal protection PREVPTOC1 is based on the calculated negative phase-sequence current. It detects too high NPS current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

The negative-sequence protection and phase reversal protection are blocked if the current circuit supervision detects failure in the current measuring circuit. The binary input X105-BI1, which indicates the motor rotation direction, is also used to block these functions by default.

Two stages LOFLPTUC1 and LOFLPTUC2 are offered for loss of load situation protection. The loss of load situation can happen, for example, if there is damaged pump or a broken conveyor.

The `OPERATE` outputs of above protections are connected to the Master Trip and alarm LED 4.

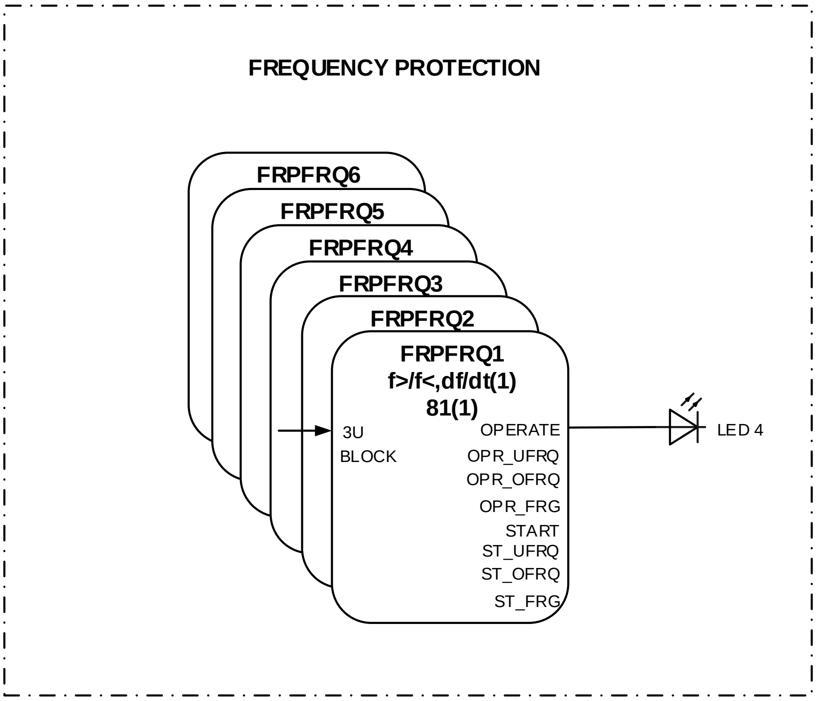


Figure 31: Frequency protection

Six underfrequency or overfrequency protection FRPFRQ1…6 stages are offered to prevent damage to network components under unwanted frequency conditions. The function 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.

The `OPERATE` outputs are connected to the Master Trip and alarm LED 4.

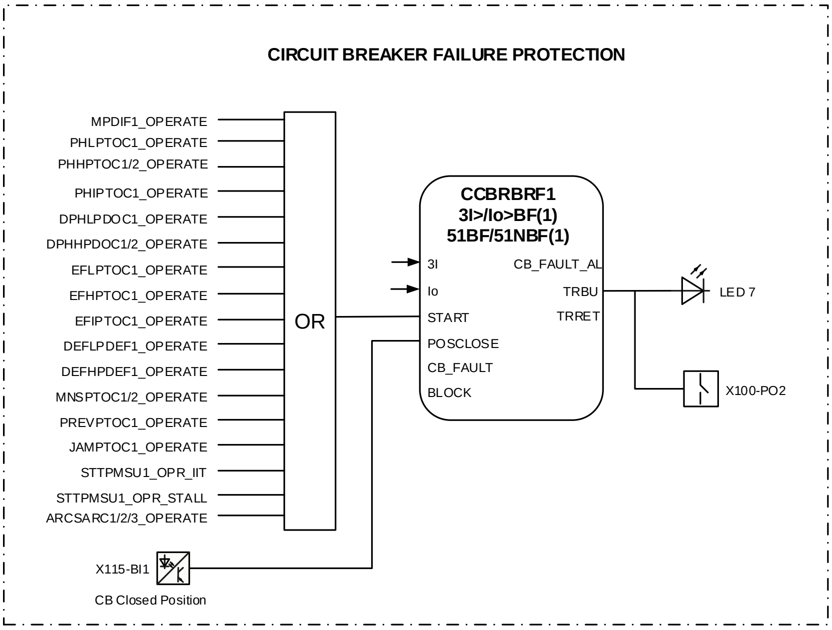


Figure 32: Circuit breaker failure protection

The breaker failure protection CCBRBRF1 is initiated via the `START` input by a number of different protection stages 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 breaker failure protection has two operating outputs: `TRRET` and `TRBU`. The `TRRET` output is used for retripping its own breaker through the Master Trip 1. The `TRBU` output is used to give a backup trip to the breaker feeding upstream. For this purpose, the `TRBU` output signal is connected to power output X100-PO2 and alarm LED 7. LED 7 is used for backup `TRBU` operate indication.

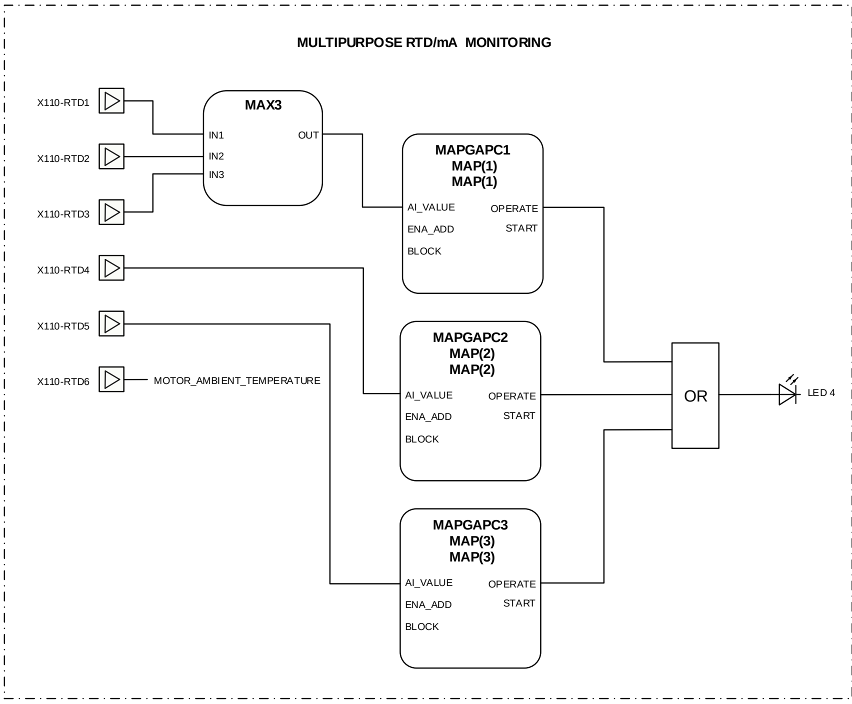


Figure 33: Multipurpose RTD/mA monitoring

RTD/mA monitoring functionality provides several temperature measurements for motor protection. Temperature of the motor windings U, V and W are measured with inputs X110-RTD1, X110-RTD2 and X110-RTD3. Measured values are connected from function X110 (RTD) to function MAX3. Maximum temperature value is then connected to the multipurpose analog protection block MAPGAPC1.

Motor cooling air temperature and motor bearing temperature can be measured with inputs X110-RTD4 and X110-RTD5. The protection functionality from these temperatures are provided by MAPGAPC2 and MAPGAPC3 functions.

Motor ambient temperature can be measured with input X110-RTD6 and it is connected to the thermal overload protection function MPTTR1.

The `OPERATE` outputs are connected to the Master Trip and alarm LED 4.

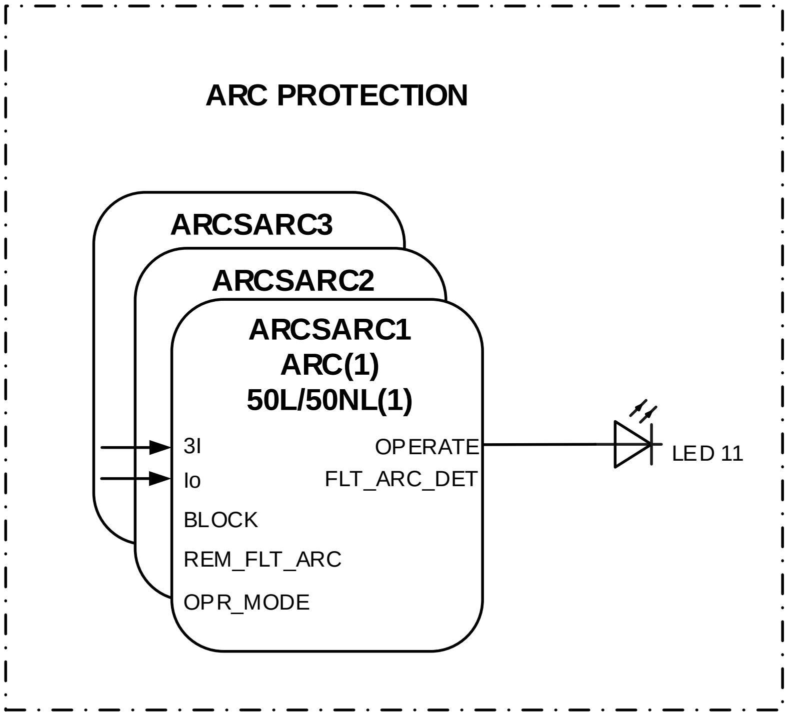


Figure 34: Arc protection

Arc protection ARCSARC1...3 is included as optional function.

The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, with or without phase and residual current check. The `OPERATE` outputs from the arc protection function blocks are connected to the Master Trip and alarm LED 11.

3.5.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

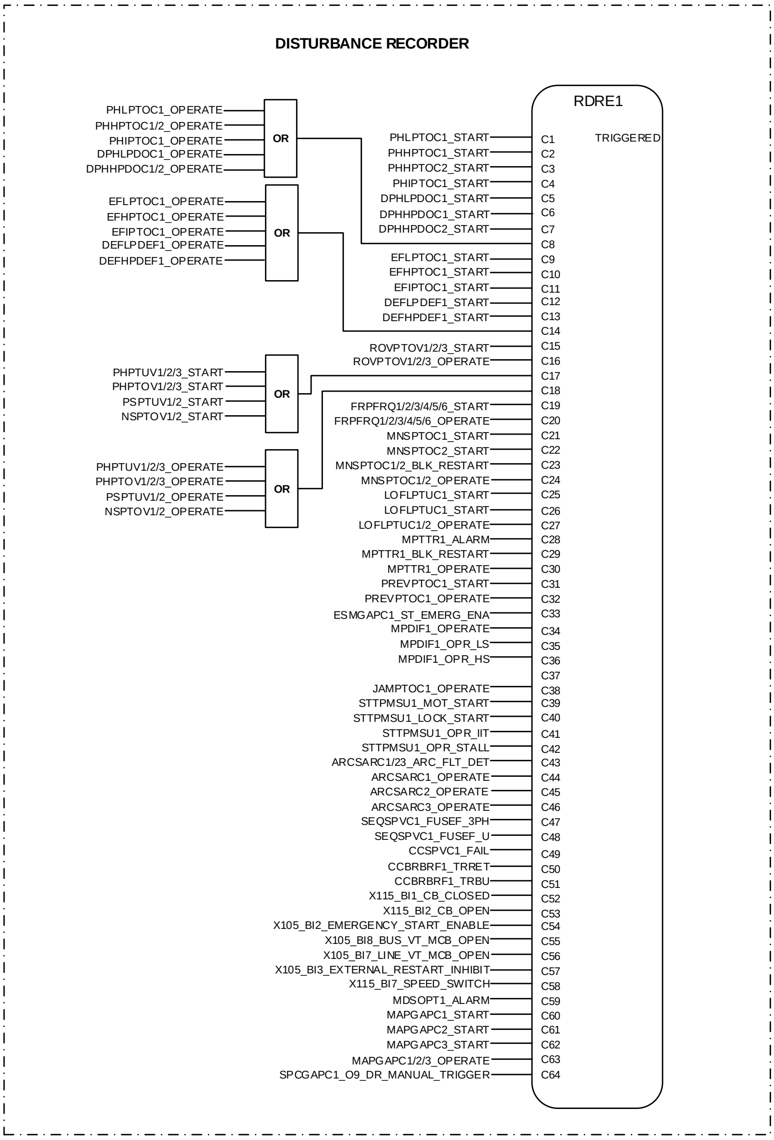


Figure 35: Disturbance recorder

All `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, some selected signals from different functions and eight binary inputs totally from X110 and X115 are also connected.

The manual trigger signal from push button is used to trigger disturbance recorder manually as needed.

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

Once the order of signals connected to binary inputs of RDRE is changed, the changes need to be made in the Parameter Setting tool.

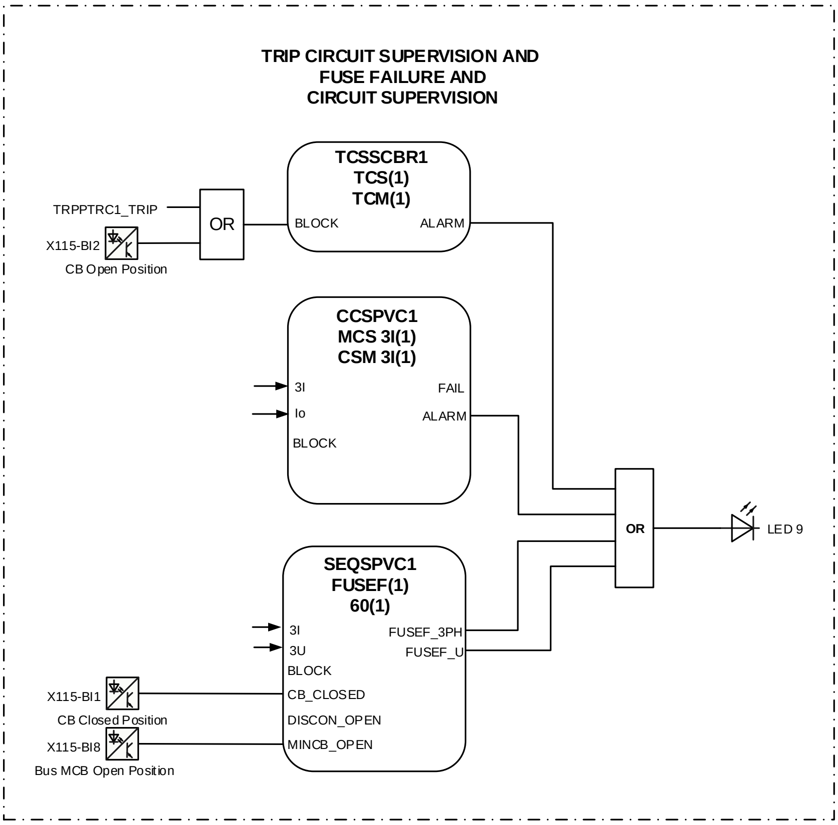


Figure 36: Circuit supervision

One trip circuit supervision function is in used by default, TCSSCBR1 for power output X100-PO3. Both functions are blocked by the Master Trip TRPPTRC1 and the circuit breaker open signal. The ALARM output indication is connected to the LED 9.

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.

Parameters for TCSSCBR1 need to be properly set.

Failures in current measuring circuits are detected by CCSPVC1. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is also connected to the alarm LED 9.

The fuse failure supervision SEQSPVC1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is also connected to the alarm LED 9.

3.5.3.3 Functional diagrams for control and interlocking

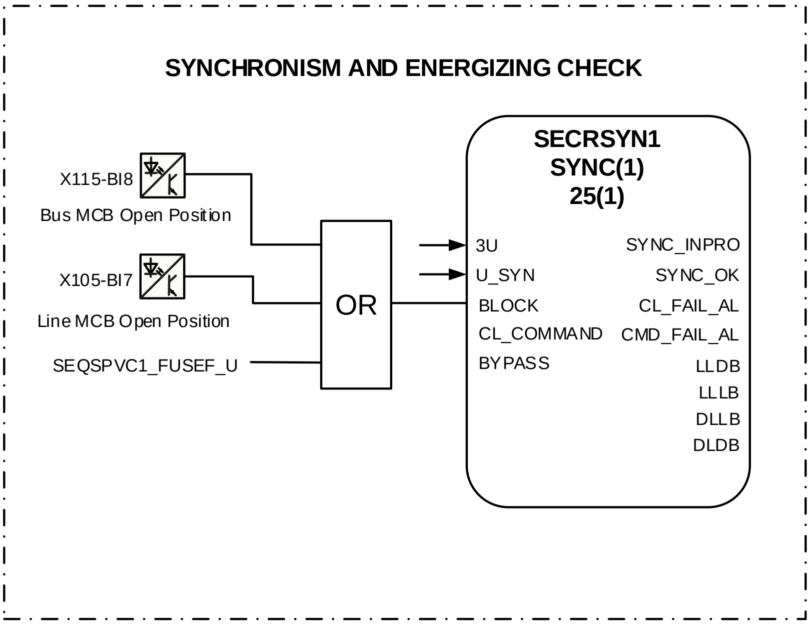


Figure 37: Synchronism and energizing check

The main purpose of the synchronism and energizing check SECRSYN1 is to provide control over the closing of the circuit breakers in power networks and prevent the closing if the conditions for synchronism are not fulfilled. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN1 measures the bus and motor terminal voltages and compares them to set conditions. When all the measured quantities are within set limits, the `SYNC_OK` output is activated for allowing closing or closing the circuit breaker. The `SYNC_OK` output signal is connected to the `ENA_CLOSE` input of CBXCBR1 through control.

To ensure the validity of the measured voltages on both sides, `Bus MCB Open Position` X115-BI8, `Line MCB Open Position` X105-BI7 and `FUSEF_U` from SEQSPVC1 are connected to block SECRSYN1.

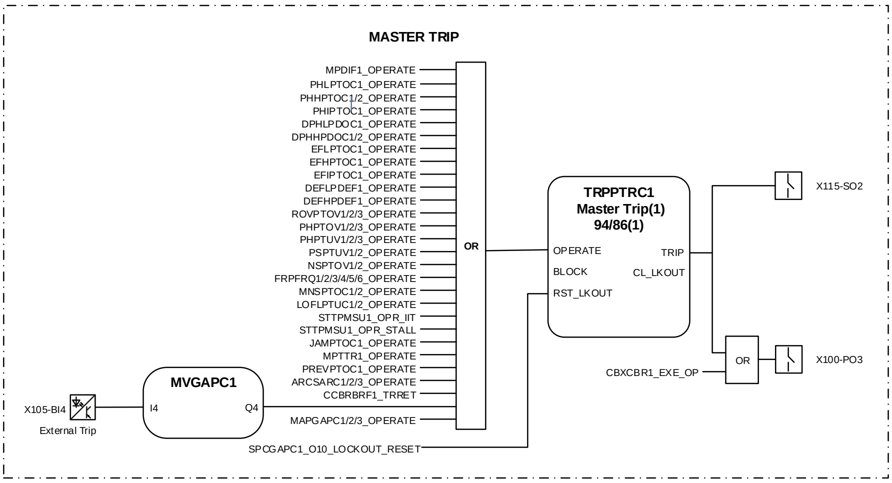


Figure 38: Master trip

The operating signals from the protections and an external trip X105-BI4 via MVGAPC1 are connected to signal output X115-SO2 and the trip output contact X100-PO3 via the corresponding Master Trip TRPPTRC1. The opening control commands to the circuit breaker from the local or remote `CBXCBR1_EXE_OP` are connected directly to the output X100-PO3.

TRPPTRC1 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, `SPCGAPC1_O10` is connected to the `RST_LKOUT` input of the Master Trip to enable external reset with a push button.

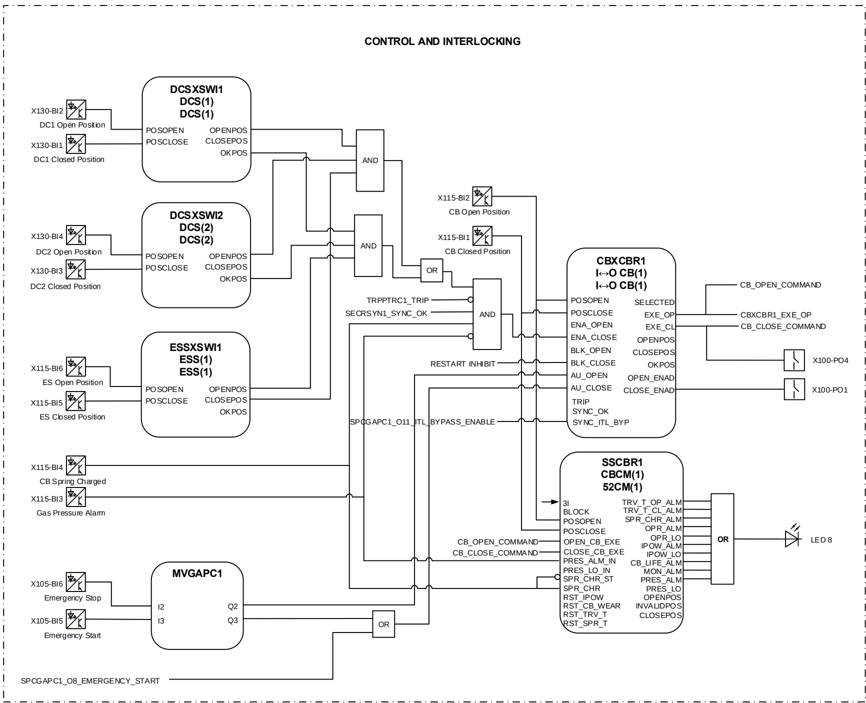


Figure 39: Circuit breaker control and interlocking

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...4 and ESSXSWI1...3 are status-only type, and DCXSWI1...4 and ESXSWI1...3 are controllable type. By default, the status-only blocks are connected in the standard configuration logic. If a controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used, instead of the status-only type. The connection and configuration of the control blocks can be made using PCM600.

The binary inputs 1 and 2 of the card X130 are used for busbar disconnector 1 DCSXSWI1 position indication. The binary inputs 3 and 4 of the card X130 are used for busbar disconnector 2 DCSXSWI2 position indication.

Table 19: Disconnector 1 position indicated by binary inputs

Primary device position	Input to be energized	
	X130-BI1	X130-BI2
Busbar disconnector 1 closed	●	
Busbar disconnector 1 open		●

Table 20: Disconnector 2 position indicated by binary inputs

Primary device position	Input to be energized	
	X130-BI3	X130-BI4
Busbar disconnector 2 closed	●	
Busbar disconnector 2 open		●

The binary inputs 7 and 8 of card X110 are designed for the position indication of the earthing switch.

Table 21: Earthing switch position indicated by binary inputs

Primary device position	Input to be energized	
	X115-BI5	X115-BI6
Earthing switch closed	●	
Earthing switch open		●

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 position statuses of related primary equipment (disconnector and earthing switch), the condition of the circuit breaker (CB gas pressure alarm, CB spring charged), and the Master Trip logics. The `OKPOS` output from the DCSXSWI block defines if the disconnector is definitely either open or close. This, together with non-active trip signal activates the ENA_CLOSE signal to the circuit breaker control function block. The open operation is always enabled.

The circuit breaker closing is blocked when the `BKL_CLOSE` input is activated, which is connected to motor restart inhibit logic. When all conditions of the circuit breaker closing are fulfilled, the `CLOSE_ENAD` output of the CBXCBR1 is activated and `PO1` output X100-PO1 is closed.

Emergency stop signal to `AU_OPEN` input of CBXCBR1 via MVGAPC1 is used to open the breaker by one push button through SPCGAPC1_O8 or by a binary input X105-BI5. Emergency start signal to `AU_CLOSE` input of CBXCBR1 via MVGAPC1 is used to close the breaker by one push button through SPCGAPC1_O16 or by a binary input X105-BI6.

One push button can be used through SPCGAPC1_O11, which is connected to `SYNC_ITL_BYP` input of the CBXCBR1, to ignore the status of `ENA_CLOSE` input However, the `BKL_CLOSE` input signals are not bypassed with the interlocking bypass functionality as they always have a higher priority.

If the `ENA_CLOSE` signal is completely removed from the breaker control function block CBXCBR1 with PCM600, the function assumes that the breaker-closing commands are allowed continuously.

The circuit breaker condition monitoring function SSCBR1 supervises the circuit breaker status based on the binary input information connected and the measured current levels. SSCBR introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

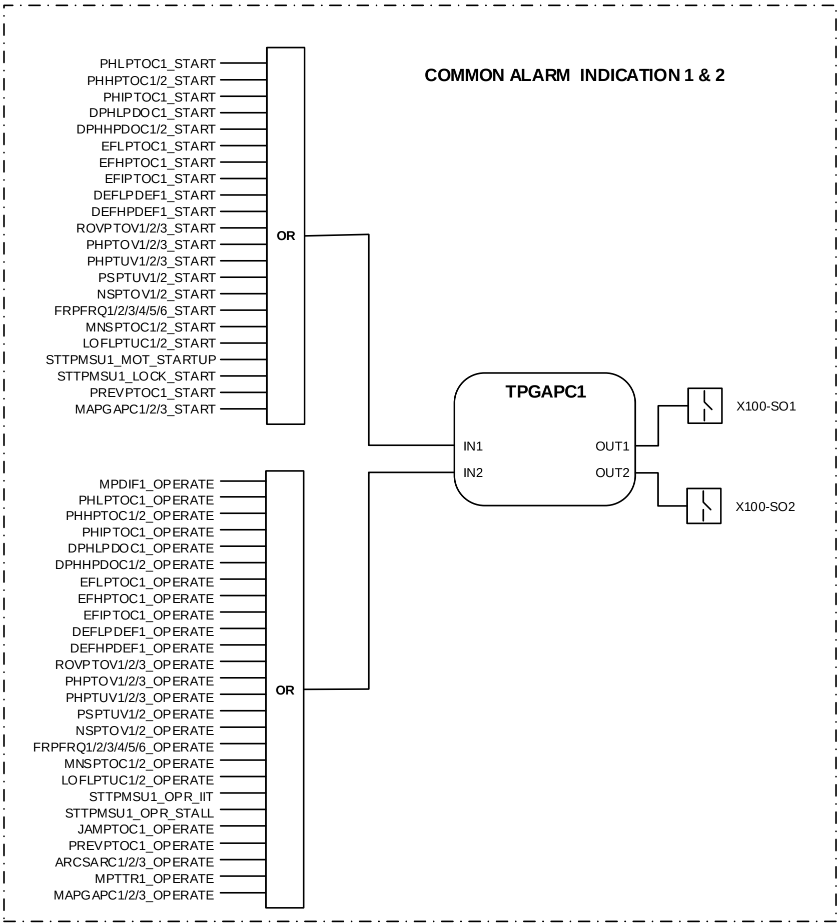


Figure 40: Common alarm indication

The signal outputs from the relay are connected to give dedicated information.

- Start of any protection function X100-SO1
- Operate of any protection function X100-SO2

TPGAPC function blocks are used for setting the minimum pulse length for the outputs. There are four generic timers TPGAPC1…4 available in the relay. The remaining ones, which are not described in the functional diagram, are available in PCM600 for connection where applicable.

3.5.3.4 Functional diagrams for power quality measurements

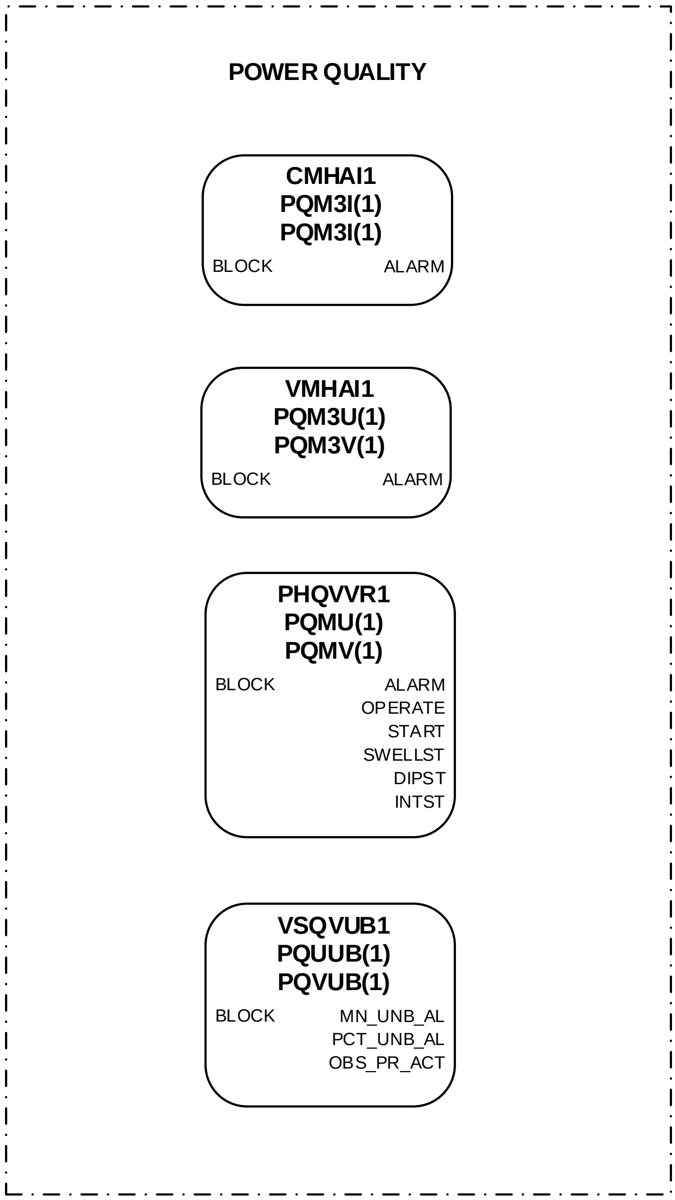


Figure 41: Power quality measurement function

The power quality function CMHAI1 is used to measure the harmonic contents of the phase current.

The power quality function VMHAI1 is used to measure the harmonic contents of the phase voltages.

The power quality function PHQVVR1 is used to measure the voltage variation, that is, sags and swells.

The voltage unbalance power quality function VSQVUB1 monitors the voltage unbalance conditions in power networks. It is used to monitor the commitment of power supply utility of providing a balanced voltage supply on a continuous basis. VSQVUB provides statistics which can be used to verify the compliance of the power quality.

The above functions are included in default configuration for demonstration purposes only, but not configured by default. The functions can be configured as needed.

3.5.3.5 Functional diagrams for measurement functions

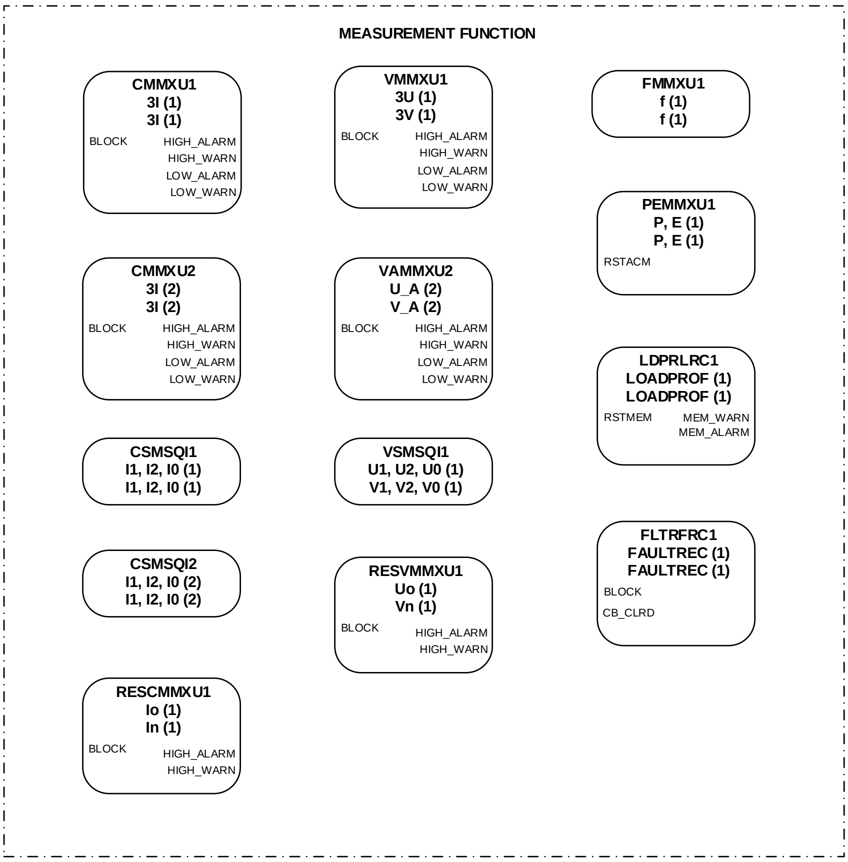


Figure 42: Measurement function

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1/2. The current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1/2 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

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

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

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding bay. FLTRFRC1 is used to record the monitored data during the fault condition. The records enable the analysis of recent power system events.

3.5.3.6 Functional diagrams for extra functions

Additional functions are available in the relay default content but they are not preengineered to be part of the default configuration. The functions can be engineered into use.

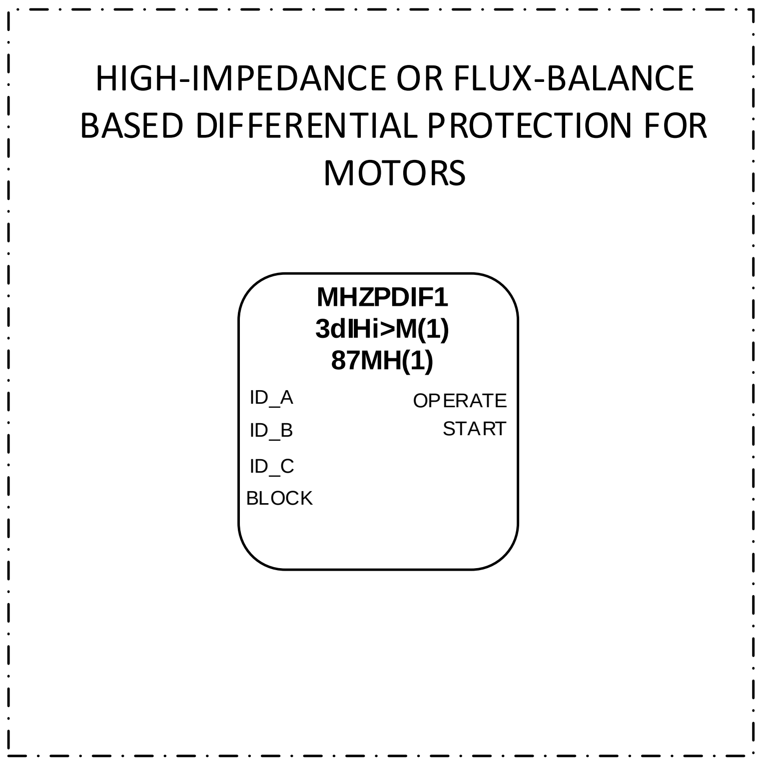


Figure 43: Flux-balance based differential protection for motors

One high-impedance or flux-balance based differential protection for motors MHZPDIF1 is offered. MHZPDIF provides the winding short-circuit and earth-fault protection for motors. Due to the capability to manage through-faults with a heavy current transformer (CT) saturation, the high-impedance or flux-balance principle has been commonly used for differential protection. MPDIF1 can alternatively be used for this function. For detailed information, see the technical manual.

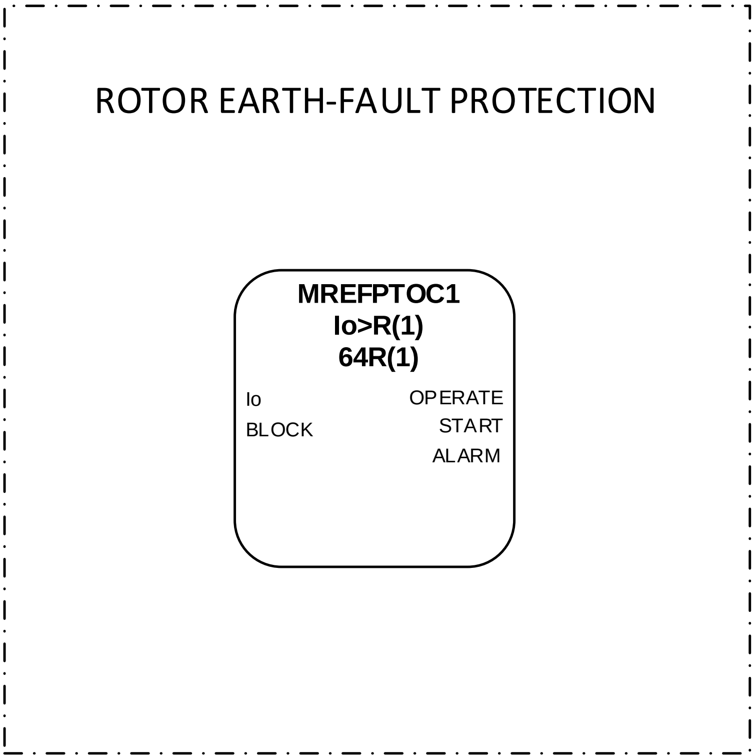


Figure 44: Rotor earth-fault protection

One rotor earth-fault protection function MREFPTOC1 is offered. MREFPTOC is used to detect an earth fault in the rotor circuit of synchronous machines. For detailed information, see the technical manual.

3.5.3.7 Functional diagrams for optional functions

Optional functions are available in the relay default content when a corresponding option is selected while ordering the relay. However, the functions are not preengineered to be part of the default configuration. The functions can be engineered into use.

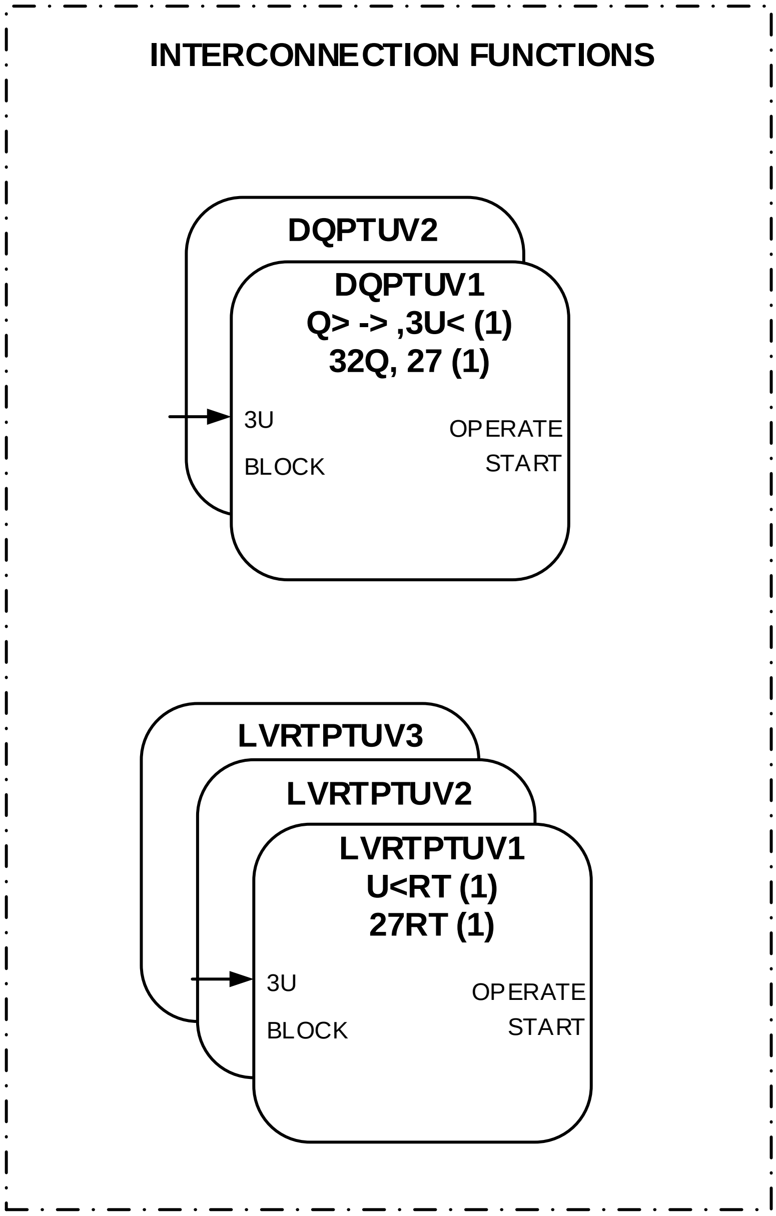


Figure 45: Interconnection function

Interconnection protection functions include the directional reactive power undervoltage protection DQPTUV1 and the three instances of low-voltage ride-through protection LVRTPTUV1...3. These functions can be used in the common point of coupling of utility grid and distributed energy resource, 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 can be used to block LVRTPTUV1...3 and DQPTUV1 protection. These interconnection functions can be engineered to work together with basic functions in relay default configuration to cover different needs placed for relay operation in different grid codes.

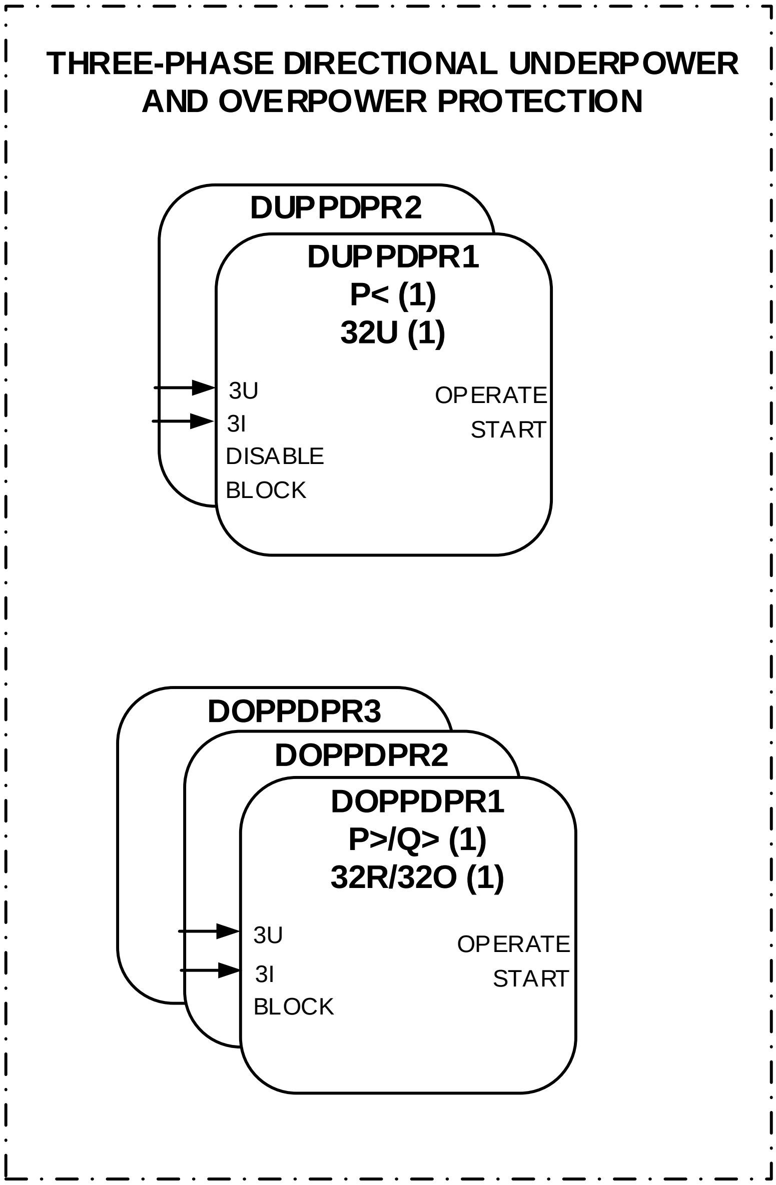


Figure 46: Three-phase directional underpower and overpower protection function

Two instances of directional underpower protection DUPPDPR1 and DUPPDPR2 are provided. Normally these are used in supervision of underpower or underloading situations.

Three instances of directional overpower protection DOPPDPR1, DOPPDPR2 and DOPPDPR3 are provided to supervision of overpower or overloading situations with power flow direction information.

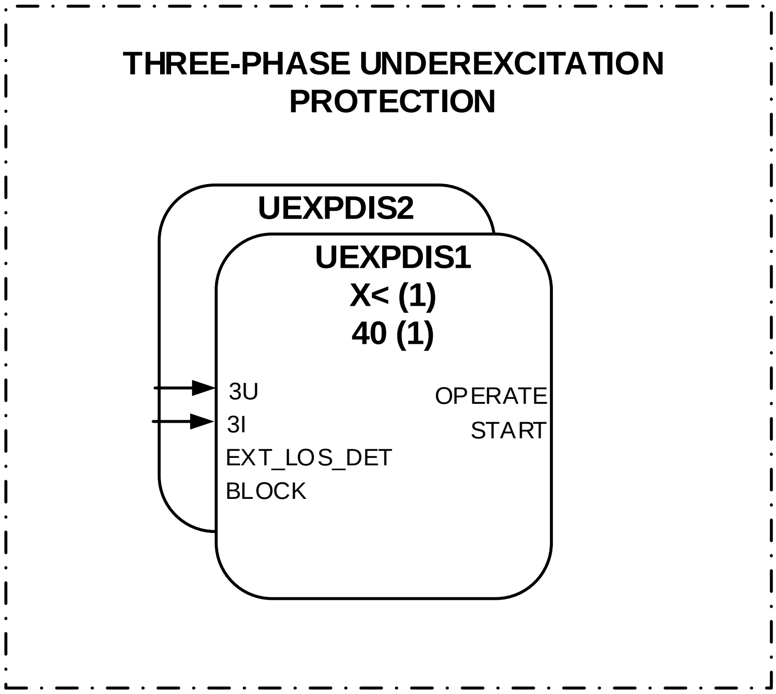


Figure 47: Three-phase underexcitation protection

On losing excitation, a motor may overspeed and operate as an induction motor 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 motor circuit breaker is in open position.

3.5.4 Application configuration of SMV receiver

This chapter describes how to configure configuration A as an SMV receiver. For overall information about SMV engineering, see the IEC 61850 engineering guide.

This configuration includes three TVTR function blocks. If no SMV receiver is defined, all TVTRs receive voltage inputs from physical channels and provide the value to different functions.

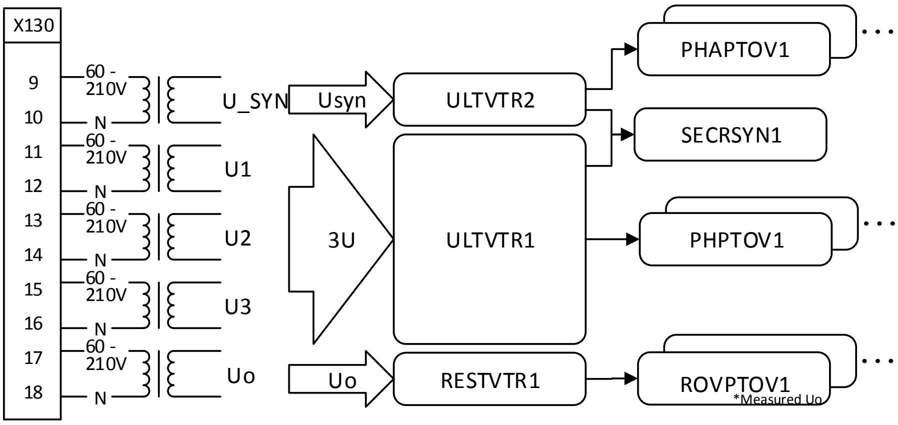


Figure 48: No SMV receiver configured

The SMV receiver application configuration is done with the Application Configuration tool in PCM600. Which physical voltage input channel is replaced by sample value voltage can be defined by connecting the SMVRCV output to different TVTR function inputs.

The IEC 61850-9-2 LE stream always contains UL1, UL2, UL3 and Uo. Thus, when the IEDs are used as senders, and the three phase-tophase voltages and Uo are connected to the hardware channels, the three phase-to-earth voltages are calculated from the input and sent through IEC 61850-9-2 LE.

The IEC 61850-9-2 LE configuration has to be done only according to the examples in this section, otherwise an engineering failure might follow.

3.5.4.1 Connection of SMVRCV to ULTVTR1

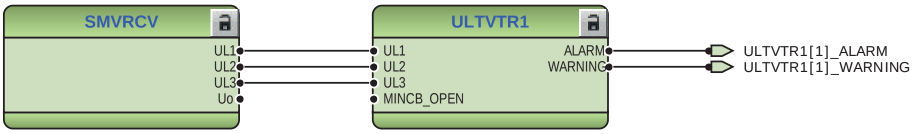


Figure 49: Connection of SMVRCV to ULTVTR1 in Application Configuration

When SMVRCV is connected to ULTVTR1 in the Application Configuration tool, ULTVTR1 is disconnected from the physical channels U1, U2 and U3 and uses three phase voltages from the received IEC 61850-9-2 LE sample value. All functions which have `3U` input begin working with the IEC 61850-9-2 LE sample value.

All three signals UL1, UL2 and UL3 must always be connected between SMVRCV and ULTVTR1 in Application Configuration.

The IEC 61850-9-2 LE stream always contains UL1, UL2, UL3 and Uo. When the three phase voltage channels are received from IEC 61850-9-2 LE, the setting *VT connection* in **Configuration** > **Analog inputs** > **Voltage (3U,VT)** must be “Wye”.

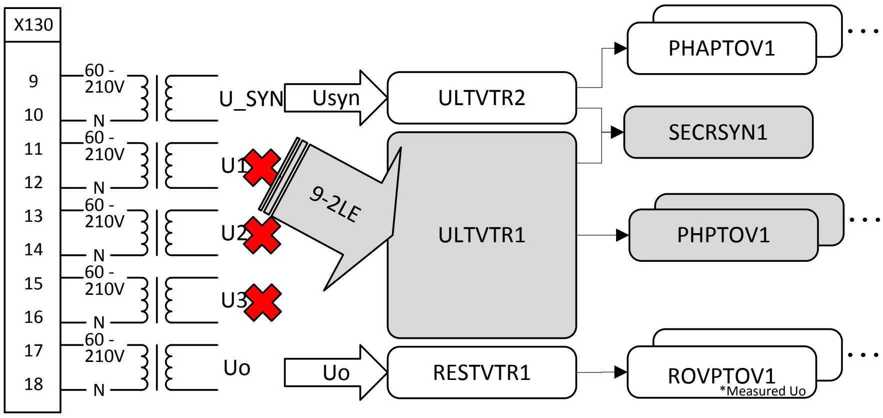


Figure 50: ULTVTR1 uses three phase voltages from received IEC 61850-9-2 LE sample value

3.5.4.2 Connection of SMVRCV to RESTVTR1

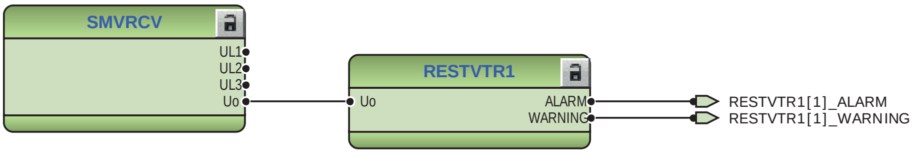


Figure 51: Connection of SMVRCV to RESTVTR1 in Application Configuration

When SMVRCV is connected to RESTVTR1 in the Application Configuration tool, RESTVTR1 is disconnected from the physical channel Uo and uses residual voltages from the received IEC 61850-9-2 LE sample value. All functions which have `Uo` input begin working with the IEC 61850-9-2 LE sample value.

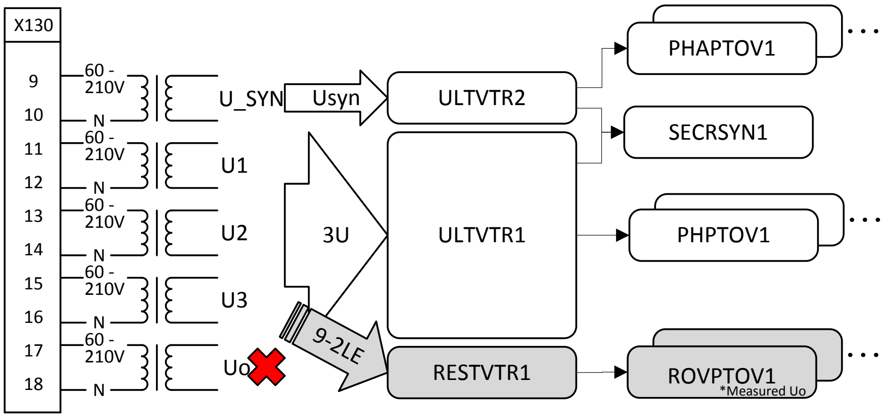


Figure 52: RESTVTR1 uses residual voltages from received IEC 61850-9-2 LE sample value

3.5.4.3 Connection of SMVRCV to both ULTVTR1 and RESTVTR1

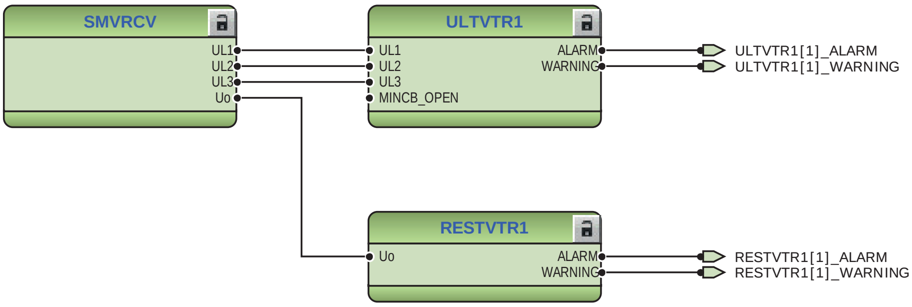


Figure 53: Connection of SMVRCV to both ULTVTR1 and RESTVTR1 in Application Configuration

SMVRCV can also be connected to both ULTVTR1 and RESTVTR1. This means that both the three phase voltages U1, U2, U3 and the residual voltage Uo are replaced by the received IEC 61850-9-2 LE sample value.

All three signals UL1, UL2 and UL3 must always be connected between SMVRCV and ULTVTR1.

The IEC 61850-9-2 LE stream always contains UL1, UL2, UL3 and Uo. When the three phase voltage channels are received from IEC 61850-9-2 LE, the setting *VT connection* in **Configuration** > **Analog inputs** > **Voltage (3U,VT)** must be “Wye”.

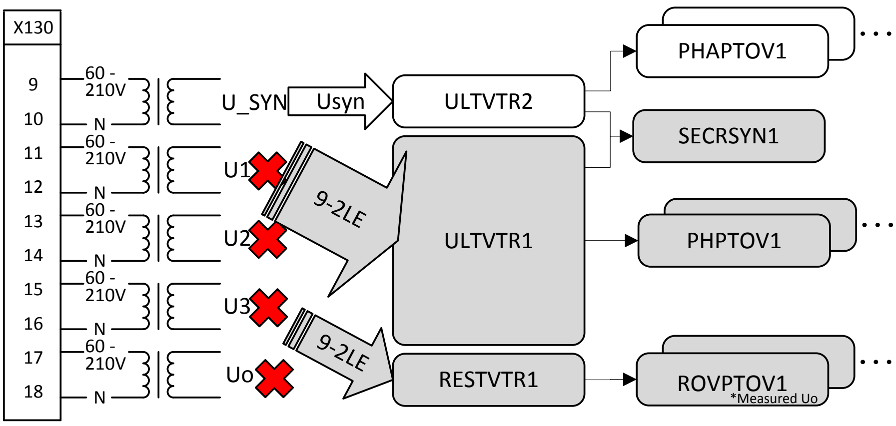


Figure 54: Both ULTVTR1 and RESTVTR1 use voltages from received IEC 61850-9-2 LE sample value

3.5.4.4 Connection of SMVRCV to ULTVTR2

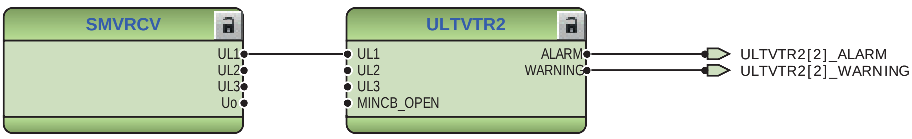


Figure 55: Connection of SMVRCV to ULTVTR2 in Application Configuration

When SMVRCV is connected to ULTVTR2 in the Application Configuration tool, ULTVTR2 is disconnected from the physical channel U_SYN and uses UL1 voltage from the received IEC 61850-9-2 LE sample value. All functions which have `U_SYN` input begin working with the IEC 61850-9-2 LE sample value.

Only UL1 must be connected between SMVRCV and ULTVTR2 in the Application Configuration tool.

The IEC 61850-9-2 LE stream always contains UL1, UL2, UL3 and Uo. When U_SYN as a single channel input is received from IEC 61850-9-2 LE, the setting *VT connection* in **Configuration** > **Analog inputs** > **Voltage (3UB,VT)**// must be “UL1”.

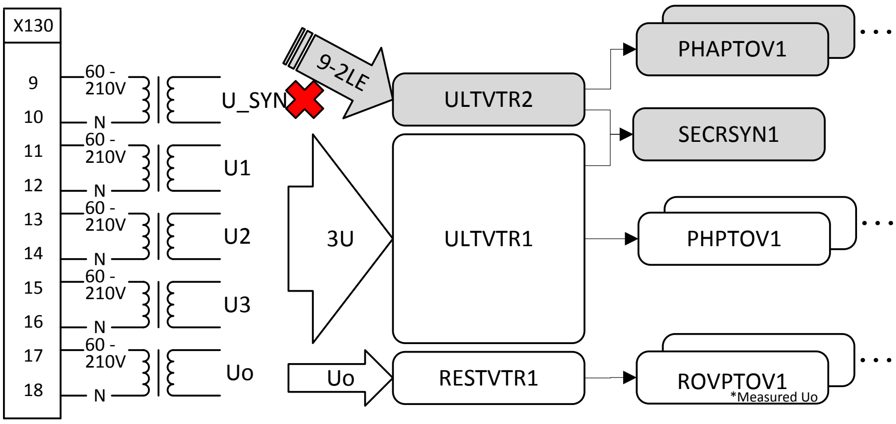


Figure 56: ULTVTR2 uses UL1 voltage from received IEC 61850-9-2 LE sample value

3.6 Default configuration B

3.6.1 Applications

The default configuration is designed for motor protection with current and voltage based protection and measurement functions and is mainly intended for comprehensive protection and control of circuit breaker controlled asynchronous motors. With minor modifications this default configuration can be applied also for contactor controlled motors. There is also an option for mA/RTD measurement and protection.

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

3.6.2 Functions

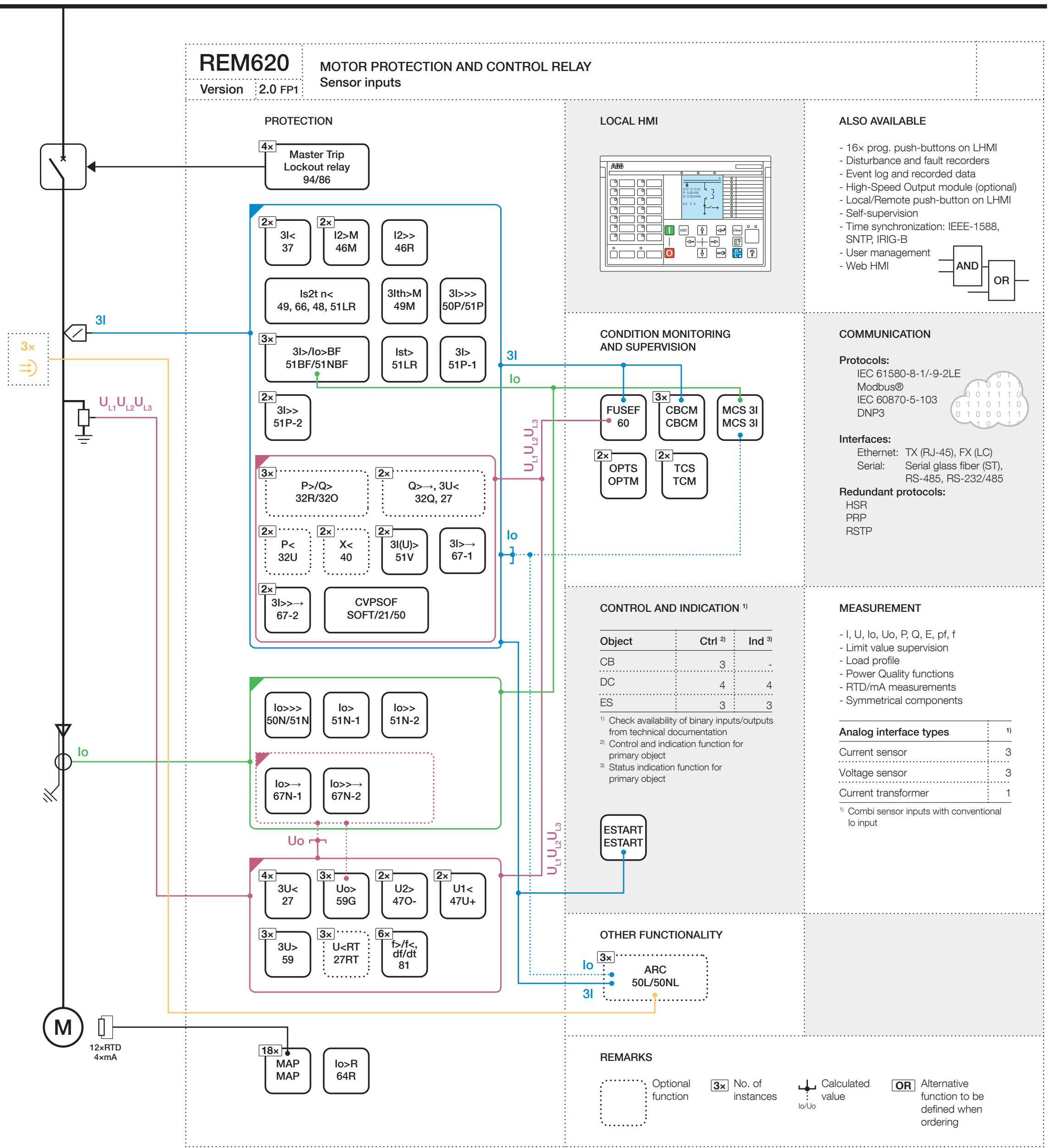


Figure 57: Functionality overview of default configuration with sensor inputs

3.6.2.1 Default I/O connections

Table 22: Default connections for analog inputs

Analog input	Default usage	Connector pins
IL1	Phase A current	X131:4,5 [1] / X131 L1/A:1,2 [2]
IL2	Phase B current	X132:4,5 [1] / X132 L2/B:1,2 [2]
IL3	Phase C current	X133:4,5 [1] / X133 L3/C:1,2 [2]
Io	Residual current	X130:1,2
U1	Phase voltage U1, feeder side	X131:7,8
U2	Phase voltage U2, feeder side	X132:7,8
U3	Phase voltage U3, feeder side	X133:7,8

Table 23: Default connections for binary inputs

Binary input	Default usage	Connector pins
X105-BI1	Rotation direction	X105:1,2
X105-BI2	Emergency start enable	X105:3,4
X105-BI3	External restart inhibit	X105:5,6
X105-BI4	External trip	X105:7,6
X105-BI5	Emergency start	X105:8,9
X105-BI6	Emergency stop	X105:10,9
X105-BI7	-	X105:11,12
X105-BI8	-	X105:13,12
X115-BI1	Circuit breaker closed position indication	X115:1,2
X115-BI2	Circuit breaker open position indication	X115:3,4
X115-BI3	Circuit breaker low gas pressure alarm	X115:5,6
X115-BI4	Circuit breaker spring charged indication	X115:7,6
X115-BI5	Earthing switch 1 closed position indication	X115:8,9
X115-BI6	Earthing switch 1 open position indication	X115:10,9
X115-BI7	Speed switch (motor running)	X115:11,12
X115-BI8	-	X115:13,12
X110-BI1	Disconnector 1 closed position indication	X110:1,2
X110-BI2	Disconnector 1 open position indication	X110:3,4
X110-BI3	Disconnector 2 closed position indication	X110:5,6
X110-BI4	Disconnector 2 open position indication	X110:7,6
X110-BI5	-	X110:8,9
X110-BI6	-	X110:10,9
X110-BI7	-	X110:11,12
X110-BI8	-	X110:13,12

[1] SIM0002
[2] SIM0005

Table 24: Default connections for binary outputs

Binary input	Default usage	Connector pins
X100-PO1	Restart enable	X100:6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8,9
X100-SO1	General start indication	X100:10,11(12)
X100-SO2	General operate indication	X100:13,14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X115-SO1	Motor start-up indication	X115:14-16
X115-SO2	Open command (for contactor applica-tions)	X115:17-19
X115-SO3	Thermal overload alarm	X115:20-22
X115-SO4	Voltage protection operate alarm	X115:23,24
X110-SO1	-	X110:14-16
X110-SO2	-	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	X110:23,24

Table 25: Default connections for LEDs

LED	Default usage	Label description
1	Short circuit protection operate	Short circuit protection
2	Earth fault protection operate	Earth-fault protection
3	Voltage or frequency protection operate	Voltage/Frequency Prot.
4	Combined protection operate indication of the other protection functions	Combined Protection
5	Thermal overload protection operate	Thermal Overload for Motors
6	Motor restart inhibit	Motor restart inhibit
7	Circuit breaker failure protection backup protec-tion operate	Breaker failure protection
8	Circuit breaker condition monitoring alarm	CB condition monitoring
9	Supervision alarm	Supervision
10	Emergency start enabled	Emergency start enabled
11	Arc fault detected	Arc detected

Table 26: Default connections for function keys

FK/ SPCGAPC number	Default usage	Operation mode	Pulsed length
1	Setting Group 1 Enabled	Pulsed	150 ms
2	Setting Group 2 Enabled	Pulsed	150 ms
3	Setting Group 3 Enabled	Pulsed	150 ms
4	Setting Group 4 Enabled	Pulsed	150 ms

Table continues on the next page

FK/ SPCGAPC number	Default usage	Operation mode	Pulsed length
5	Setting Group 5 Enabled	Pulsed	150 ms
6	Setting Group 6 Enabled	Pulsed	150 ms
7	-	Off	1000 ms
8	Emergency Start	Pulsed	150 ms
9	Disturbance Recorder Manual Trig- ger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms
11	Circuit Breaker Block Bypass	Toggle	1000 ms
12	Restart Inhibit	Toggle	1000 ms
13	-	Off	1000 ms
14	-	Off	1000 ms
15	-	Off	1000 ms
16	-	Off	1000 ms

3.6.2.2 Default disturbance recorder settings

Table 27: Default disturbance recorder settings binary channels

Channel	Id text	Level trigger mode
1	PHLPTOC1_START	Positive or Rising
2	PHHPTOC1_START	Positive or Rising
3	PHHPTOC2_START	Positive or Rising
4	PHIPTOC1_START	Positive or Rising
5	DPHLPDOC1_START	Positive or Rising
6	DPHHPDOC1_START	Positive or Rising
7	DPHHPDOC2_START	Positive or Rising
8	PHxPTOC or DPHxPDOC_OPERATE	Level trigger off
9	EFLPTOC1_START	Positive or Rising
10	EFHPTOC1_START	Positive or Rising
11	EFIPTOC1_START	Positive or Rising
12	DEFLPDEF1_START	Positive or Rising
13	DEFHPDEF1_START	Positive or Rising
14	EFxPTOC or DEFxPDEF_OPERATE	Level trigger off
15	ROVPTOV1/2/3_START	Positive or Rising
16	ROVPTOV1/2/3_OPERATE	Level trigger off
17	PHPTUV or PHPTOV or PSPTUV or NSPTOV_START	Positive or Rising
18	PHPTUV or PHPTOV or PSPTUV or NSPTOV_OPERATE	Level trigger off
19	FRPFRQ_START	Positive or Rising
20	FRPFRQ_OPERATE	Level trigger off

Table continues on the next page

Channel	Id text	Level trigger mode
21	MNSPTOC1_START	Positive or Rising
22	MNSPTOC2_START	Positive or Rising
23	MNSPTOC1/2_BLK_RESTART	Level trigger off
24	MNSPTOC1/2_OPERATE	Level trigger off
25	LOFLPTUC1_START	Positive or Rising
26	LOFLPTUC2_START	Positive or Rising
27	LOFPTUC1/2_OPERATE	Level trigger off
28	MPTTR1_ALARM	Level trigger off
29	MPTTR1_BLK_RESTART	Level trigger off
30	MPTTR1_OPERATE	Level trigger off
31	PREVPTOC1_START	Positive or Rising
32	PREVPTOC1_OPERATE	Level trigger off
33	ESMGAPC_ST_EMERG_ENA	Level trigger off
34	-	Level trigger off
35	-	Level trigger off
36	-	Level trigger off
37	-	Level trigger off
38	JAMPTOC1_OPERATE	Positive or Rising
39	STTPMSU1_MOT_START	Positive or Rising
40	STTPMSU1_LOCK_START	Level trigger off
41	STTPMSU1_OPR_IIT	Positive or Rising
42	STTPMSU1_OPR_STALL	Positive or Rising
43	ARCSARC1/2/3_ARC_FLT_DET	Level trigger off
44	ARCSARC1_OPERATE	Positive or Rising
45	ARCSARC2_OPERATE	Positive or Rising
46	ARCSARC3_OPERATE	Positive or Rising
47	SEQSPVC1_FUSEF_3PH	Level trigger off
48	SEQSPVC1_FUSEF_U	Level trigger off
49	CCSPVC1_FAIL	Level trigger off
50	CCBRBRF1_TRRET	Level trigger off
51	CCBRBRF1_TRBU	Level trigger off
52	CB Closed	Level trigger off
53	CB Open	Level trigger off
54	Emergency Start Enable	Level trigger off
55	-	-
56	-	-
57	External Restart Inhibit	Level trigger off
58	Speed Switch	Level trigger off
59	MDSOPT1_ALARM	Level trigger off
60	-	-
61	-	-

Table continues on the next page

Channel	Id text	Level trigger mode
62	-	-
63	-	-
64	FKEY K9_DR Manual Trigger	Positive or Rising

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

Table 28: Default analog channel selection and text settings

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

3.6.2.3 Default operation mode for generic control point

Table 29: Default operation modes

Channel	Signal name	Value	Pulse length
1	SG1 Enabled	Pulsed	150 ms
2	SG2 Enabled	Pulsed	150 ms
3	SG3 Enabled	Pulsed	150 ms
4	SG4 Enabled	Pulsed	150 ms
5	SG5 Enabled	Pulsed	150 ms
6	SG6 Enabled	Pulsed	150 ms
7		Off	1000 ms
8	Emergency Start	Pulsed	150 ms
9	DR Trigger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms
11	CB Block Bypass	Toggle	1000 ms
12	Restart Inhibit	Toggle	1000 ms
13		Off	1000 ms
14		Off	1000 ms

Table continues on the next page

Channel	Signal name	Value	Pulse length
15		Off	1000 ms
16	Emergency Stop	Pulsed	150 ms
Grey cells indicate different default settings.			

3.6.2.4 Physical analog channels

There are four current channels and three voltage channels in this configuration.

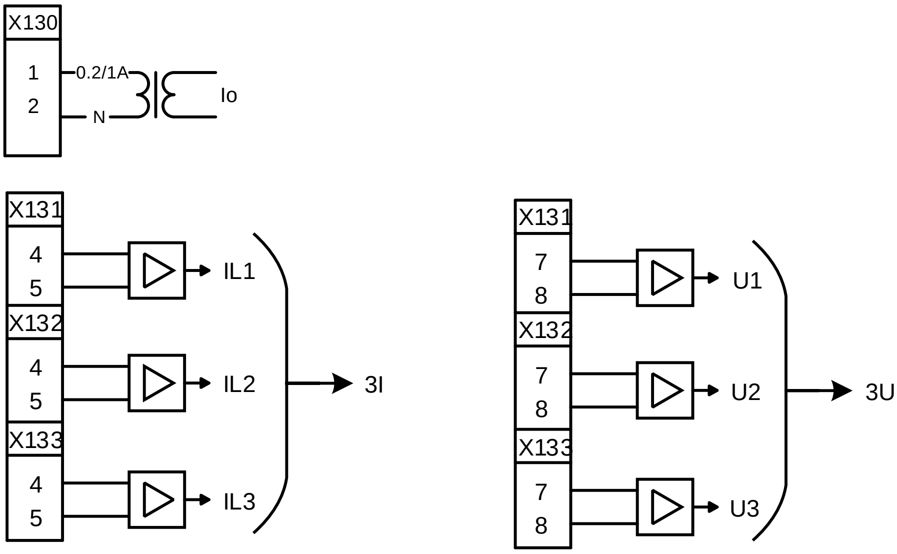


Figure 58: Physical analog channels in default configuration B

The physical analog channels of all functions which require current or voltage inputs in this configuration are listed in *Table 31*. Meaning of the symbols is explained in *Table 30*.

Table 30: Explanations of symbols in the physical analog channel table

Symbol	Description
x	The analog channel is assigned to the function by default.
C	The function can be set to use residual voltage or current calculated based on the three-phase input. Only applicable for functions which need residual voltage or current as input.
D	The analog channel is dedicated to the function. When the corresponding function is taken into use, other functions cannot use this analog channel any more. The other functions can be set to use calculated values instead of physical measured value or select an alternative operation mode not requiring this physical measured channel. However, some functions might not have such operation modes and might become unusable in the configuration. All functions marked to use the same HW channel under the same column should be checked to make sure the functions work.

Table 31: Physical analog channels of functions

IEC61850	3I	3U	Io
Protection			
PHLPTOC1	x		
PHHPTOC1	x		
PHHPTOC2	x		
PHIPTOC1	x		
DPHLPDOC1	x	x	
DPHHPDOC1	x	x	
DPHHPDOC2	x	x	
PHPVOC1	x	x	
PHPVOC2	x	x	
EFLPTOC1	C		x
EFHPTOC1	C		x
EFIPTOC1	C		x
DEFLPDEF1	C	x	x
DEFHPDEF1	C	x	x
ROVPTOV1		x	
ROVPTOV2		x	
ROVPTOV3		x	
PHPTUV1		x	
PHPTUV2		x	
PHPTUV3		x	
PHPTUV4		x	
PHPTOV1		x	
PHPTOV2		x	
PHPTOV3		x	
PSPTUV1		x	
PSPTUV2		x	
NSPTOV1		x	
NSPTOV2		x	
FRPFRQ1		x	
FRPFRQ2		x	
FRPFRQ3		x	
FRPFRQ4		x	
FRPFRQ5		x	
FRPFRQ6		x	
MNSPTOC1	x		
MNSPTOC2	x		
LOFLPTUC1	x		
LOFLPTUC2	x		
JAMPTOC1	x		

Table continues on the next page

IEC61850	3I	3U	Io
STTPMSU1	x		
PREVPTOC1	x		
MPTTR1	x		
CCBRBRF1	x		x
CCBRBRF2	x		x
CCBRBRF3	x		x
ARCSARC1	x		
ARCSARC2	x		
ARCSARC3	x		
CVPSOF1	x	x	
DQPTUV1	x	x	
DQPTUV2	x	x	
DUPPDPR1	x	x	
DUPPDPR2	x	x	
DOPPDPR1	x	x	
DOPPDPR2	x	x	
DOPPDPR3	x	x	
UEXPDIS1	x	x	
UEXPDIS2	x	x	
LVRTPTUV1		x	
LVRTPTUV2		x	
LVRTPTUV3		x	
MREFPTOC1			D
Control			
ESMGAPC1	x		
SECRSYN1	9-2 specific function		
Condition monitoring			
SSCBR1	x		
SSCBR2	x		
SSCBR3	x		
CCSPVC1	x		x
SEQSPVC1	x	x	
Measurement			
CMMXU1	x		
CSMSQI1	x		
RESCMMXU1			x
VMMXU1		x	
VAMMXU2	9-2 specific function		
VSMSQI1		x	
PEMMXU1	x	x	

Table continues on the next page

IEC61850	3I	3U	Io
FMMXU1		x	
Power quality			
CMHAI1	x		
VMHAI1		x	
PHQVVR1	x	x	
VSQVUB1		x	

SECRSYN1 and VAMMXU2 require IEC 61850-9-2 LE voltage to work. For detailed configuration, see the SMV receiver chapter in this manual.

3.6.3 Functional diagrams

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

The analog channels, measurements from CTs and VTs have fixed connections towards the different function blocks inside the relay's default configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

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

The 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 relay.

As there is no dedicated physical channel to measure the residual voltage, for all functions which need the residual voltage as input, it is forced to use the calculated residual voltage.

There are 16 programmable push buttons offered in the front panel of the unit. The relay offers six different setting groups which can be set based on individual needs. Each group can then be activated or deactivated by using a programmable button. In addition to this, the programmable button can also be used, for example, for the manual trigger of disturbance recorder, enabling/disabling the autoreclosing function, circuit breaker control interlocking bypass or master trip lockout reset.

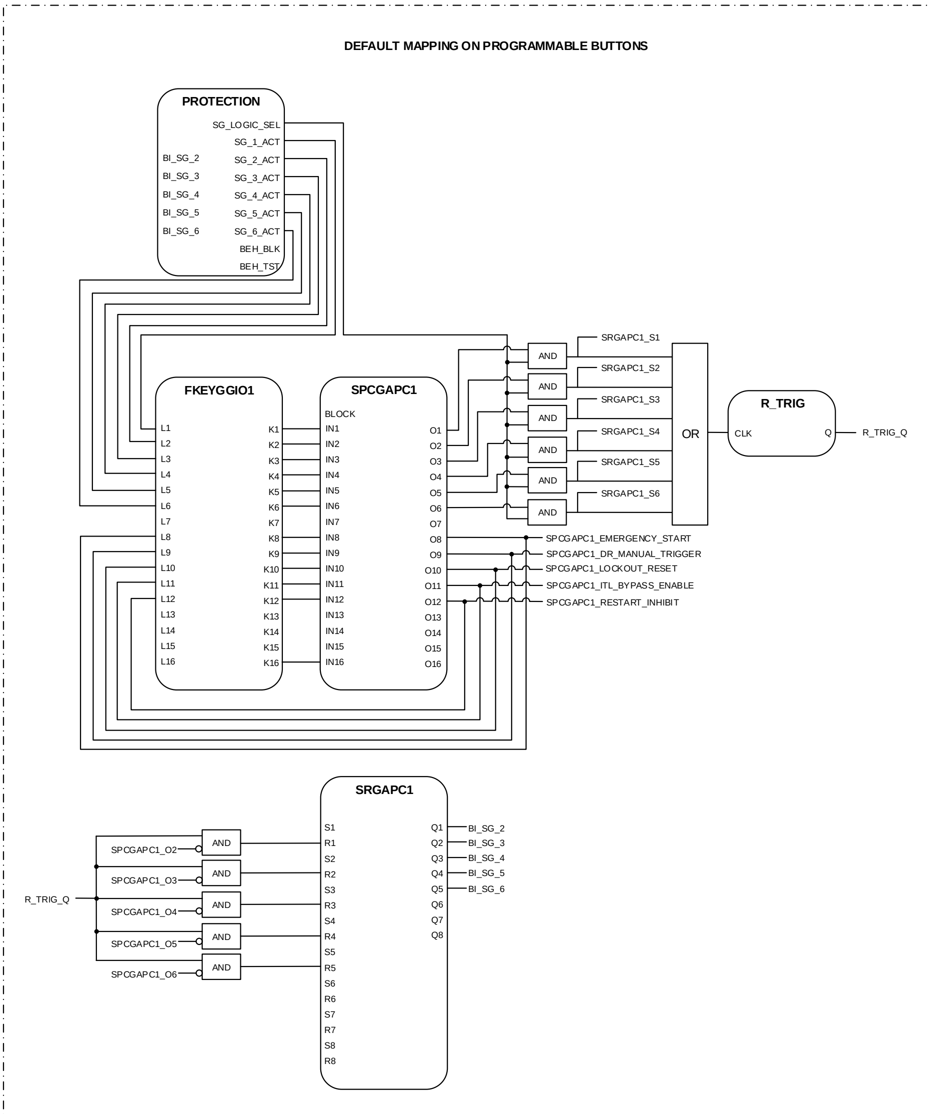


Figure 59: Default mapping on programmable buttons

3.6.3.1 Functional diagrams for protection

The functional diagrams describe the relay’s protection functionality in detail and picture the default connections.

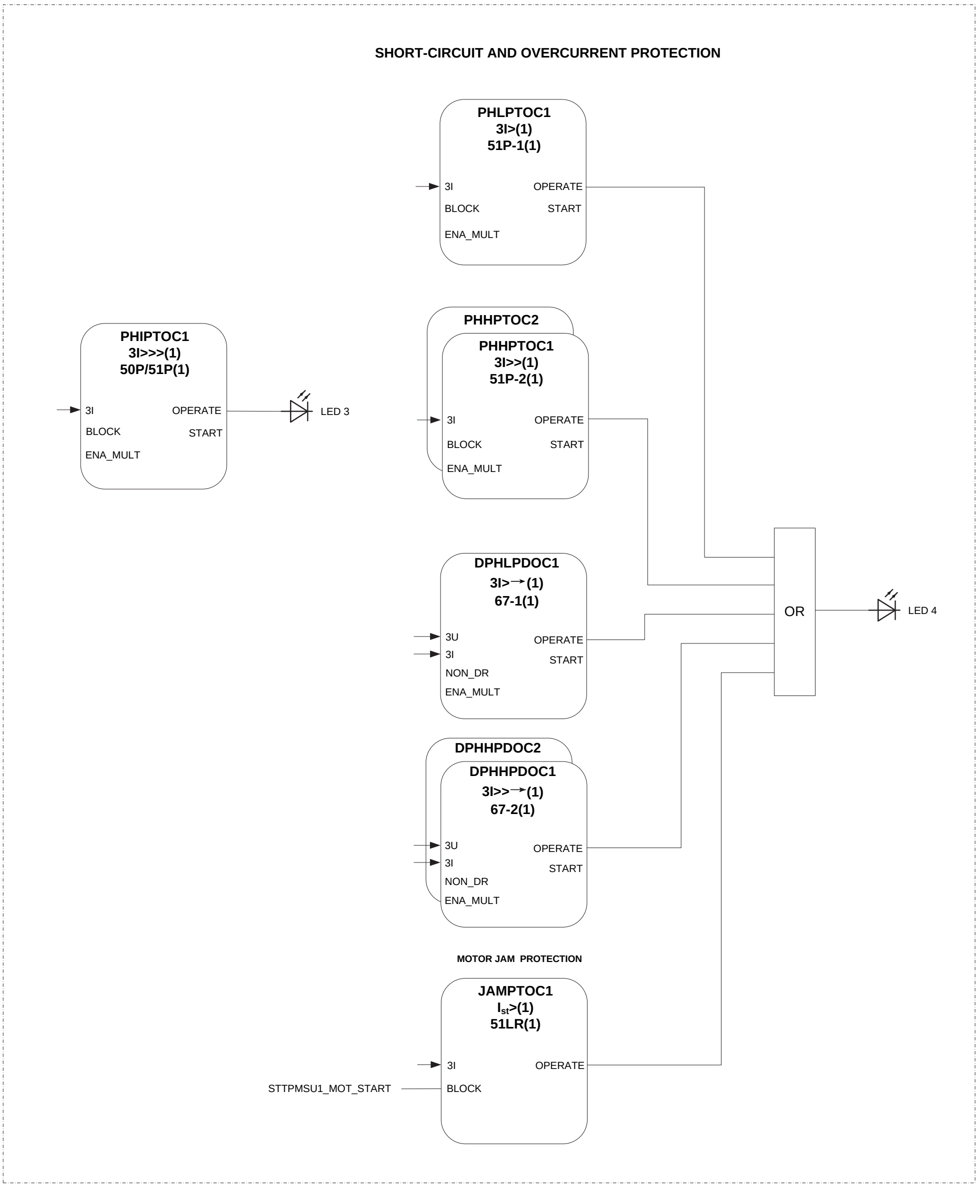


Figure 60: Overcurrent and motor jam protection

Seven overcurrent stages in total are offered for overcurrent and short-circuit protection. Three stages are for directional functionality DPHxPDOC, while the others are only for non-directional overcurrent protection PHxPTOC.

PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation.

The motor load jam protection JAMPTOC1 is used for protecting the motor in stall or mechanical jam situations during the running state. The motor jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

The `OPERATE` outputs are connected to the Master Trip. The `OPERATE` outputs are also connected to the alarm LED 4, except for PHIPTOC1, which is connected to the alarm LED 1. LED 1 is used for short-circuit protection alarm indication, and LED 4 is used for combined protection alarm indication, including overcurrent protection, earth-fault protection, phase unbalance protection, voltage protection, motor jam protection, loss of load protection and frequency protection.

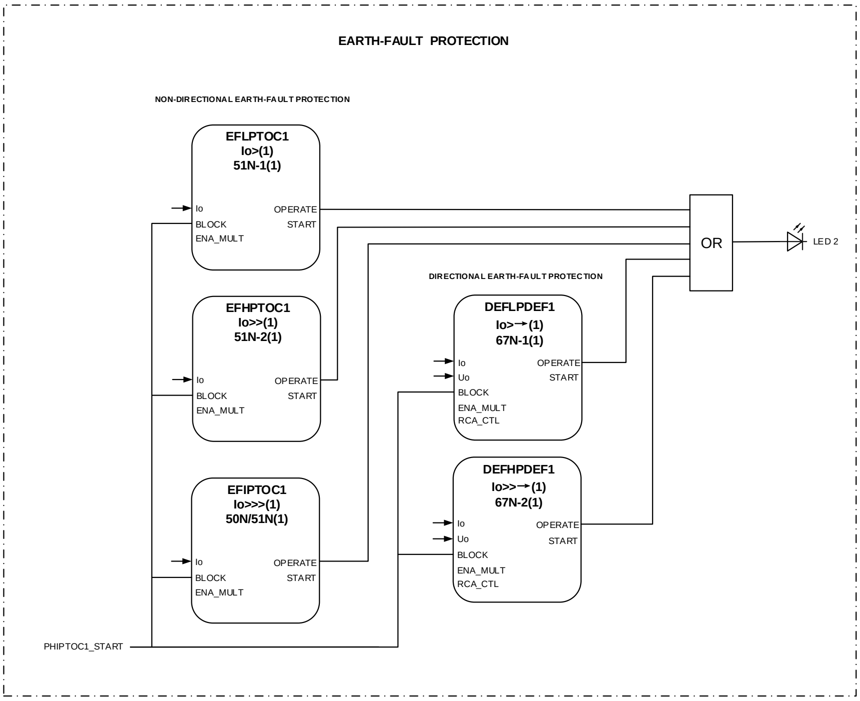


Figure 61: Earth-fault protection

Three stage non-directional earth-fault protection EFxPTOC are offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing. In addition, there are two directional protection stages DEFxPDEF which can also be used as non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor start-up.

The earth-fault protection is blocked when the short-circuit protection PHIPTOC1 is started. The `OPERATE` outputs of the earth-fault protection functions are connected to the Master Trip and alarm LED 2.

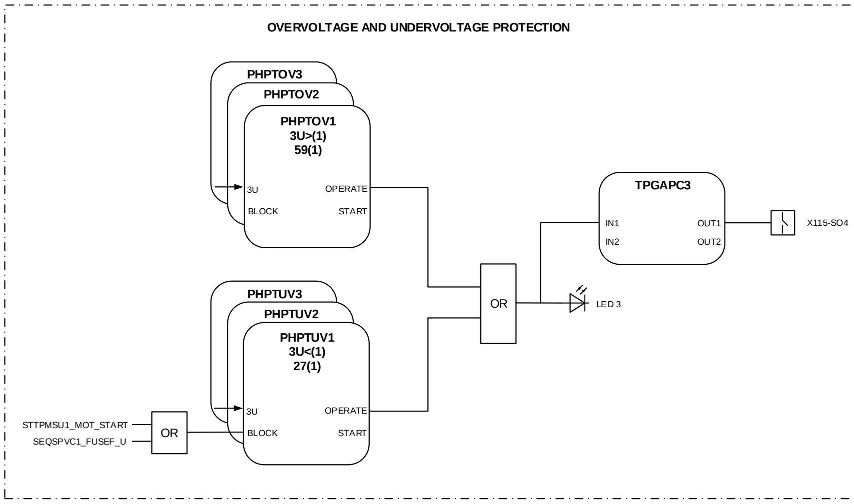


Figure 62: Overvoltage and undervoltage protection

Three instances of overvoltage protection PHPTOV1…3 and undervoltage protection PHPTUV1…3 offer protection against abnormal phase voltage conditions. The three-phase undervoltage protection is blocked during motor start-up to prevent unwanted operation in case there is a short voltage drop. Also if the fuse failure is detected, the undervoltage function is blocked.

The `OPERATE` outputs of voltage functions are connected to the Master Trip and alarm LED 3 and also to output X115-SO4 via generic timer TPGAPC3.

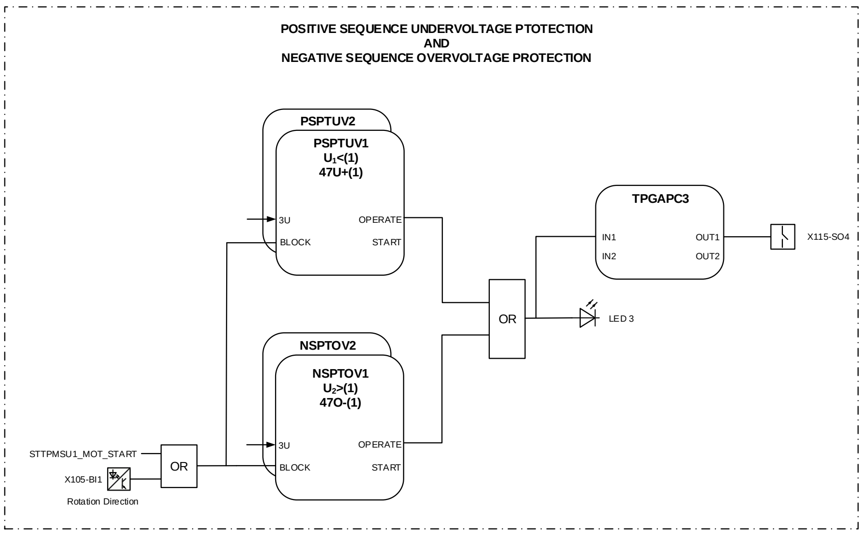


Figure 63: Positive-sequence undervoltage and negative-sequence overvoltage protection

The positive-sequence undervoltage PSPTUV1/2 and negative-sequence overvoltage NSPTOV1/2 protections are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order. The positive-sequence undervoltage and negative-sequence overvoltage functions are blocked during motor start-up to prevent unwanted operation in case there is a short voltage drop. Also the binary input X105-BI1, which indicates the motor rotation direction, is used to block these functions by default.

The OPERATE outputs of voltage-sequence functions are connected to the Master Trip and also to alarm LED 3 and also connected to output X115-SO4 via generic timer TPGAPC3.

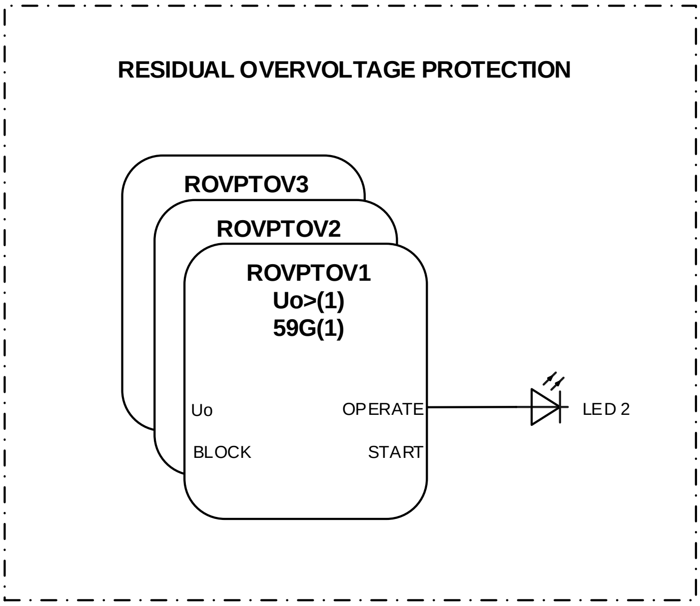


Figure 64: Residual overvoltage protection

The residual overvoltage protection ROVPTOV1...3 provides earth-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The OPERATE outputs are connected to the Master Trip and alarm LED 2.

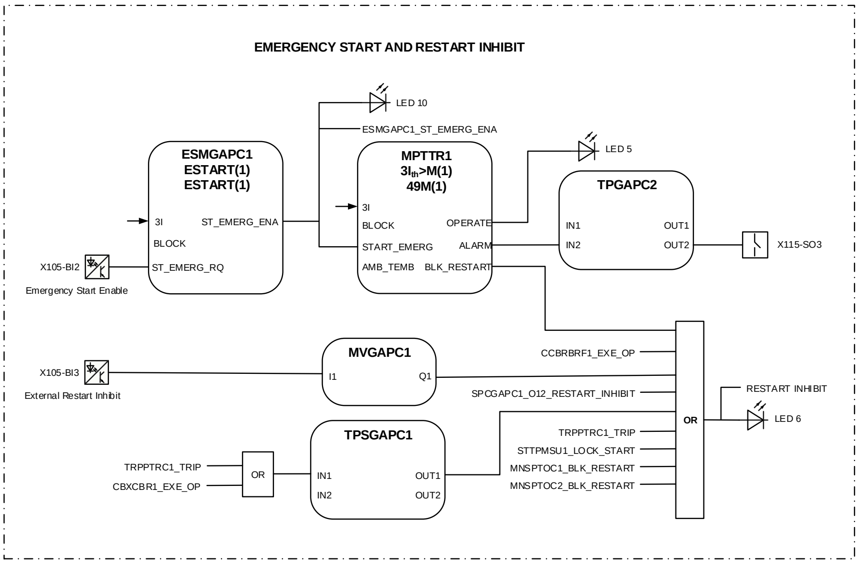


Figure 65: Emergency start and restart inhibit

The emergency start function ESMGAPC1 allows motor start-ups although the calculated thermal level or cumulative start-up time counter is blocking the restart. The emergency start is enabled for ten minutes after the selected binary input X105- BI2 is energized. On the rising edge of the emergency start signal, various events occur.

- The calculated thermal level in MPTTR1 is set slightly below the restart inhibit level to allow at least one motor start-up
- The value of the cumulative start-up time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor start-up
- Alarm LED 10 is activated

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time of ten minutes has expired.

The thermal overload protection function MPTTR1 detects short and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor. The `OPERATE` output of MPTTR1 is connected to alarm LED 5, which is used for thermal overload protection alarm indication. The `ALARM` output of MPTTR1 is connected to output X115-SO3 via generic timer TPGAPC2.

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection where the motor has damping remanence voltage after circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1. The alarm LED 6 is used for restart inhibit alarm indication.

The restart inhibit is also activated when one of the conditions is met.

- An active trip command
- Motor start-up supervision has issued lockout

- Motor unbalance function has issued restart blocking
- An external restart inhibit is activated by one push button through SPCGAPC1_O12 or by a binary input X105-BI3 via MVGAPC1

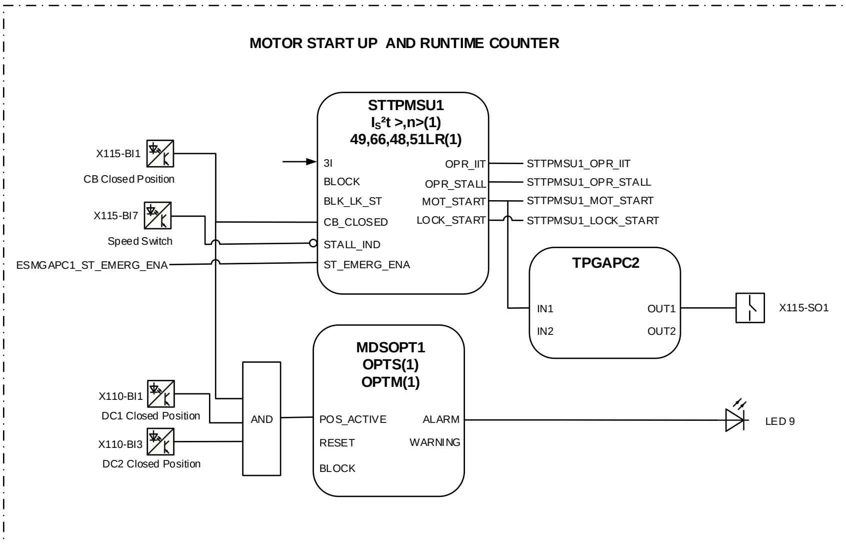


Figure 66: Motor start-up supervision

With the motor start-up supervision function STTPMSU1 the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor.

When the emergency start request is activated by ESMGAPC1 and STTPMSU1 is in lockout state, the lockout LOCK_START is deactivated and emergency starting is available. The `MOT_START` output of STTPMSU1 is connected to output X115-SO1 via generic timer TPGAPC2.

The motor running time counter MDSOPT1 provides history data since last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 9. LED 9 is used for general supervision of trip circuit, current measurement circuit, voltage measurement circuit and motor operation time.

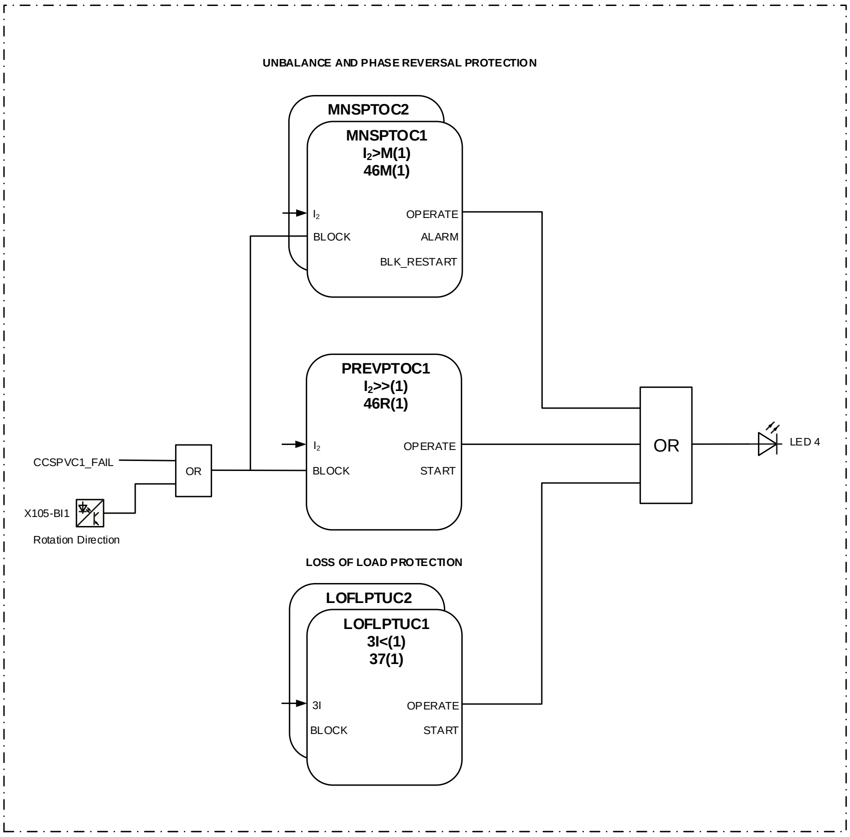


Figure 67: Phase unbalance and loss of load protection

Two negative-sequence overcurrent stages MNSPTOC1/2 are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The phase reversal protection PREVPTOC1 is based on the calculated negative phase-sequence current. It detects too high NPS current values during motor start up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

The negative-sequence protection and phase reversal protection are blocked if the current circuit supervision detects failure in the current measuring circuit. The binary input X105-BI1, which indicates the motor rotation direction, is also used to block these functions by default.

Two stages LOFLPTUC1/2 are offered for loss of load situation protection. The loss of load situation can happen, for example, if there is damaged pump or a broken conveyor.

The `OPERATE` outputs of above protections are connected to the Master Trip and alarm LED 4.

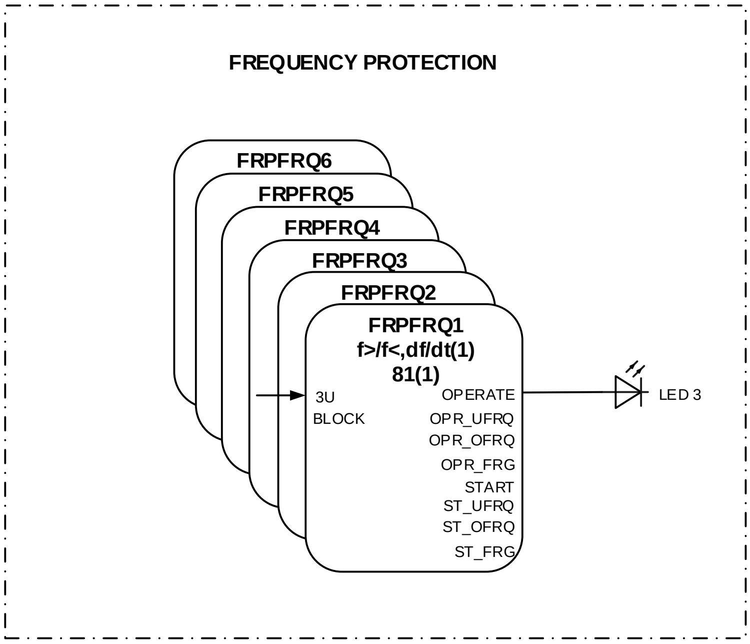


Figure 68: Frequency protection

Six underfrequency or overfrequency protection FRPFRQ1…6 stages are offered to prevent damage to network components under unwanted frequency conditions. The function 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.

The `OPERATE` outputs are connected to the Master Trip and alarm LED 3.

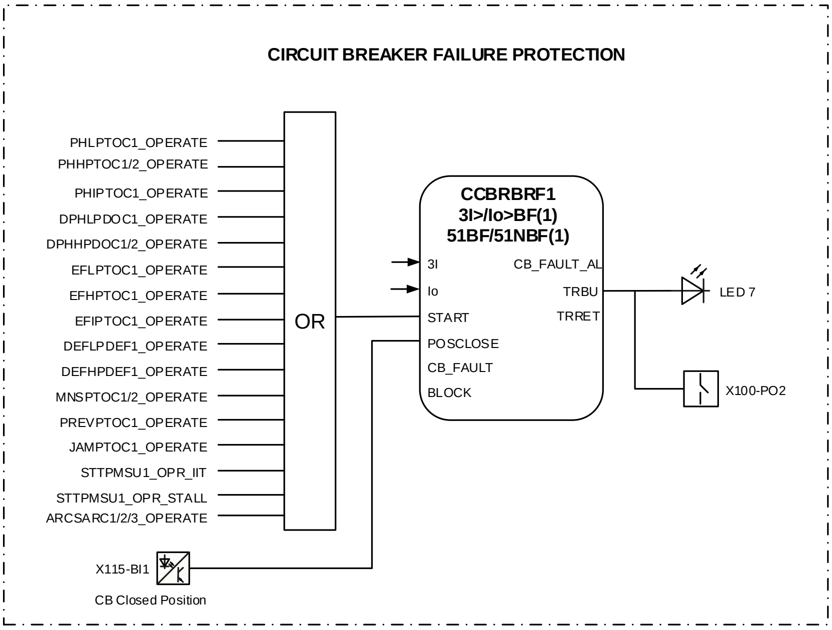


Figure 69: Circuit breaker failure protection

The breaker failure protection CCBRBRF1 is initiated via the start input by a number of different protection stages 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 breaker failure protection has two operating outputs: `TRRET` and `TRBU`. The `TRRET` output is used for retripping its own breaker through the Master Trip 1. The `TRBU` output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the `TRBU` output signal is connected to the output X100-PO2 and alarm LED 7. LED 7 is used for back-up TRBU operate indication.

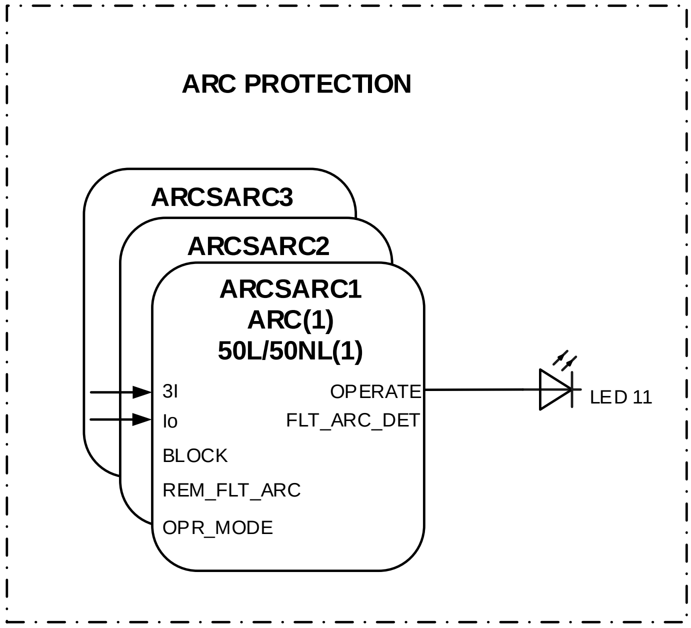


Figure 70: Arc protection

Arc protection ARCSARC1...3 is included as optional function.

The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, with or without phase and residual current check. The `OPERATE` outputs from the arc protection function blocks are connected to the Master Trip and alarm LED 11.

3.6.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

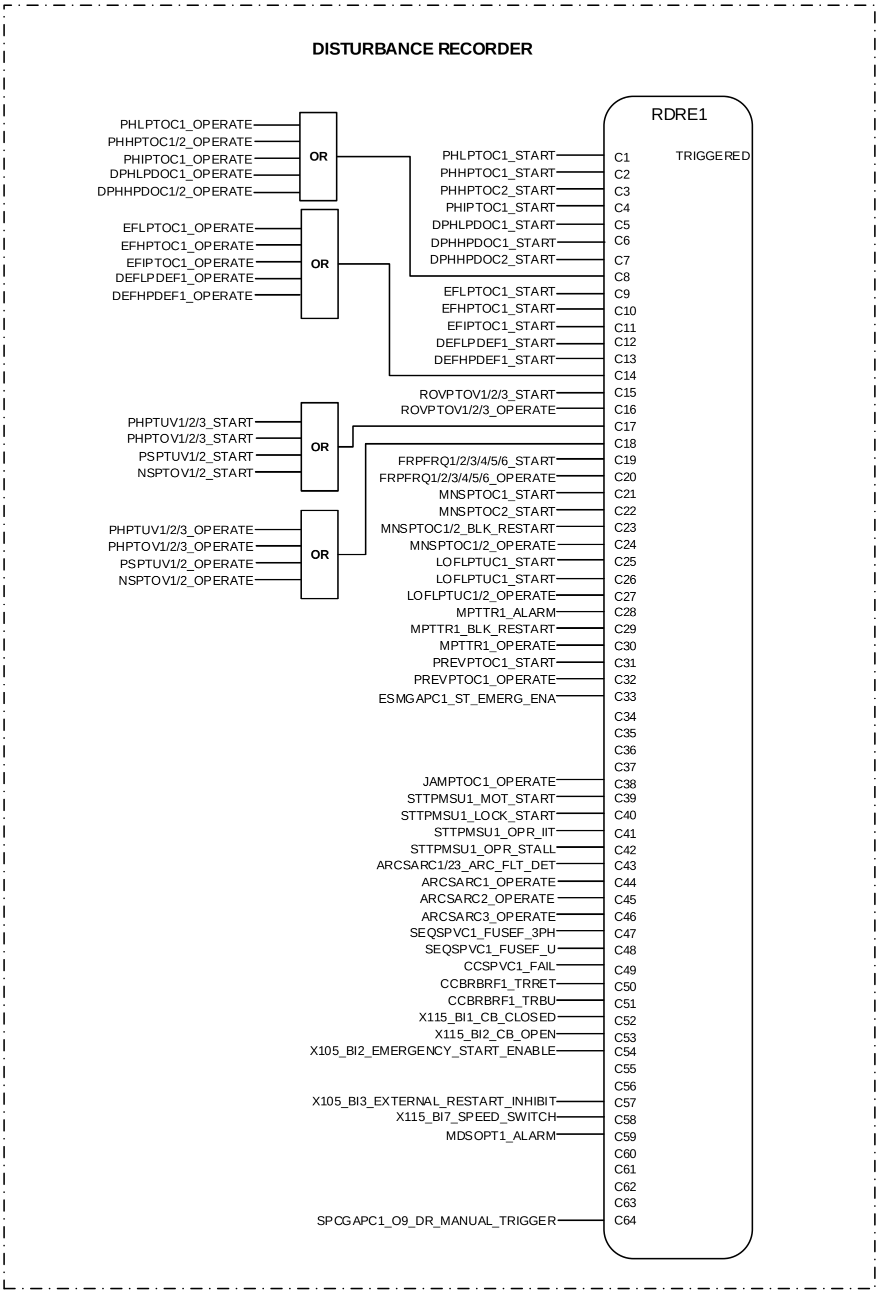


Figure 71: Disturbance recorder

All `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, some selected signals from different functions and five binary inputs totally from X105 and X115 are also connected.

The manual trigger signal from push button is used to trigger disturbance recorder manually as needed.

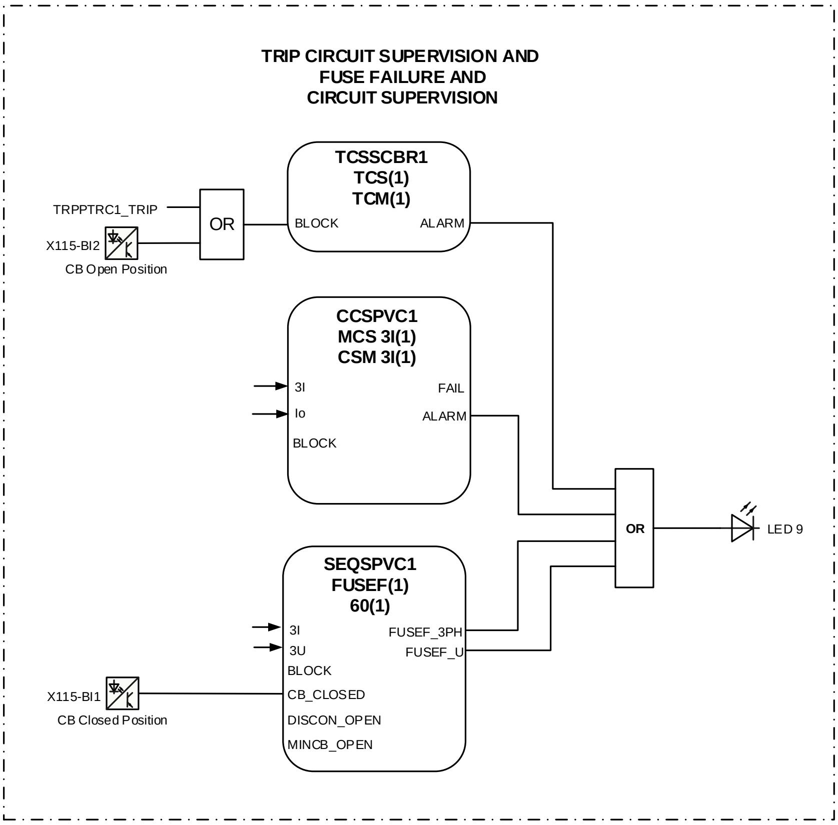


Figure 72: Circuit supervision

One trip circuit supervision function is used by default, TCSSCBR1 for X100-PO3. Both functions are blocked by the Master Trip TRPPTRC1 and the circuit breaker open signal. The `ALARM` output indication is connected to the LED 9.

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

Failures in current measuring circuits are detected by CCSPVC1. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is also connected to the alarm LED 9.

The fuse failure supervision SEQSPVC1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is also connected to the alarm LED 9.

3.6.3.3 Functional diagrams for control and interlocking

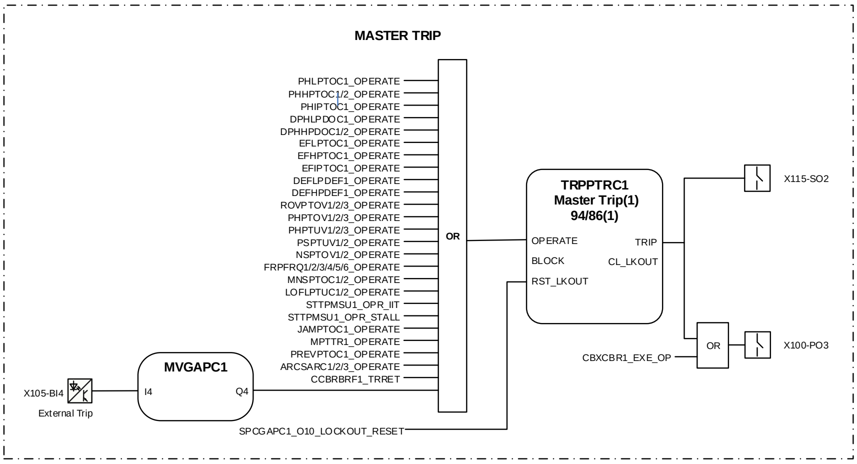


Figure 73: Master trip

The operate signals from the protections, and an external trip X105-BI4 via MVGAPC1 are connected to the output X115-SO2 and the trip output contact X100-PO3 via the corresponding Master Trip TRPPTRC1. Open control commands to the circuit breaker from the local or remote CBXCBR1_EXE_OP are connected directly to the output X100-PO3.

TRPPTRC1 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

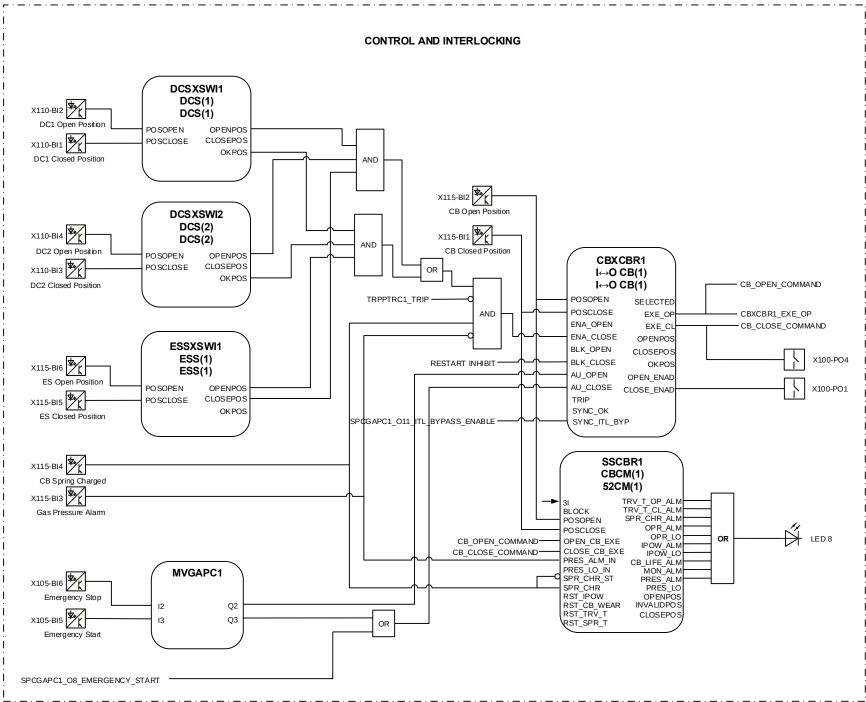


Figure 74: Circuit breaker control and interlocking

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...4 and ESSXSWI1...3 are status only type, and DCXSWI1...4 and ESXSWI1...3 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 1 and 2 of the card X130 are used for busbar disconnector 1 DCSXSWI1 position indication. The binary inputs 3 and 4 of the card X130 are used for busbar disconnector 2 DCSXSWI2 position indication.

Table 32: Disconnector 1 position indicated by binary inputs

Primary device position	Input to be energized	
	X110-BI1	X110-BI2
Busbar disconnector 1 closed	•	
Busbar disconnector 1 open		•

Table 33: Disconnector 2 position indicated by binary inputs

Primary device position	Input to be energized	
	X110-BI3	X110-BI4
Busbar disconnector 2 closed	•	
Busbar disconnector 2 closed		•

The binary inputs 7 and 8 of card X110 are designed for the position indication of the earthing switch.

Table 34: Earthing switch position indicated by binary inputs

Primary device position	Input to be energized	
	X115-BI5	X115-BI6
Earthing switch closed	•	
Earthing switch open		•

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 position statuses of related primary equipment (disconnector and earthing switch), the condition of the circuit breaker (CB gas pressure alarm, CB spring charged), and the Master Trip logics. The OKPOS output from the DCSXSWI block defines if the disconnector is definitely either open or close. This, together with non-active trip signal activates the ENA_CLOSE signal to the circuit breaker control function block. The open operation is always enabled.

The circuit breaker closing is blocked when the BKL_CLOSE input is activated, which is connected to motor restart inhibit logic. When all conditions of the circuit breaker closing are fulfilled, the CLOSE_ENAD output of the CBXCBR1 is activated and PO1 output X100-PO1 is closed.

Emergency stop signal to AU_OPEN input of CBXCBR1 via MVGAPC1 is used to open the breaker by one push button through SPCGAPC1_O8 or by a binary input X105-BI5. Emergency start signal to AU_CLOSE input of CBXCBR1 via MVGAPC1 is used to close the breaker by one push button through SPCGAPC1_O16 or by a binary input X105-BI6.

One push button can be used through SPCGAPC1_O11, which is connected to SYNC_ITL_BYP input of CBXCBR1, to ignore the status of ENA_CLOSE input. However, the BLK_CLOSE input signals is not bypassed with the interlocking bypass functionality as they always have the higher priority.

If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR1 with PCM600, the function assumes that the breaker close commands are allowed continuously.

The circuit breaker condition monitoring function SSCBR1 supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

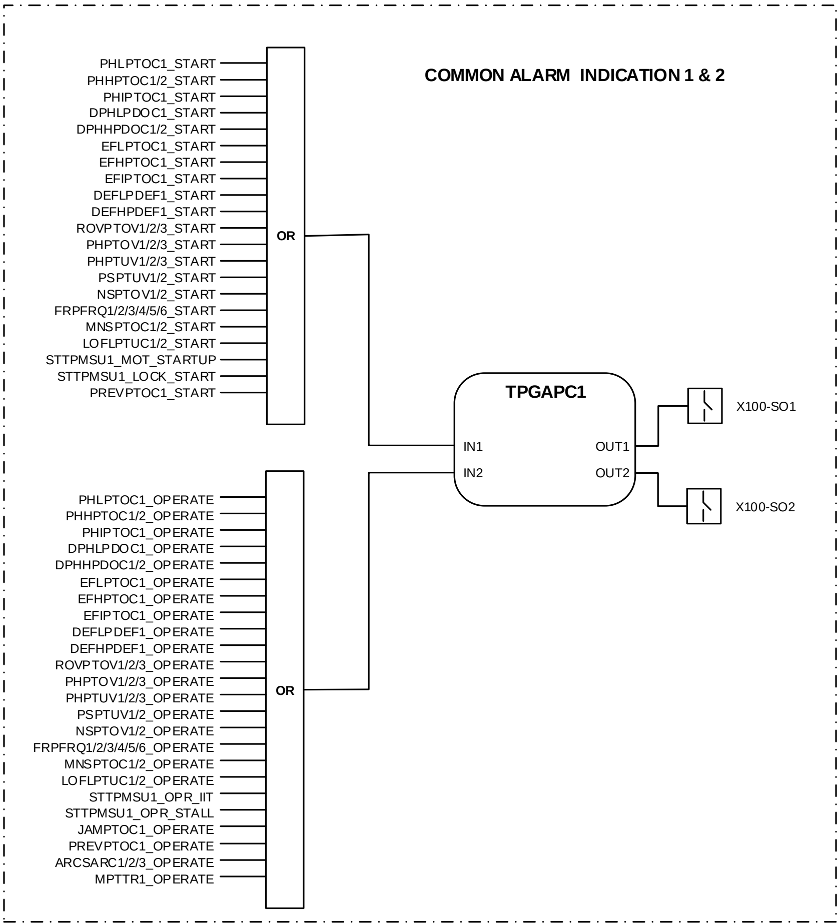


Figure 75: Common alarm indication

The signal outputs from the relay are connected to give dedicated information.

- Start of any protection function X100-SO1
- Operate of any protection function X100-SO2

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers TPGAPC1…4 available in the relay. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.6.3.4 Functional diagrams for power quality measurements

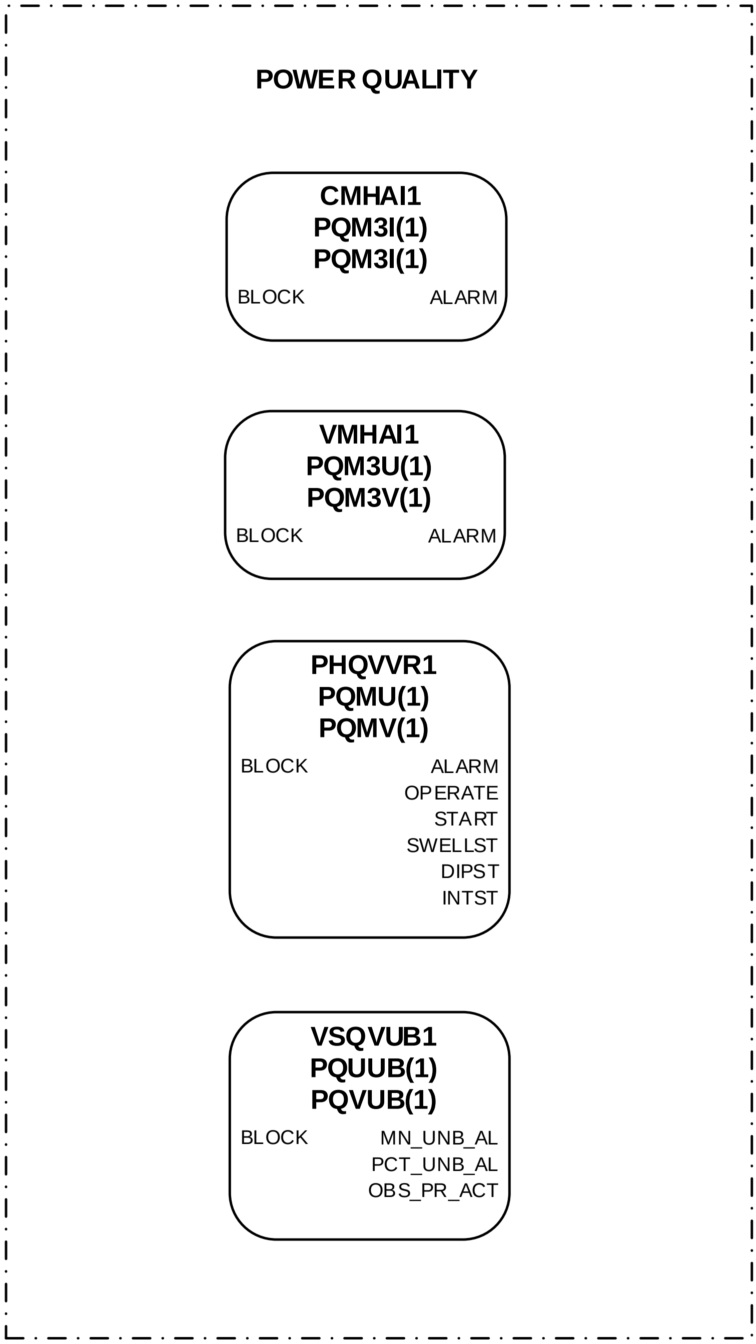


Figure 76: Power quality measurement function

The power quality function CMHAI1 is used to measure the harmonic contents of the phase current.

The power quality function VMHAI1 is used to measure the harmonic contents of the phase voltages.

The power quality function PHQVVR1 is used to measure the voltage variation, that is, sags and swells.

The voltage unbalance power quality function VSQVUB1 monitors the voltage unbalance conditions in power networks. It is used to monitor the commitment of power supply utility of providing a balanced voltage supply on a continuous basis.

VSQVUB provides statistics which can be used to verify the compliance of the power quality.

The above functions are included in default configuration for demonstration purposes only, but not configured by default. The functions can be configured as needed.

3.6.3.5 Functional diagrams for measurement functions

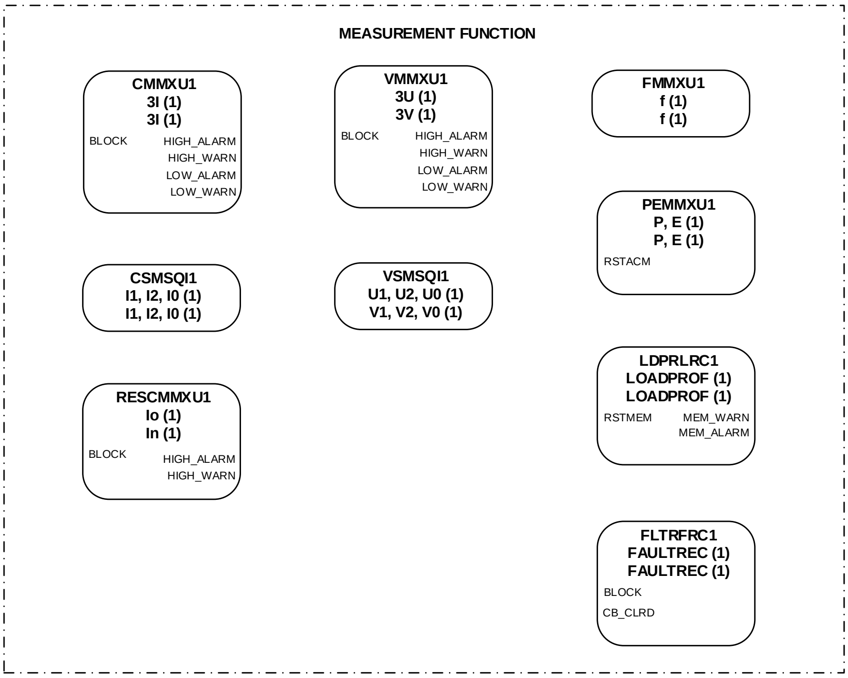


Figure 77: Measurement function

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

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

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

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding bay. FLTRFRC1 is used to record the monitor data during the fault condition. The records enable the analysis of recent power system events.

3.6.3.6 Functional diagrams for extra functions

Additional functions are available in the relay default content but they are not preengineered to be part of the default configuration. The functions can be engineered into use.

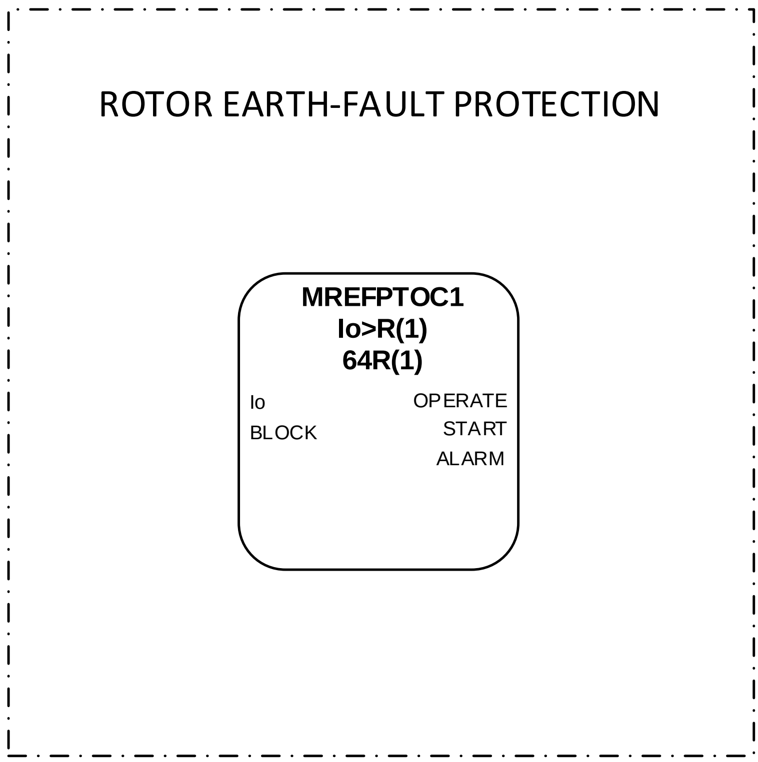


Figure 78: Rotor earth-fault protection

One rotor earth-fault protection function MREFPTOC1 is offered. MREFPTOC is used to detect an earth fault in the rotor circuit of synchronous machines. For detailed information, see the technical manual.

3.6.3.7 Functional diagrams for optional functions

Optional functions are available in the relay default content when a corresponding option is selected while ordering the relay. However, the functions are not pre-engineered to be part of the default configuration. They can be engineered into use.

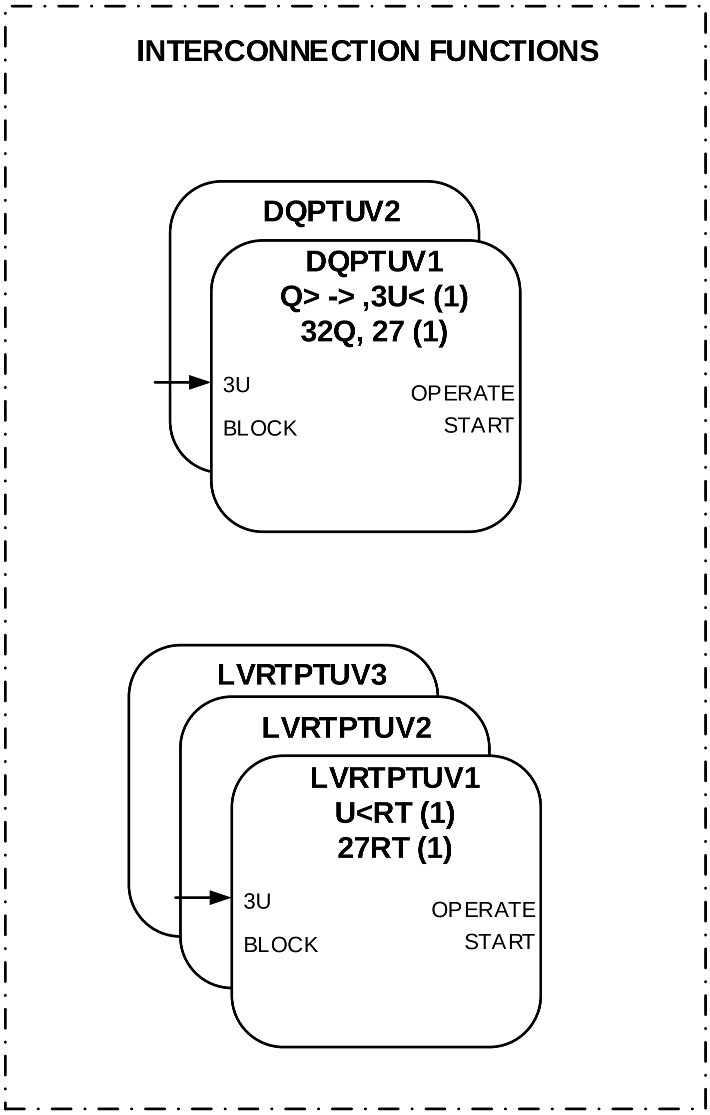


Figure 79: Interconnection function

Interconnection protection functions include directional reactive power undervoltage protection DQPTUV1 and three instances of low-voltage ride-through protection LVRTPTUV1…3. These functions can be used in the common point of coupling of utility grid and distributed energy resource, 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 can be used to block LVRTPTUV1…3 and DQPTUV1 protection. These interconnection functions can be engineered to work together with basic functions in relay default configuration to cover different needs placed for relay operation in different grid codes.

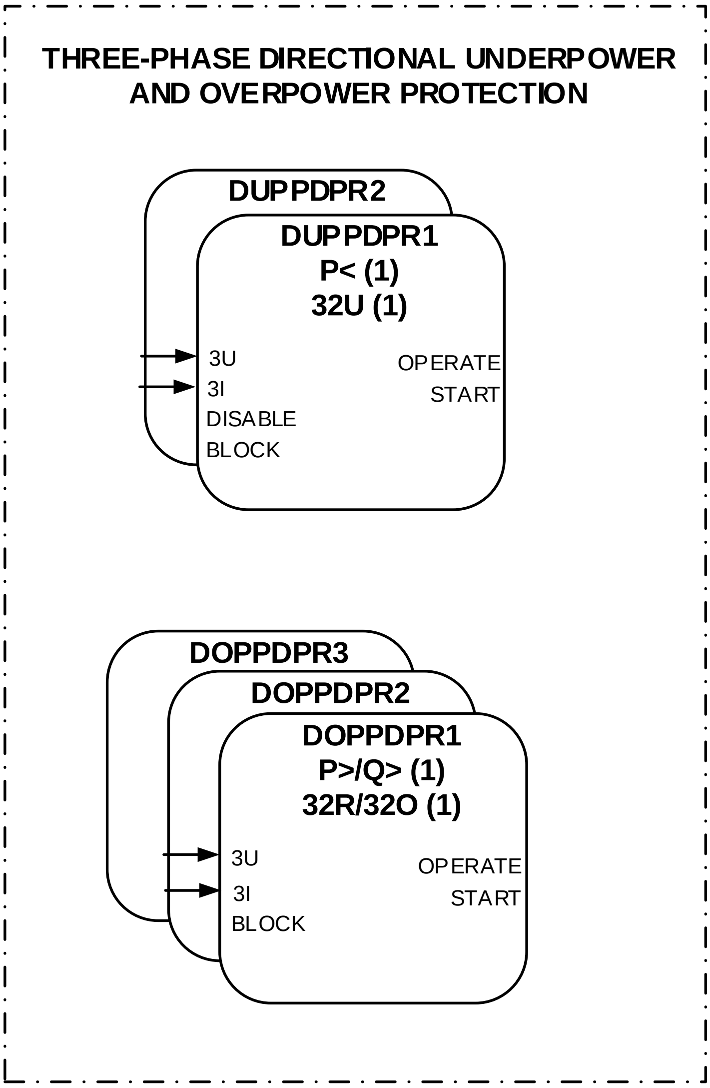


Figure 80: Three-phase directional underpower and overpower protection function

Two instances of directional underpower protection DUPPDPR1/2 are provided. Normally these are used in supervision of underpower or underloading situations.

Three instances of directional overpower protection DOPPDPR1/2/3 are provided to supervision of overpower or overloading situations with power flow direction information.

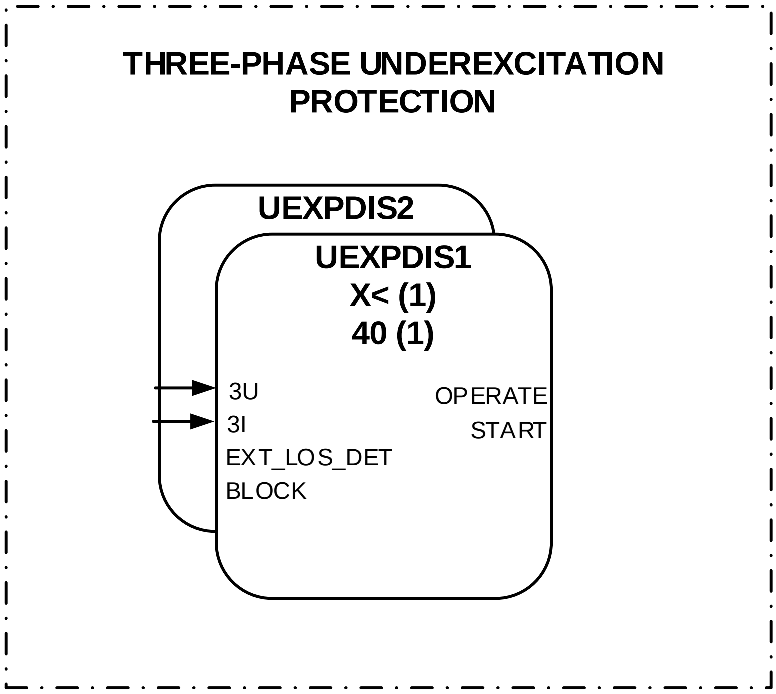


Figure 81: Three-phase underexcitation protection

On losing excitation, motor may overspeed and operate as an induction motor 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 motor circuit breaker is in open position.

3.6.4 Application configuration of SMV receiver

This chapter describes how to configure configuration B as an SMV receiver. For overall information about SMV engineering, see the IEC 61850 engineering guide.

This configuration includes two TVTR function blocks. If no SMV receiver is defined, ULTVTR1 receives three phase voltage inputs from the sensor and provides the value to different functions. ULTVTR2 is dedicated for IEC 61850-9-2 LE receiving only. SECRSYN1 and VAMMXU2 cannot be used if a IEC 61850-9-2 LE sample value is not configured to be received by ULTVTR2.

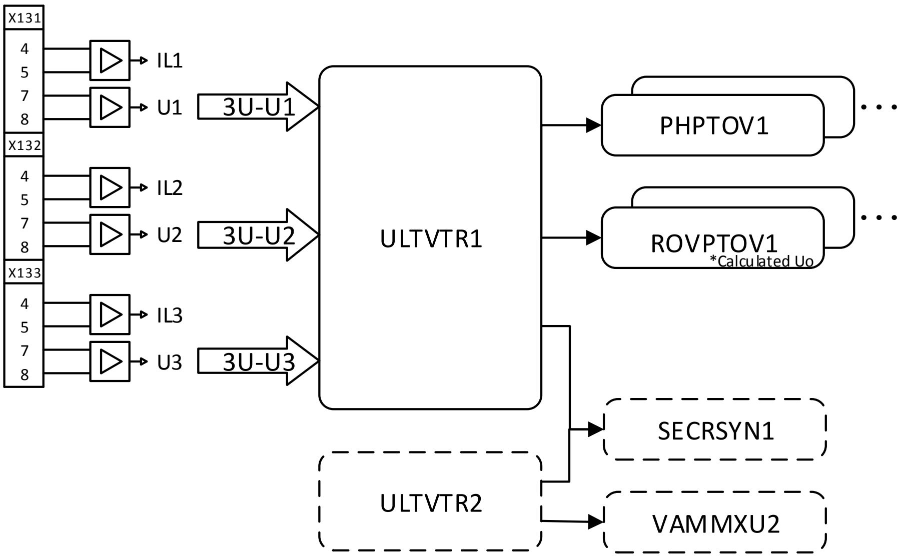


Figure 82: No SMV receiver configured

The SMV receiver application configuration is done with the Application Configuration tool in PCM600. Which physical voltage input channel is replaced by sample value voltage can be defined by connecting the SMVRCV output to different TVTR function inputs.

The IEC 61850-9-2 LE stream always contains UL1, UL2, UL3 and Uo. Thus, when the IEDs are used as senders, and the three phase-tophase voltages and the residual voltage are connected to the hardware channels, the three phase-to-earth voltages are calculated from the input and sent through IEC 61850-9-2 LE.

The IEC 61850-9-2 LE configuration has to be done only according to the examples in this section, otherwise an engineering failure might follow.

3.6.4.1 Connection of SMVRCV to ULTVTR1

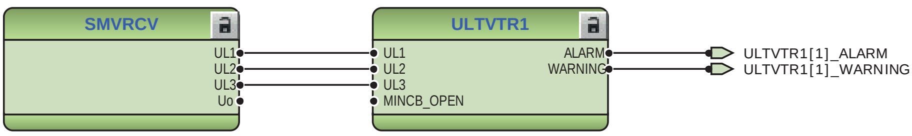


Figure 83: Connection of SMVRCV to ULTVTR1 in Application Configuration

When SMVRCV is connected to ULTVTR1 in the Application Configuration tool, ULTVTR1 is disconnected from the physical channels U1, U2 and U3 and uses three phase voltages from the received IEC 61850-9-2 LE sample value. All functions which have `3U` input begin working with the IEC 61850-9-2 LE sample value.

All three signals UL1, UL2 and UL3 must be connected between SMVRCV and ULTVTR1 in the Application Configuration tool.

ULTVTR2, SECRSYN1 and VAMMUX2 cannot be used in this configuration.

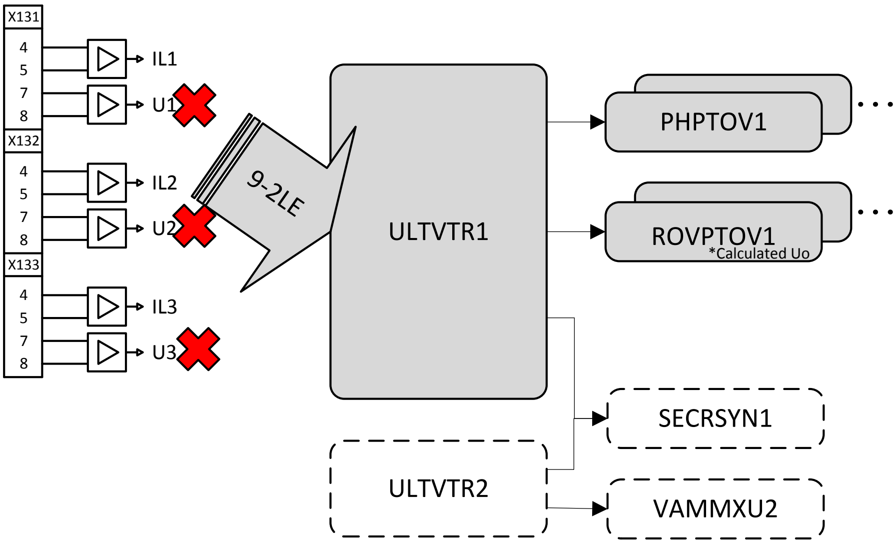


Figure 84: ULTVTR1 uses three phase voltages from received IEC 61850-9-2 LE sample value

3.6.4.2 Connection of SMVRCV to ULTVTR2

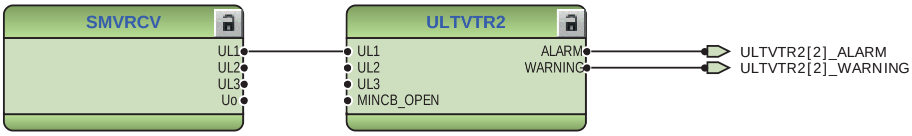


Figure 85: Connection of SMVRCV to ULTVTR2 in Application Configuration

When SMVRCV is connected to ULTVTR2 in the Application Configuration tool, ULTVTR2 receives UL1 voltage from the received IEC 61850-9-2 LE sample value. In this configuration, SECRSYN1 and VAMMUX2 begin working with the IEC 61850-9-2 LE sample value.

Only UL1 must be connected between SMVRCV and ULTVTR2 in the Application Configuration tool.

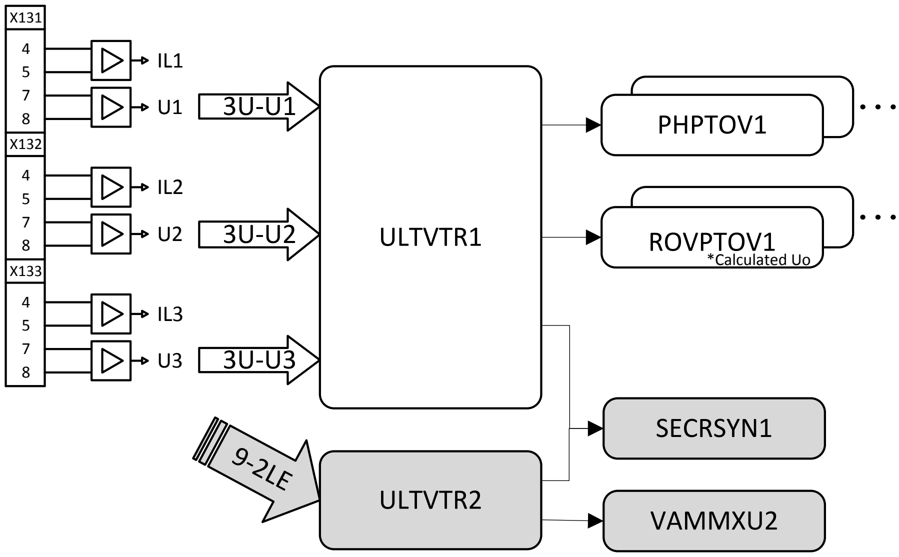


Figure 86: ULTVTR2 uses UL1 voltage from received IEC 61850-9-2 LE sample value

4 IED physical connections

4.1 Inputs

4.1.1 Energizing inputs

4.1.1.1 Phase currents

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

Table 35: Phase current inputs included in configuration A

Terminal	Description
X120:1-2	IL1_N
X120:3-4	IL2_N
X120:5-6	IL3_N
X120:7-8	IL1
X120:9-10	IL2
X120:11-12	IL3

4.1.1.2 Residual current

Table 36: Residual current input included in configuration A

Terminal	Description
X120:13-14	Io

Table 37: Residual current input included in configuration B

Terminal	Description
X130:1-2	Io

4.1.1.3 Phase voltages

Table 38: Phase voltage inputs included in configuration A

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

Table 39: Reference voltage input for SECRSYN1 included in configuration A

Terminal	Description
X130:9-10	U_SYN

4.1.1.4 Residual voltage

Table 40: Additional residual voltage input included in configurations A

Terminal	Description
X130:17-18	Uo

4.1.1.5 Sensor inputs

Table 41: Combi sensor inputs included in configuration B with SIM0002

Terminal	Description
X131:4-5 X131:7-8	IL1 U1
X132:4-5 X132:7-8	IL2 U2
X133:4-5 X133:7-8	IL3 U3

Table 42: Combi sensor inputs included in configuration B with SIM0005

Terminal	Description
X131 L1/A:1-2 X131 L1/A:7-8	IL1 U1
X132 L2/B:1-2 X132 L2/B:7-8	IL2 U2
X133 L3/C:1-2 X133 L3/C:7-8	IL3 U3

4.1.2 RTD/mA inputs

RTD/mA inputs are alternatively included in configuration A.

Table 43: RTD/mA inputs

Terminal	Description
X110:5-6	mA1 (AI1), + mA1 (AI1), -
X110:7-8	mA2 (AI2), + mA2 (AI2), -
X110:9-10	RTD1 (AI3), + RTD1 (AI3), -
X110:11-12	RTD2 (AI4), + RTD2 (AI4), -
X110:13-14	RTD3 (AI5), + RTD3 (AI5), -
X110:15	Common [1]
X110:16	Common [2]
X110:17-18	RTD4 (AI6), + RTD4 (AI6), -
X110:19-20	RTD5 (AI7), + RTD5 (AI7), -
X110:21-22	RTD6 (AI8), + RTD6 (AI8), -

RTD/mA inputs of slot X105 are optional for configurations A and B.

Table 44: RTD/mA inputs

Terminal	Description
X105:5-6	mA1 (AI1), + mA1 (AI1), -
X105:7-8	mA2 (AI2), + mA2 (AI2), -
X105:9-10	RTD1 (AI3), + RTD1 (AI3), -
X105:11-12	RTD2 (AI4), + RTD2 (AI4), -
X105:13-14	RTD3 (AI5), + RTD3 (AI5), -
X105:15	Common [3]
X105:16	Common [4]

Table continues on the next page

[1] Common ground for RTD channels 1-3.
[2] Common ground for RTD channels 4-6
[3] Common ground for RTD channels 1-3

Terminal	Description
X105:17-18	RTD4 (AI6), + RTD4 (AI6), -
X105:19-20	RTD5 (AI7), + RTD5 (AI7), -
X105:21-22	RTD6 (AI8), + RTD6 (AI8), -

4.1.3 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 45: Auxiliary voltage supply

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

4.1.4 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 alternatively included in configuration A, and mandatorily included in configuration B.

Table 46: Binary input terminals X110:1-13

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

Table continues on the next page

[4] Common ground for RTD channels 4-6

Terminal	Description
X110:12 X110:13	BI8, - BI8, +

Binary inputs of slot X115 are available with configurations A and B.

Table 47: Binary input terminals X115:1-13

Terminal	Description
X115:1 X115:2	BI1,+ BI1,-
X115:3 X115:4	BI2,+ BI2,-
X115:5 X115:6	BI3,+ BI3,-
X115:6 X115:7	BI4,- BI4,+
X115:8 X115:9	BI5,+ BI5,-
X115:9 X115:10	BI6,- BI6,+
X115:11 X115:12	BI7,+ BI7,-
X115:12 X115:13	BI8,- BI8,+

Binary inputs of slot X130 are available with configuration A.

Table 48: Binary input terminals X130:1-8

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

Binary inputs of slot X105 are optional for configurations A and B. One option is to use BIO0005 and the other one is to use BIO0007.

Table 49: Binary input terminals X105:1-13 (with optional BIO0005)

Terminal	Description
X105:1 X105:2	BI1,+ BI1,-
X105:3 X105:4	BI2,+ BI2,-
X105:5 X105:6	BI3,+ BI3,-
X105:6 X105:7	BI4,- BI4,+
X105:8 X105:9	BI5,+ BI5,-
X105:9 X105:10	BI6,- BI6,+
X105:11 X105:12	BI7,+ BI7,-
X105:12 X105:13	BI8,- BI8,+

Table 50: Binary input terminals X105:1-10 (with optional BIO0007)

Terminal	Description
X105:1 X105:5	BI1,+ BI1,-
X105:2 X105:5	BI2,+ BI2,-
X105:3 X105:5	BI3,+ BI3,-
X105:4 X105:5	BI4,- BI4,+
X105:6 X105:10	BI5,+ BI5,-
X105:7 X105:10	BI6,- BI6,+
X105:8 X105:10	BI7,+ BI7,-
X105:9 X105:10	BI8,- BI8,+

4.1.5 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 51: Light sensor input connectors

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

4.2 Outputs

4.2.1 Outputs for tripping and controlling

Output contacts PO1, PO2, PO3 and PO4 in slot X100 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 52: 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

4.2.2 Outputs for signalling

All other outputs can be used for signaling 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 signaling outputs.

Table 53: 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 alternatively included in configuration A, and mandatorily included in configuration B.

Table 54: Output contacts X110:14-24

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

Output contacts of slot X115 are available with configurations A and B.

Table 55: Output contacts X115:14-24

Terminal	Description
X115:14	SO1,common
X115:15	SO1,NO
X115:16	SO1,NC
X115:17	SO2,common
X115:18	SO2,common
X115:19	SO2,common
X115:20	SO3,common
X115:21	SO3,NO
X115:22	SO3,NC
X115:23	SO4,common
X115:24	SO4,NO

Output contacts of X105 are optional for configurations A and B. One option is to use BIO0005 and the other one is to use BIO0007.

Table 56: Output contacts X105:14-24 (with optional BIO0005)

Terminal	Description
X105:14	SO1,common
X105:15	SO1,NO
X105:16	SO1,NC
X105:17	SO2,common
X105:18	SO2,NO
X105:19	SO2,NC
X105:20	SO3,common
X105:21	SO3,NO
X105:22	SO3,NC
X105:23	SO4,common
X105:24	SO4,NO

Table 57: High-speed output contacts X105:15-24 (with optional BIO0007)

Terminal	Description
X105:15	HSO1,NO
X105:16	HSO1,NO
X105:19	HSO2,NO
X105:20	HSO2,NO
X105:23	HSO3,NO
X105:24	HSO3,NO

4.2.3 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 58: IRF contact

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

5 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
620 series	Series of numerical protection and control relays for high-end protection and supervision applications of utility substations, and industrial switch-gear and equipment
AC	Alternating current
ANSI	American National Standards Institute
AR	Autoreclosing
ASCII	American Standard Code for Information Interchange
BI	Binary input
BI/O	Binary input/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
IED	Intelligent electronic device
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
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
NPS	Negative phase sequence
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
REM620	Motor protection and control relay
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.
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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ABB Distribution Solutions
Digital Substation Products
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

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