RELION® 620 SERIES

Feeder Protection and Control REF620

Application Manual

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Product version: 2.0 FP1

Warranty

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

www.abb.com/relion

Disclaimer

The data, examples and diagrams in this manual are included solely for the concept or product description and are not to be deemed as a statement of guaranteed properties. All persons responsible for applying the equipment addressed in this manual must satisfy themselves that each intended application is suitable and acceptable, including that any applicable safety or other operational requirements are complied with. In particular, any risks in applications where a system failure and/or product failure would create a risk for harm to property or persons (including but not limited to personal injuries or death) shall be the sole responsibility of the person or entity applying the equipment, and those so responsible are hereby requested to ensure that all measures are taken to exclude or mitigate such risks.

This product has been designed to be connected and communicate data and information via a network interface which should be connected to a secure network. It is the sole responsibility of the person or entity responsible for network administration to ensure a secure connection to the network and to take the necessary measures (such as, but not limited to, installation of firewalls, application of authentication measures, encryption of data, installation of anti virus programs, etc.) to protect the product and the network, its system and interface included, against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB is not liable for any such damages and/or losses.

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 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

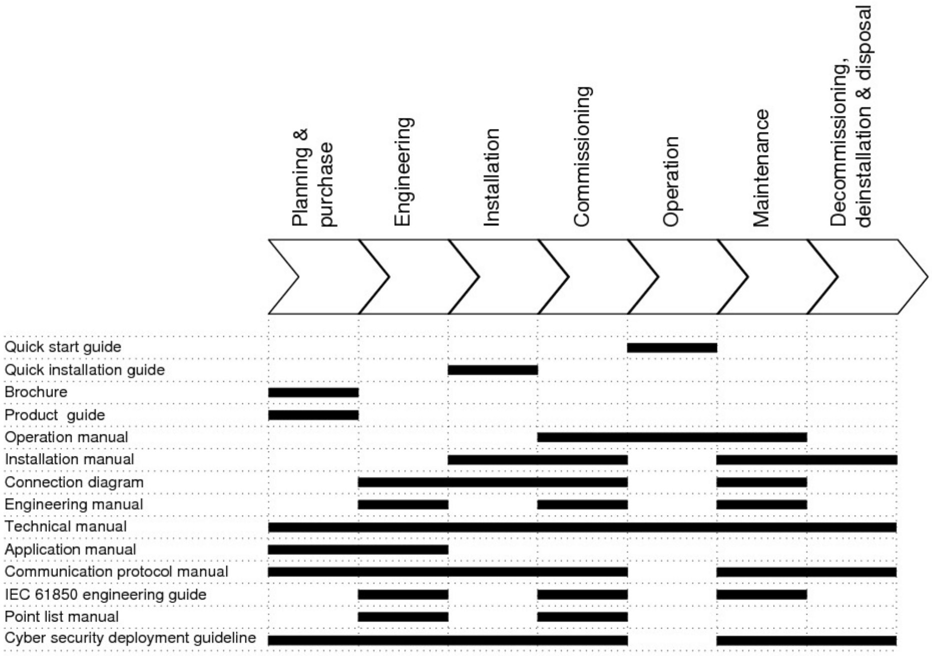

Figure 1: The intended use of documents during the product life cycle

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/2016-01-05	2.0 FP1	Content updated to correspond to the product version
E/2019-06-19	2.0 FP1	Content updated
F/2021-12-16	2.0 FP1	Content updated

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

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

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

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

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

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

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

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

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to all products.

Table 1: Functions included in the relays

Function	IEC 61850	IEC 60617	ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
	PHLPTOC2	3I> (2)	51P-1 (2)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
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)
	PHIPTOC2	3I>>> (2)	50P/51P (2)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67-1 (1)
	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67-2 (1)
	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)
	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
	EFHPTOC2	Io>> (2)	51N-2 (2)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)
	DEFLPDEF3	Io> -> (3)	67N-1 (3)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Admittance-based earth-fault protection	EFPADM1	Yo> -> (1)	21YN (1)
	EFPADM2	Yo> -> (2)	21YN (2)
	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric-based earth-fault protection	WPWDE1	Po> -> (1)	32N (1)
	WPWDE2	Po> -> (2)	32N (2)
	WPWDE3	Po> -> (3)	32N (3)
Multifrequency admittance-based earth-fault protection	MFADPSDE1	Io> -> Y (1)	67YN (1)
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF (1)
Harmonics-based earth-fault protection	HAEFPTOC1	Io>HA (1)	51NHA (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1> (1)	46PD (1)
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
	PHPTUV3	3U< (3)	27 (3)
	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)
Overexcitation protection	OEPVPH1	U/f> (1)	24 (1)
	OEPVPH2	U/f> (2)	24 (2)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F (1)	49F (1)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T/G/C (1)
Negative-sequence overcurrent protection for machines	MNSPTOC1	I2>M (1)	46M (1)
	MNSPTOC2	I2>M (2)	46M (2)
Loss of phase (undercurrent)	PHPTUC1	3I< (1)	37 (1)
	PHPTUC2	3I< (2)	37 (2)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
Loss of load supervision	LOFLPTUC1	3I< (1)	37 (1)
	LOFLPTUC2	3I< (2)	37 (2)
Motor load jam protection	JAMPTOC1	Ist> (1)	51LR (1)
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	3dl>M/G (1)	87M/G (1)
High-impedance/ flux-balance based differential protection for motors	MHZPDIF1	3dIHi>M (1)	87MH (1)
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF1	3dI>T (1)	87T (1)
Numerical stabilized low-impedance restricted earth-fault protection	LREFPNDF1	dIoLo> (1)	87NL (1)
	LREFPNDF2	dIoLo> (2)	87NL (2)
High-impedance based restricted earth-fault protection	HREFPDIF1	dIoHi> (1)	87NH (1)
	HREFPDIF2	dIoHi> (2)	87NH (2)
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)
Three-phase inrush detector	INRPHAR1	3I2f> (1)	68 (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
	TRPPTRC3	Master Trip (3)	94/86 (3)
	TRPPTRC4	Master Trip (4)	94/86 (4)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
High-impedance fault detection	PHIZ1	HIF (1)	HIZ (1)
Load-shedding and restoration	LSHDPFRQ1	UFLS/R (1)	81LSH (1)
	LSHDPFRQ2	UFLS/R (2)	81LSH (2)
	LSHDPFRQ3	UFLS/R (3)	81LSH (3)
	LSHDPFRQ4	UFLS/R (4)	81LSH (4)

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Function	IEC 61850	IEC 60617	ANSI
	LSHDPFRQ5	UFLS/R (5)	81LSH (5)
	LSHDPFRQ6	UFLS/R (6)	81LSH (6)
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-on-to-fault logic (SOF)	CVPSOF1	CVPSOF (1)	SOFT/21/50 (1)
Voltage vector shift protection	VVSPPAM1	VS (1)	78V (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)
High-impedance differential protection for phase A	HIAPDIF1	dHi_A> (1)	87A (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
High-impedance differential protection for phase B	HIBPDIF1	dHi_B> (1)	87B (1)
High-impedance differential protection for phase C	HICPDIF1	dHi_C> (1)	87C (1)
Circuit breaker uncorresponding position start-up	UPCALH1	CBUPS (1)	CBUPS (1)
	UPCALH2	CBUPS (2)	CBUPS (2)
	UPCALH3	CBUPS (3)	CBUPS (3)
Three-independent-phase non- directional overcurrent protection, low stage	PH3LPTOC1	3I_3> (1)	51P-1_3 (1)
	PH3LPTOC2	3I_3> (2)	51P-1_3 (2)
Three-independent-phase non- directional overcurrent protection, high stage	PH3HPTOC1	3I_3>> (1)	51P-2_3 (1)
	PH3HPTOC2	3I_3>> (2)	51P-2_3 (2)
Three-independent-phase non- directional overcurrent protection, instantaneous stage	PH3IPTOC1	3I_3>>> (1)	50P/51P_3 (1)
Directional three-independent-phase directional overcurrent protection, low stage	DPH3LPDOC1	3I_3> -> (1)	67-1_3 (1)
	DPH3LPDOC2	3I_3> -> (2)	67-1_3 (2)
Directional three-independent-phase directional overcurrent protection, high stage	DPH3HPDOC1	3I_3>> -> (1)	67-2_3 (1)
	DPH3HPDOC2	3I_3>> -> (2)	67-2_3 (2)
Three-phase overload protection for shunt capacitor banks	COLPTOC1	3I> 3I< (1)	51C/37 (1)
Current unbalance protection for shunt capacitor banks	CUBPTOC1	dI>C (1)	51NC-1 (1)
Shunt capacitor bank switching resonance protection, current based	SRCPTOC1	TD> (1)	55TD (1)
Control			
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)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
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)
Autoreclosing	DARREC1	O -> I (1)	79 (1)
	DARREC2	O -> I (2)	79 (2)
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (1)
Tap changer position indication	TPOSYLTC1	TPOSM (1)	84M (1)
Tap changer control with voltage regulator	OLATCC1	COLTC (1)	90V (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)
	CCSPVC2	MCS 3I (2)	MCS 3I (2)
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC1	MCS I_A (1)	MCS I_A (1)
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC1	MCS I_B (1)	MCS I_B (1)
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC1	MCS I_C (1)	MCS I_C (1)
Advanced current circuit supervision for transformers	CTSRCTF1	MCS 3I,I2 (1)	MCS 3I,I2 (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	ANSI
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)
	RESCMMXU2	Io (2)	In (2)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
Single-phase voltage measurement	VAMMXU2	U_A (2)	V_A (2)
	VAMMXU3	U_A (3)	V_A (3)
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)
Fault location			
Fault locator	SCEFRFLO1	FLOC (1)	21FL (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)
	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)

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Function	IEC 61850	IEC 60617	ANSI
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)

Table continues on the next page

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

2 REF620 overview

2.1 Overview

REF620 is a dedicated feeder management relay perfectly aligned for the protection, control, measurement and supervision of utility and industrial power distribution systems, including radial, looped and meshed networks, with or without distributed power generation. REF620 can also be used to protect feeders including motors or capacitor banks. Additionally REF620 offers functionality for interconnection protection used with distributed generation like wind or solar power connection to utility grid. Furthermore, REF620 includes functionality for high-impedance based busbar protection. REF620 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
2.1 FP1	• 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 relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- REF620 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
- 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
- Fault locator
- Power protection package
- Intertie/Interconnection/Distributed generation protection package
- Capacitor bank protection package (configuration A only)

2.3 Physical hardware

Table 2: Plug-in unit and case

Main unit	Slot ID	Content	Module ID	Details
Plug-in unit	-	HMI	DIS0009	Large (10 rows, 20 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	BI/O module	BIO0005	With configurations A and B 8 binary inputs 4 SO contacts
	X115	BI/O module	BIO0005	With configurations A and B 8 binary inputs 4 SO contacts
	X120	AI/BI module	AIM0016 or AIM0017	With configuration A 4 binary inputs 3 phase current inputs (1/5A) 1 residual current input (1/5 A or 0.2/1 A)[1]

Table continues on the next page

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

Main unit	Slot ID	Content	Module ID	Details
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	4	5	-	32	4 PO + 14 SO	-	-
		AB				24	4 PO + 10 SO	6	2
		AC				32	4 PO + 10 SO + 3 HSO	-	-
		NN				24	4 PO + 10 SO	-	-
B	AC/DB	AA	1	-	3	24	4 PO + 14 SO	-	-
		AB				16	4 PO + 10 SO	6	2
		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.

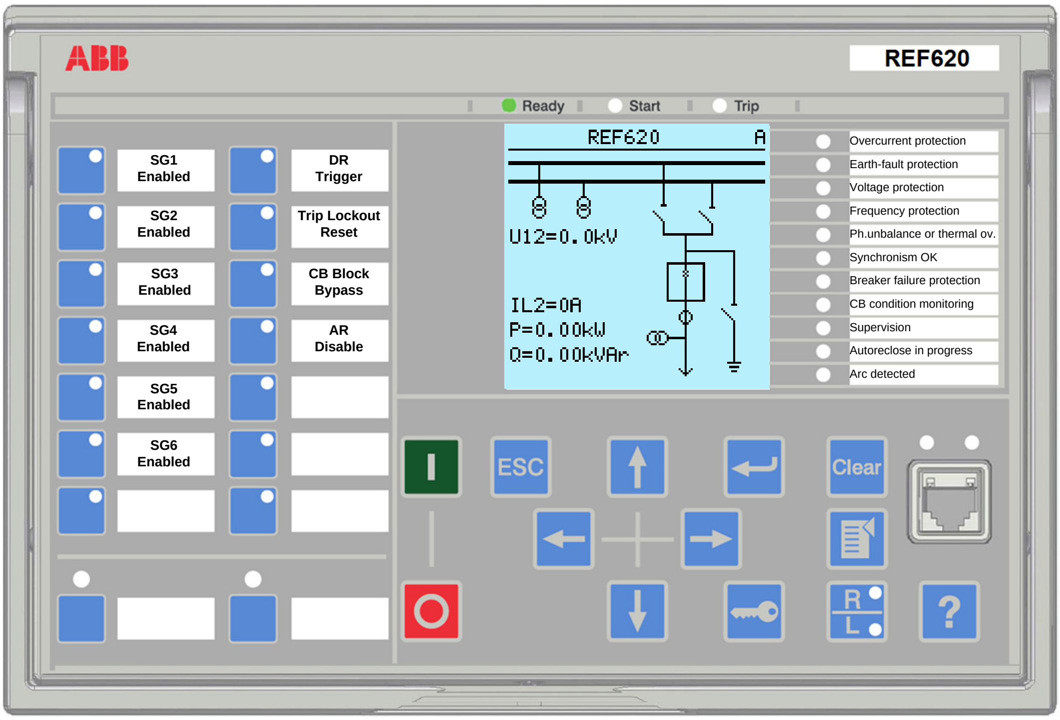


Figure 2: Example of the LHMI

2.4.1 Display

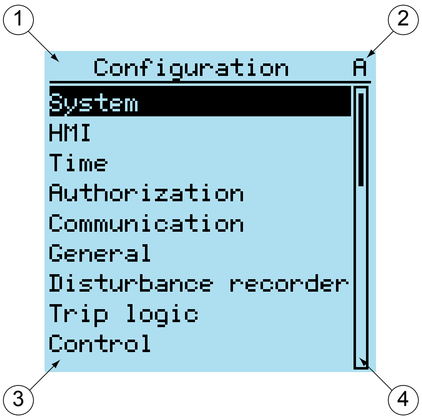
The LHMI includes a graphical display that supports one character size. The character size depends on the selected language. The amount of characters and rows fitting the view depends on the character size.

Table 4: 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] Depending on the selected language



1	Header	3	Content
2	Icon	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.

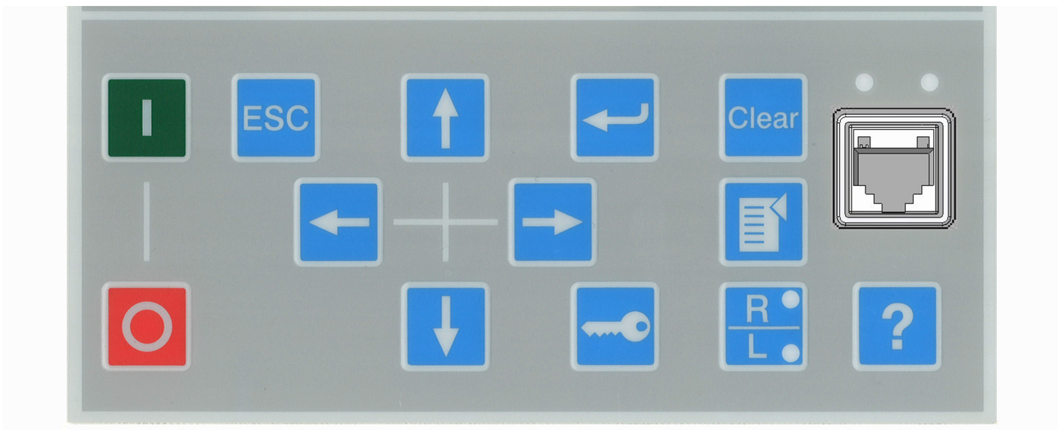


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.4.3.1 Programmable push buttons with LEDs

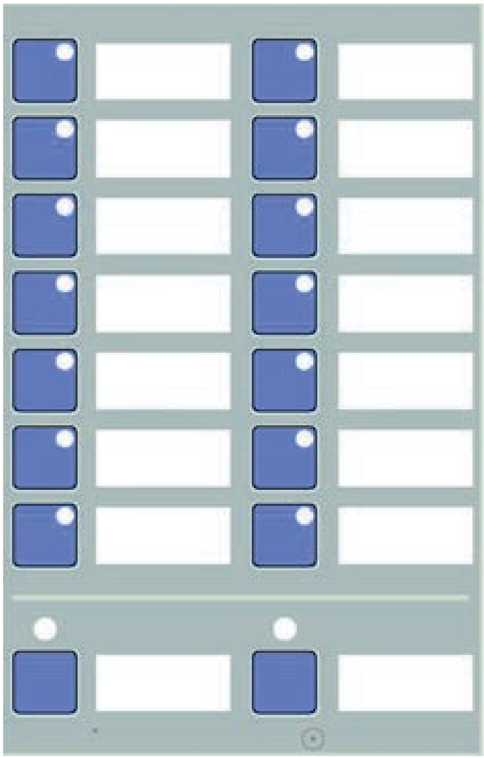


Figure 5: Programmable push buttons with LEDs

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.

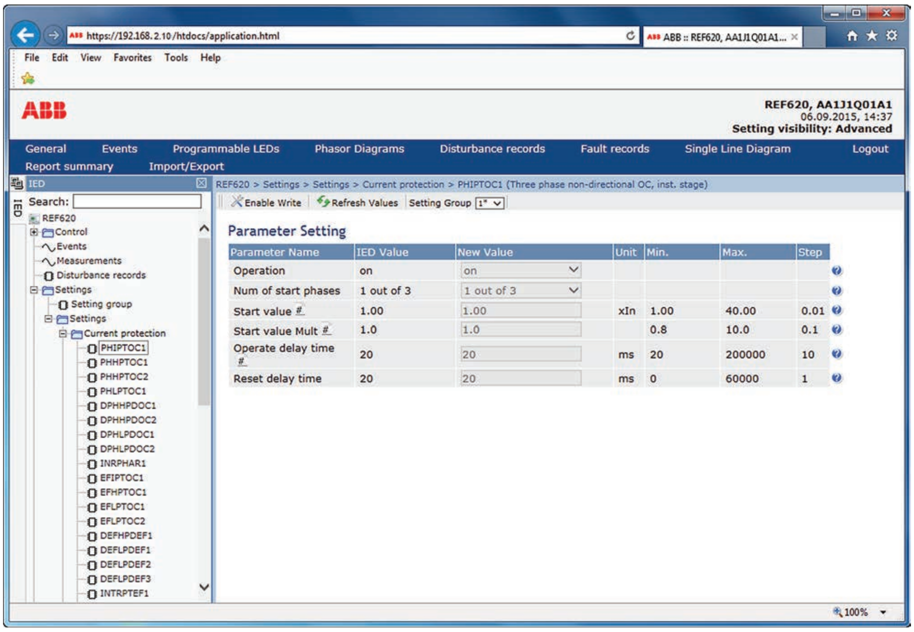


Figure 6: Example view of the WHMI

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	Configura-tion change	Setting group	Setting group, con-trol	Settings edit	All
Configuration change		●	●	●	●	●
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 funtionality, for example, remote parametrization and 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.

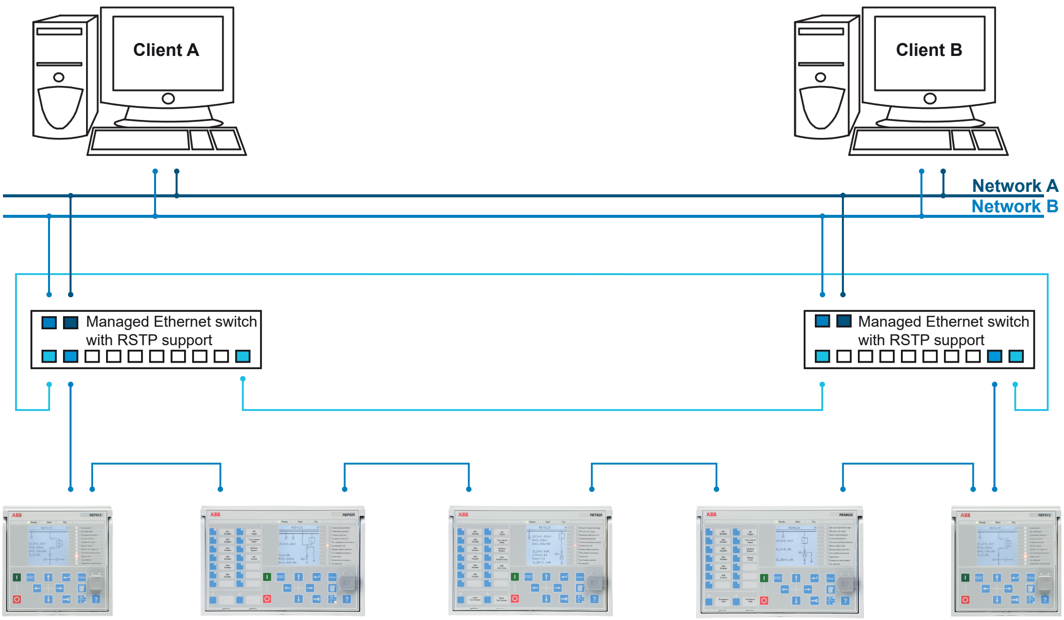


Figure 7: Self-healing Ethernet ring solution

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.

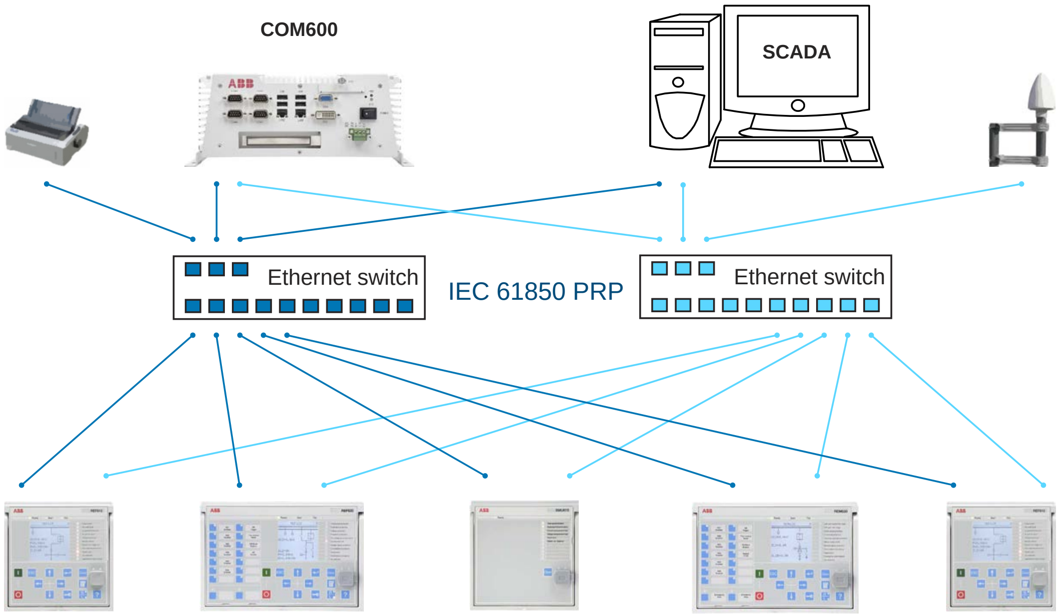


Figure 8: PRP solution

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.

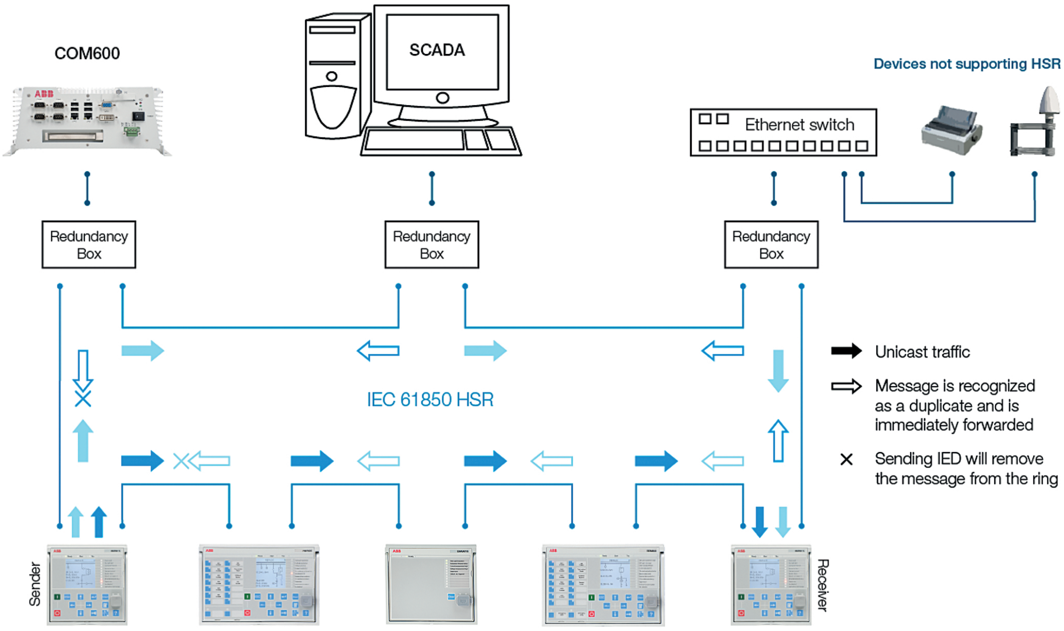


Figure 9: HSR solution

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.

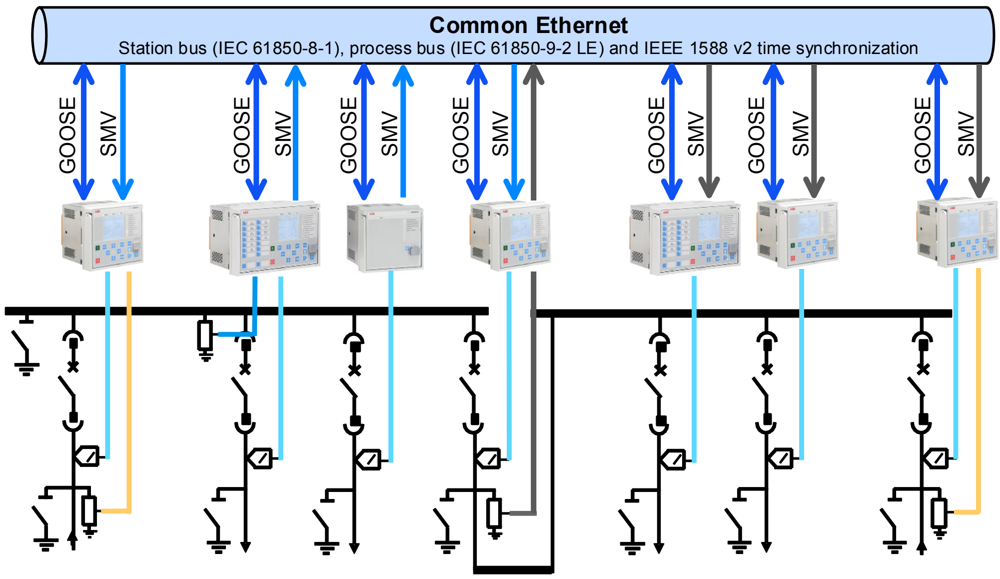


Figure 10: Process bus application of voltage sharing and synchrocheck

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.

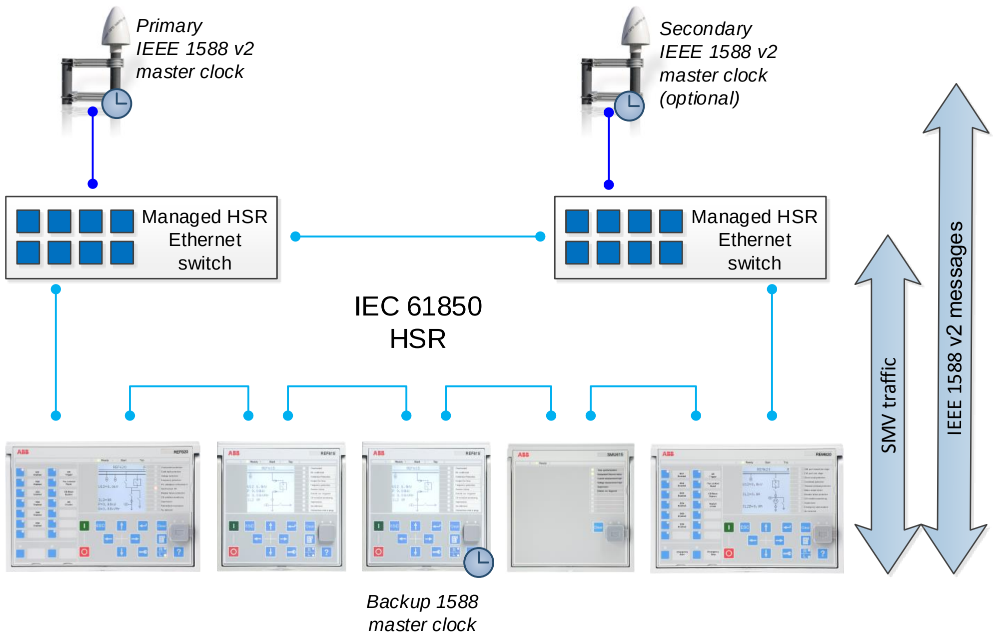


Figure 11: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

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 REF620 default configurations

3.1 Default configurations

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.

REF620 is available in two alternative default configurations: configuration A with traditional current and voltage measurement transducers and configuration B with current and voltage sensors. Default configuration A with measurement transducers has more voltage measurements and I/Os than default configuration B. This gives more possibilities in applications supported by default configuration A. 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 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.

Table 8: Supported functions

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
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	2	2
Three-phase directional overcurrent protection, high stage	DPHHPDOC	2	2

Table continues on the next page

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
Three-phase voltage-dependent overcurrent protection	PHPVOC	2	2
Non-directional earth-fault protection, low stage	EFLPTOC	2	2
Non-directional earth-fault protection, high stage	EFHPTOC	1	1
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	1	1
Directional earth-fault protection, low stage	DEFLPDEF	3	3 [1]
Directional earth-fault protection, high stage	DEFHPDEF	1	1[1)]
Admittance-based earth-fault protection	EFPADM	3	3[1)]
Wattmetric-based earth-fault protection	WPWDE	3	3[1)]
Multifrequency admittance-based earth-fault protection	MFADPSDE	1	1[1)]
Transient/intermittent earth-fault protection	INTRPTEF	1	1[1)]
Harmonics-based earth-fault protection	HAEFPTOC	1	1
Negative-sequence overcurrent protection	NSPTOC	2	2
Phase discontinuity protection	PDNSPTOC	1	1
Residual overvoltage protection	ROVPTOV	3	3[1)]
Three-phase undervoltage protection	PHPTUV	4	4
Single-phase undervoltage protection, secondary side	PHAPTUV	1	
Three-phase overvoltage protection	PHPTOV	3	3

Table continues on the next page

[1] Uo is calculated from the measured phase voltages

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
Single-phase over-voltage protection, secondary side	PHAPTOV	1	
Positive-sequence undervoltage protection	PSPTUV	2	2
Negative-sequence overvoltage protection	NSPTOV	2	2
Frequency protection	FRPFRQ	6	6
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	1	1
Loss of phase (undercurrent)	PHPTUC	1	1
Circuit breaker failure protection	CCBRBRF	3	3
Three-phase inrush detector	INRPHAR	1	1
Master trip	TRPPTRC	4	4
Arc protection	ARCSARC	(3)	(3)
High-impedance fault detection	PHIZ	1	1
Load-shedding and restoration	LSHDPFRQ	6	6
Multipurpose protection	MAPGAPC	18	18
Automatic switch-on-to-fault logic (SOF)	CVPSOF	1	1
Voltage vector shift protection	VVSPPAM	(1)	(1)
Directional reactive power undervoltage protection	DQPTUV	(2)	(2)
Underpower protection	DUPPDPR	(2)	(2)
Reverse power/directional overpower protection	DOPPDPR	(2)	(2)
Low-voltage ride-through protection	LVRTPTUV	(3)	(3)
High-impedance differential protection for phase A	HIAPDIF	1	
High-impedance differential protection for phase B	HIBPDIF	1	

Table continues on the next page

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
High-impedance differential protection for phase C	HICPDIF	1	
Circuit breaker uncorresponding position start-up	UPCALH	3	3
Three-independent-phase non-directional overcurrent protection, low stage	PH3LPTOC	2	2
Three-independent-phase non-directional overcurrent protection, high stage	PH3HPTOC	2	2
Three-independent-phase non-directional overcurrent protection, instantaneous stage	PH3IPTOC	1	1
Directional three-independent-phase directional overcurrent protection, low stage	DPH3LPDOC	2	2
Directional three-independent-phase directional overcurrent protection, high stage	DPH3HPDOC	2	2
Three-phase overload protection for shunt capacitor banks	COLPTOC	(1)	
Current unbalance protection for shunt capacitor banks	CUBPTOC	(1)	
Shunt capacitor bank switching resonance protection, current based	SRCPTOC	(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
Autoreclosing	DARREC	2	2

Table continues on the next page

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
Synchronism and energizing check	SECRSYN	1	(1)[2]
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR	3	3
Trip circuit supervision	TCSSCBR	2	2
Current circuit supervision	CCSPVC	1	1
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC	1	
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC	1	
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC	1	
Fuse failure supervision	SEQSPVC	1	1
Runtime counter for machines and devices	MDSOPT	2	2
Measurement			
Three-phase current measurement	CMMXU	1	1
Sequence current measurement	CSMSQI	1	1
Residual current measurement	RESCMMXU	1	1
Three-phase voltage measurement	VMMXU	1	1
Single-phase voltage measurement	VAMMXU	1	(1)[2)]
Residual voltage measurement	RESVMMXU	1	
Sequence voltage measurement	VSMSQI	1	1
Three-phase power and energy measurement	PEMMXU	1	1

Table continues on the next page

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

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
Load profile record	LDPRLRC	1	1
Frequency measurement	FMMXU	1	1
Fault location			
Fault locator	SCEFRFLO	(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
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

Table continues on the next page

Function	IEC 61850	A (CTs/VTs)	B (Sensors)
		FE201	FE202
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			

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

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

3.1.2 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.

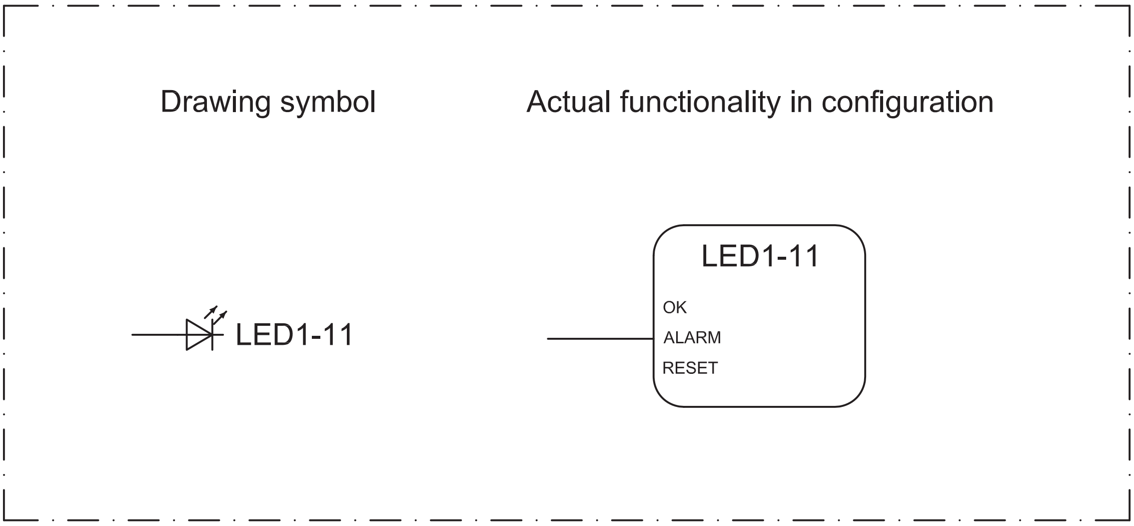


Figure 12: Drawing symbol used in the manual and the default connection of the LED function blocks in the configurations

3.2 Connection diagrams

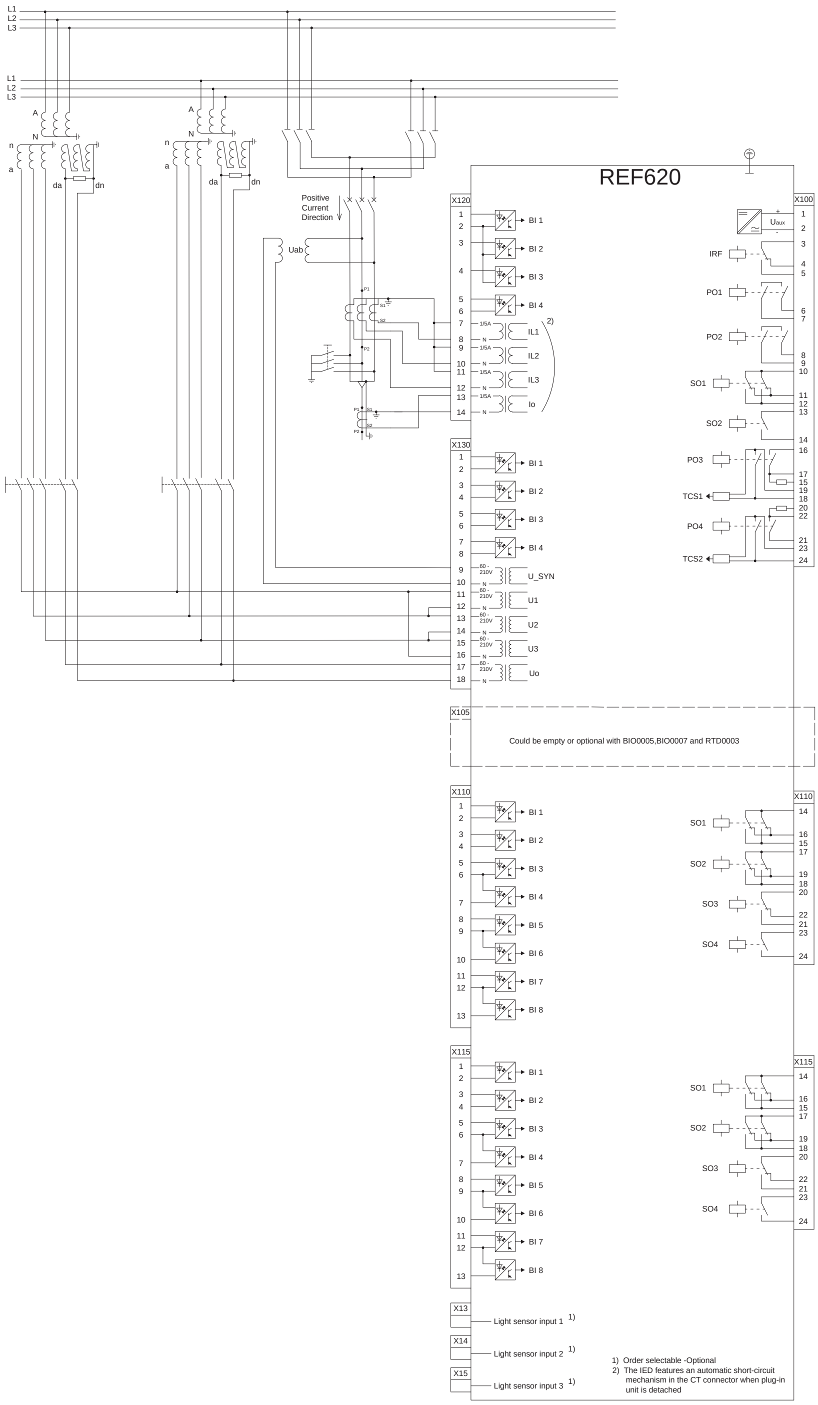


Figure 13: Connection diagram for the configuration with CTs and VTs

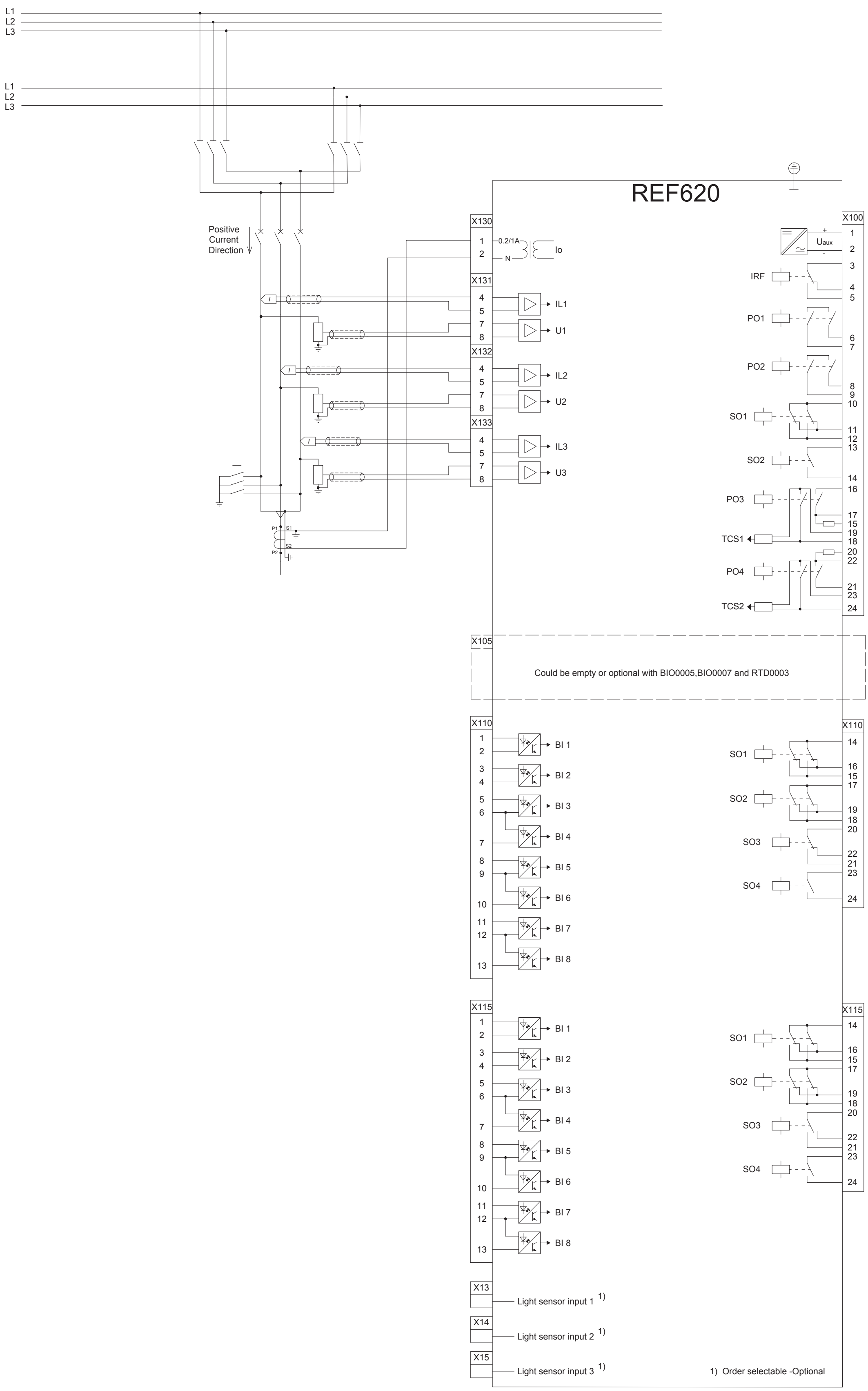


Figure 14: Connection diagram for the configuration with SIM0002 module

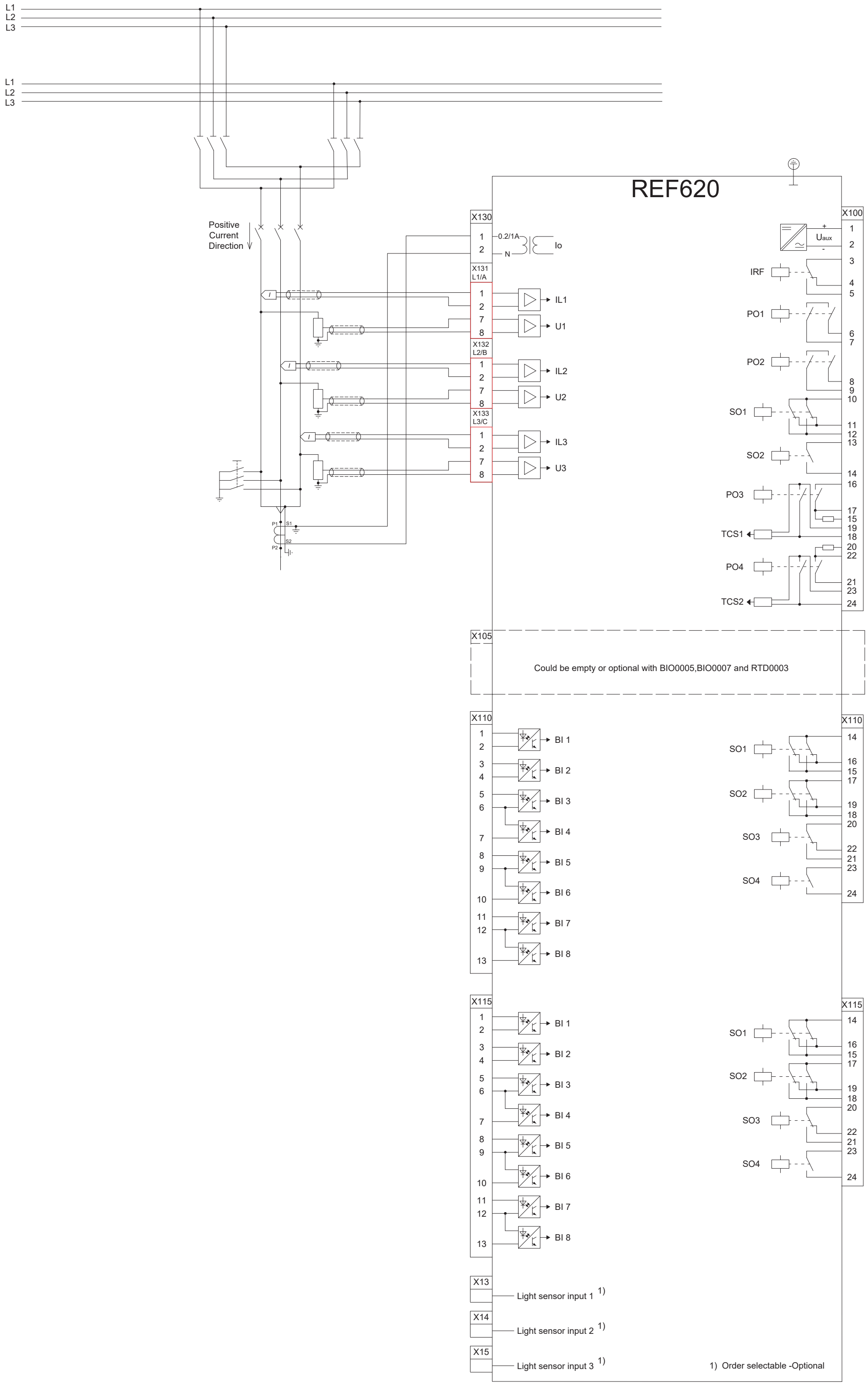


Figure 15: Connection diagram for the configuration with SIM0005 module

3.3 Optional modules

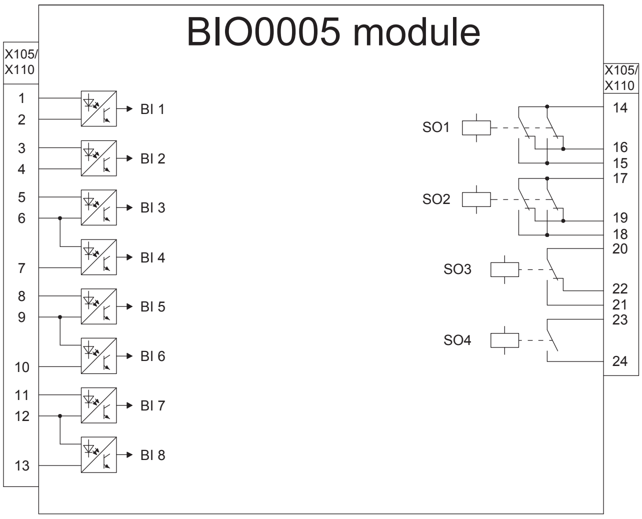


Figure 16: Optional BIO0005 module (slot X105)

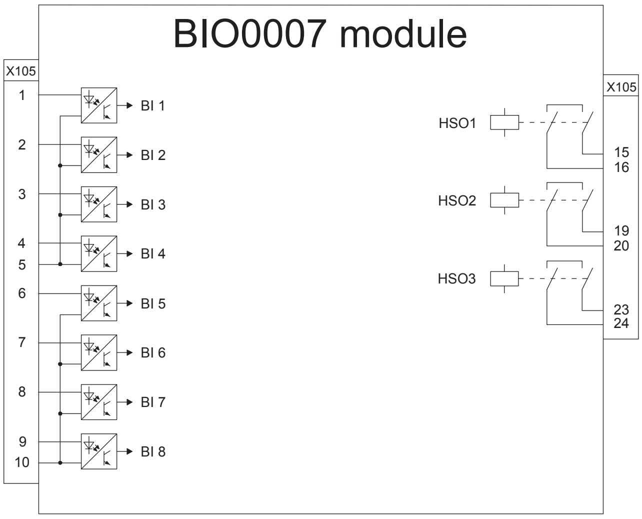


Figure 17: Optional BIO0007 module for fast outputs (slot X105)

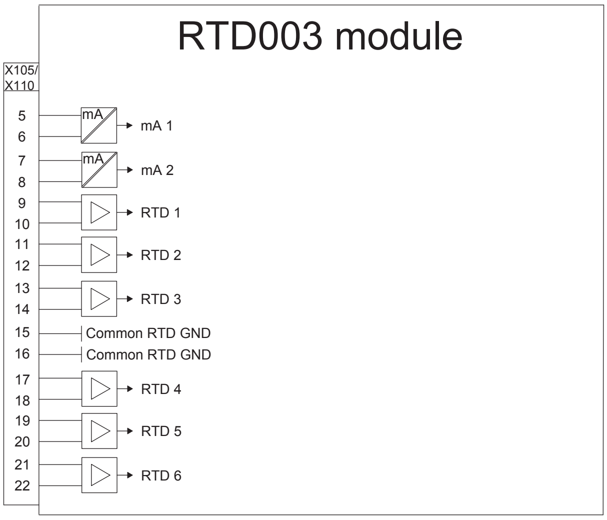


Figure 18: Optional RTD0003 module (slot X105)

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

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.

This configuration utilizes traditional current and voltage transducers.

3.5.2 Functions

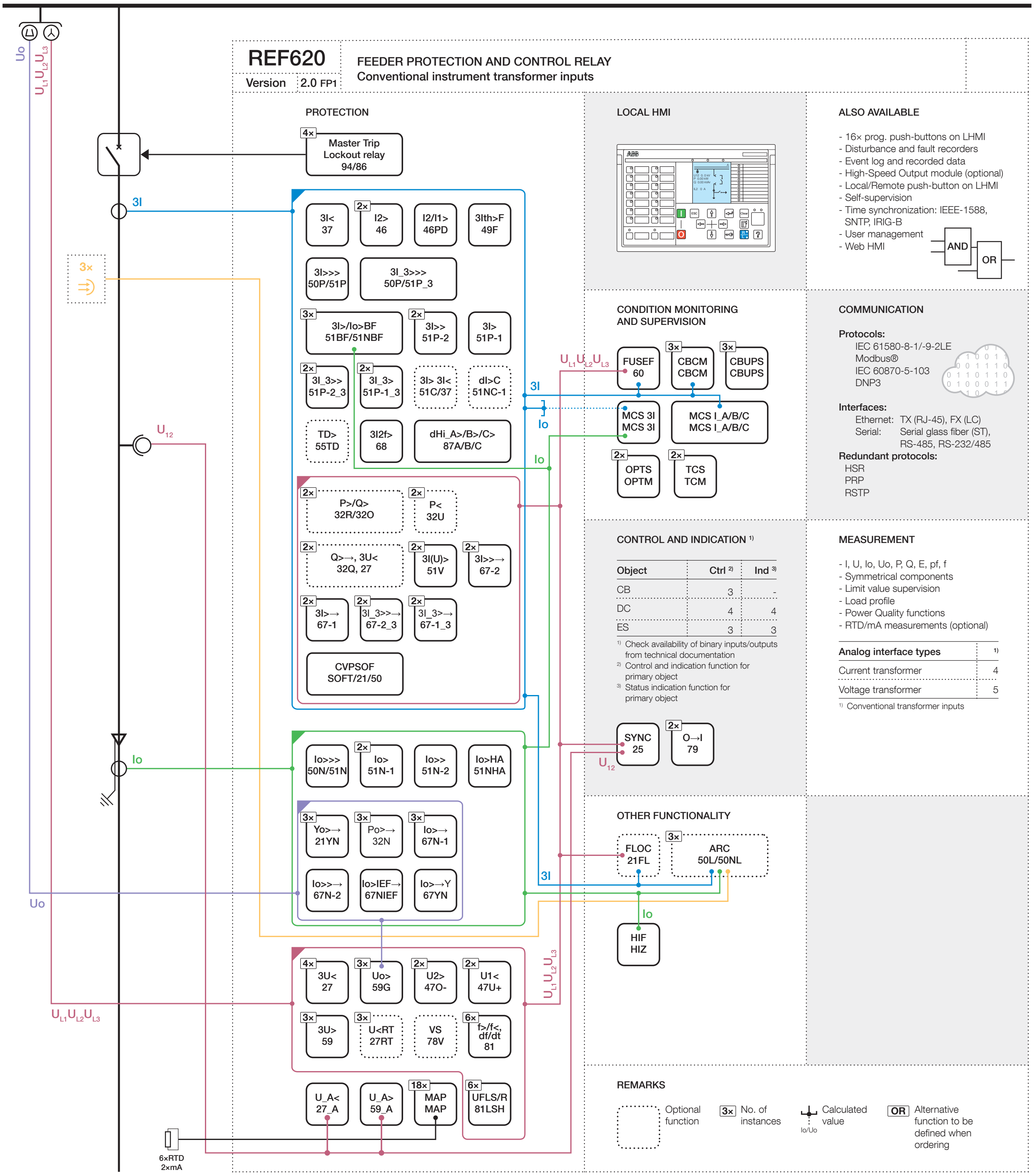


Figure 19: Functionality overview of default configuration with conventional instrument transformer inputs

3.5.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Default usage	Connector pins
IL1	Phase A current	X120:7,8
IL2	Phase B current	X120:9,10
IL3	Phase C current	X120:11,12
Io	Residual current	X120:13,14
U_SYN	Phase-to-phase voltage U12, line 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

Table 10: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	Circuit breaker closed position indication	X110:1,2
X110-BI2	Circuit breaker open position indication	X110:3,4
X110-BI3	Circuit breaker low gas pressure alarm	X110:5,6
X110-BI4	Circuit breaker spring charged indication	X110:7,6
X110-BI5	Disconnector 1 closed position indication	X110:8,9
X110-BI6	Disconnector 1 open position indication	X110:10,9
X110-BI7	Earthing switch 1 closed position indication	X110:11,12
X110-BI8	Earthing switch 1 open position indication	X110:13,12
X115-BI1	Disconnector 2 closed position indication	X115:1,2
X115-BI2	Disconnector 2 open position indication	X115:3,4
X115-BI3	Blocking of overcurrent instantaneous stage	X115:5,6
X115-BI4	Directional earth fault protection's basic angle control	X115:7,6
X115-BI5	Bus MCB open position indication	X115:8,9
X115-BI6	Line MCB open position indication	X115:10,9
X115-BI7	-	X115:11,12
X115-BI8	-	X115:13,12

Table 11: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100:6,7
X100-PO2	Circuit breaker failure protection trip to up-stream 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 coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Close disconnector 1	X110:14-16
X110-SO2	Open disconnector 1	X110:17-19
X110-SO3	Close earthing switch 1	X110:20-22
X110-SO4	Open earthing switch 1	X110:23,24
X115-SO1	Close disconnector 2	X115:14-16
X115-SO2	Open disconnector 2	X115:17-19
X115-SO3	Upstream overcurrent blocking	X115:20-22
X115-SO4	-	X115:23,24

Table 12: Default connections for LEDs

LED	Default usage	Label description
1	Overcurrent protection operate	Overcurrent protection
2	Earth-fault protection operate	Earth-fault protection
3	Voltage protection operate	Voltage protection
4	Frequency protection operate	Frequency protection
5	Negative seq. overcurrent/phase discontinui-ty/ thermal overload protection operate	Ph. unbalance or thermal ov.
6	Synchronism or energizing check OK	Synchronism OK
7	Circuit breaker failure protection backup pro-tection operate	Breaker failure protection
8	Circuit breaker condition monitoring alarm	CB condition monitoring
9	Supervision alarm	Supervision
10	Autoreclose in progress	Autoreclose in progress
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
3	Setting Group 3 Enabled	Pulsed	150 ms

Table continues on the next page

FK/SPCGAPC number	Default usage	Operation mode	Pulsed length
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	-	Off	1000 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	Autorecloser Disable	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 binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1_START	Positive or Rising
2	PHLPTOC1_OPERATE	Level trigger off
3	PHHPTOC1_START	Positive or Rising
4	PHHPTOC2_START	Positive or Rising
5	PHHPTOC1/2_OPERATE	Level trigger off
6	PHIPTOC1_START	Positive or Rising
7	PHIPTOC1_OPERATE	Level trigger off
8	DPHLPDOC1_START	Positive or Rising
9	DPHLPDOC2_START	Positive or Rising
10	DPHLPDOC1/2_OPERATE	Level trigger off
11	DPHHPDOC1_START	Positive or Rising
12	DPHHPDOC2_START	Positive or Rising
13	DPHHPDOC1/2_OPERATE	Level trigger off
14	EFLPTOC1 or EFPADM1 or WPWDE1_START	Positive or Rising
15	EFLPTOC2 or EFPADM2 or WPWDE2_START	Positive or Rising
16	EFHPTOC1 or EFPADM3 or WPWDE3_START	Positive or Rising
17	EFIPTOC1_START	Positive or Rising
18	EFxPTOC or EFPADM or WPWDE_OPERATE	Level trigger off
19	DEFLPDEF1_START	Positive or rising

Table continues on the next page

Channel	ID text	Level trigger mode
20	DEFLPDEF2_START	Positive or rising
21	DEFLPDEF3_START	Positive or rising
22	DEFHPDEF1_START	Positive or rising
23	DEFxPDEF_OPERATE	Level trigger off
24	ROVPTOV1/2/3_START	Positive or rising
25	ROVPTOV1/2/3_OPERATE	Level trigger off
26	INTRPTEF1_START	Positive or rising
27	INTRPTEF1_OPERATE	Level trigger off
28	HAEFPTOC1_START	Positive or rising
29	HAEFPTOC1_OPERATE	Positive or rising
30	NSPTOC1_START	Positive or rising
31	NSPTOC2_START	Positive or rising
32	PDNSPTOC1_START	Positive or rising
33	NSPTOC1/2 or PDNSPTOC1_OPERATE	Level trigger off
34	PHPTUV or PHPTOV or PSPTUV or NSPTOV_START	Positive or rising
35	PHPTUV or PHPTOV or PSPTUV or NSPTOV_OPERATE	Level trigger off
36	FRPFRQ or LSHDPFRQ_START	Positive or rising
37	FRPFRQ or LSHDPFRQ_OPERATE	Level trigger off
38	T1PTTR1_START	Positive or rising
39	T1PTTR1_OPERATE	Level trigger off
40	PHPTUC1_START	Positive or rising
41	PHPTUC1_OPERATE	Level trigger off
42	ARCSARC1/2/3_ARC_FLT_DET	Level trigger off
43	ARCSARC1_OPERATE	Positive or rising
44	ARCSARC2_OPERATE	Positive or rising
45	ARCSARC3_OPERATE	Positive or rising
46	INRPHAR1_BLK2H	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	DARREC1_INPRO	Level trigger off
53	DARREC1_CLOSE_CB	Level trigger off
54	DARREC1_UNSUC_RECL	Level trigger off
55	BI Blocking	Level trigger off
56	CB Closed	Level trigger off
57	CB Open	Level trigger off
58	Bus MCB Open	Level trigger off
59	Line MCB Open	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
60	MFADPSDE1_START	Positive or rising
61	MFADPSDE1_OPERATE	Level trigger off
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 15: Default analog channel selection and text settings

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

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		Off	1000 ms
9	DR Trigger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms
11	CB Block Bypass	Toggle	1000 ms
12	AR Disable	Toggle	1000 ms

Table continues on the next page

Channel	Signal name	Value	Pulse length
13		Off	1000 ms
14		Off	1000 ms
15		Off	1000 ms
16		Off	1000 ms

Grey cells indicate different default settings.

3.5.2.4 Physical analog channels

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

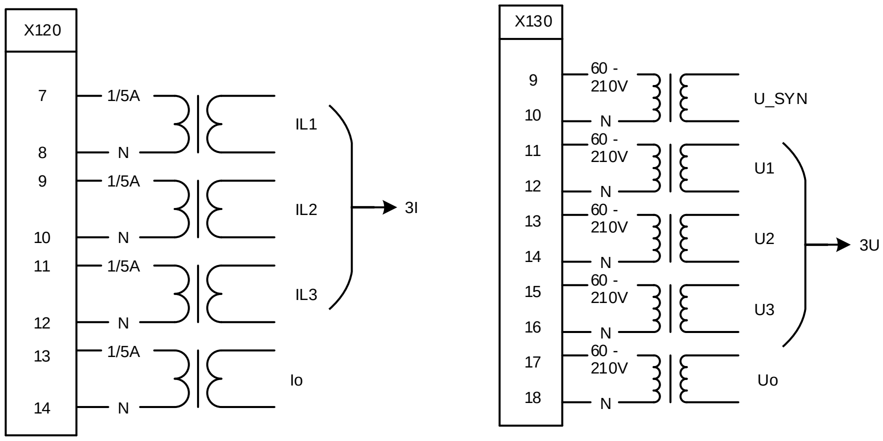


Figure 20: Physical analog channels in default configuration A

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	U_SYN
Protection					
PHLPTOC1	x				
PHHPTOC1	x				
PHHPTOC2	x				
PHIPTOC1	x				
DPHLPDOC1	x	x			
DPHLPDOC2	x	x			
DPHHPDOC1	x	x			
DPHHPDOC2	x	x			
PHPVOC1	x	x			
PHPVOC2	x	x			
EFLPTOC1	C		x		
EFLPTOC2	C		x		
EFHPTOC1	C		x		
EFIPTOC1	C		x		
DEFLPDEF1	C	C	x	x	
DEFLPDEF2	C	C	x	x	
DEFLPDEF3	C	C	x	x	
DEFHPDEF1	C	C	x	x	
EFPADM1	C	C	x	x	
EFPADM2	C	C	x	x	
EFPADM3	C	C	x	x	
WPWDE1	C	C	x	x	
WPWDE2	C	C	x	x	
WPWDE3	C	C	x	x	
MFADPSDE1	C	C	x	x	
INTRPTEF1		C	x	x	
HAEFPTOC1			x		
NSPTOC1	x				
NSPTOC2	x				
PDNSPTOC1	x				
ROVPTOV1		C		x	
ROVPTOV2		C		x	
ROVPTOV3		C		x	
PHPTUV1		x			
PHPTUV2		x			
PHPTUV3		x			
PHPTUV4		x			
PHAPTUV1					x
PHPTOV1		x			

Table continues on the next page

IEC61850	3I	3U	Io	Uo	U_SYN
PHPTOV2		x			
PHPTOV3		x			
PHAPTOV1					x
PSPTUV1		x			
PSPTUV2		x			
NSPTOV1		x			
NSPTOV2		x			
FRPFRQ1		x			
FRPFRQ2		x			
FRPFRQ3		x			
FRPFRQ4		x			
FRPFRQ5		x			
FRPFRQ6		x			
T1PTTR1	x				
PHPTUC1	x				
CCBRBRF1	x		x		
CCBRBRF2	x		x		
CCBRBRF3	x		x		
INRPHAR1	x				
ARCSARC1	x		x		
ARCSARC2	x		x		
ARCSARC3	x		x		
PHIZ1			x		
LSHDPFRQ1		x			
LSHDPFRQ2		x			
LSHDPFRQ3		x			
LSHDPFRQ4		x			
LSHDPFRQ5		x			
LSHDPFRQ6		x			
CVPSOF1	x	x			
VVSPPAM1		x			
DQPTUV1	x	x			
DQPTUV2	x	x			
DUPPDPR1	x	x			
DUPPDPR2	x	x			
DOPPDPR1	x	x			
DOPPDPR2	x	x			
LVRTPTUV1		x			
LVRTPTUV2		x			
LVRTPTUV3		x			
HIAPDIF1	D				

Table continues on the next page

IEC61850	3I	3U	Io	Uo	U_SYN
HIBPDIF1	D				
HICPDIF1	D				
PH3LPTOC1	x				
PH3LPTOC2	x				
PH3HPTOC1	x				
PH3HPTOC2	x				
PH3IPTOC1	x				
DPH3LPDOC1	x	x			
DPH3LPDOC2	x	x			
DPH3HPDOC1	x	x			
DPH3HPDOC2	x	x			
COLPTOC1	x				
CUBPTOC1	x		D		
SRCPTOC1	x				
Control					
SECRSYN1		x			x
Condition monitoring					
SSCBR1	x				
SSCBR2	x				
SSCBR3	x				
CCSPVC1	x		x		
HZCCASPVC1	D				
HZCCBSPVC1	D				
HZCCCSPVC1	D				
SEQSPVC1	x	x			
Measurement					
CMMXU1	x				
CSMSQI1	x				
RESCMMXU1			x		
VMMXU1		x			
VAMMXU2					x
RESVMMXU1				x	
VSMSQI1		x			
PEMMXU1	x	x			
FMMXU1		x			
Fault location					
SCEFRFLO1	x	x	x	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.

The analog channels and the measurements from CTs and VTs have fixed connections to the different function blocks inside the relay. Exceptions to 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. 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 a star-connected VT is available in the system, the VT inputs in the relay 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 phase-to-earth or phase-to-phase voltage from the VT on the feeder side of the breaker. This signal is used to check the synchronizing. Care is taken in setting the synchro-check function with the correct phase angle correction, especially in applications such as voltages fed to synchro-check across a transformer with vector shift.

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.

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 with a programmable button. In addition, the programmable button can be used for example for the manual trigger of disturbance recorder, circuit breaker control interlocking bypass, master trip lockout reset or for setting the autoreclosing function on or off.

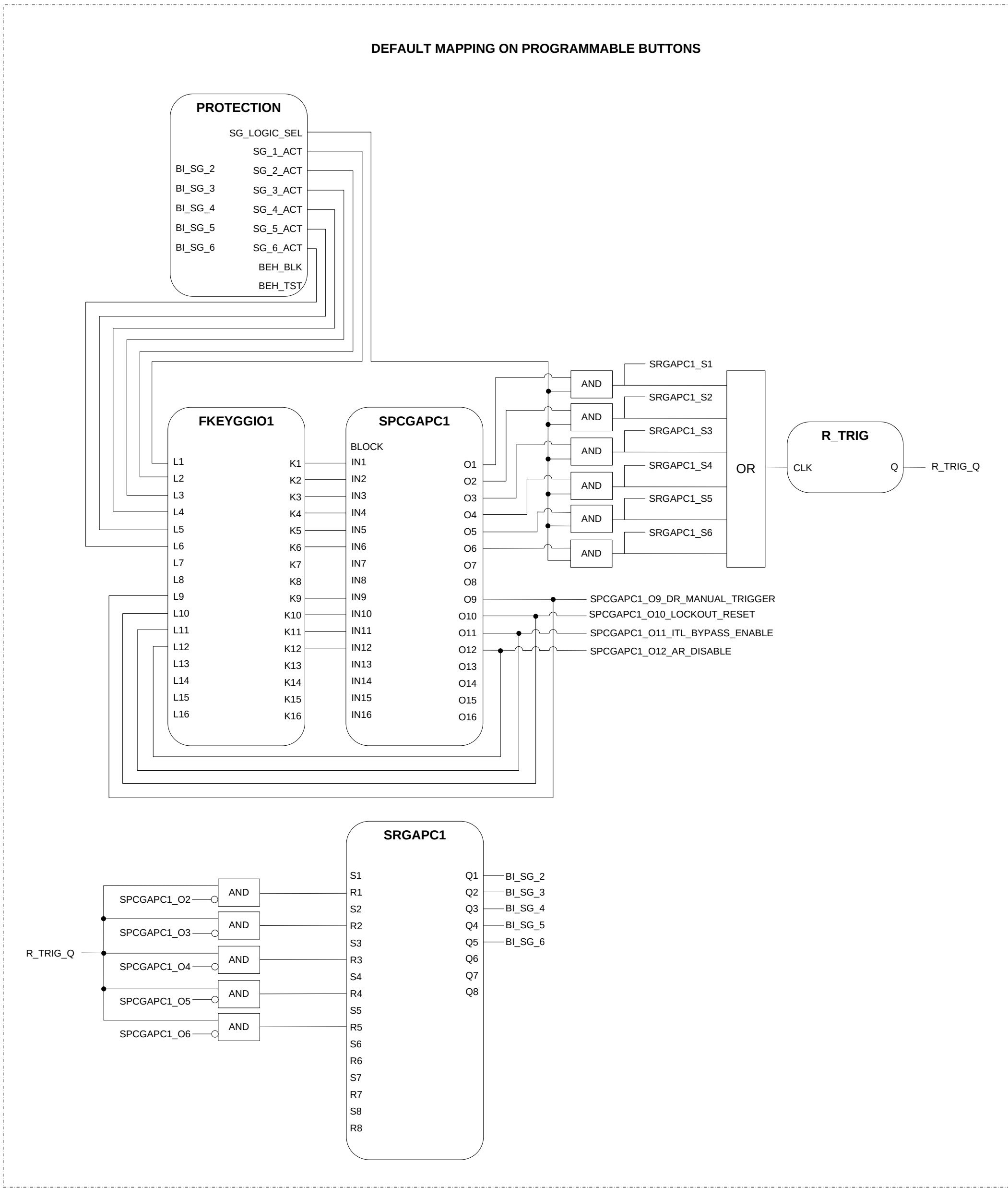


Figure 21: Default mapping on programmable buttons

3.5.3.1 Functional diagrams for protection

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

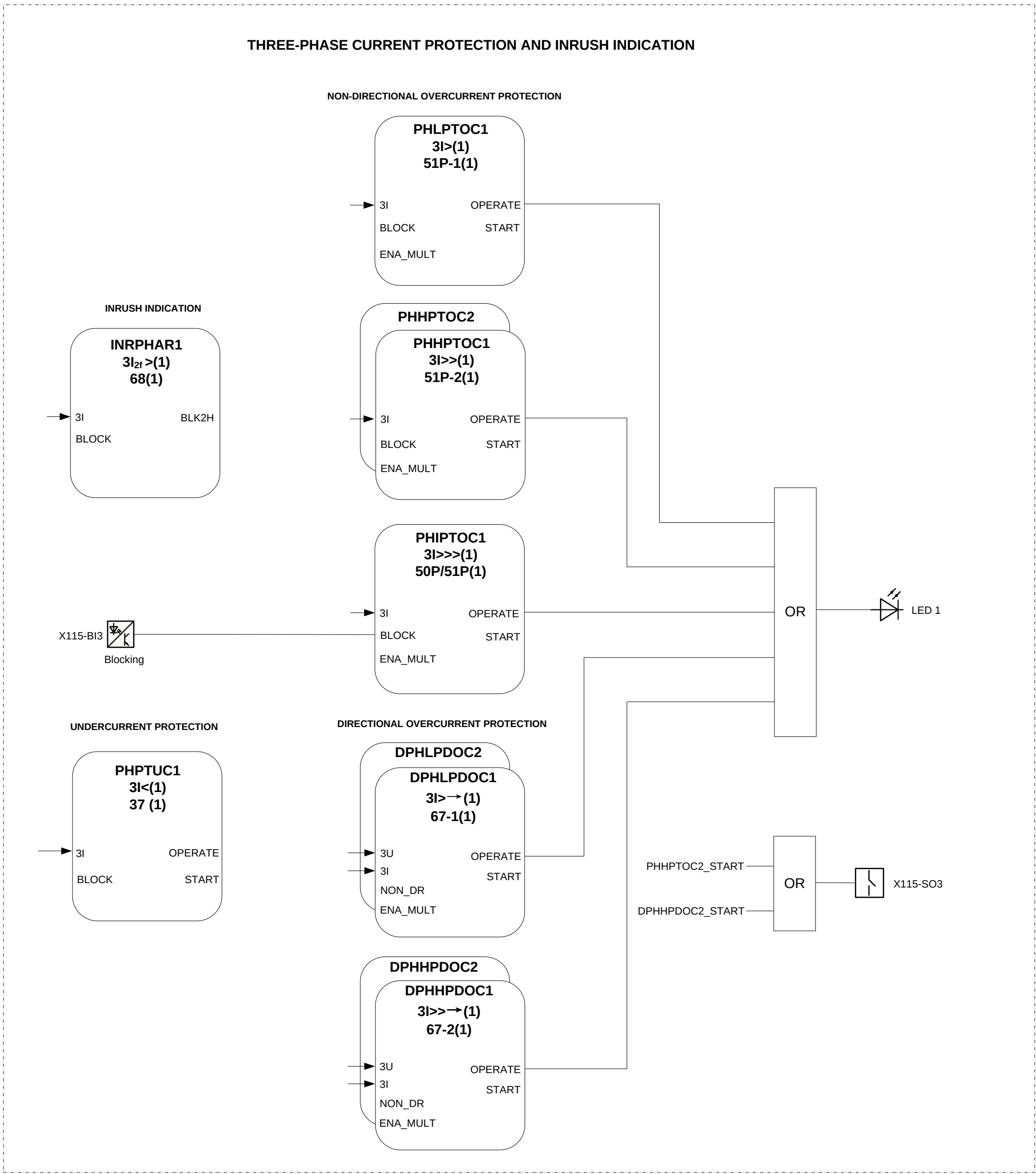


Figure 22: Overcurrent and undercurrent protection

Eight overcurrent stages in total are offered for overcurrent and short circuit protection. Four stages are directional functionality DPHxPDOC, while the others are only for non-directional overcurrent protection PHxPTOC. The instantaneous stage PHIPTOC1 can be blocked by energizing the binary input X115-BI3. The inrush detection INRPHAR1 output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

One undercurrent stage PHPTUC1 is offered for undercurrent protection. The `START` and `OPERATE` outputs from this function are connected to disturbance recorder, but this function is not configured to trip the circuit breaker by default.

The `OPERATE` outputs are connected to the Master Trip and alarm LED 1, except for PHPTUC1. LED 1 is used for overcurrent protection indication.

The START signals of PHHPTOC2 and DPHHPDOC2 are connected to signal output X115-SO3. This output is used for sending a blocking signal to the relevant overcurrent protection stage of the relay at the infeeding bay for upstream blocking.

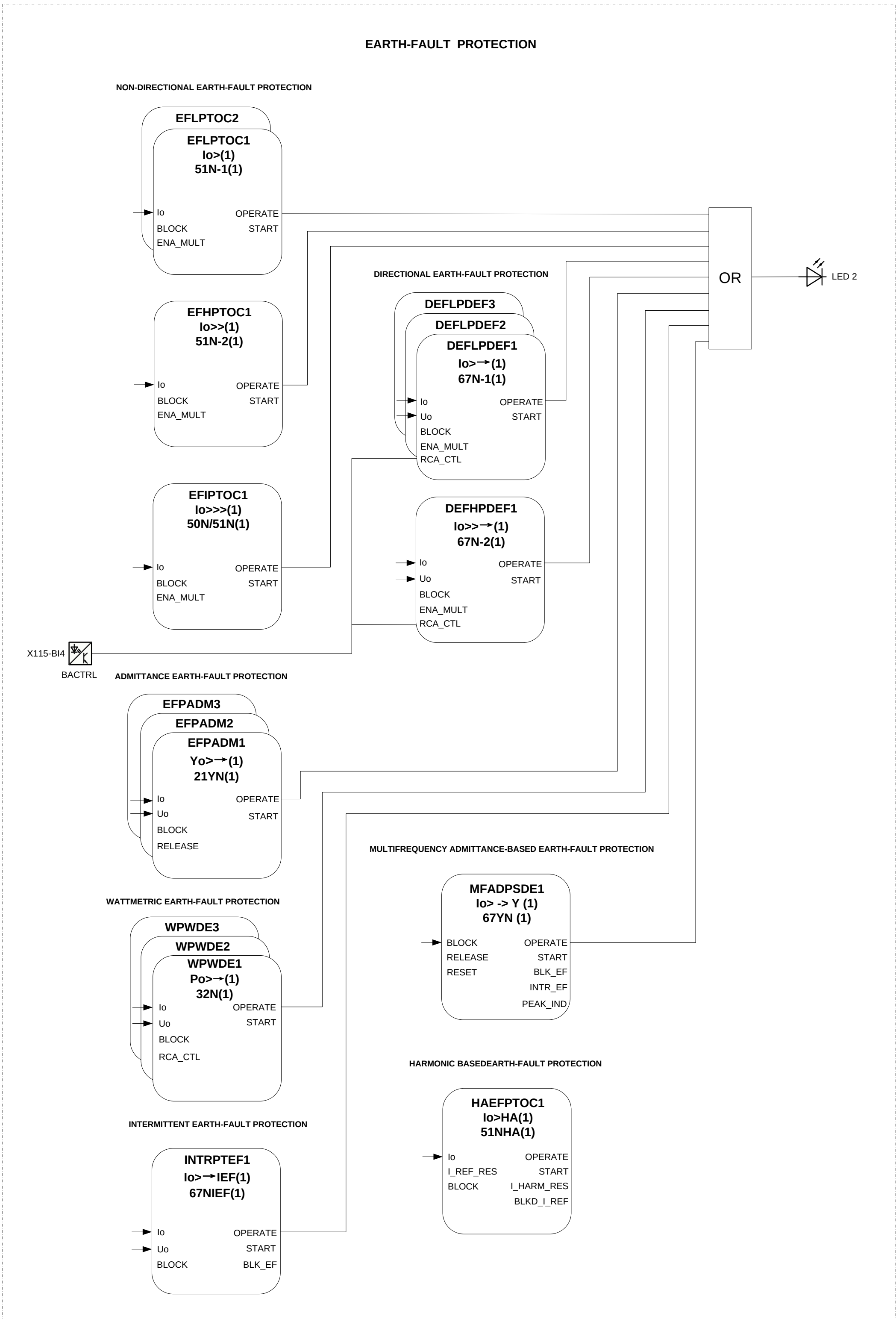


Figure 23: Earth-fault protection

Eight stages in total are offered for earth-fault protection. Four stages are directional functionality DEFxPDEF, while the others are only for non-directional earth-fault protection EFxPTOC. The directional earth-fault protection method can be achieved by using conventional directional earth fault DEFxPDEF or with admittance-based EFPADM1...3 or wattmetric earth-fault protection WPWDE1...3. In addition, there is a dedicated protection stage INTRPTEF1 either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks. A multifrequency neutral admittance earth-fault protection MFADPSDE1 is offered. The START and OPERATE outputs from this function are connected to disturbance recorder.

A harmonic-based earth-fault protection HAEFPTOC1 is offered. The `START` and `OPERATE` outputs from this function are connected to disturbance recorder, but this function is not configured to trip the circuit breaker by default.

The binary input X115-BI4 is intended for either directional earth-fault protection functions' relay characteristic angle (RCA: 0°/-90°) or operation mode (IoSinϕ/ IoCosϕ) change.

`OPERATE` outputs are connected to the Master Trip and alarm LED 2, except for those specially mentioned previously. LED 2 is used for earth-fault protection indication.

All of these functions are normally not used in the same application. Different functions have different suitability and operability in different electrical network types such as the earthed, isolated and compensated networks. Especially in some network types and applications the earth-fault currents are so small that they cannot be detected by the normal earth-fault protection functions. In these cases, it is recommended to use a hardware variant with a sensitive Io channel to better reach operational sensitivity for low earth-fault currents.

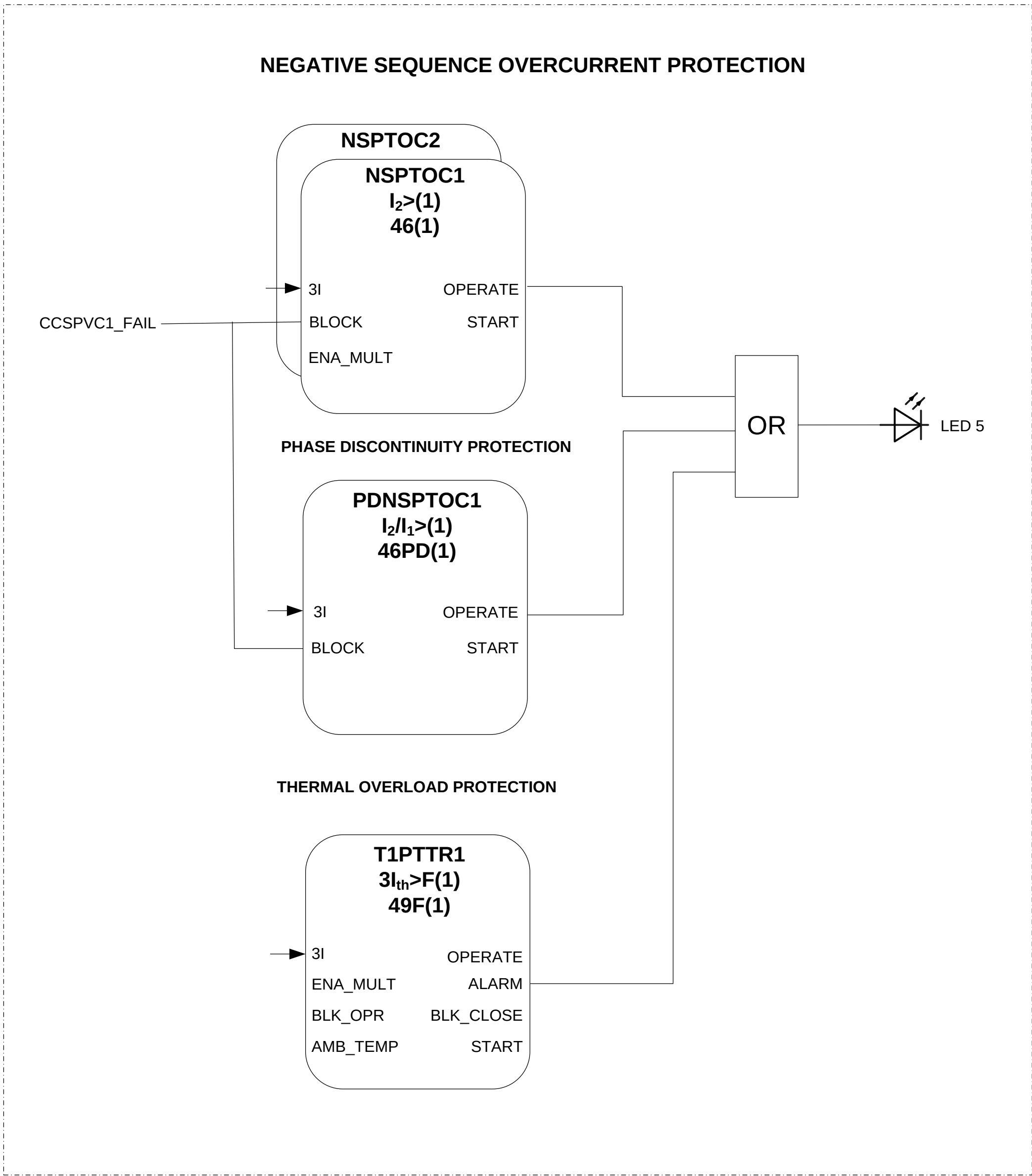


Figure 24: Negative-sequence current protection, phase discontinuity and thermal overload protection

Two negative sequence overcurrent instances NSPTOC1 and NSPTOC2 are offered for phase unbalance protection. A failure in the current measuring circuit is detected by the current circuit supervision function CCSPVC1 to avoid faulty tripping. The phase discontinuity protection PDNSTOC1 provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The thermal overload protection T1PTTR1 provides indication on overload situations.

The `OPERATE` outputs of NSPTOC1 and NSPTOC2 and PDNSPTOC1 are connected to the Master Trip and alarm LED 5. The `ALARM` output of T1PTTR1 is also connected to LED 5. LED 5 is used for unbalance protection and thermal overload protection alarm indication.

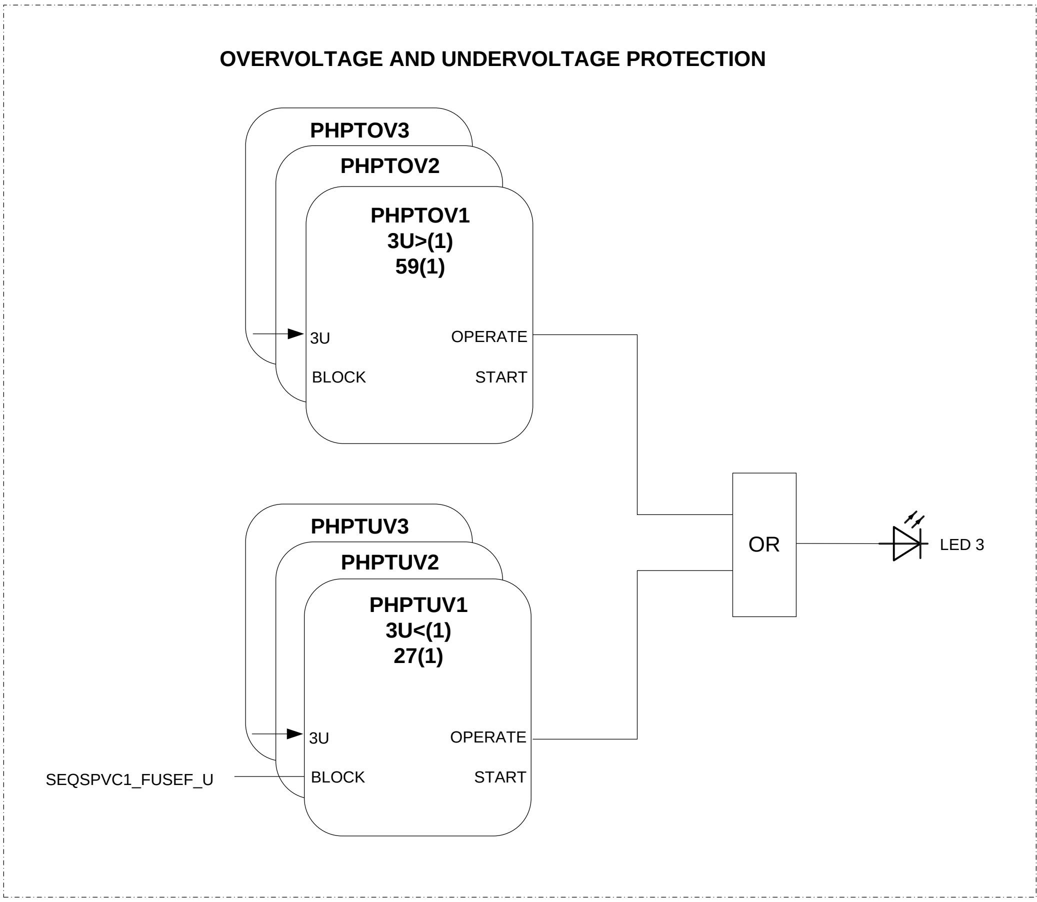


Figure 25: Overvoltage and undervoltage protection

Three instances of overvoltage protection PHPTOV1…3 and undervoltage protection PHPTUV1…3 offer protection against abnormal phase voltage conditions. A failure in the voltage-measuring circuit is detected by the fuse failure function SEQSPVC, and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

The `OPERATE` outputs of voltage functions are connected to alarm LED 3. LED 3 is used for combined voltage protection alarm indication.

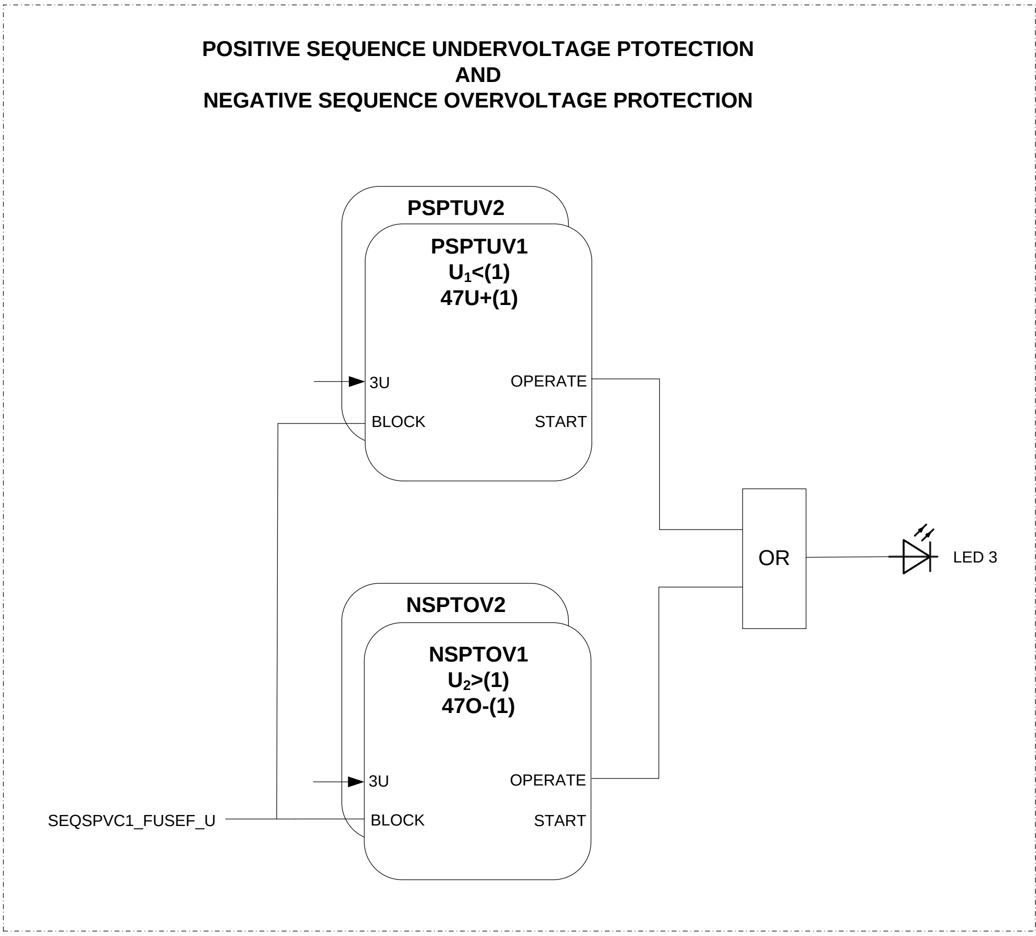


Figure 26: Positive-sequence undervoltage and negative-sequence overvoltage protection

Positive-sequence undervoltage PSPTUV1 and PSPTUV2 and negative-sequence overvoltage NSPTOV1 and NSPTOV2 protection functions enable a voltage-based unbalance protection. A failure in the voltage-measuring circuit is detected by the fuse failure function SEQSPVC. The activation is connected to the positive-sequence undervoltage PSPTUV1 and PSPTUV2 and negative-sequence overvoltage NSPTOV1 and NSPTOV2 protection functions to avoid faulty tripping.

The `OPERATE` outputs of the voltage-sequence functions are also connected to alarm LED 3.

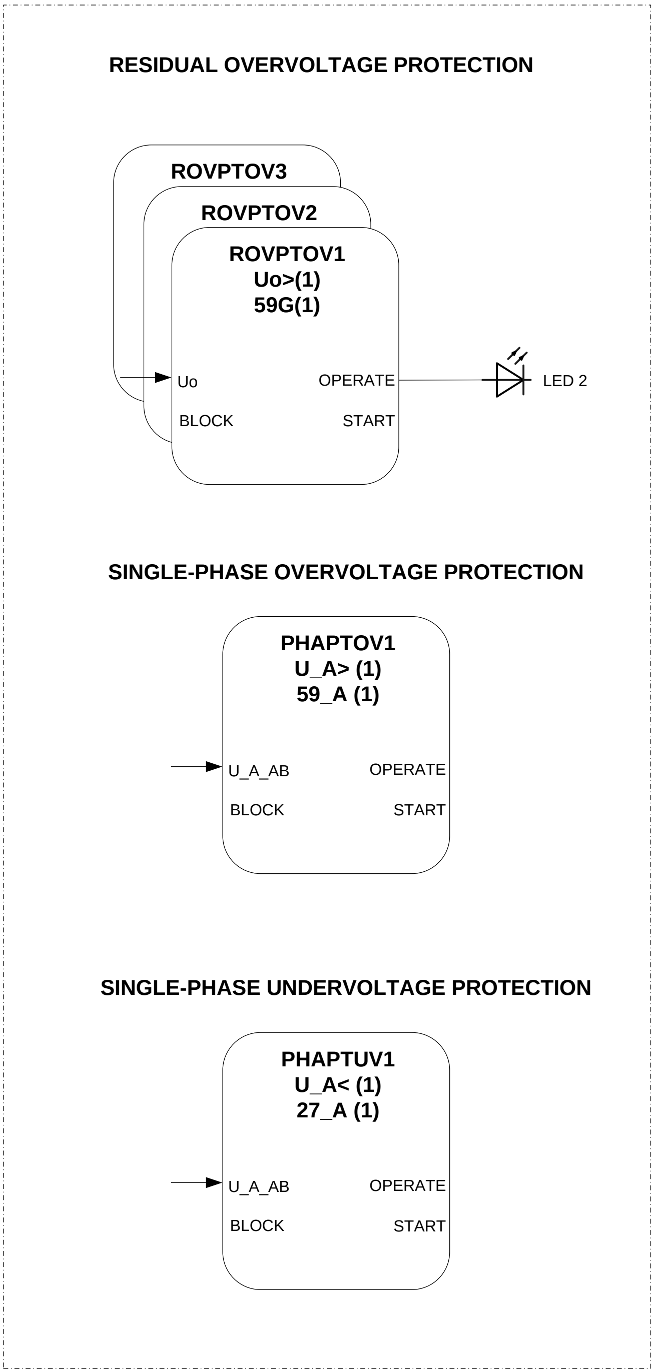


Figure 27: Residual overvoltage protection

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 nonselective backup protection for the selective directional earth-fault functionality. The OPERATE outputs are connected to the Master Trip and alarm LED 2.

The single-phase overvoltage protection PHAPTOV1 and single-phase undervoltage protection PHAPTUV1 are used for voltage protection by using the measured voltage from extra single phase/phase-to-phase voltage channel. These functions are not connected to disturbance recorder and not configured to trip the circuit breaker by default.

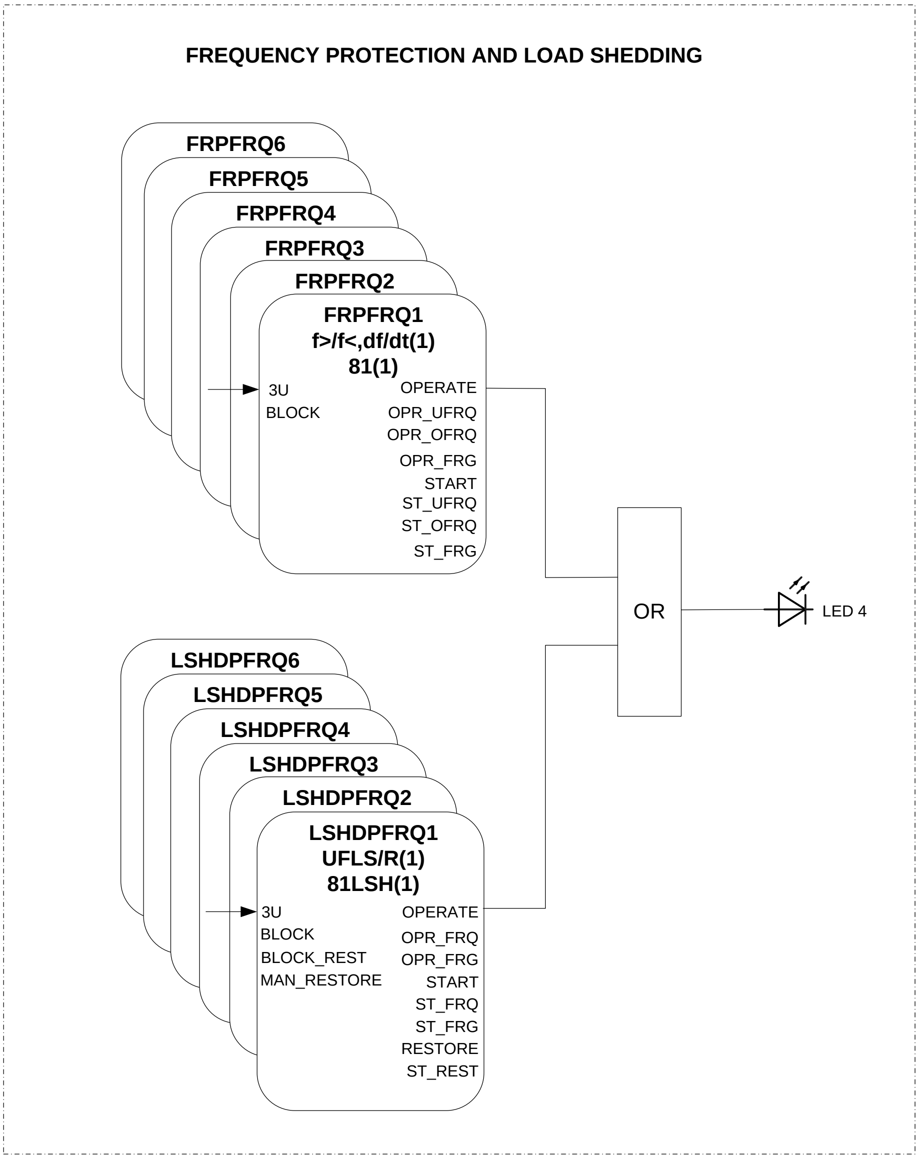


Figure 28: Frequency and load-shedding protection

Six instances of frequency protection FRPFRQ1…6 are offered to prevent damage to the 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 alarm LED 4. LED 4 is used for frequency protection operating indication.

Six load-shedding and restoration protection LSHDPFRQ1…6 stages are offered in the default configuration. The load-shedding and restoration function is capable of shedding the load based on underfrequency and the rate of change of the frequency. The load that is shed during frequency disturbance can be restored once the frequency is stabilized to the normal level. Also manual restoring commands can be given via binary inputs, but by default, they are not connected. The OPERATE outputs are also connected to the alarm LED 4.

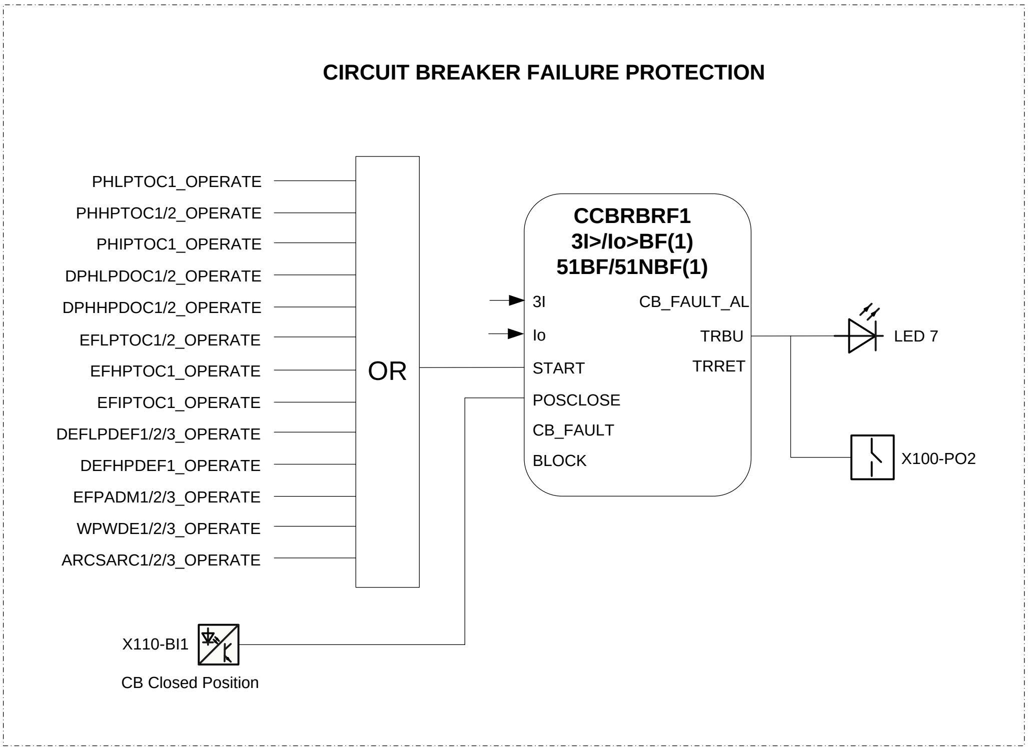


Figure 29: Circuit breaker failure protection

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 2. 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) operating indication.

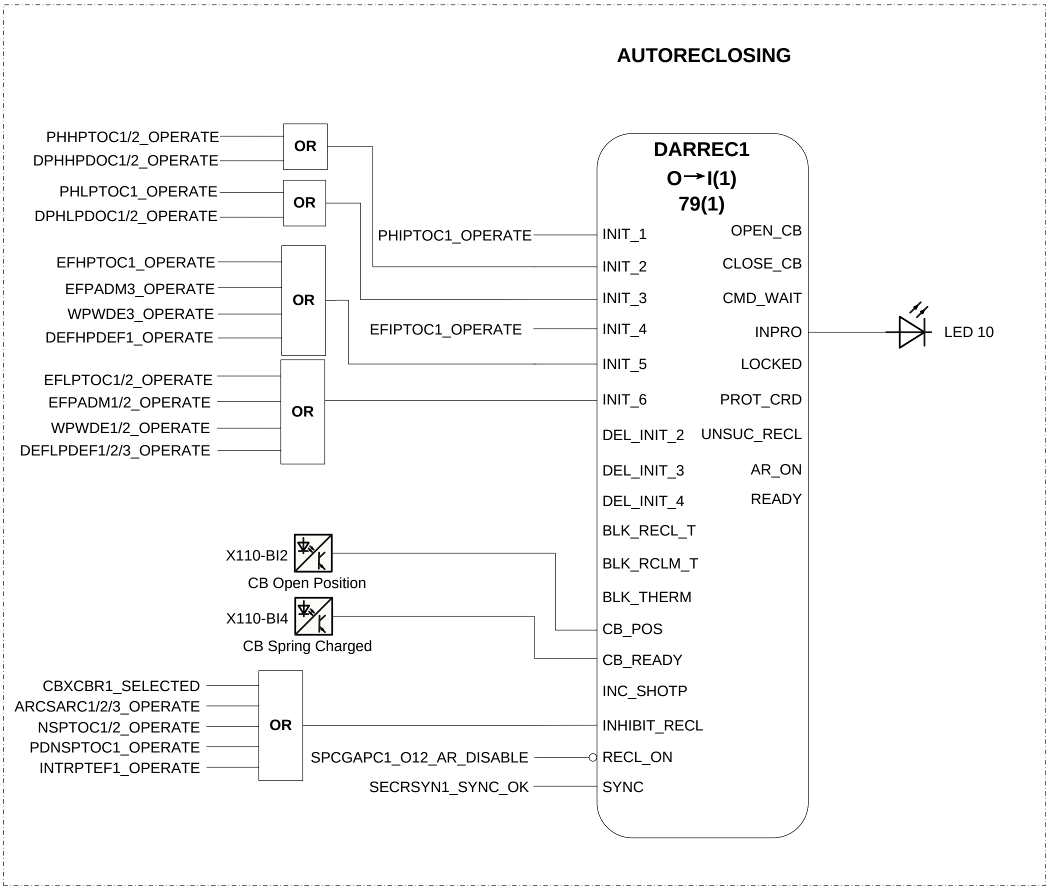


Figure 30: Autoreclosing

The autoreclosing function is configured to be initiated by the operating signals from a number of protection stages through the INIT_1...6. It is possible to create individual autoreclosing sequences for each input.

The autoreclosing function can be blocked with the `INHIBIT_RECL` input. By default, the operations of the selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclosing function via the CBXCBR1_SELECTED signal.

The autoreclosing function could be disabled with one push button through SPCGAPC1_O12, which is connected to the `RECL_ON` input of DARREC1.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1. In the default configuration, this signal is connected to CB spring charged binary input X110-BI4. As a result, the function is available only when CB spring is charged.

The autoreclosing sequence in progress indication INPRO is connected to the alarm LED 10.

Set parameters for the DARREC1 function.

Check the initialization signals of DARREC1.

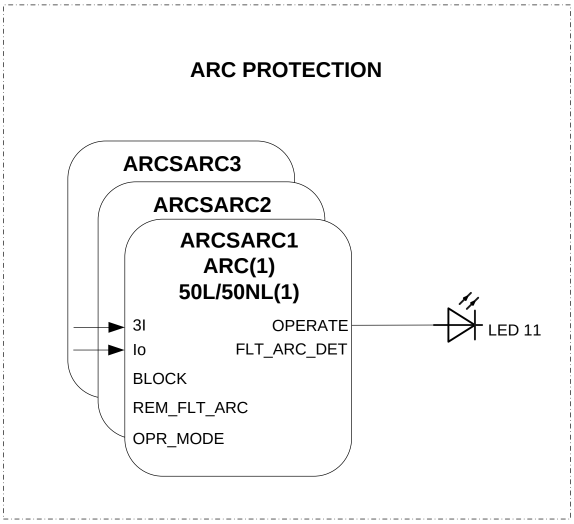


Figure 31: Arc protection

Arc protection ARCSARC1...3 is included as an optional function in this configuration.

The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes that is, with or without 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

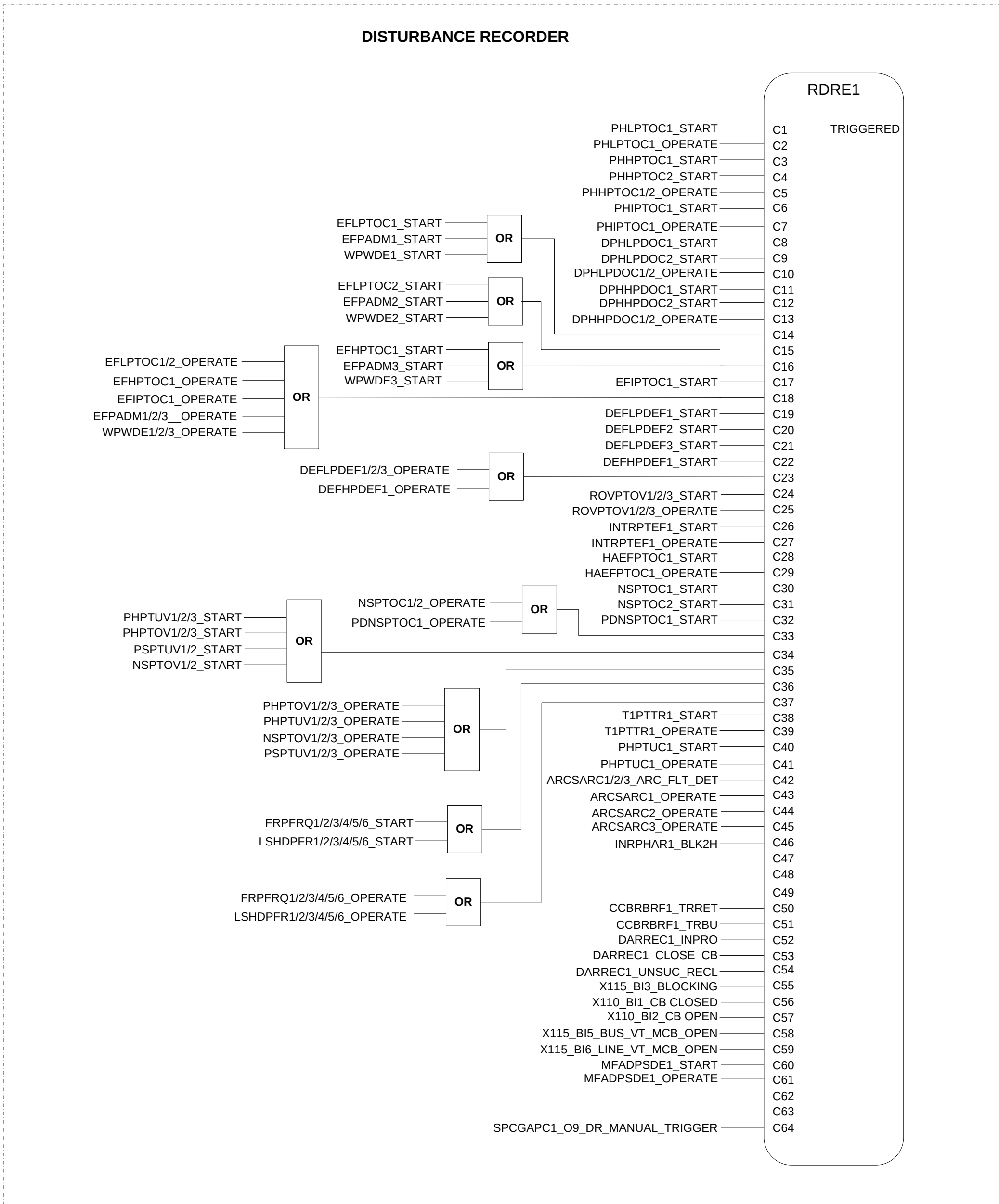


Figure 32: Disturbance recorder

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 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, make the changes to the parameter setting tool.

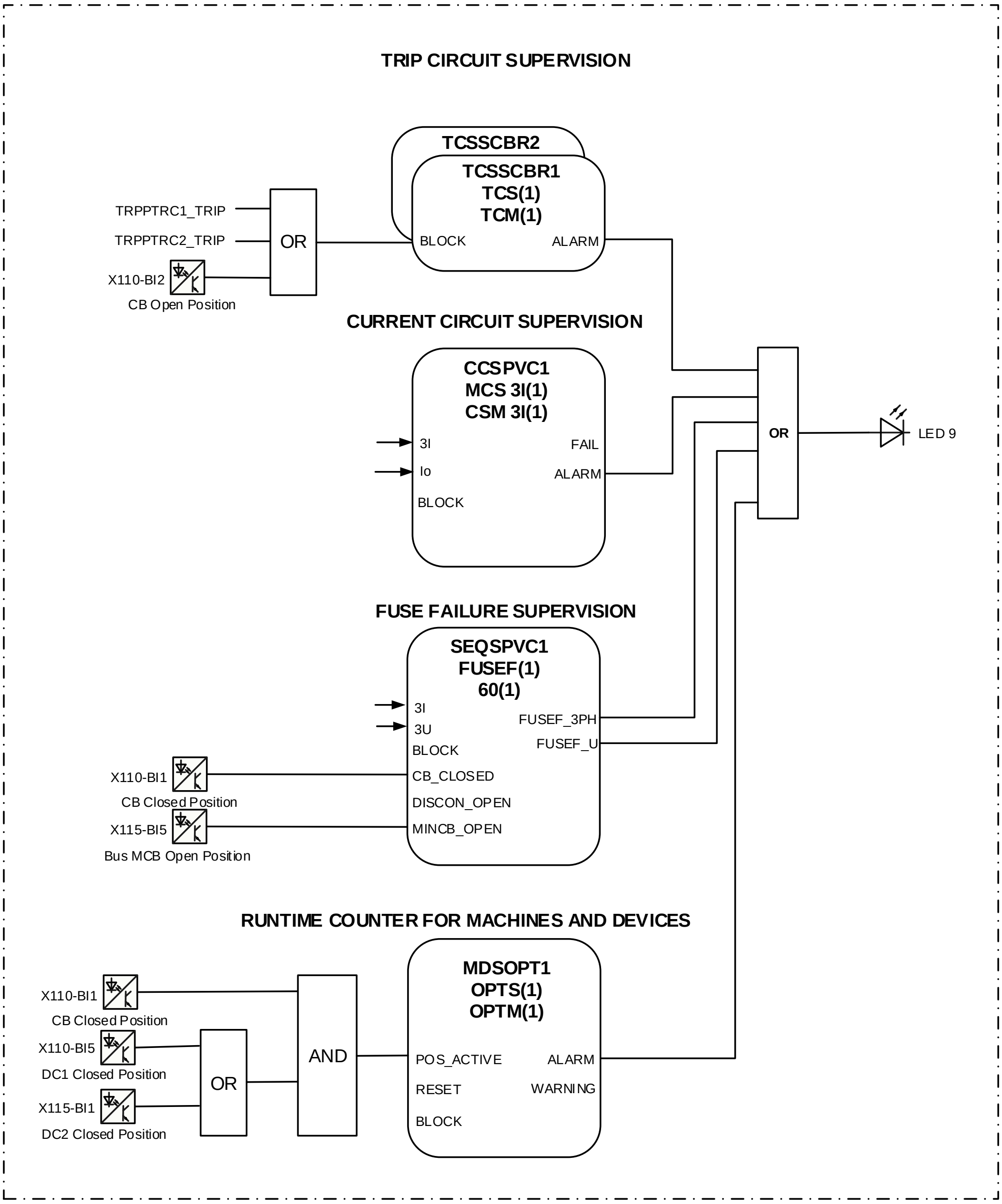


Figure 33: Circuit supervision

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

The relay can also be engineered to operate with different TCS circuits where TCS supervision also works when the CB is open.

Set the parameters for TCSSCBR1 properly.

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. When a failure is detected, blocking signal is activated in voltage protection functions that are measuring calculated sequence component voltages, undervoltage protection and synchro-check, and unnecessary operation can be avoided.

3.5.3.3 Functional diagrams for control and interlocking

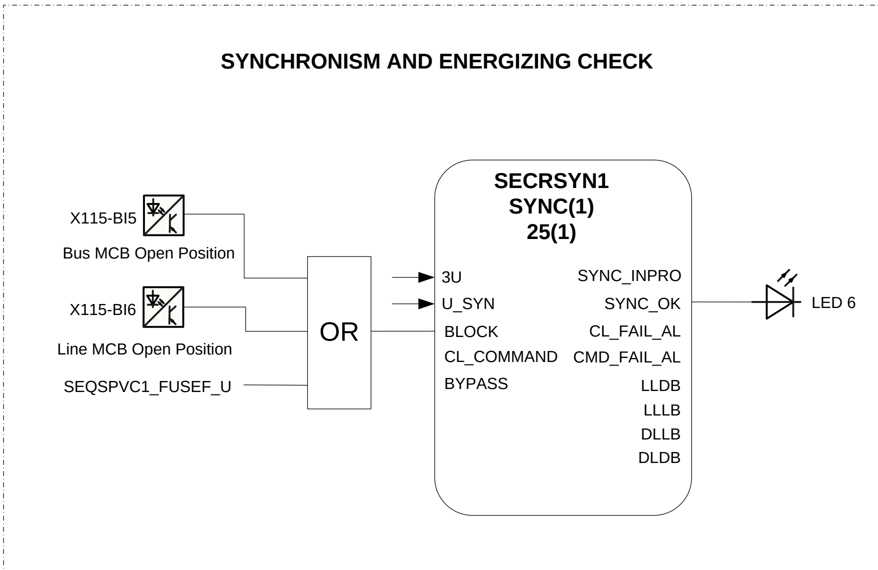


Figure 34: Synchronism and energizing check

The main purpose of the synchronism and energizing check SECRSYN1 is to provide control over the closing of the circuit breakers in power networks to prevent the closing if the conditions for synchronism are not fulfilled.

SECRSYN1 measures the bus and line voltages and compares them to the set conditions. When all the measured quantities are within set limits, the output `SYNC_OK` is activated for allowing closing or closing the circuit breaker. The `SYNC_OK` output signal is connected to the `ENA_CLOSE` input of CBXCBR1 through control logic and also to the alarm LED 6. The colors of LED 6 indicate the status of `SYNC_OK`. If `SYNC_OK` is true, LED 6 is green, and if `SYNC_OK` is false, LED 6 is red.

To ensure the validity of the measured voltages on both sides, Bus MCB Open Position (X115-BI5), Line MCB Open Position (X115-BI6) and SEQSPVC1_FUSEF_U are connected to block SECRSYN1.

SECRSYN can be set to the bypass mode by setting the parameters Synchro check mode and Energizing check mode to "Off" or alternatively, by activating the `BYPASS` input. In the bypass mode, the closing conditions are always considered to be fulfilled by SECRSYN function.

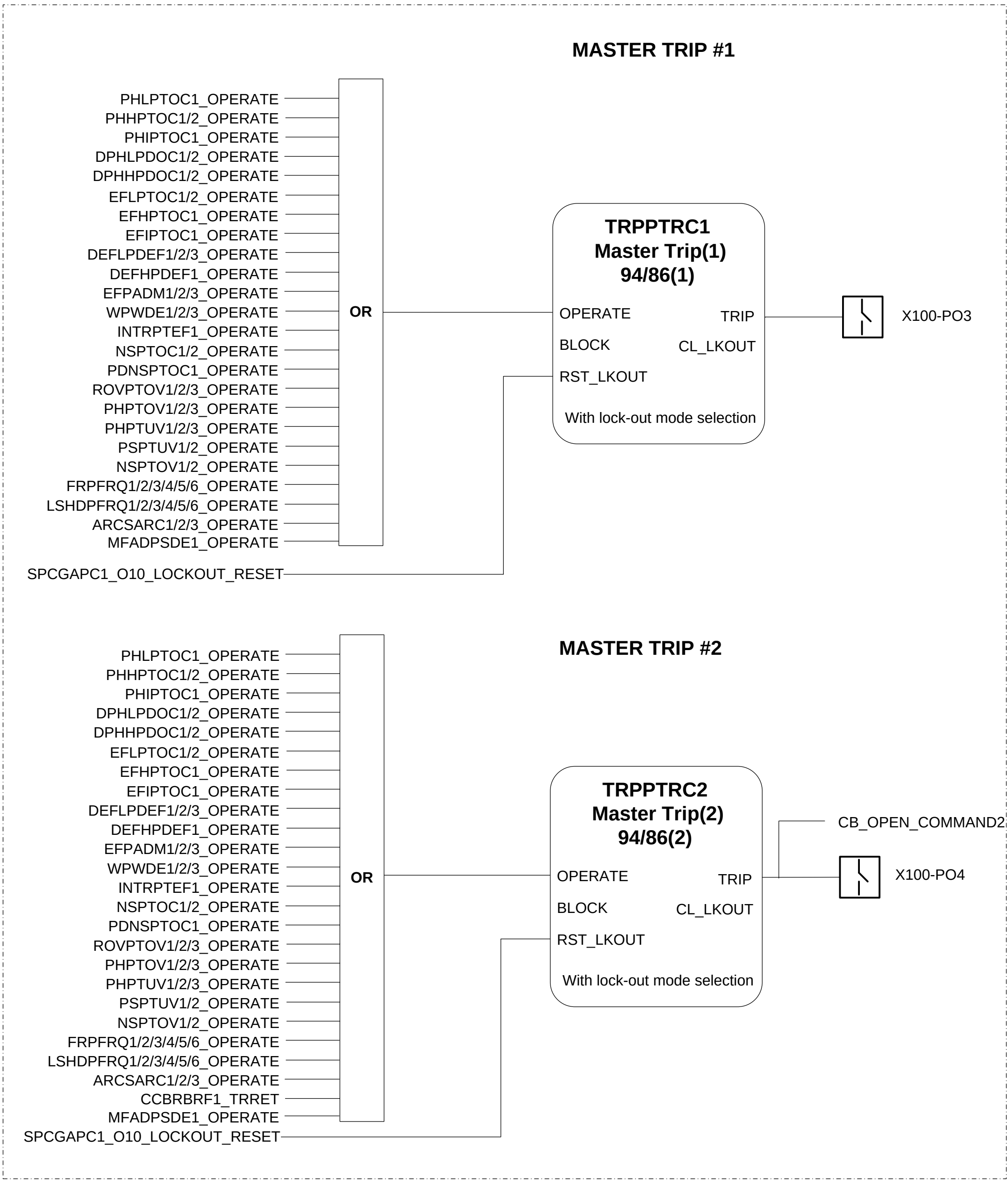


Figure 35: Master trip

The operating signals from the protections are connected to the two trip output contacts, power output X100-PO3 and power output X100-PO4, via the corresponding Master Trips TRPPTRC1 and TRPPTRC2.

TRPPTRC1 and TRPPTRC2 provide lockout/latching function, event generation and trip signal duration setting. If the lockout operation mode is selected, one push button can be used to reset the lockout through SPCGAPC1_O10.

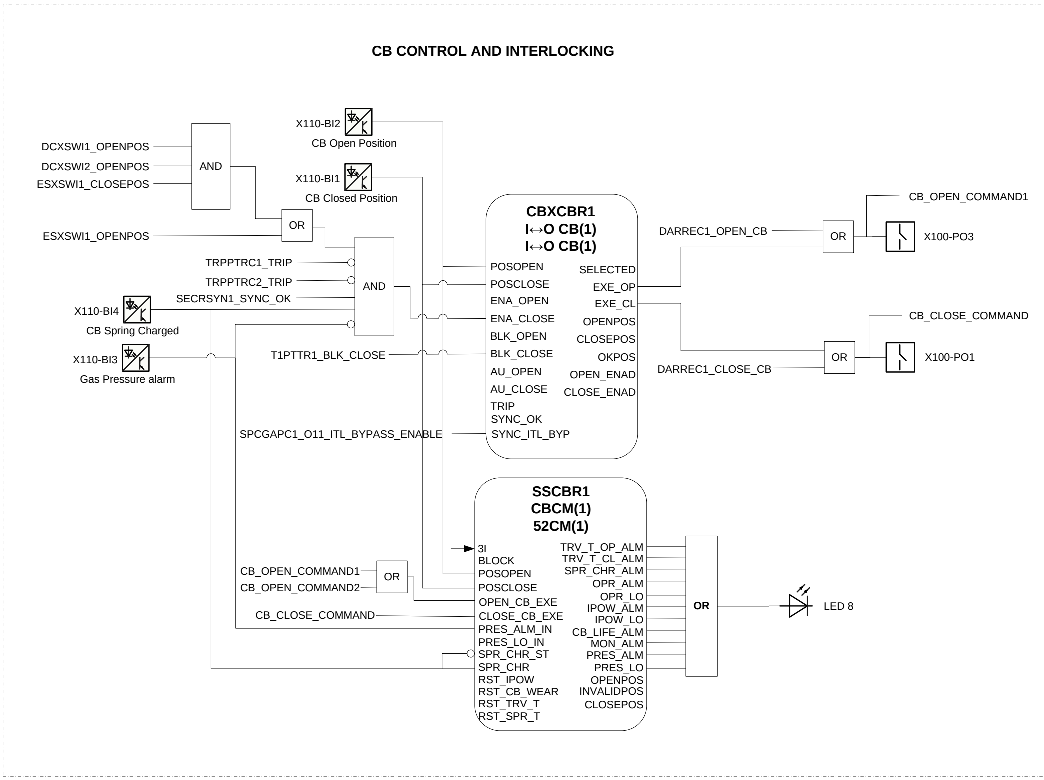


Figure 36: Circuit breaker control and interlocking

The circuit breaker opening is enabled when the ENA_OPEN is activated, but blocked when BLK_OPEN is activated. The CB opening is always allowed because by default ENA_OPEN is activated and BLK_OPEN is deactivated when they are left unconnected.

The circuit breaker closing is enabled when the `ENA_CLOSE` input is activated, and this input is activated when four conditions are met.

- The CB condition check is OK (CB spring is charged, no gas pressure alarm)
- The synchronism/energizing check is OK
- There are no active control trip signals
- The position status check for the related primary equipment is OK meaning that either the earthing switch is open or both disconnectors are open when the earthing switch is closed

The circuit breaker closing is blocked when `BLK_CLOSE` input is activated. This input is activated when the `BLK_CLOSE` output of T1PTTR1 is active.

One push button can be used through SPCGAPC1_O11, which is connected to the `SYNC_ITL_BYP` input of CBXCBR1 to ignore the status of the `ENA_CLOSE` input. However, the BLK_CLOSE input signals are 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-closing commands are allowed continuously.

The relay also includes two extra CB control blocks, with related CB condition monitoring, though they are not used in the default configuration. Those extra instances use the same measurement values as the first instances.

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

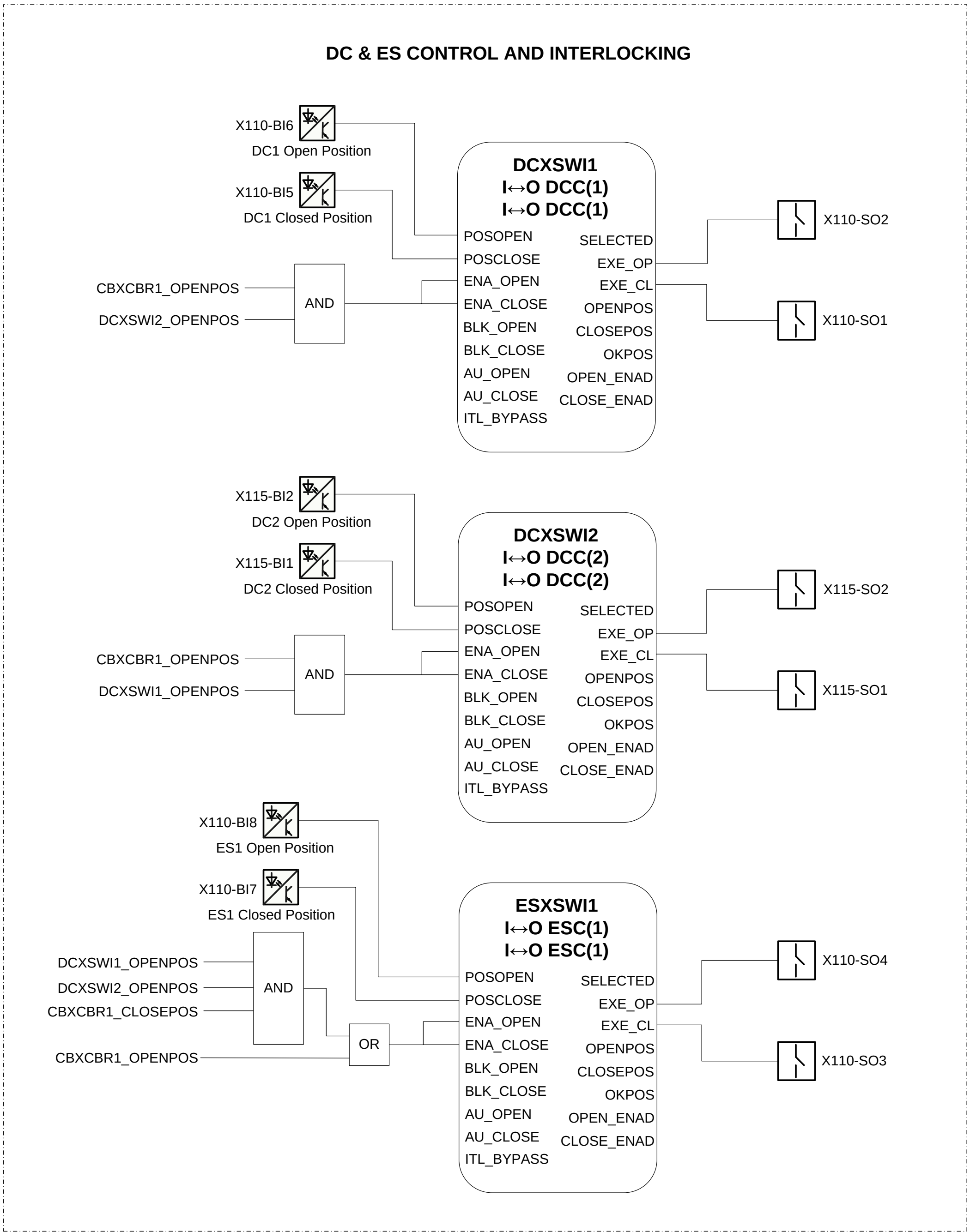


Figure 37: Disconnector and earthing switch control and interlocking

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

The binary inputs 5 and 6 of the card X110 are used for the busbar disconnector 1 (DCXSWI1) position indication. The binary inputs 1 and 2 of the card X115 are used for the busbar disconnector 2 (DCXSWI2) position indication.

Table 19: Disconnector 1 position indicated by binary inputs

Primary device position	Input to be energized	
	X110-BI5	X110-BI6
Busbar disconnector 1 closed	x	
Busbar disconnector 1 open		x

Table 20: Disconnector 2 position indicated by binary inputs

Primary device position	Input to be energized	
	X115-BI1	X115-BI2
Busbar disconnector 2 closed	x	
Busbar disconnector 2 open		x

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	
	X110-BI7	X110-BI8
Earthing switch closed	x	
Earthing switch open		x

The control (opening or closing) of disconnector 1 and disconnector 2 is enabled only when both the circuit breaker and the other disconnector is in the open position.

The control (opening or closing) of the earthing switch is enabled under either of the two conditions:

- The circuit breaker is in the open position
- The circuit breaker is in the closed position, while both disconnector 1 and disconnector 2 are in the open position

With this simplified default disconnector control logic, the busbar is transferred by opening the circuit breaker first. In a normal double-busbar system, the busbar is transferred without a power supply break.

Cooperation is needed on the bus coupler bay to support live busbar transfer, so necessary information exchange between different bays and bus coupler bay is also required. The control logic for disconnector 1 and disconnector 2 mentioned earlier needs to be revised accordingly. The information exchange can be done either with binary inputs or through a GOOSE message.

The general rule for live busbar transfer is to have the two busbars interconnected, as shown in *Figure 38*. The outgoing feeder has been connected to busbar I. Under this condition, DC11 and CB1 are closed while DC12 is open. The busbar coupler bay apparatuses (DC21, DC22 and CB2) are also open.

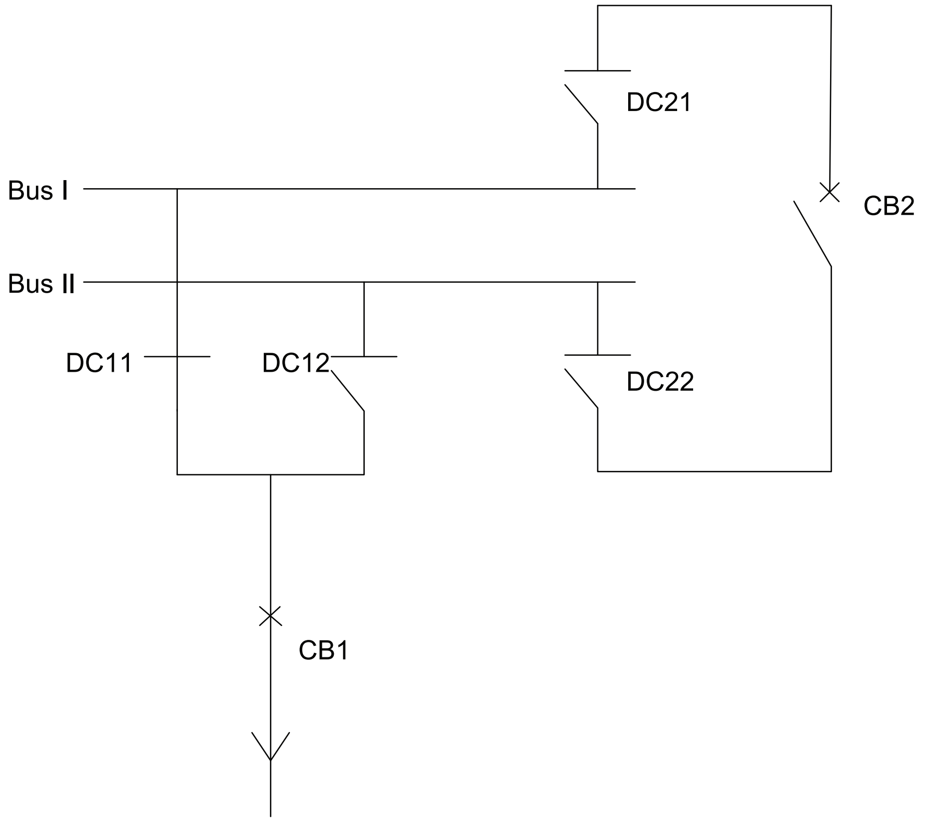


Figure 38: Disconnector control logic

There are four general steps to transfer the power supply from busbar I to busbar II.

1. DC21, DC2 and CB2 in the bus coupler bay have to be closed to have busbar I and busbar II connected.
2. DC12 has to be closed to have the feeder connected to busbar II.
3. DC11 has to opened to disconnect the feeder from busbar I.
4. CB2, DC21 and DC22 have to be opened to disconnect the two busbars. This transfers the load of the outgoing feeder to busbar II.

These four steps assure that there is no power supply interruption on the feeder. After step 1, the two busbars are connected to ensure that the operation on DC12 and DC11, in steps 2 and 3, is safe.

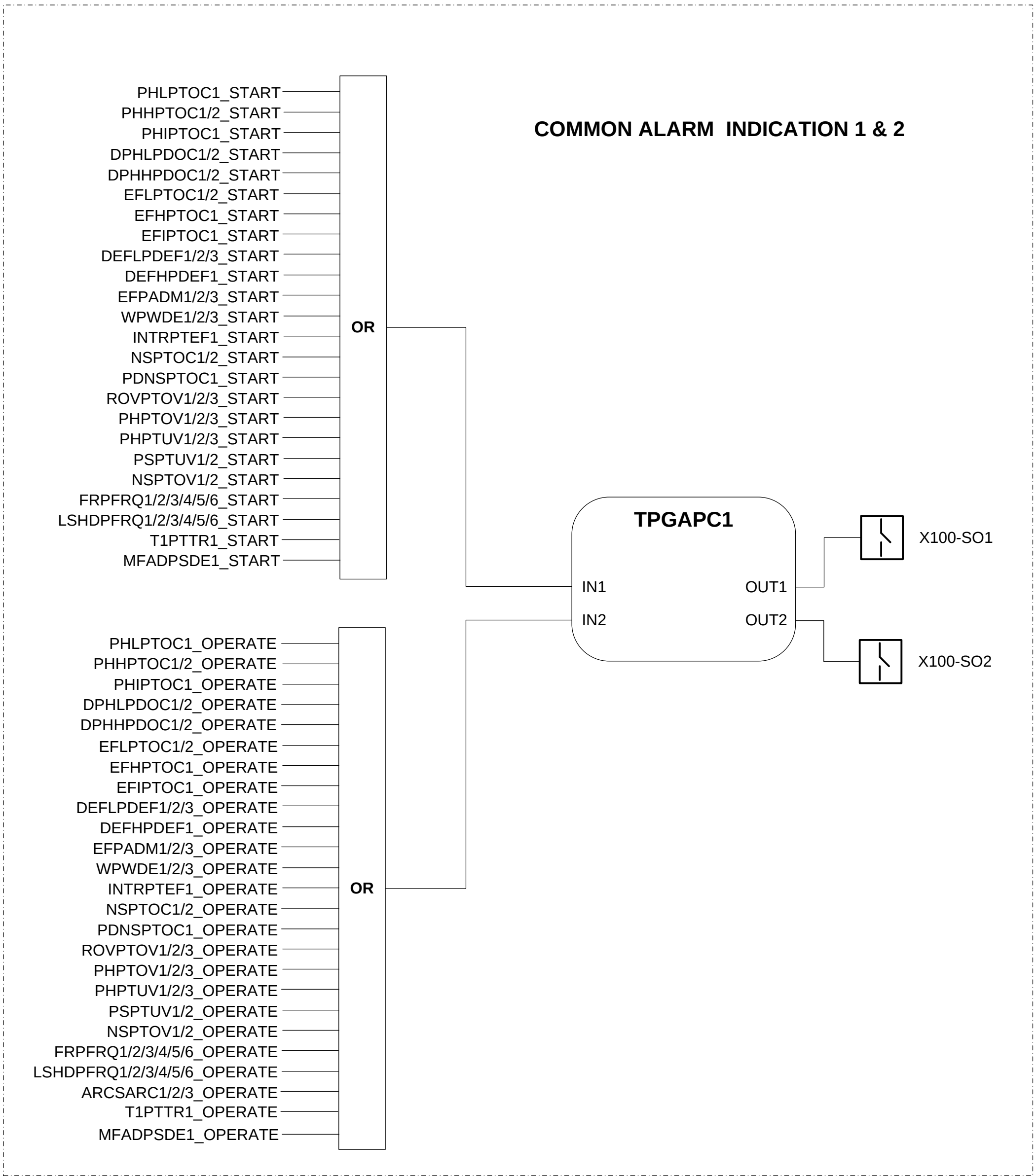


Figure 39: Common alarm indication

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

- 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

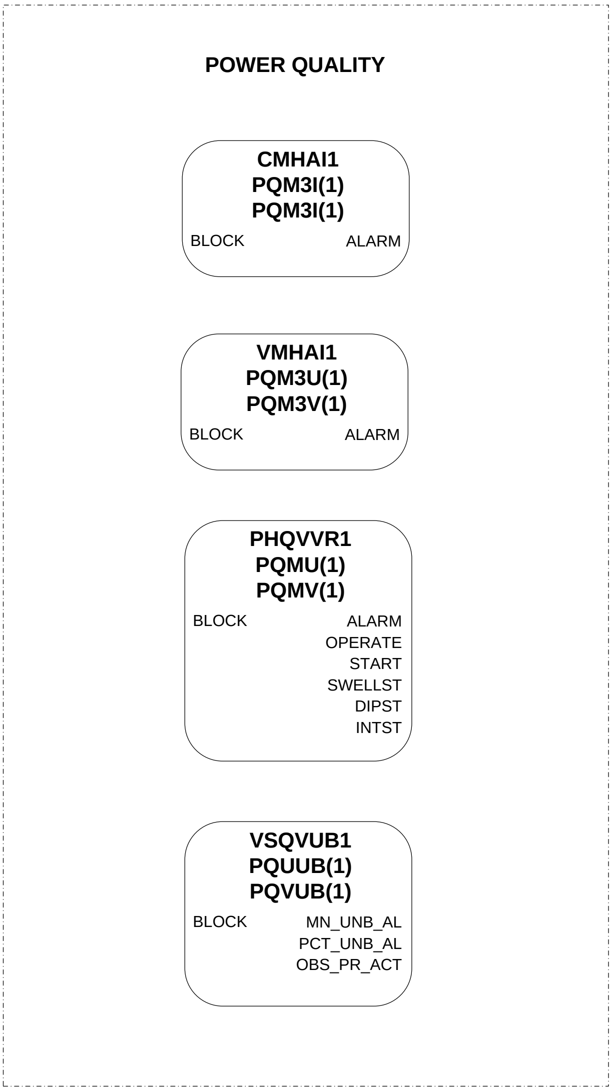


Figure 40: Power quality measurement function

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

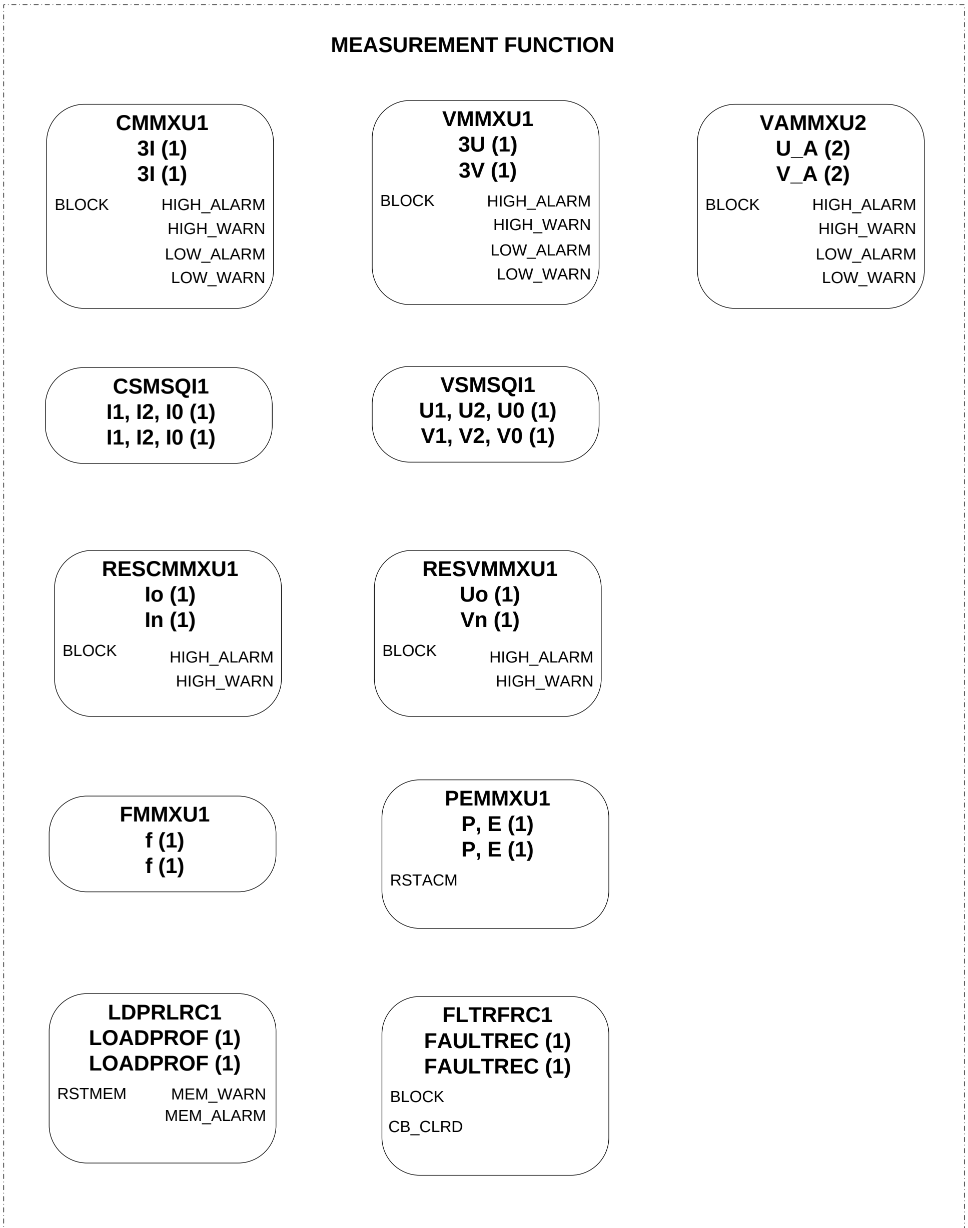


Figure 41: Measurement function

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

The three-phase bus side phase voltage inputs to the relay are measured by the threephase 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 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. These functions can be engineered into use.

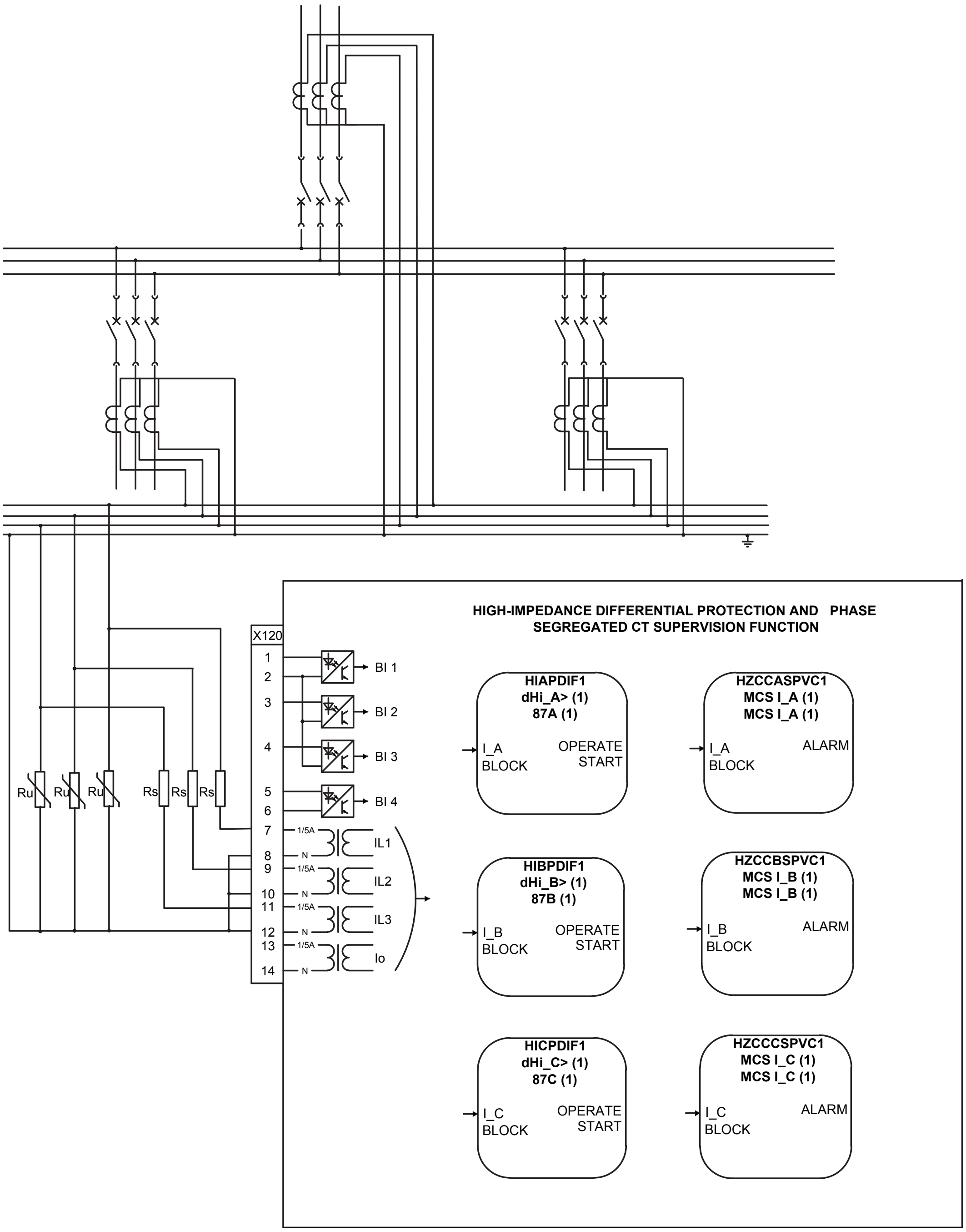


Figure 42: High-impedance differential protection and segregated CT supervision function

Three high-impedance differential protection instances are offered. HIPDIF1 is for phase A, HIPDIF2 is for phase B, and HIPDIF3 is for phase C.

Three phase-segregated current transformer supervision instances are offered. HZCCASPVC1 is for phase A, HZCCBSPVC1 is for phase B, and HZCCCSPVC1 is for phase C.

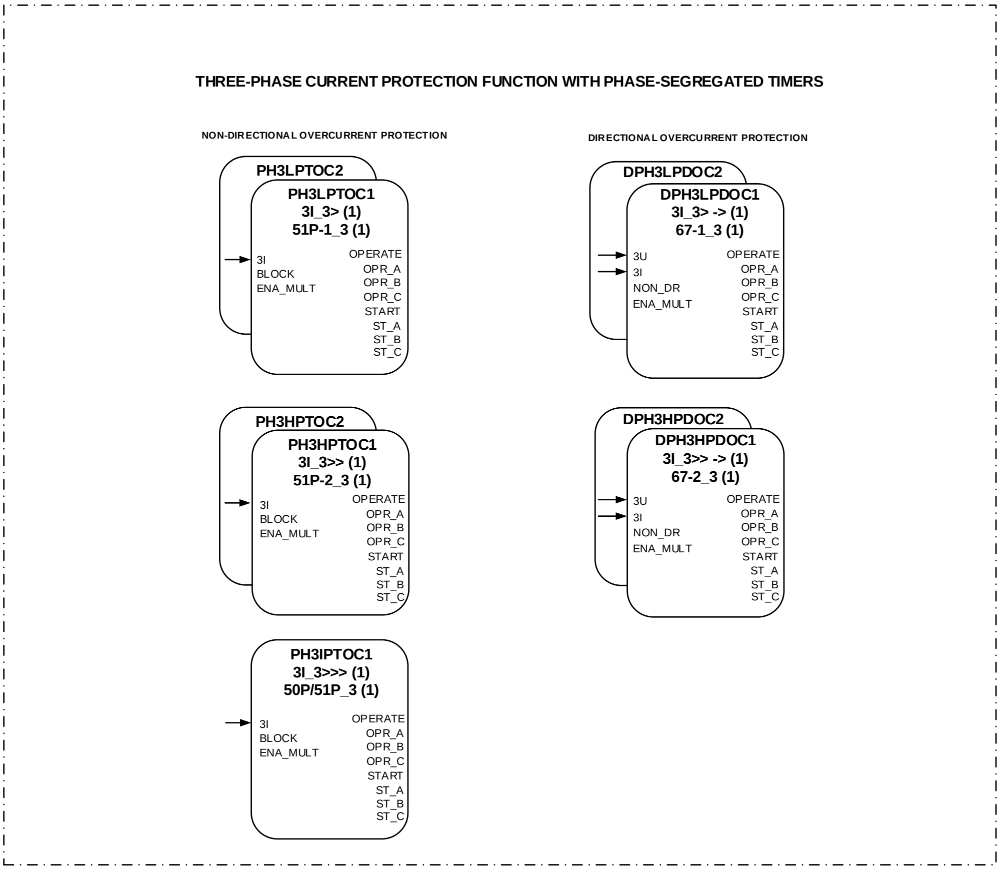


Figure 43: Three-phase current protection function with phase-segregated timers

Nine overcurrent stages in total are offered for overcurrent and short circuit protection. Four stages are directional functionality DPH3xPDOC, while the others are only for non-directional overcurrent protection PH3xPTOC.

The function design contains three independent phase-segregated timers that are controlled by common settings. Those functions have separate timers for each phase, which is useful in some applications. Common `START` and `OPERATE` outputs are created by ORing the phase-specific start and operating outputs. Each phase has its own phase-specific start and operating outputs `ST_A, ST_B, ST_C`, `OPR_A`, `OPR_B` and `OPR_C`.

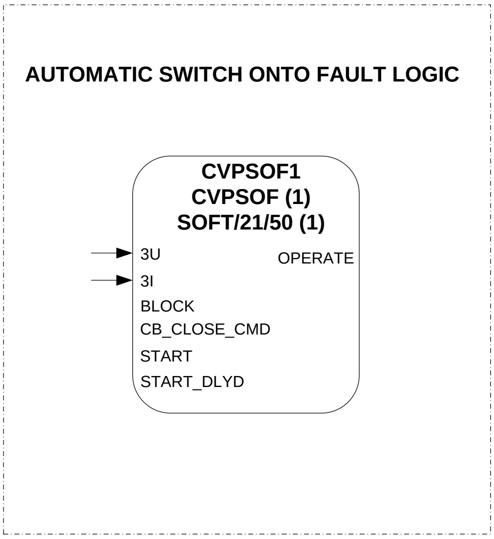


Figure 44: Automatic switch onto fault logic

One automatic switch onto fault logic is offered. CVPSOF1 is used as a complement to instantaneous and high stage overcurrent protection to accelerate the operation of the protection, ensuring a fast trip when the breaker is closed during a fault.

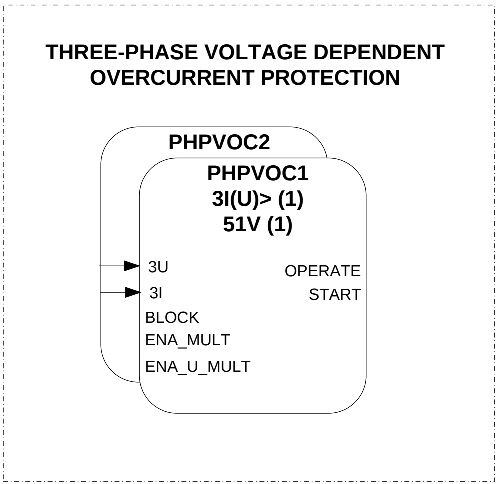


Figure 45: Three-phase voltage dependent overcurrent protection

Two instances of voltage-dependent overcurrent protection PHPVOC1 and PHPVOC2 are provided which can be used as a backup protection against phase faults. During certain conditions, the fault current for three-phase faults may be less than full load current of the feeder. This may not get noticed by phase overcurrent protection, but the fault causes feeder terminal voltage to drop. Voltage-dependent overcurrent protection can be used to detect and operate such faults.

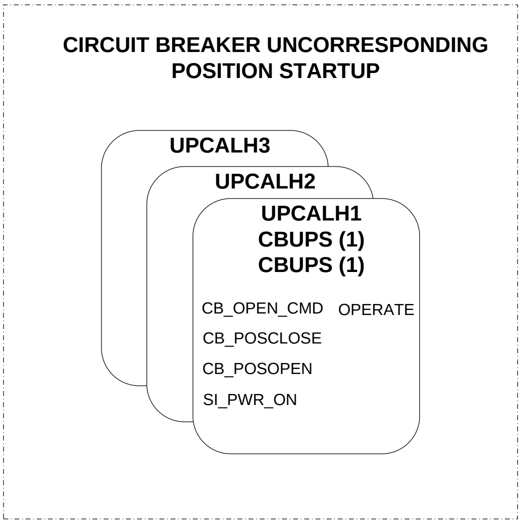


Figure 46: Circuit breaker uncorresponding position startup function

Three instances of circuit breaker uncorresponding position start-up UPCALH1…3 are provided. This function detects circuit breaker openings in unknown situations. UPCALH can be used independently. When detecting a circuit breaker opening under unknown situation, the function output is activated.

In most cases, the function module is used together with the autoreclosing function module, the operate output signal can be one of the start-up signals of the autoreclosing function.

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.

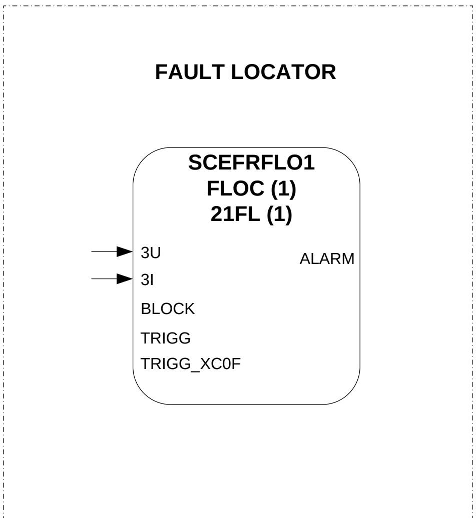


Figure 47: Fault locator function

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

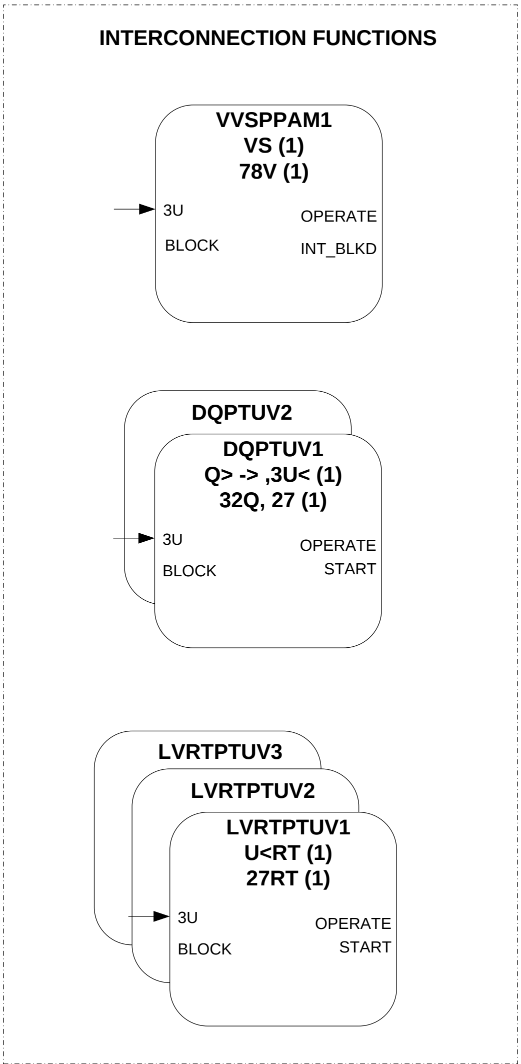


Figure 48: Interconnection function

Interconnection protection functions include the voltage vector shift protection VVSPPAM1, 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.

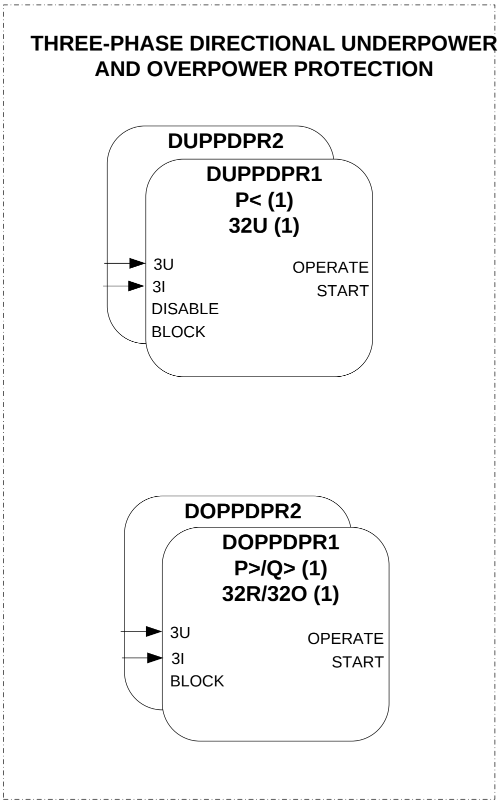


Figure 49: Three-phase directional underpower and overpower protection function

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

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

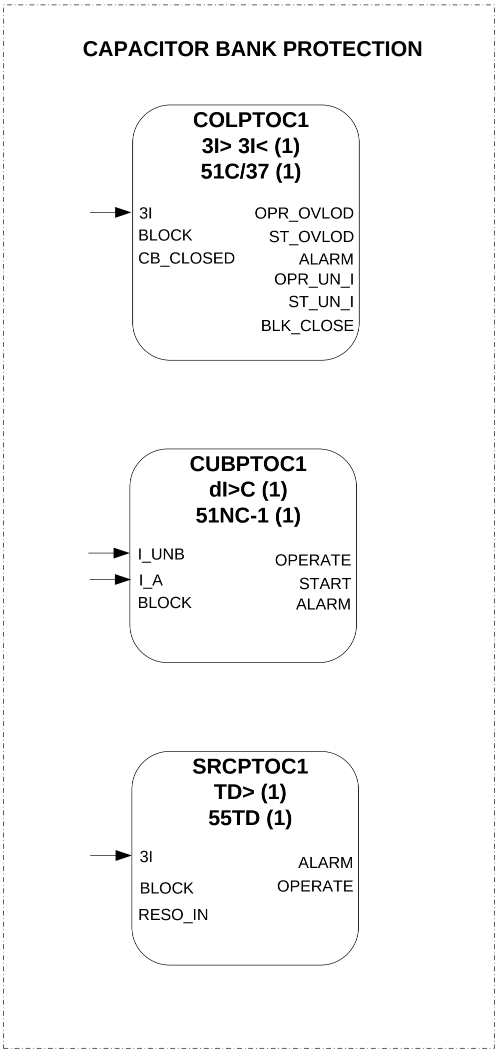


Figure 50: Capacitor bank protection function

The functionality can be used to protect single star capacitor banks or double star capacitor banks with an isolated or compensated neutral.

The three-phase overload protection for shunt capacitor banks COLPTOC1 provides protection against overloads caused due to harmonic currents and overvoltage in shunt capacitor banks. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

The three-phase current unbalance protection for shunt capacitor banks CUBPTOC1 is provided. It has been designed for double-Y type capacitor banks against internal faults. The function is suitable for protection of internally fused, externally fused and fuseless capacitor bank applications.

The shunt capacitor bank switching resonance protection, current based, SRCPTOC1 is used for three-phase resonance detection caused by capacitor switching or due to topology changes in the network.

3.5.4 Application configuration of the 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.

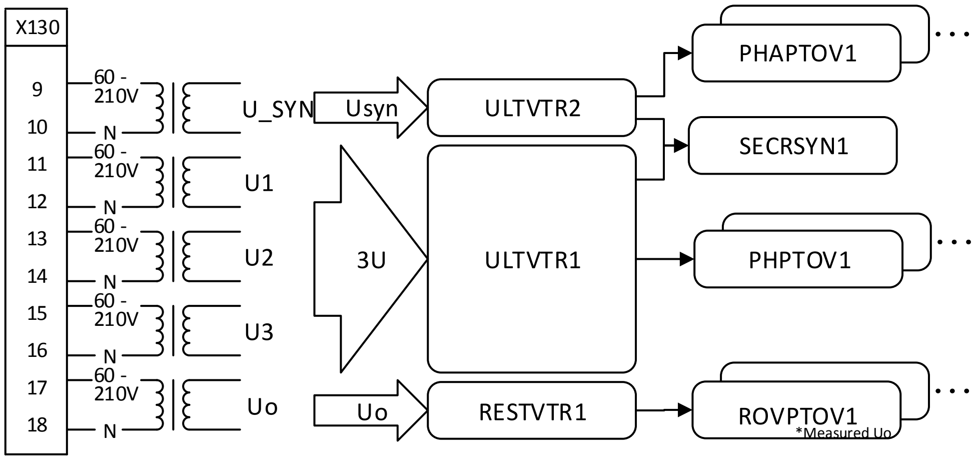


Figure 51: No SMV receiver configured

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.

3.5.4.1 Connection of SMVRCV to ULTVTR1

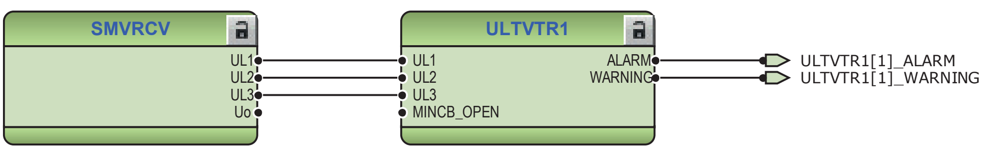


Figure 52: Connection of SMVRCV to ULTVTR1 in Application Configuration

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.

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”.

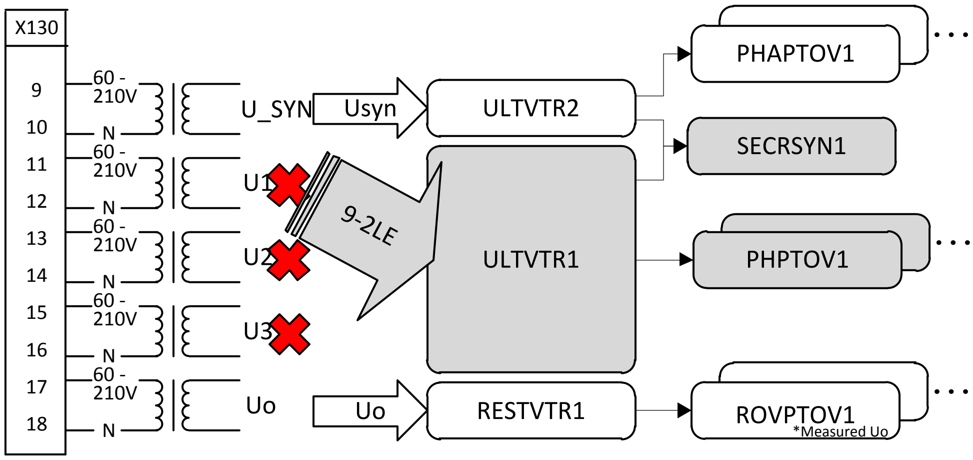


Figure 53: ULTVTR1 uses three phase voltages from received IEC 61850-9-2 LE sample value

3.5.4.2 Connection of SMVRCV to RESTVTR1

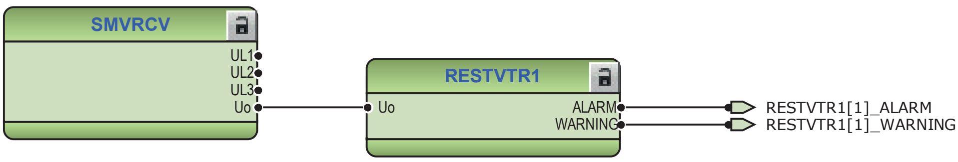


Figure 54: Connection of SMVRCV to RESTVTR1 in Application Configuration

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.

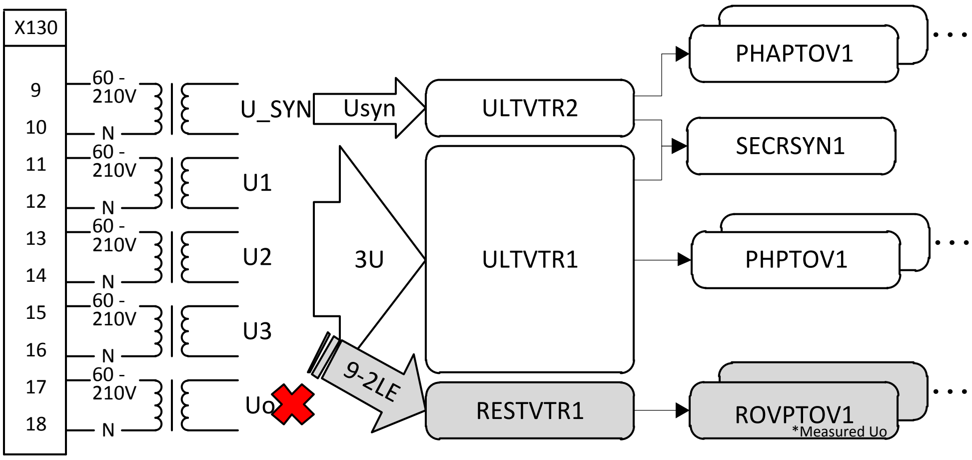


Figure 55: RESTVTR1 uses residual voltages from received IEC 61850-9-2 LE sample value

3.5.4.3 Connection of SMVRCV to both ULTVTR1 and RESTVTR1

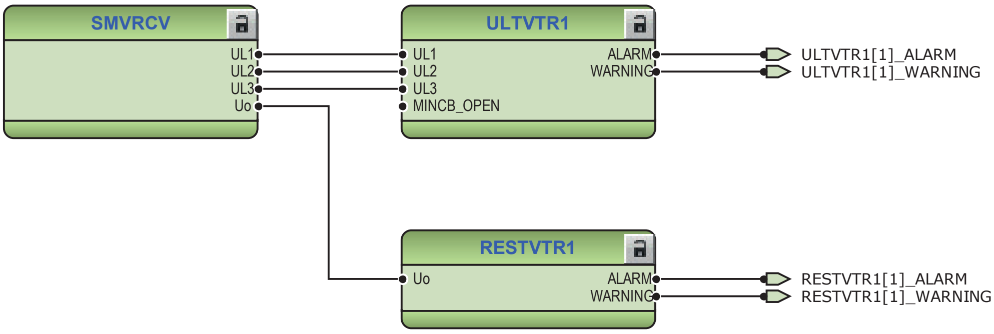


Figure 56: Connection of SMVRCV to both ULTVTR1 and RESTVTR1 in Application Configuration

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”.

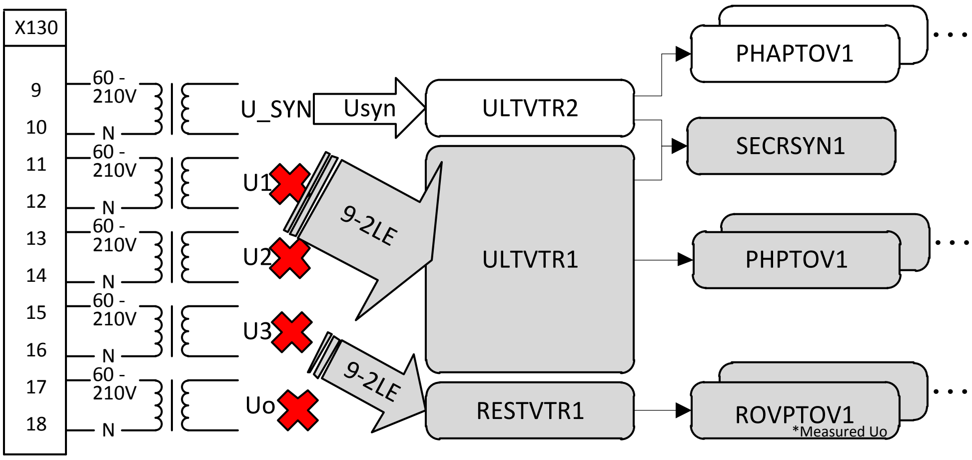


Figure 57: Both ULTVTR1 and RESTVTR1 use voltages from received IEC 61850-9-2 LE sample value

3.5.4.4 Connection of SMVRCV to ULTVTR2

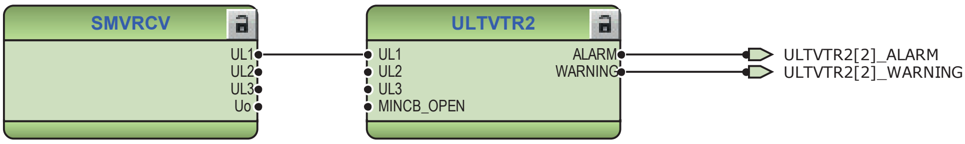


Figure 58: Connection of SMVRCV to ULTVTR2 in Application Configuration

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”.

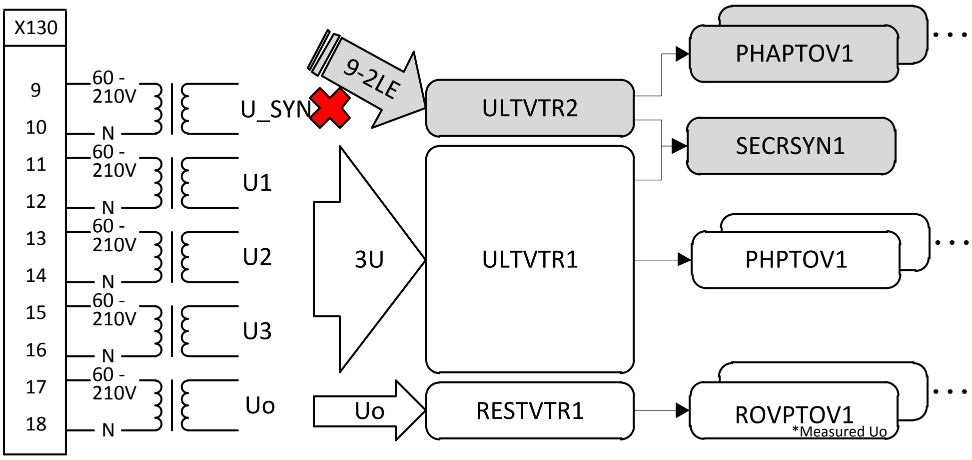


Figure 59: ULTVTR2 uses UL1 voltage from received IEC 61850-9-2 LE sample value

3.6 Default configuration B

3.6.1 Applications

The default configuration for non-directional overcurrent and directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration is used with sensor measurements - phase currents and voltages measured with sensors and Io with a traditional ring core CT. The configuration also includes additional options to select earth-fault protection based on admittance or wattmetric based principle.

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.

This configuration can be utilized in single and double busbar arrangements where the measurements are located on the feeder side.

3.6.2 Functions

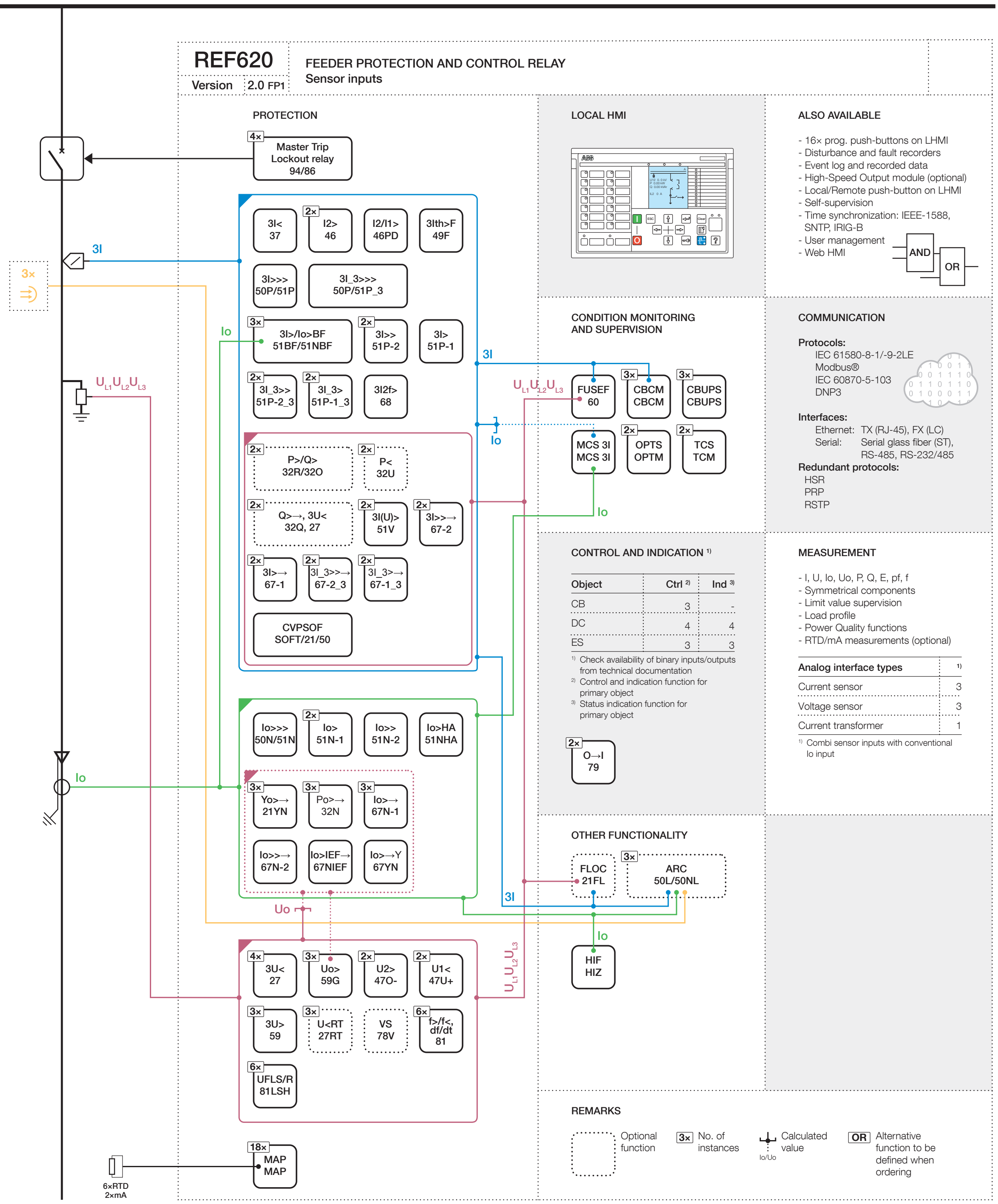


Figure 60: Functionality overview of default configuration with sensor inputs

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 U12, feeder side	X131:7,8
U2	Phase voltage U23, feeder side	X132:7,8
U3	Phase voltage U31, feeder side	X133:7,8

Table 23: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	Circuit breaker closed position indication	X110:1,2
X110-BI2	Circuit breaker open position indication	X110:3,4
X110-BI3	Circuit breaker low gas pressure alarm	X110:5,6
X110-BI4	Circuit breaker spring charged indication	X110:7,6
X110-BI5	Disconnector 1 closed position indication	X110:8,9
X110-BI6	Disconnector 1 open position indication	X110:10,9
X110-BI7	Earthing switch 1 closed position indication	X110:11,12
X110-BI8	Earthing switch 1 open position indication	X110:13,12
X115-BI1	Disconnector 2 closed position indication	X115:1,2
X115-BI2	Disconnector 2 open position indication	X115:3,4
X115-BI3	Blocking of overcurrent instantaneous stage	X115:5,6
X115-BI4	Directional earth fault protection's basic angle control	X115:7,6
X115-BI5	-	X115:8,9
X115-BI6	-	X115:10,9
X115-BI7	-	X115:11,12
X115-BI8	-	X115:13,12

[1] SIM0002
[2] SIM0005

Table 24: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100:6,7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8,9
X100-SO1	General start indication	X100:10,11,(12)
X100-SO2	General operate indication	X100:13,14
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Close disconnector 1	X110:14-16
X110-SO2	Open disconnector 1	X110:17-19
X110-SO3	Close earthing switch 1	X110:20-22
X110-SO4	Open earthing switch 1	X110:23,24
X115-SO1	Close disconnector 2	X115:14-16
X115-SO2	Open disconnector 2	X115:17-19
X115-SO3	Upstream overcurrent blocking	X115:20-22
X115-SO4	-	X115:23,24

Table 25: Default connections for LEDs

LED	Default usage	Label description
1	Overcurrent protection operate	Overcurrent protection
2	Earth-fault protection operate	Earth-fault protection
3	Voltage protection operate	Voltage protection
4	Frequency protection operate	Frequency protection
5	Negative seq. overcurrent/phase discontinuity	Phase unbalance protection
6	Thermal overload protection operate	Thermal overload protection
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	Autoreclose in progress	Autoreclose in progress
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

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	-	Off	1000 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	Autorecloser Disable	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 binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1_START	Positive or Rising
2	PHLPTOC1_OPERATE	Level trigger off
3	PHHPTOC1_START	Positive or Rising
4	PHHPTOC2_START	Positive or Rising
5	PHHPTOC1/2_OPERATE	Level trigger off
6	PHIPTOC1_START	Positive or Rising
7	PHIPTOC1_OPERATE	Level trigger off
8	DPHLPDOC1_START	Positive or Rising
9	DPHLPDOC2_START	Positive or Rising
10	DPHLPDOC1/2_OPERATE	Level trigger off
11	DPHHPDOC1_START	Positive or Rising
12	DPHHPDOC2_START	Positive or Rising
13	DPHHPDOC1/2_OPERATE	Level trigger off
14	EFLPTOC1 or EFPADM1 or WPWDE1_START	Positive or Rising
15	EFLPTOC2 or EFPADM2 or WPWDE2_START	Positive or Rising
16	EFHPTOC1 or EFPADM3 or WPWDE3_START	Positive or Rising
17	EFIPTOC1_START	Positive or Rising
18	EFxPTOC or EFPADM or WPWDE_OPERATE	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
19	DEFLPDEF1_START	Positive or rising
20	DEFLPDEF2_START	Positive or rising
21	DEFLPDEF3_START	Positive or rising
22	DEFHPDEF1_START	Positive or rising
23	DEFxPDEF_OPERATE	Level trigger off
24	ROVPTOV1/2/3_START	Positive or rising
25	ROVPTOV1/2/3_OPERATE	Level trigger off
26	INTRPTEF1_START	Positive or rising
27	INTRPTEF1_OPERATE	Level trigger off
28	HAEFPTOC1_START	Positive or rising
29	HAEFPTOC1_OPERATE	Level trigger off
30	NSPTOC1_START	Positive or rising
31	NSPTOC2_START	Positive or rising
32	PDNSPTOC1_START	Positive or rising
33	NSPTOC1/2 or PDNSPTOC1_OPERATE	Level trigger off
34	PHPTUV or PHPTOV or PSPTUV or NSPTOV_START	Positive or rising
35	PHPTUV or PHPTOV or PSPTUV or NSPTOV_OPERATE	Level trigger off
36	FRPFRQ or LSHDPFRQ_START	Positive or rising
37	FRPFRQ or LSHDPFRQ_OPERATE	Level trigger off
38	T1PTTR1_START	Positive or rising
39	T1PTTR1_OPERATE	Level trigger off
40	PHPTUC1_START	Positive or rising
41	PHPTUC1_OPERATE	Level trigger off
42	ARCSARC1/2/3_ARC_FLT_DET	Level trigger off
43	ARCSARC1_OPERATE	Positive or rising
44	ARCSARC2_OPERATE	Positive or rising
45	ARCSARC3_OPERATE	Positive or rising
46	INRPHAR1_BLK2H	Level trigger off
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	DARREC1_INPRO	Level trigger off
53	DARREC1_CLOSE_CB	Level trigger off
54	DARREC1_UNSUC_RECL	Level trigger off
55	BI Blocking	Level trigger off
56	CB Closed	Level trigger off
57	CB Open	Level trigger off
58	-	-

Table continues on the next page

Channel	ID text	Level trigger mode
59	-	-
60	MFADPSDE1_START	Positive or rising
61	MFADPSDE1_OPERATE	Level trigger off
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		Off	1000 ms
9	DR Trigger	Pulsed	150 ms
10	Trip Lockout Reset	Pulsed	150 ms
11	CB Block Bypass	Toggle	1000 ms

Table continues on the next page

Channel	Signal name	Value	Pulse length
12	AR Disable	Toggle	1000 ms
13		Off	1000 ms
14		Off	1000 ms
15		Off	1000 ms
16		Off	1000 ms

Grey cells indicate different default settings.

3.6.2.4 Physical analog channels

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

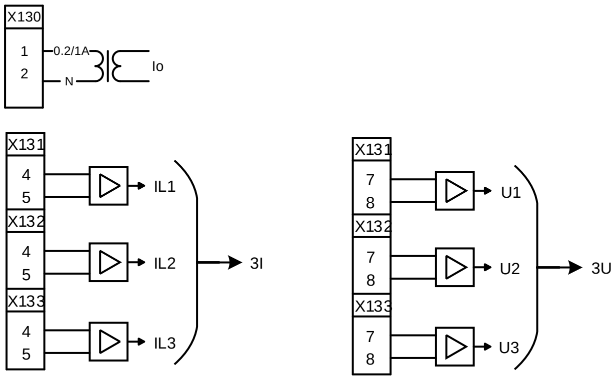


Figure 61: Physical analog channels in default configuration B

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.

Table 31: Physical analog channels of functions

IEC61850	3I	3U	Io
Protection			
PHLPTOC1	x		
PHHPTOC1	x		
PHHPTOC2	x		
PHIPTOC1	x		
DPHLPDOC1	x	x	
DPHLPDOC2	x	x	

Table continues on the next page

IEC61850	3I	3U	Io
DPHHPDOC1	x	x	
DPHHPDOC2	x	x	
PHPVOC1	x	x	
PHPVOC2	x	x	
EFLPTOC1	C		x
EFLPTOC2	C		x
EFHPTOC1	C		x
EFIPTOC1	C		x
DEFLPDEF1		x	x
DEFLPDEF2		x	x
DEFLPDEF3		x	x
DEFHPDEF1		x	x
EFPADM1		x	x
EFPADM2		x	x
EFPADM3		x	x
WPWDE1		x	x
WPWDE2		x	x
WPWDE3		x	x
MFADPSDE1		x	x
INTRPTEF1		x	x
HAEFPTOC1			x
NSPTOC1	x		
NSPTOC2	x		
PDNSPTOC1	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	

Table continues on the next page

IEC61850	3I	3U	Io
FRPFRQ4		x	
FRPFRQ5		x	
FRPFRQ6		x	
T1PTTR1	x		
PHPTUC1	x		
CCBRBRF1	x		x
CCBRBRF2	x		x
CCBRBRF3	x		x
INRPHAR1	x		
ARCSARC1	x		x
ARCSARC2	x		x
ARCSARC3	x		x
PHIZ1			x
LSHDPFRQ1		x	
LSHDPFRQ2		x	
LSHDPFRQ3		x	
LSHDPFRQ4		x	
LSHDPFRQ5		x	
LSHDPFRQ6		x	
CVPSOF1	x	x	
VVSPPAM1		x	
DQPTUV1	x	x	
DQPTUV2	x	x	
DUPPDPR1	x	x	
DUPPDPR2	x	x	
DOPPDPR1	x	x	
DOPPDPR2	x	x	
LVRTPTUV1		x	
LVRTPTUV2		x	
LVRTPTUV3		x	
PH3LPTOC1	x		
PH3LPTOC2	x		
PH3HPTOC1	x		
PH3HPTOC2	x		
PH3IPTOC1	x		
DPH3LPDOC1	x	x	
DPH3LPDOC2	x	x	
DPH3HPDOC1	x	x	
DPH3HPDOC2	x	x	
Control			
SECRSYN1	9-2 specific function		

Table continues on the next page

IEC61850	3I	3U	Io
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	
FMMXU1		x	
Fault location			
SCEFRFLO1	x	x	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.

3.6.2.5 Sensor inputs for currents and voltages

This chapter gives short examples on how to define the correct parameters for sensor measurement interfaces.

Sensors can have correction factors, measured and verified by the sensor manufacturer, to increase the measurement accuracy. Correction factors are recommended to be set to the relay. Two types of correction factors are available for voltage and current (Rogowski) sensors. The Amplitude correction factor is named *Amplitude corr. A(B/C)* and Angle correction factor is named *Angle corr A(B/C)*. These correction factors can be found on the Sensor's rating plate and/or sensor routine test protocol. If the correction factors are not available, contact the sensor manufacturer for more information.

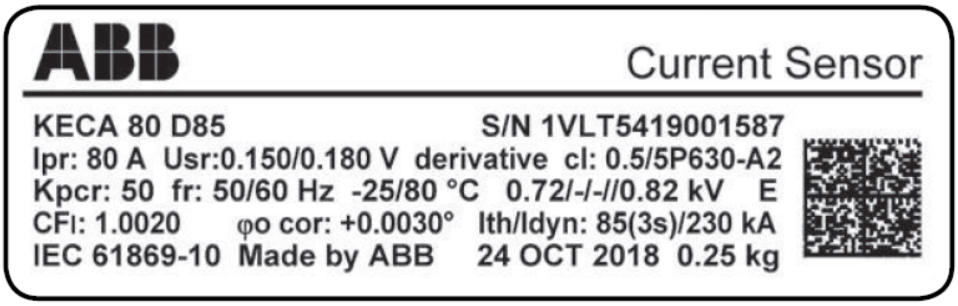


Figure 62: Example of ABB Rogowski current sensor KECA 80 D85 rating plate

Current (Rogowski) sensor setting example

In this example, an 80 A/0.150 V at 50 Hz (0.180 V at 60 Hz) sensor, such as the example shown in *Figure 62*, is used in a 50 Hz electrical network. The application has a 150 A nominal current (In) corresponding to the protected object’s nominal current. The application nominal current is set to Rogowski sensor setting *Primary current*. Taken from the sensor’s technical data, this example sensor can be used with up to 4000 A application nominal current. As the Rogowski sensor is linear and does not saturate, the 80 A/0.150 V at 50 Hz sensor also works as a 150 A/0.28125 V at 50 Hz sensor. When defining another primary value for the sensor, also the nominal voltage has to be redefined to maintain the same transformation ratio. However, the setting in the protection relay (*Rated Secondary Value*) is not in V but in mV/Hz, which makes the same setting *Rated Secondary Value* valid for both 50 and 60 Hz nominal frequency.

$$RSV = \frac{\frac{I_n}{I_{pr}} \times K_r}{f_n}$$

(Equation 1)

RSV	*Rated Secondary Value* in mV/Hz
I_n	Application nominal current
I_{pr}	Sensor-rated primary current
f_n	Network nominal frequency
K_r	Sensor-rated voltage at the rated current in mV

In this example, the value is as calculated using the equation.

$$\frac{\frac{150A}{80A} \times 150mV}{50Hz} = 5.625\frac{mV}{Hz}$$

(Equation 2)

With this information, the protection relay's current (Rogowski) sensor settings can be set.

Table 32: Example setting values for current (Rogowski) sensor

Setting	Value
Primary current	150 A
Rated secondary value	5.625 mV/Hz

When considering setting values for current sensor interfaces and for protection functions utilizing these measurements, it should be noted that the sensor measurement inputs in the relay have limits for linear behavior. When this limit is exceeded, the input starts to saturate. The saturation is reflected to the protection functions connected to the sensor inputs. To ensure that the related protection functions operate correctly, the start value setting for protection functions utilizing either instantaneous or definite minimum time characteristics must not exceed the linear measurement range. Furthermore, the effect on protection functions utilizing inverse time characteristics should be considered. The upper limit of the linear measurement range depends on the selected application nominal current and the type of the current sensor used. *Table 33* shows the limits for an 80A/150mV 50Hz sensor.

Table 33: Application nominal current relation to the upper limit of linear measurement range

Application nominal current (In)	Rated secondary value with 80A / 0.150 V at 50 Hz (0.180 V at 60 Hz)	Upper limit of linear measurement range
40...800 A	1.500...30.000 mV/Hz	60 × I_n
800...1250 A	30.000...46.875 mV/Hz	60...40 × I_n
1250...2500 A	46.875...93.750 mV/Hz	40...20 × I_n
2500...4000 A	93.750...150.000 mV/Hz	20...12.5 × I_n

Table 33 shows the upper limits of the linear measurement range based on a certain range in application nominal current. The linear measurement limit for a given application nominal current can be derived from the values stated in the table with a simple proportion equation. For example, the upper limit for linear measurement for 3000 A application nominal current would be 17.5 xIn.

It can also be calculated from *Table 33* that with the stated sensor the relay input can linearly measure up to 50 kA (RMS) short circuit currents.

Rogowski sensor and overcurrent protection setting evaluation example

A 20 kV utility substation with a single busbar switchgear rated up to 40 kA shortcircuit currents has one incomer and 20 outgoing feeder relays using 80 A/0.150 V at 50 Hz Rogowski current sensors with rating plate values similar to *Figure 62*. For the incomer panel, electrical system designer has evaluated the application nominal current to be 1250 A. Customer specification for these protection relays defines normal instantaneous and time-delayed overcurrent and earth-fault protection functions. Overcurrent protection requires functions to be settable up to 20 xIn.

The sensor setting *Primary current* is set to be the same as the evaluated application nominal current 1250 A. According to the sensor's technical data, the application nominal current matches the sensor's capability which is up to 4000 A.

The setting *Rated secondary value* is calculated by using *Equation 1*.

$$\frac{\frac{1250A}{80A} \cdot 150mV}{50Hz} = 46.875\frac{mV}{Hz}$$

(Equation 3)

From *Table 33* it is seen that with the 1250 A application nominal current value, the maximum setting for overcurrent protection is 40 xIn. This covers the customer specification requirements for overcurrent settings of up to 20 xIn.

Voltage sensor setting example

The voltage sensor is based on the resistive divider or capacitive divider principle. Therefore, the voltage is linear throughout the whole measuring range. The output signal is a voltage, directly proportional to the primary voltage. For the voltage sensor, all parameters are readable directly from its rating plate and/or sensor routine test protocol, and conversions are not needed.

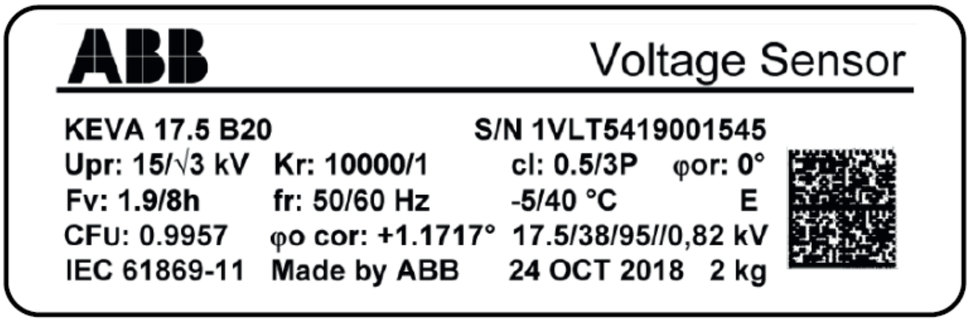


Figure 63: Example of ABB voltage sensor KEVA 17.5 B21 rating plate

In this example the system phase-to-phase voltage rating is 10 kV. Thus, the *Primary voltage* parameter is set to 10 kV. For protection relays with sensor measurement support, the *Voltage input type* is set to "Voltage sensor". The VT connection parameter is set to the "WYE" type. The division ratio for ABB voltage sensors is most often 10000:1. Thus, the *Division ratio* parameter is usually set to "10000". The primary voltage is proportionally divided by this division ratio.

Table 34: Example setting values for voltage sensor

Setting	Value
Primary voltage	10 kV
VT connection	Wye

Table continues on the next page

Setting	Value
Voltage input type	3=Voltage sensor
Division ratio	10000

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 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.

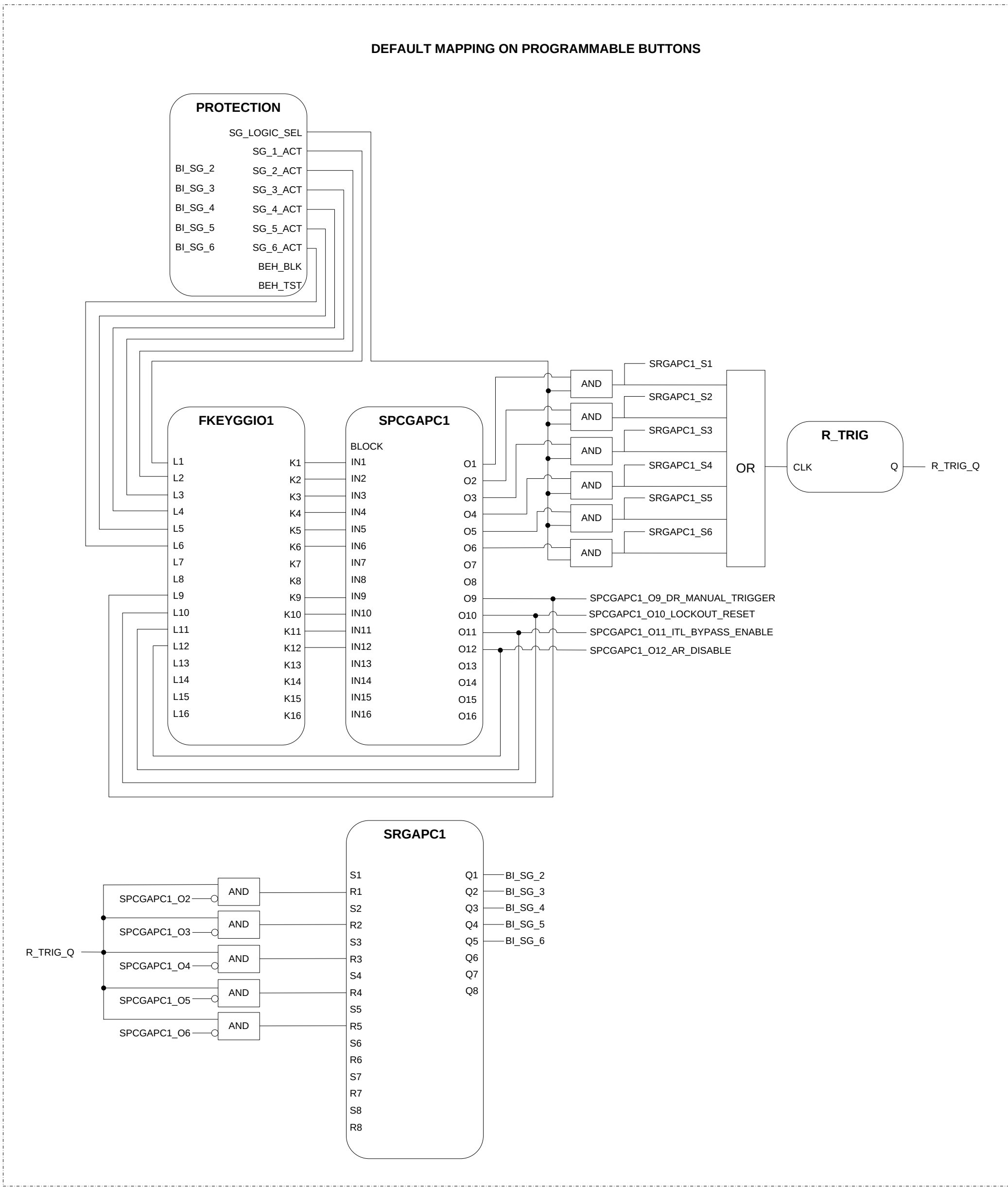


Figure 64: Default mapping on programmable buttons

3.6.3.1 Functional diagrams for protection

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

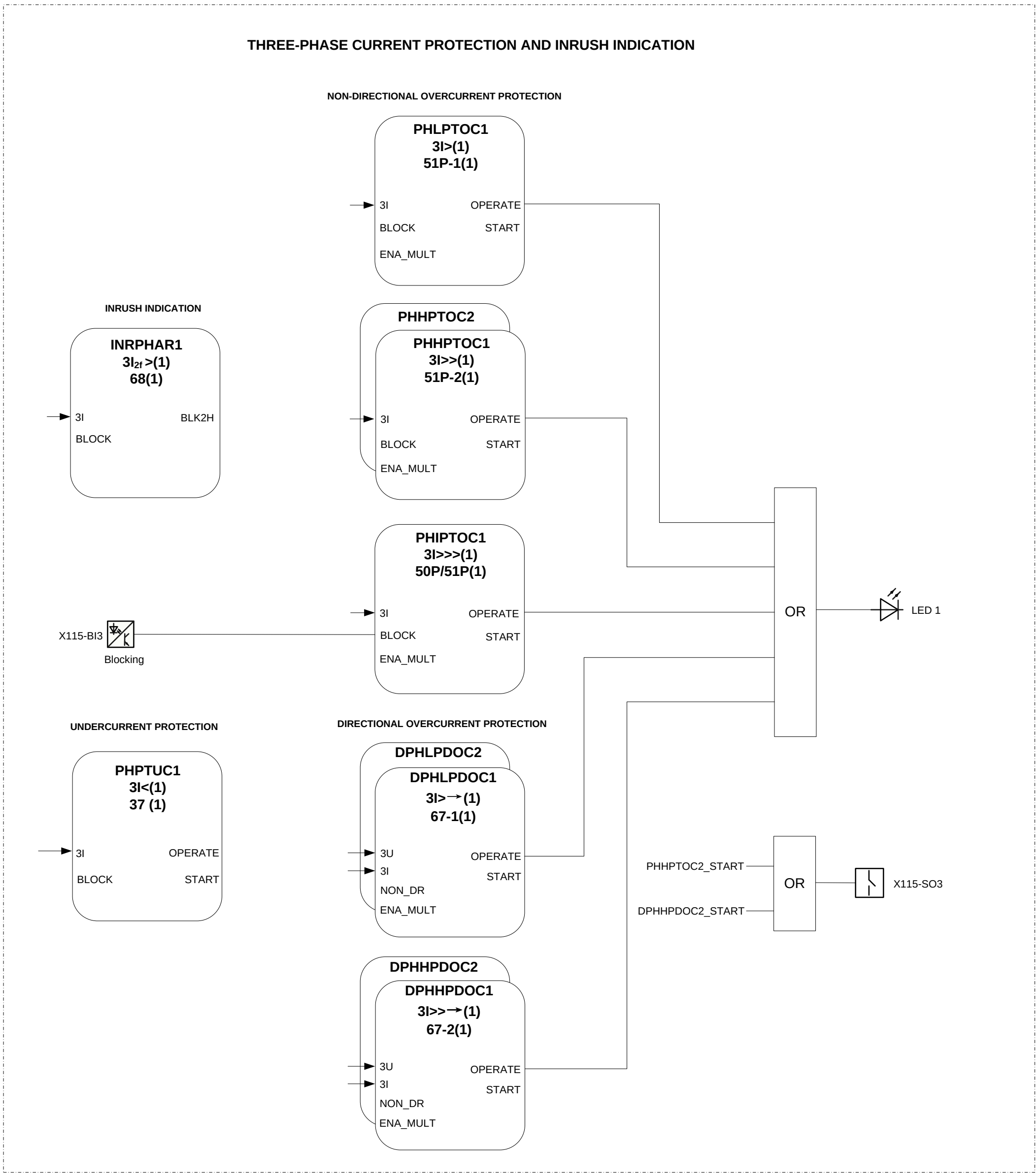


Figure 65: Overcurrent and undercurrent protection

Eight overcurrent stages in total are offered for overcurrent and short-circuit. Three stages are for directional functionality DPHxPDOC, while the others are only for nondirectional overcurrent protection PHxPTOC. The instantaneous stage PHIPTOC1 can be blocked by energizing the binary input X115-BI3. The inrush detection INRPHAR1 output `BLK2H` enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

One undercurrent stage PHPTUC1 is offered for undercurrent protection. The `START` and `OPERATE` outputs from this function are connected to disturbance recorder, but this function is not configured to trip the circuit breaker by default.

The `OPERATE` outputs are connected to the Master Trip and alarm LED 1, except for those specially mentioned previously. LED 1 is used for overcurrent protection indication.

The upstream blocking from the START signals of the overcurrent second high stage PHHPTOC2 and DPHLPDOC2 are connected to signal output X115-SO3. This output is used for sending a blocking signal to the relevant overcurrent protection stage of the relay at the infeeding bay.

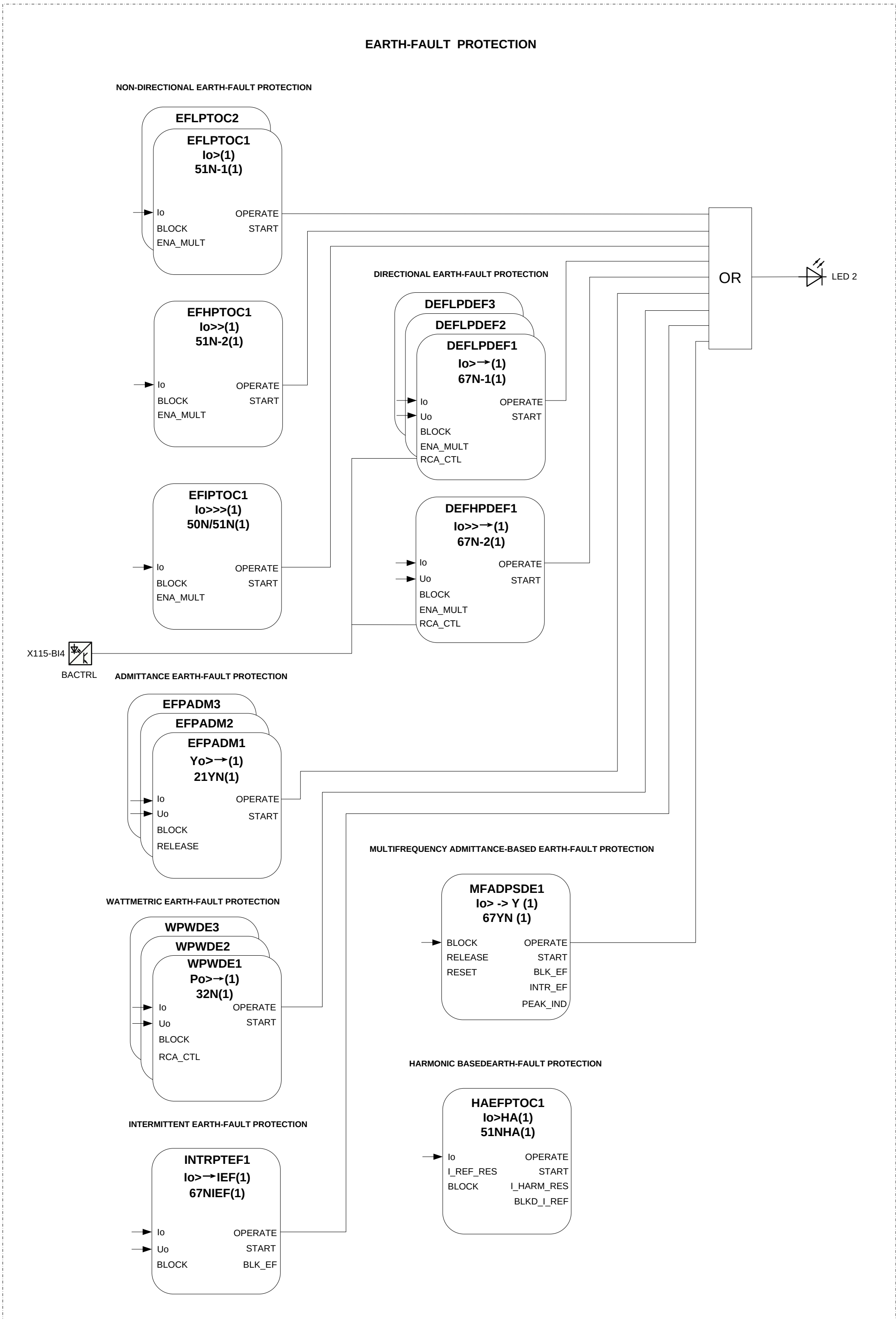


Figure 66: Earth-fault protection

Eight stages in total are offered for earth-fault protection. Four stages are for directional functionality DEFxPDEF, while the others are only for non-directional earth-fault protection EFxPTOC. The directional earth-fault protection can be achieved by using conventional directional earth-fault DEFxPDEF or with admittance-based EFPADM1...3, or wattmetric earth-fault protection WPWDE1...3. In addition, there is a dedicated protection stage INTRPTEF1 either for transientbased earth-fault protection or for cable intermittent earth-fault protection in compensated networks. A multifrequency neutral admittance earth-fault protection MFADPSDE1 is offered. The START and OPERATE outputs from this function are connected to the disturbance recorder.

A harmonic based earth-fault protection HAEFPTOC1 is offered. The `START` and `OPERATE` outputs from this function are connected to the disturbance recorder, but this function is not configured to trip the circuit breaker by default.

The binary input X115-BI4 is intended for either directional earth-fault protection blocks' relay characteristic angle (RCA: 0°/-90°) or operation mode (IoSinφ/ IoCosφ) change.

`OPERATE` outputs are connected to the Master Trip and alarm LED 2, except for those specially mentioned previously. LED 2 is used for earth-fault protection indication.

All of these functions are normally not used in the same application. Different functions have different suitability and operability in different electrical network types such as the earthed, isolated and compensated networks. Especially in some network types and applications the earth-fault currents are so small that they cannot be detected by the normal earth-fault protection functions. In these cases, it is recommended to use a hardware variant with a sensitive Io channel to better reach operational sensitivity for low earth-fault currents.

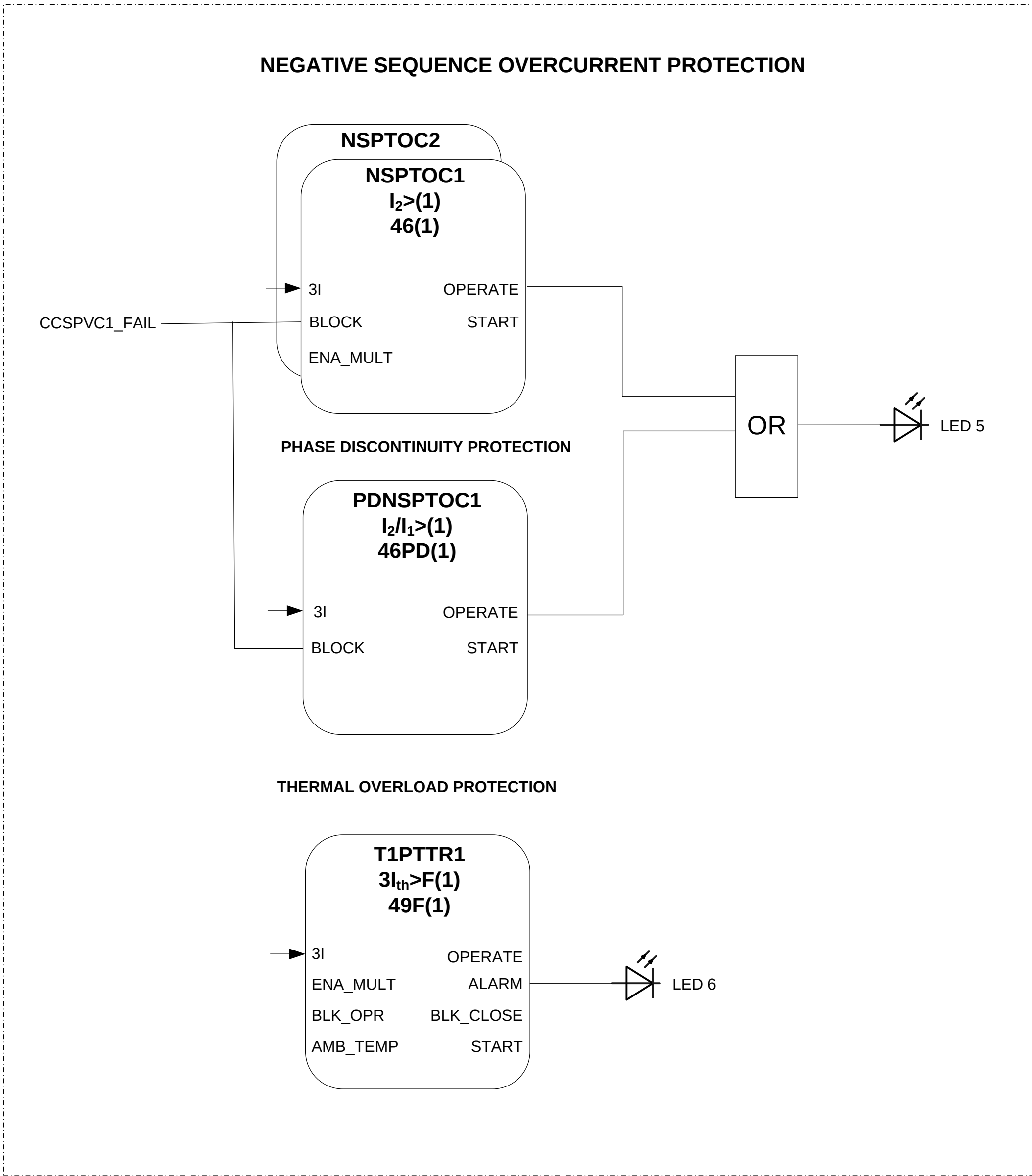


Figure 67: Negative-sequence current protection, phase discontinuity and thermal overload protection

Two negative sequence overcurrent stages NSPTOC1 and NSPTOC2 are offered for phase unbalance protection. A failure in the current measuring circuit is detected by the current circuit supervision function CCSPVC1 to avoid faulty tripping. The phase discontinuity protection PDNSTOC1 provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The thermal overload protection T1PTTR1 provides indication on overload situations.

The `OPERATE` outputs of NSPTOC1/2 and PDNSPTOC1 are connected to the Master Trip and alarm LED 5. LED 5 is used for unbalance protection. The `ALARM` output of T1PTTR1 is also connected to LED 6. LED 6 is used for thermal overload protection alarm indication.

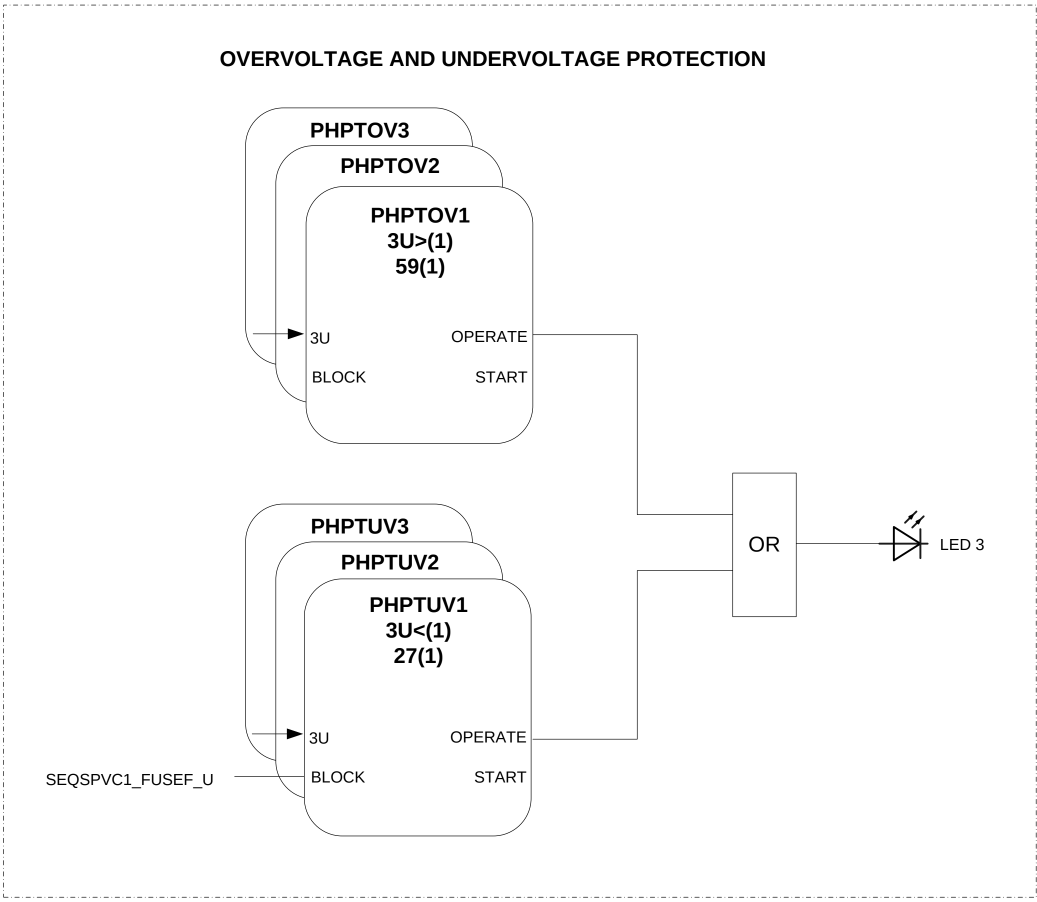


Figure 68: Overvoltage and undervoltage protection

Three instances of overvoltage protection PHPTOV1…3 and undervoltage protection PHPTUV1…3 offer protection against abnormal phase voltage conditions. A failure in the voltage-measuring circuit is detected by the fuse failure function SEQSPVC, and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

The `OPERATE` outputs of voltage functions are connected to alarm LED 3. LED 3 is used for combined voltage protection alarm indication.

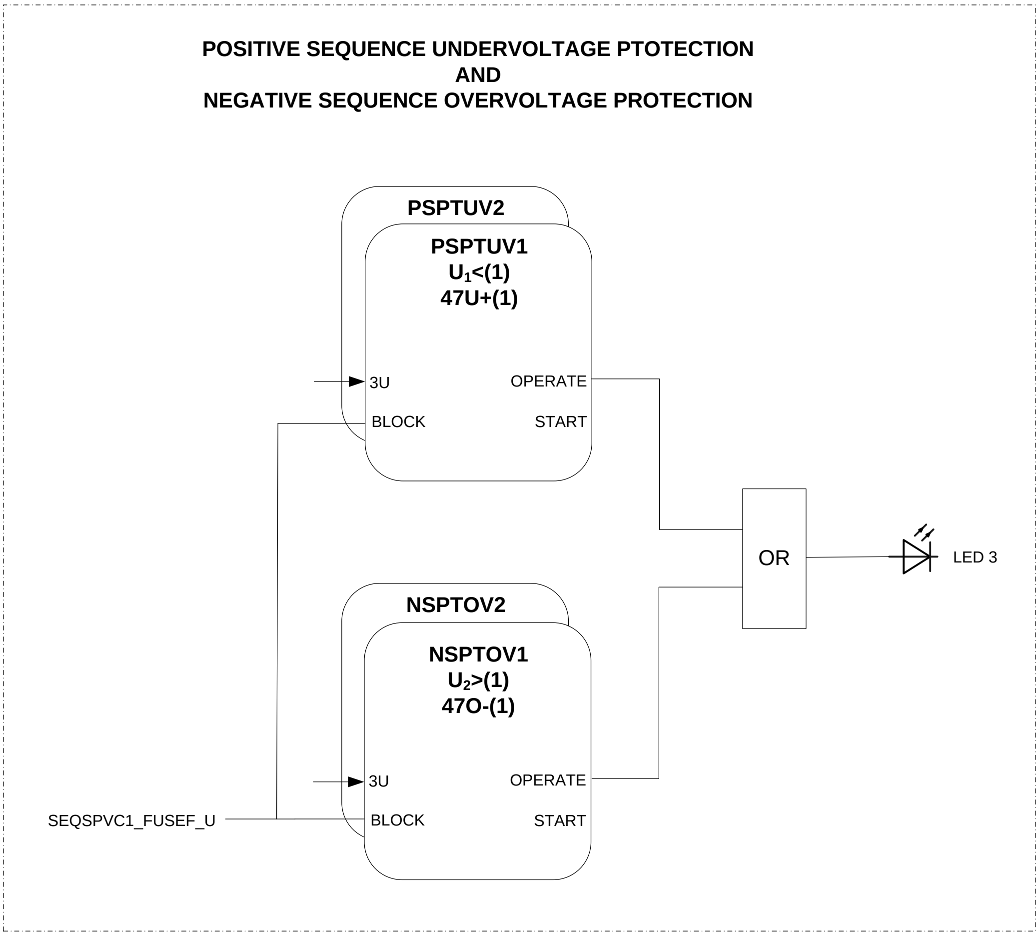


Figure 69: Positive-sequence undervoltage and negative-sequence overvoltage protection

Positive-sequence undervoltage PSPTUV1/2 and negative-sequence overvoltage NSPTOV1/2 protection functions enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function SEQSPVC. The activation is connected to positive-sequence undervoltage PSPTUV1/2 and negative-sequence overvoltage NSPTOV1/2 protection functions, to avoid faulty tripping.

The `OPERATE` outputs of voltage-sequence functions are also connected to alarm LED 3.

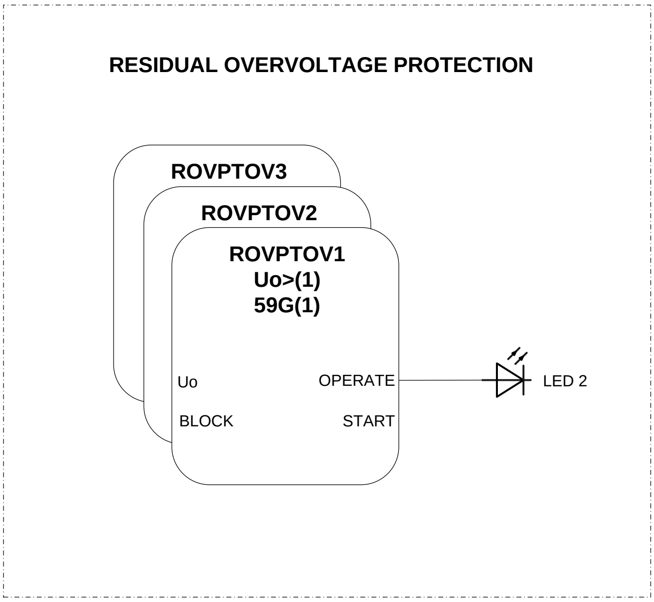


Figure 70: Residual overvoltage protection

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

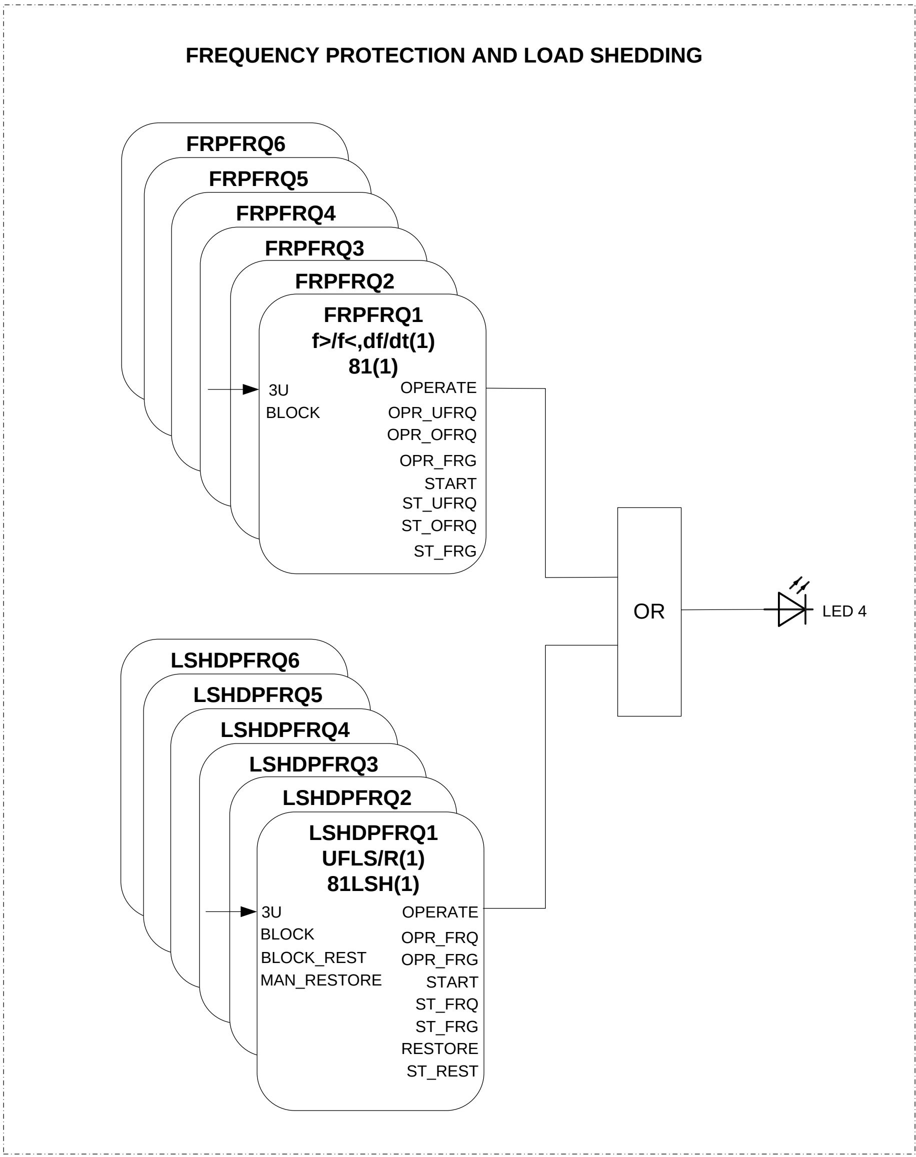


Figure 71: Frequency and load shedding protection

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` output's signal is connected to the alarm LED 4. LED 4 is used for frequency protection operate indication.

Six load shedding and restoration protection LSHDPFRQ1…6 instances are offered in the default configuration. The load shedding and restoration function is capable of shedding load based on under frequency and the rate of change of the frequency. The load that is shed during the frequency disturbance can be restored once the frequency is stabilized to the normal level. Also manual restore commands can be given via binary inputs, but by default, they are not connected. The `OPERATE` output's signal is also connected to the alarm LED 4.

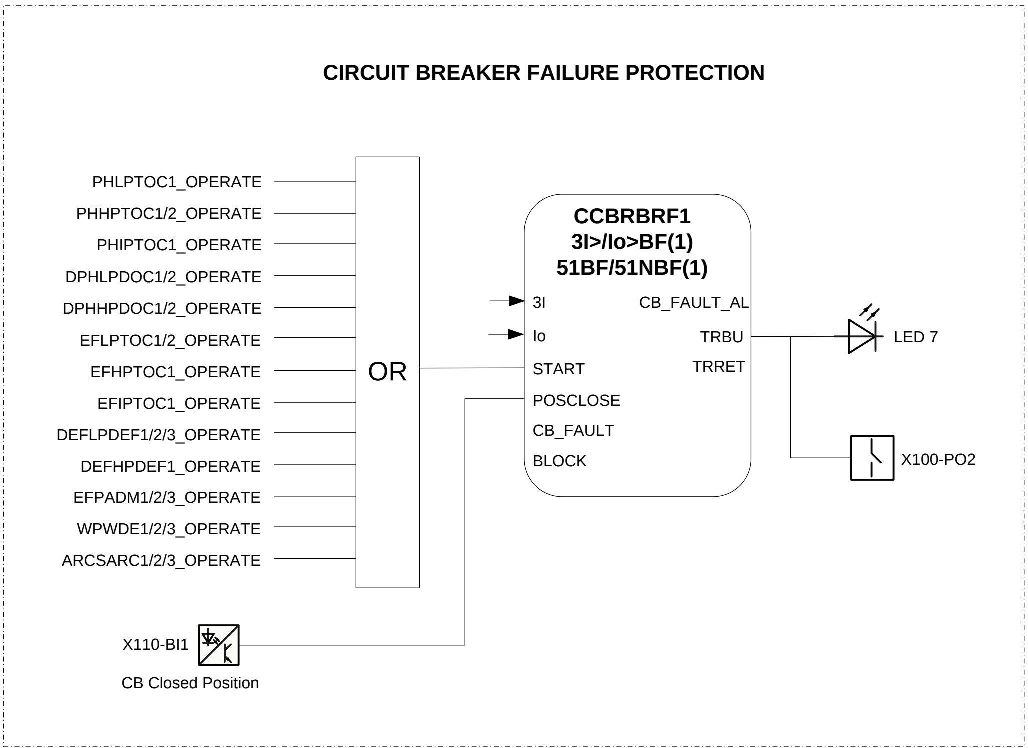


Figure 72: Circuit breaker failure protection

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 2. 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` operating indication.

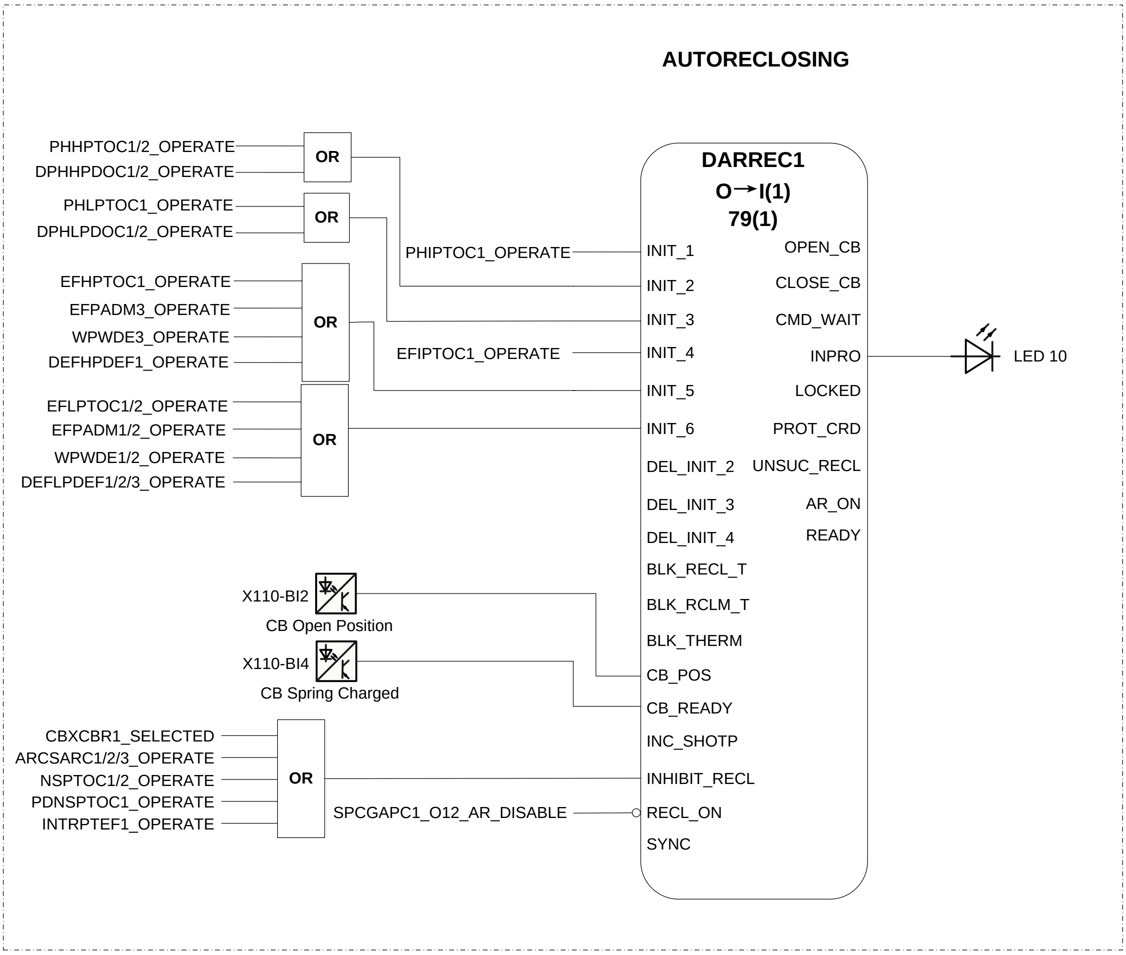


Figure 73: Autoreclosing

The autoreclosing function is configured to be initiated by the operating signals from a number of protection stages through the INT_1...6. It is possible to create individual autoreclosing sequences for each input.

The autoreclosing function can be blocked with the `INHIBIT_RECL` input. By default, the operations of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclosing function via the `CBXCBR1_SELECTED` signal.

Autoreclosing function could be disabled via one push button through `SPCGAPC1_O12`, which is connected to the `RECL_ON` input of the DARREC1.

The circuit breaker availability for the autoreclosing sequence is expressed with the `CB_READY` input in DARREC1. In the default configuration, this signal is connected to CB spring charged binary input X110-BI4. As a result, the function is available only when CB spring is charged.

The autoreclosing sequence in progress indication `INPRO` is connected to the alarm LED 10.

Set parameters for the DARREC1 function.

Check the initialization signals of DARREC1.

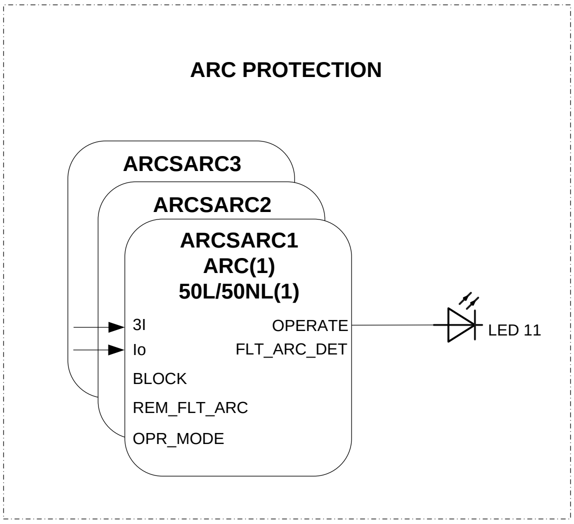


Figure 74: Arc protection

Arc protection ARCSARC1...3 is included as optional function in this configuration.

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

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

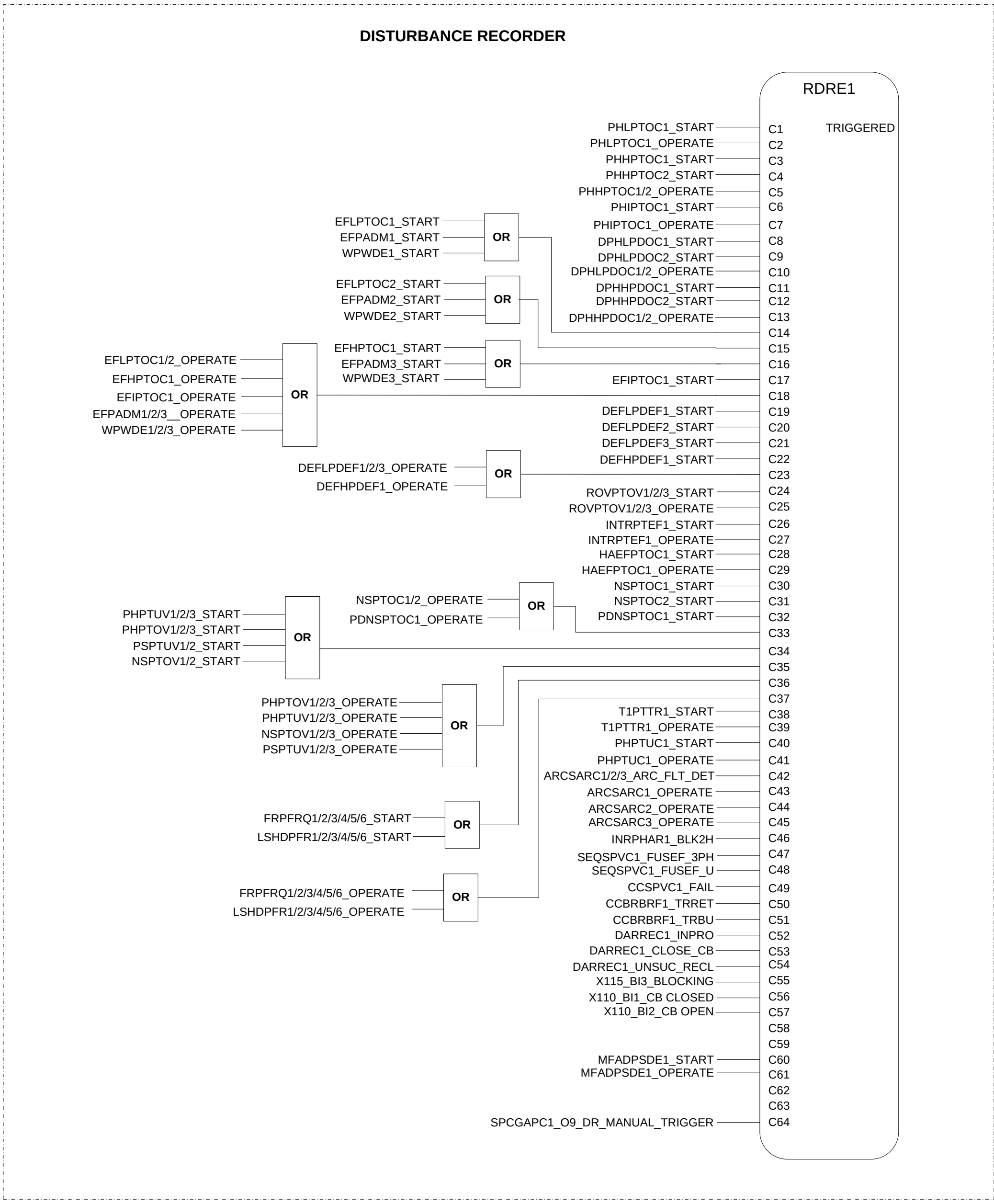


Figure 75: Disturbance recorder

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 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, make the changes to the parameter setting tool.

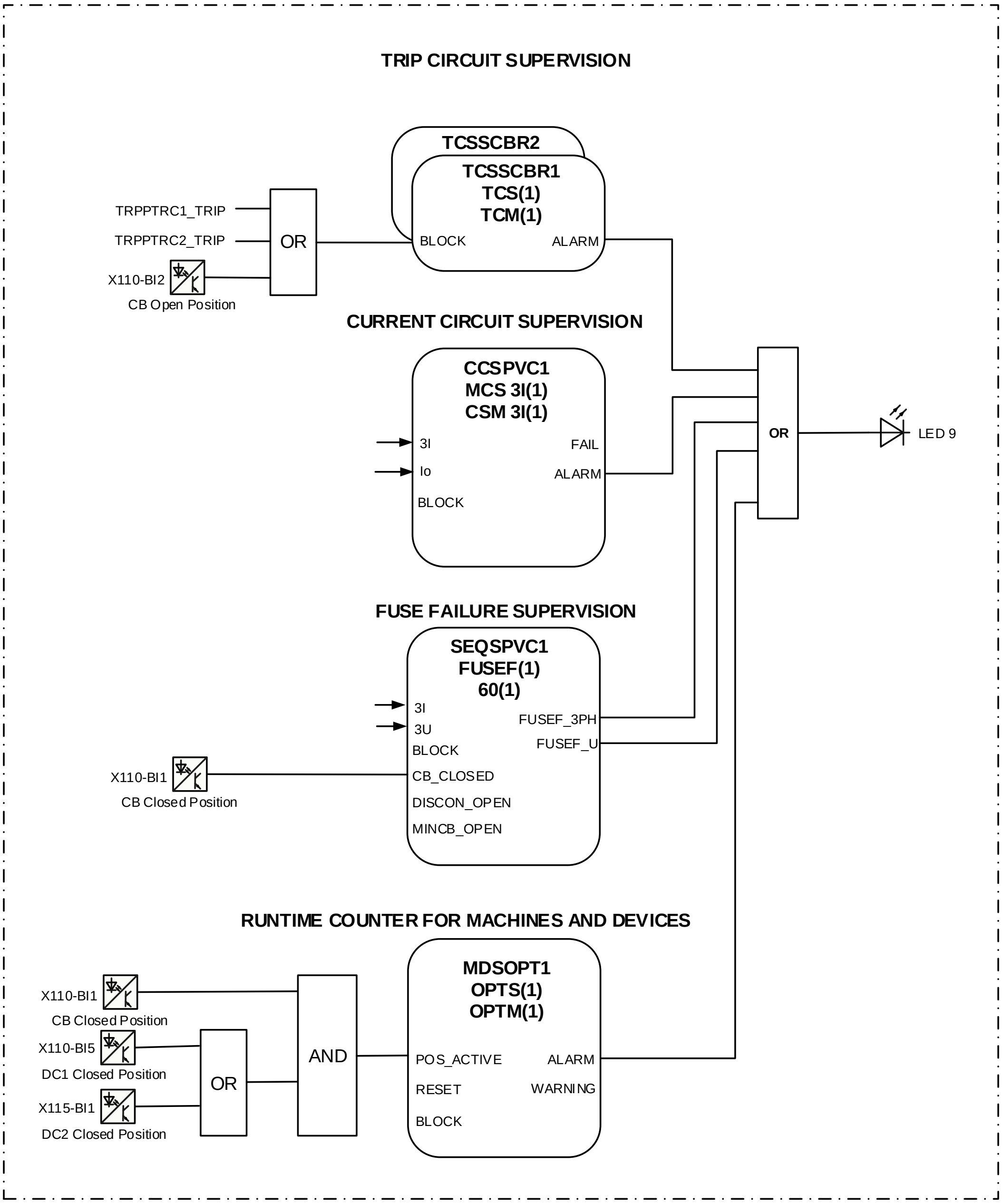


Figure 76: Circuit supervision

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

Set the parameters for TCSSCBR1 properly.

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. When a failure is detected, a blocking signal is activated in voltage protection functions that are measuring calculated sequence component voltages, undervoltage protection and synchro-check, so that unnecessary operation can be avoided.

3.6.3.3 Functional diagrams for control and interlocking

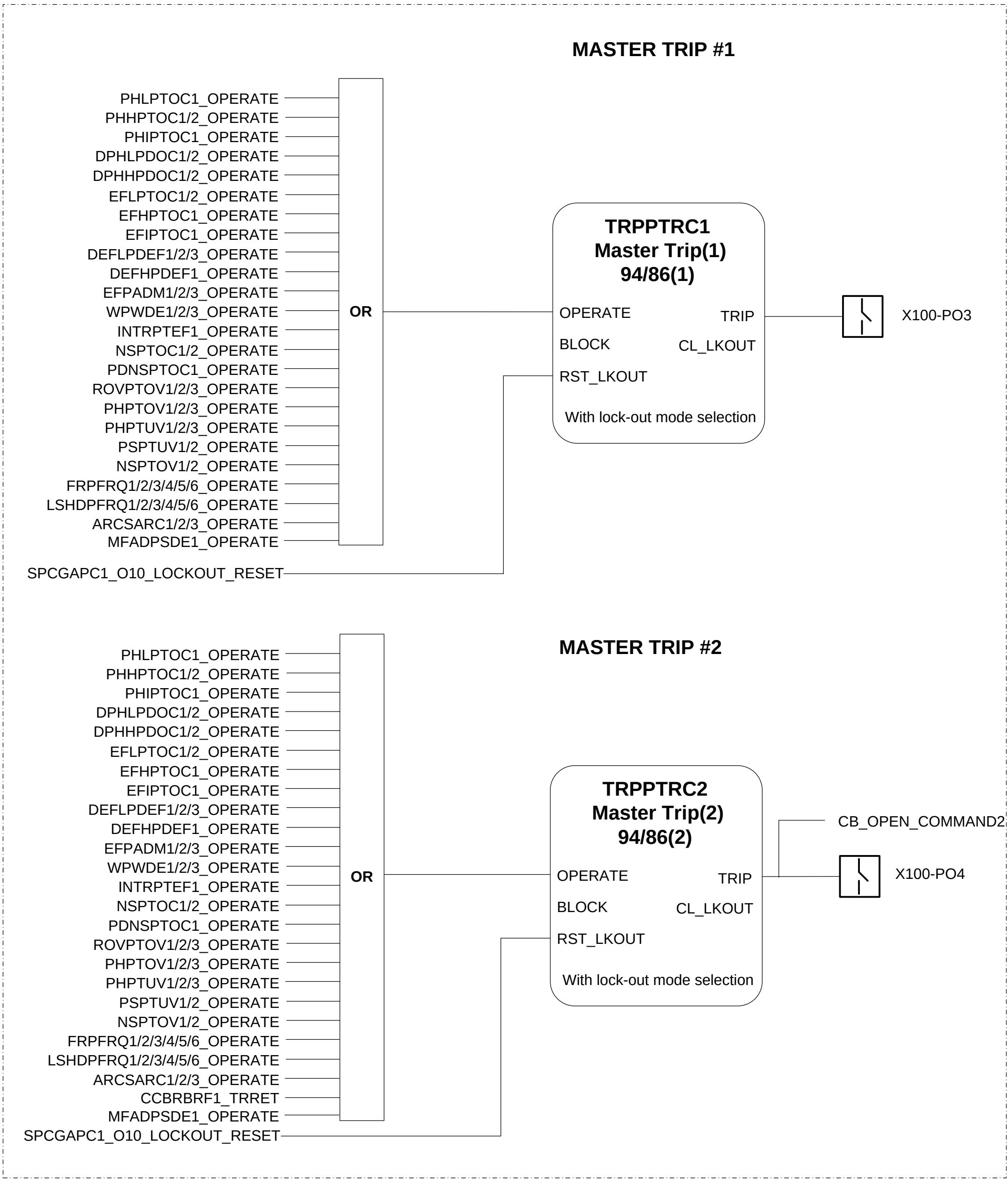


Figure 77: Master trip

The operating signals from the protections are connected to the two trip output contacts, power output X100-PO3 and power output X100-PO4 via the corresponding Master Trips TRPPTRC1 and TRPPTRC2.

TRPPTRC1 and TRPPTRC2 provide lockout/latching function, event generation and trip signal duration setting. If the lockout operation mode is selected, one push button can be used to reset the lockout through `SPCGAPC1_O10`.

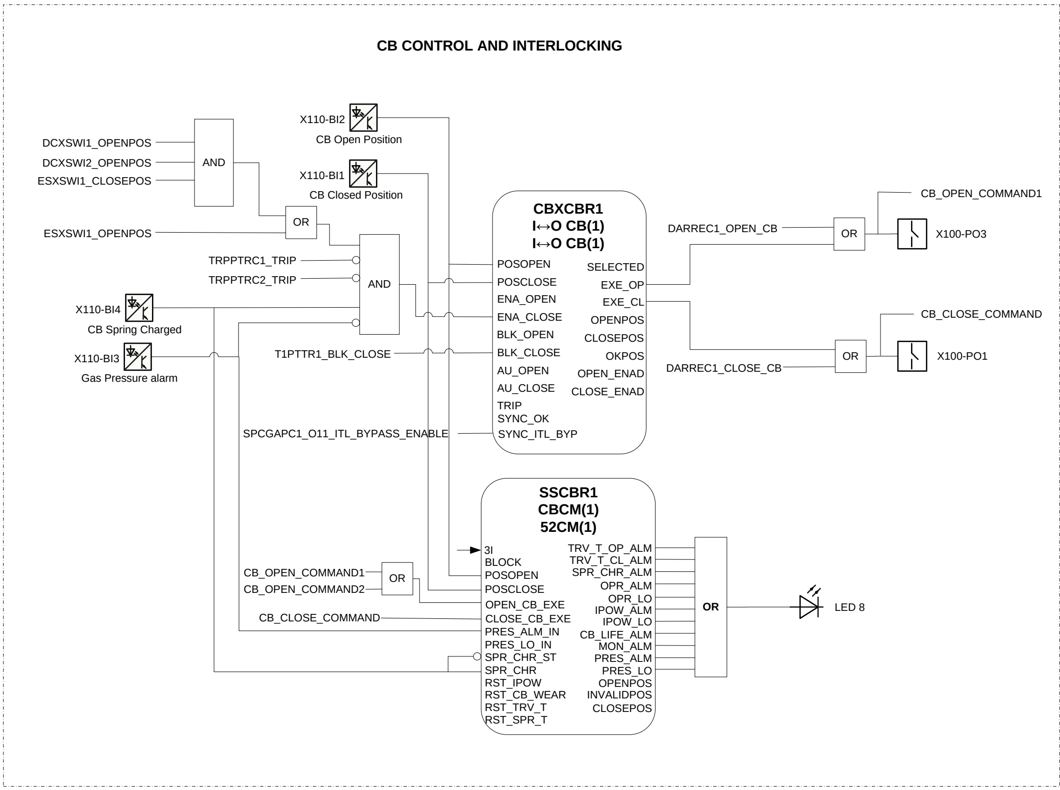


Figure 78: Circuit breaker control and interlocking

The circuit breaker opening is enabled when the `ENA_OPEN` is activated, but blocked when `BLK_OPEN` is activated. The CB opening is always allowed because by default ENA_OPEN is activated and BLK_OPEN is deactivated when they are left unconnected.

The circuit breaker closing is enabled when the `ENA_CLOSE` input is activated, and this input is activated when four conditions are met.

- The CB condition check is OK (CB spring is charged, no gas pressure alarm)
- There are no active control trip signals
- The position status check for the related primary equipment is OK meaning that either the earthing switch is open or both disconnectors are open when the earthing switch is closed

The circuit breaker closing is blocked when `BLK_CLOSE` input is activated. This input is activated when the `BLK_CLOSE` output of T1PTTR1 is active.

One push button can be used through SPCGAPC1_O11, which is connected to the `SYNC_ITL_BYP` input of CBXCBR1 to ignore the status of the `ENA_CLOSE` input. However, the `BLK_CLOSE` input 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 continuously allowed.

The relay also includes a second CB control block, with related CB condition monitoring, not used in the default configuration. The second instances use the same measurement values as the first instances.

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

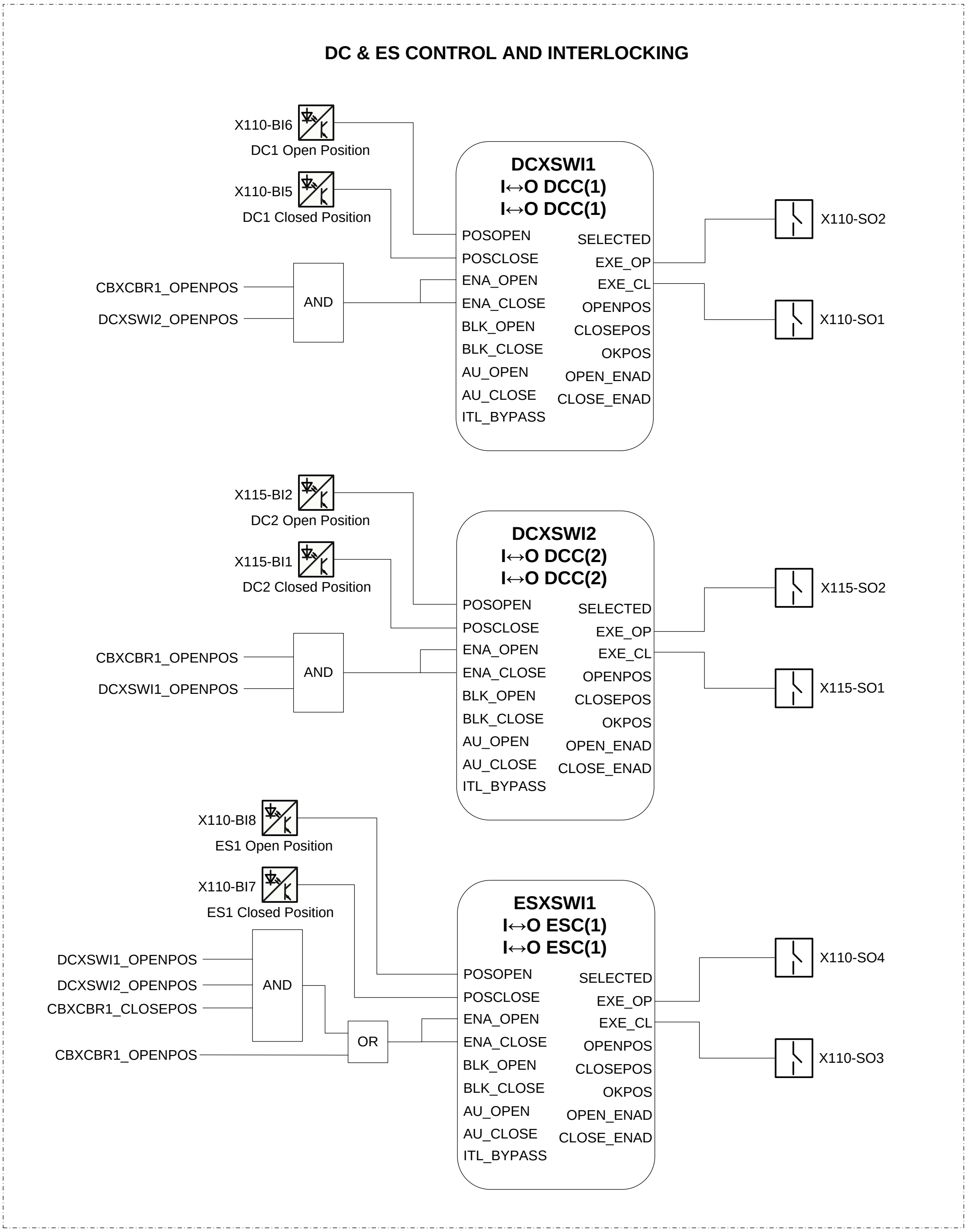


Figure 79: Disconnector and earthing switch control and interlocking

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

The binary inputs 5 and 6 of the card X110 are used for busbar disconnector 1 (DCXSWI1) position indication. The binary inputs 1 and 2 of the card X115 are used for busbar disconnector 2 (DCXSWI2) position indication.

Table 35: Disconnector 1 position indicated by binary inputs

Primary device position	Input to be energized	
	X110-BI5	X110-BI6
Busbar disconnector 1 closed	x	
Busbar disconnector 1 open		x

Table 36: Disconnector 2 position indicated by binary inputs

Primary device position	Input to be energized	
	X115-BI1	X115-BI2
Busbar disconnector 2 closed	x	
Busbar disconnector 2 open		x

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

Table 37: Earthing switch position indicated by binary inputs

Primary device position	Input to be energized	
	X110-BI7	X110-BI8
Earthing switch closed	x	
Earthing switch open		x

The control (opening or closing) of disconnector 1 and disconnector 2 is enabled only when both circuit breaker and the other disconnector are in open position.

The control (opening or closing) of earthing switch is enabled under either of the two conditions.

- The circuit breaker is in open position
- The circuit breaker is in closed position, while both disconnector 1 and disconnector 2 are in open position

With this simplified default disconnector control logic, the busbar is transferred by opening the circuit breaker. In a normal double-busbar system, the busbar is transferred without a power supply break.

Cooperation is needed on the bus coupler bay to support live busbar transfer, so necessary information exchange between different bays and bus coupler bay is also required. The control logic for disconnector 1 and disconnector 2 mentioned earlier needs to be revised accordingly. The information exchange can be done either with binary inputs or through a GOOSE message.

The general rule for live busbar transfer is to have the two busbars interconnected, as shown in *Figure 80*. The outgoing feeder has been connected to busbar I. Under this condition, DC11 and CB1 are closed while DC12 is open. The busbar coupler bay apparatuses (DC21, DC22 and CB2) are also open.

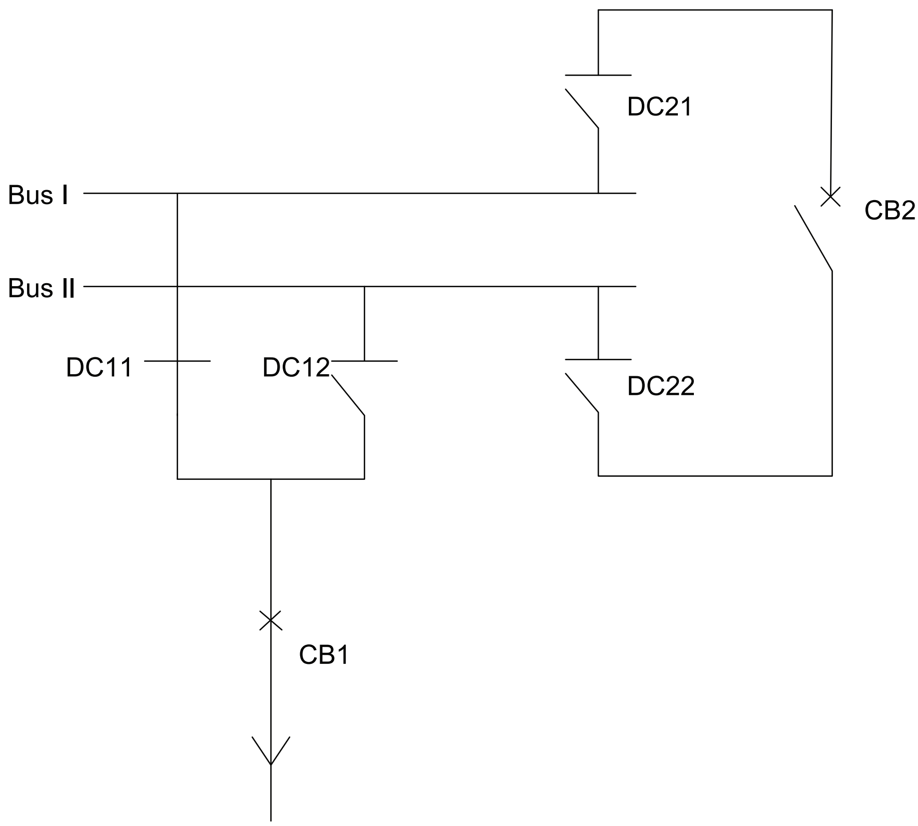


Figure 80: Disconnector control logic

There are four general steps to transfer the power supply from busbar I to busbar II.

1. DC21, DC2 and CB2 in the bus coupler bay have to be closed to have busbar I and busbar II connected.
2. DC12 has to be closed to have the feeder connected to busbar II.
3. DC11 has to opened to disconnect the feeder from busbar I.
4. CB2, DC21 and DC22 have to be opened to disconnect the two busbars. This transfers the load of the outgoing feeder to busbar II.

These four steps assure that there is no power supply interruption on the feeder. After step 1, the two busbars are connected to ensure that the operation on DC12 and DC11, in steps 2 and 3, is safe.

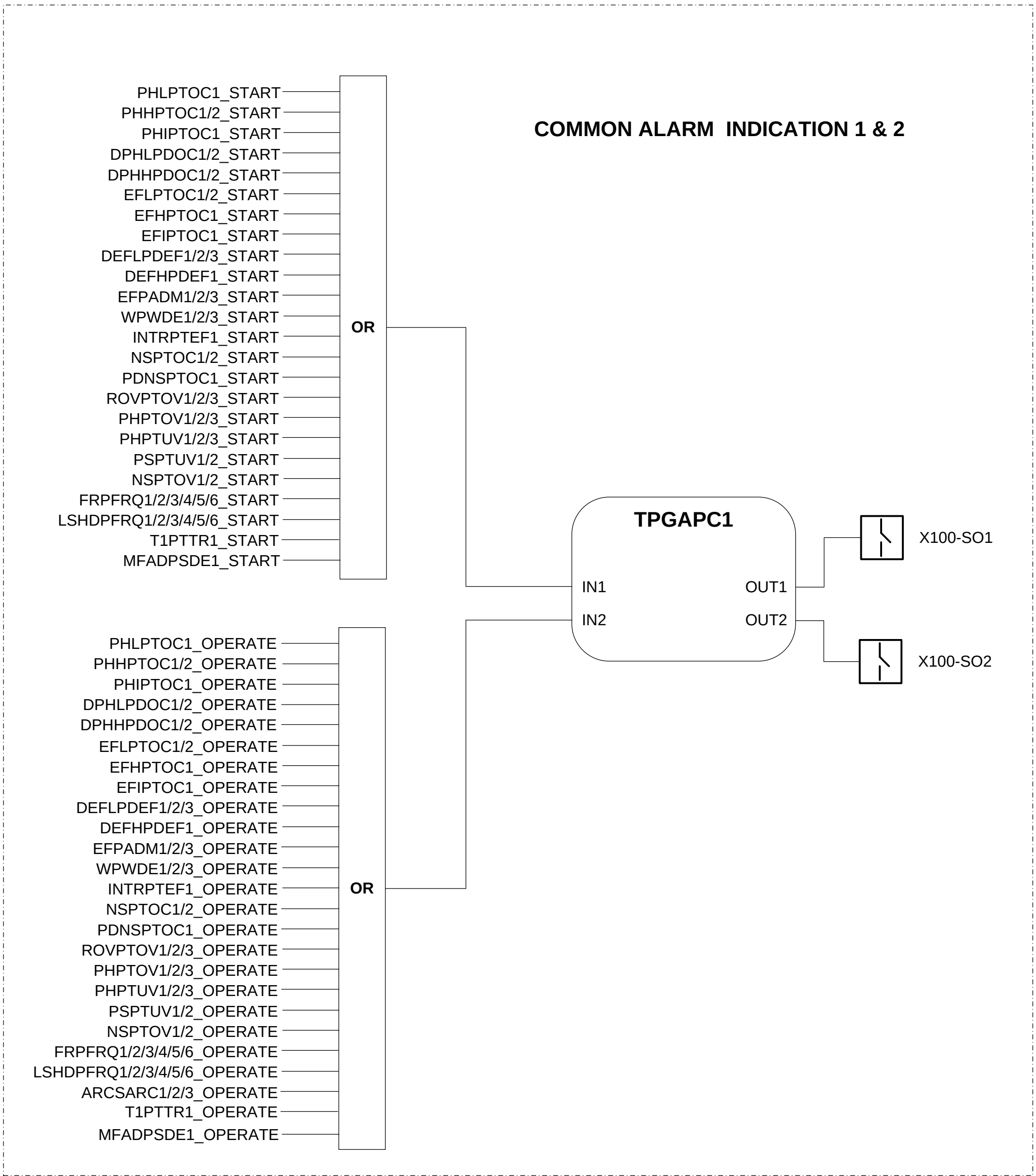


Figure 81: Common alarm indication

The signal outputs from the IED 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.

3.6.3.4 Functional diagrams for power quality measurements

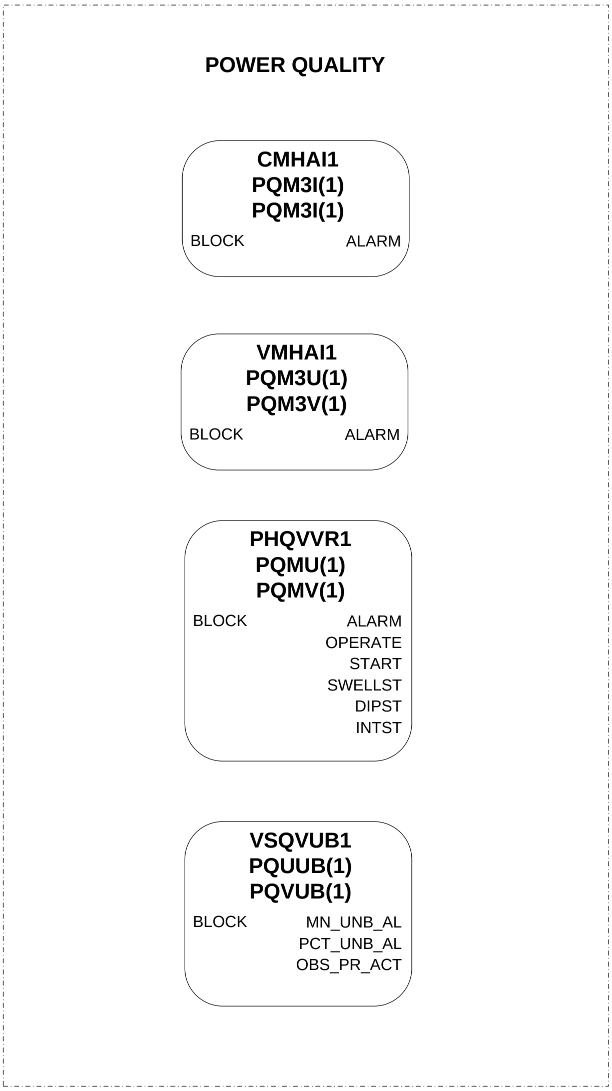


Figure 82: Power quality measurement function

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

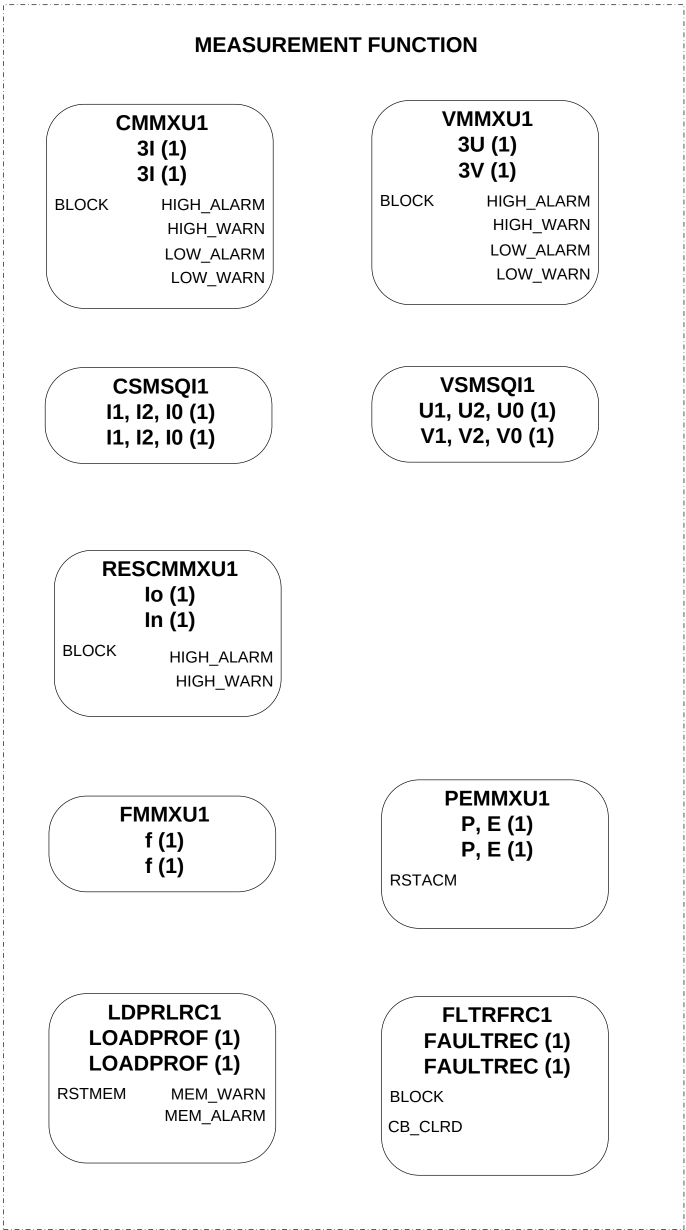


Figure 83: Measurement function

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

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

3.6.3.6 Functional diagrams for extra functions

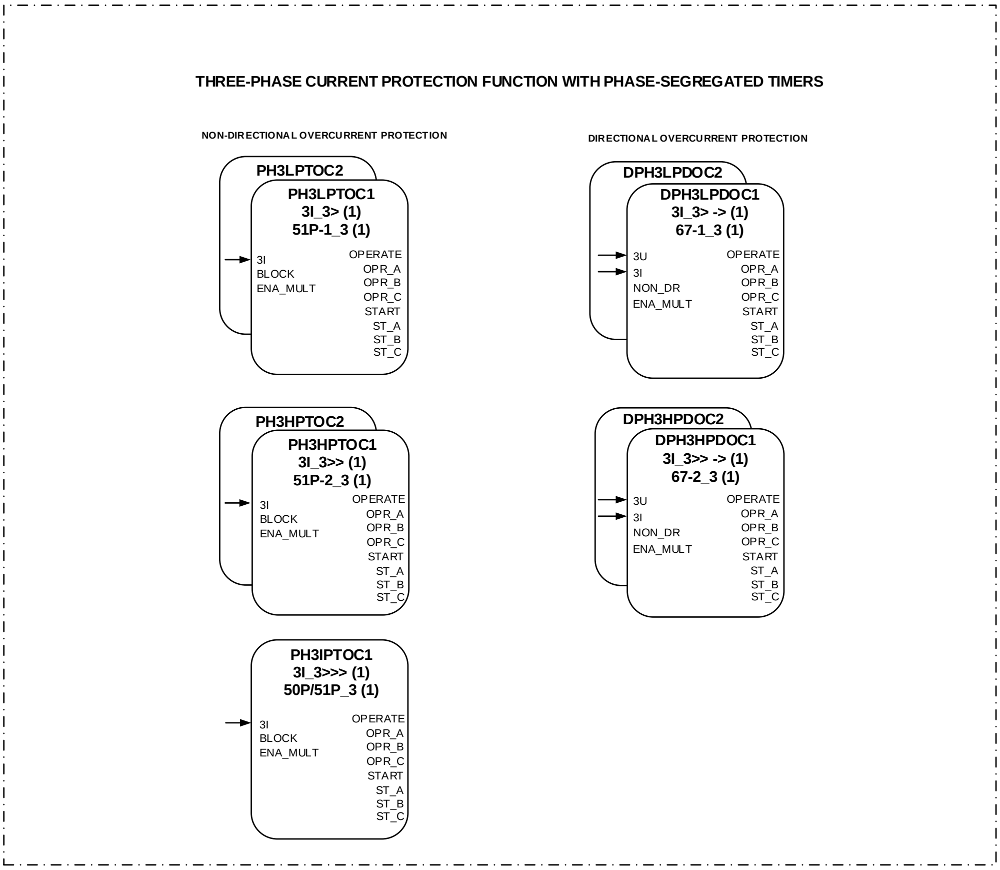


Figure 84: Three-phase current protection function

Nine overcurrent stages in total are offered for overcurrent and short circuit protection. Four stages are for the directional functionality DPH3xPDOC, while the others are only for non-directional overcurrent protection PH3xPTOC.

The function design contains three independent phase-segregated timers that are controlled by common settings. Those functions have separate timers for each phase, which is useful in some applications. Common `START` and `OPERATE` outputs are created by ORing the phase-specific start and operating outputs. Each phase has its own phase-specific start and operating outputs: `ST_A, ST_B, ST_C, OPR_A`, `OPR_B` and `OPR_C`.

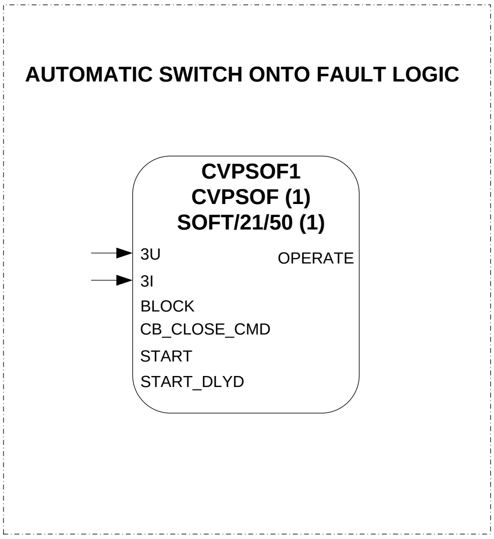


Figure 85: Automatic switch onto fault logic

One automatic switch onto fault logic is offered. CVPSOF1 is used as a complement to instantaneous and high stage overcurrent protection to accelerate the operation of the protection, ensuring a fast trip when the breaker is closed during a fault.

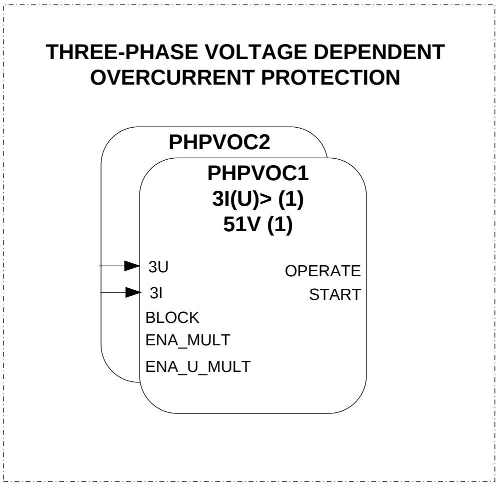


Figure 86: Three-phase voltage dependent overcurrent protection

Two instances of voltage-dependent overcurrent protection PHPVOC1 and PHPVOC2 are provided, which can be used as a backup protection against phase faults. During certain conditions, the fault current for three-phase faults may be less than full load current of the feeder. This may not get noticed by phase overcurrent protection, but the fault causes feeder terminal voltage to drop. Voltage dependent overcurrent protection can be used to detect and operate such faults.

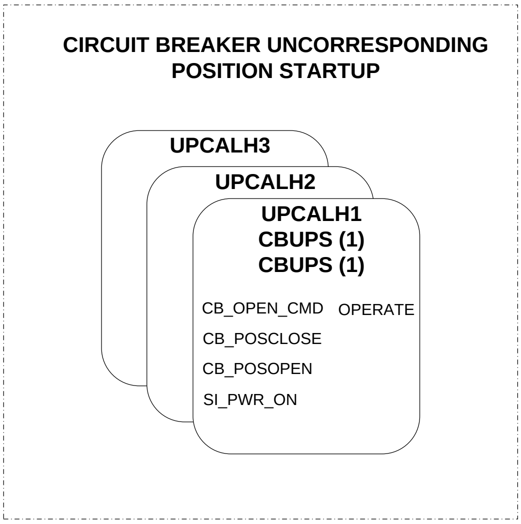


Figure 87: Uncorresponding position start-up function

Three instances of circuit breaker uncorresponding position start-up UPCALH1…3 are provided which are the function that detects circuit breaker openings in unknown situations. UPCALH can be used independently. When detecting a circuit breaker opening under unknown situation, the function output is activated.

In most cases, the function module is used together with the autoreclosing function module, the operate output signal can be one of the start-up signals of the autoreclosing function.

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 preengineered to be part of the default configuration. They can be engineered into use.

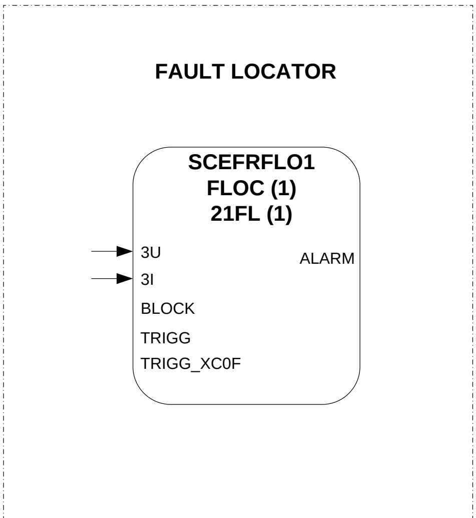


Figure 88: Fault locator function

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

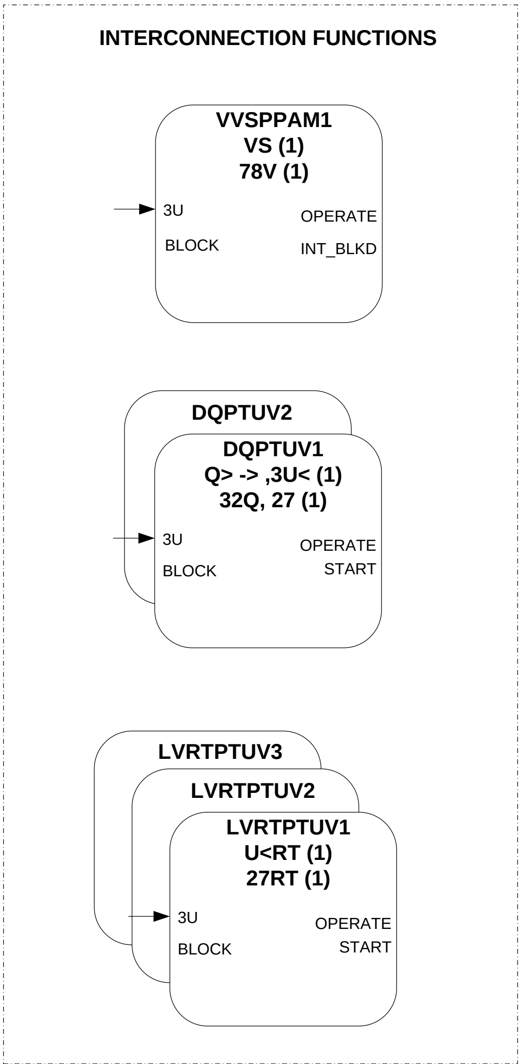


Figure 89: Interconnection function

Interconnection protection functions include the voltage vector shift protection VVSPPAM1, the directional reactive power undervoltage protection DQPTUV1 and three instances of the 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.

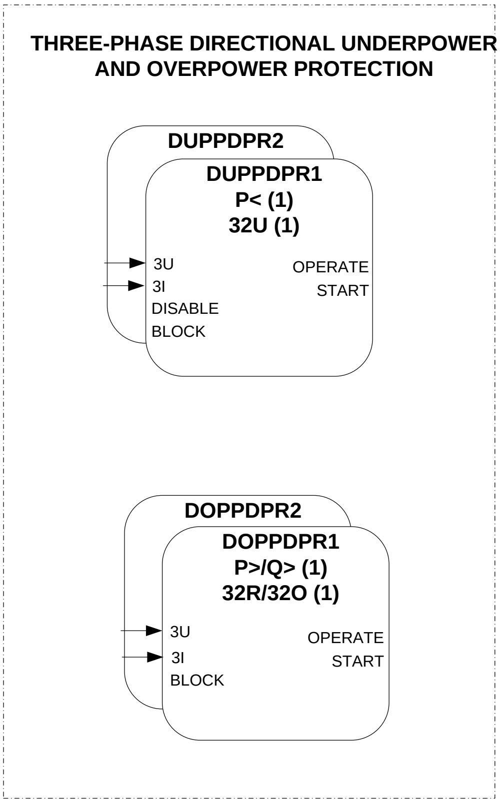


Figure 90: Three-phase directional underpower and overpower protection function

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

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

3.6.4 Application configuration of the 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.

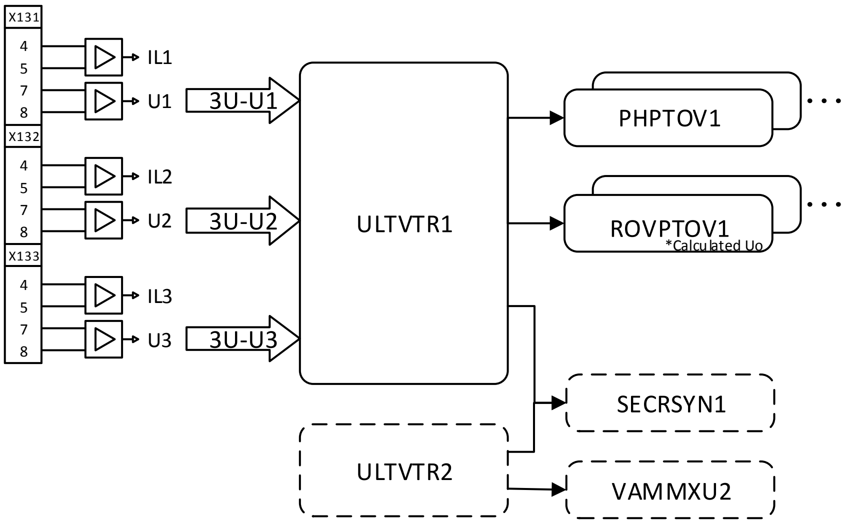


Figure 91: No SMV receiver configured

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

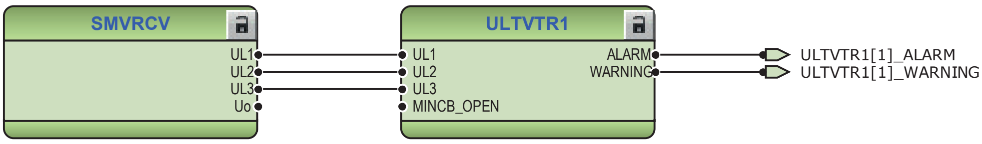


Figure 92: Connection of SMVRCV to ULTVTR1 in Application Configuration

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 the Application Configuration tool.

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

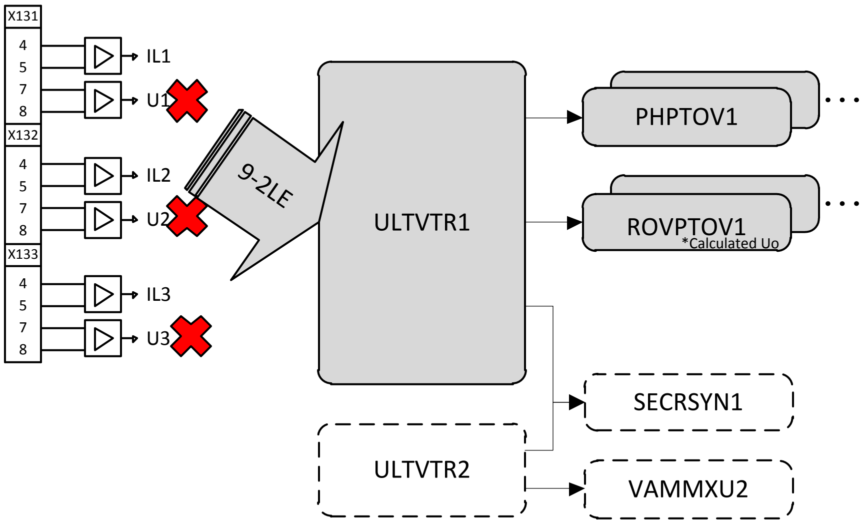


Figure 93: ULTVTR1 uses three phase voltages from received IEC 61850-9-2 LE sample value

3.6.4.2 Connection of SMVRCV to ULTVTR2

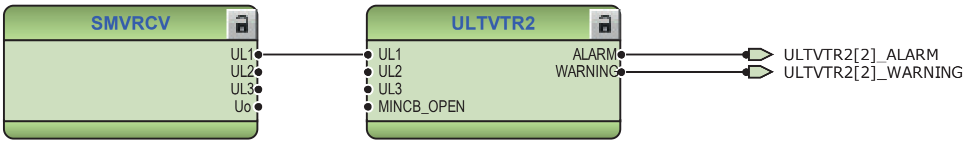


Figure 94: Connection of SMVRCV to ULTVTR2 in Application Configuration

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.

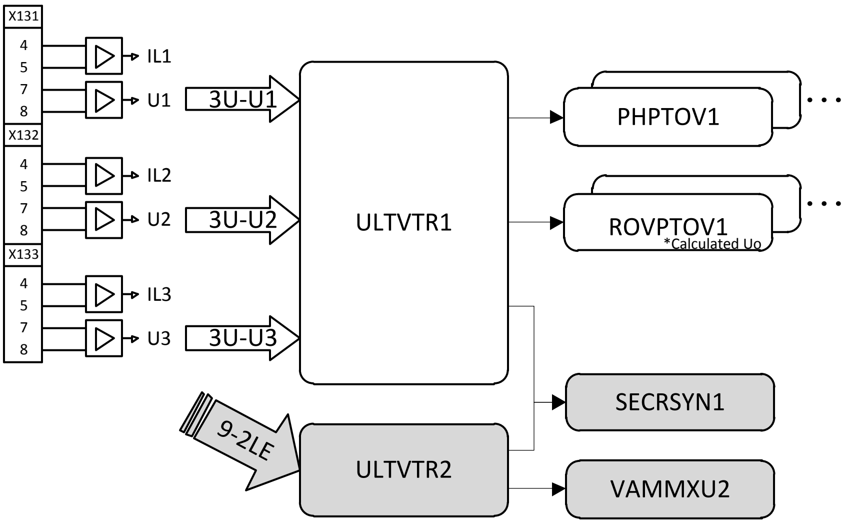


Figure 95: ULTVTR2 uses UL1 voltage from received IEC 61850-9-2 LE sample value

4 Protection relay's 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 38: Phase current inputs included in configuration A

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

4.1.1.2 Residual current

Table 39: Residual current input included in configuration A

Terminal	Description
X120:13-14	Io

Table 40: Residual current input included in configuration B

Terminal	Description
X130:1-2	Io

4.1.1.3 Phase voltages

Table 41: Phase voltage inputs included in configuration A

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

Table 42: Reference voltage input for SECRSYN1 included in configuration A

Terminal	Description
X130:9-10	U_SYN

4.1.1.4 Residual voltage

Table 43: Additional residual voltage input included in configuration A

Terminal	Description
X130:17-18	Uo

4.1.1.5 Sensor inputs

Table 44: 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 45: 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 of slot X105 are optional for configurations A and B.

Table 46: 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[2]
X105:16	Common [3]
X105:17-18	RTD4 (AI6), + RTD4 (AI6), -
X105:19-20 X130:18	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 47: 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 available with configurations A and B.

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

Table 48: 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, -
X110:12 X110:13	BI8, - BI8, +

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

Table 49: 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, +

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

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

Binary inputs of slot X120 are available with configuration A.

Table 51: Binary input terminals X120:1-4

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

Binary inputs of slot X130 are available with configuration A.

Table 52: Binary input terminals X130:1-9

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

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

Table 53: Binary input terminals X105:1-13 (with optional BIO0005)

Terminal	Description
X105:1	BI1, +
X105:2	BI1, -

Table continues on the next page

Terminal	Description
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 54: 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 55: 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 56: Output contacts

Terminal	Description
X100:6 X100:7	PO1, NO PO1, NO
X100:8 X100:9	PO2, NO PO2, NO
X100:15 X100:16 X100:17 X100:18 X100:19	PO3, NO (TCS resistor) PO3, NO PO3, NO PO3 (TCS1 input), NO PO3 (TCS1 input), NO
X100:20 X100:21 X100:22 X100:23 X100:24	PO4, NO (TCS resistor) PO4, NO PO4, NO PO4 (TCS2 input), NO 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 57: Output contacts X100:10-14

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

Output contacts of slot X110 are available for configurations A and B.

Table 58: Output contacts X110:14-24

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

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

Table 59: Output contacts X115:14-24

Terminal	Description
X115:14 X115:15 X115:16	SO1, common SO1, NO SO1, NC
X115:17 X115:18 X115:19	SO2, common SO2, common SO2, common
X115:20 X115:21 X115:22	SO3, common SO3, NO SO3, NC
X115:23 X115:24	SO4, common 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 60: 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, common
X105:19	SO2, common
X105:20	SO3, common
X105:21	SO3, NO
X105:22	SO3, NC
X105:23	SO4, common
X105:24	SO4, NO

Table 61: 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 62: 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 protection and supervision applications of utility substations, and industrial switchgear and equipment
AC	Alternating current
AI	Analog input
ANSI	American National Standards Institute
AR	Autoreclosing
ASCII	American Standard Code for Information Interchange
BI	Binary input
BI/O	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure

Table continues on the next page

HW	Hardware
I/O	Input/output
IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IED	Intelligent electronic device
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
RCA	Also known as MTA or base angle. Characteristic angle.
REF620	Feeder protection and control relay
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol

Table continues on the next page

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

—
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