RELION® 615 SERIES

# Transformer Protection and Control
# RET615

Application Manual


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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 the third party testing laboratory Intertek 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.

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# Table of contents

# Section 1 Introduction

## 1.1 This manual

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

## 1.2 Intended audience

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

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

# 1.3 Product documentation

## 1.3.1 Product documentation set

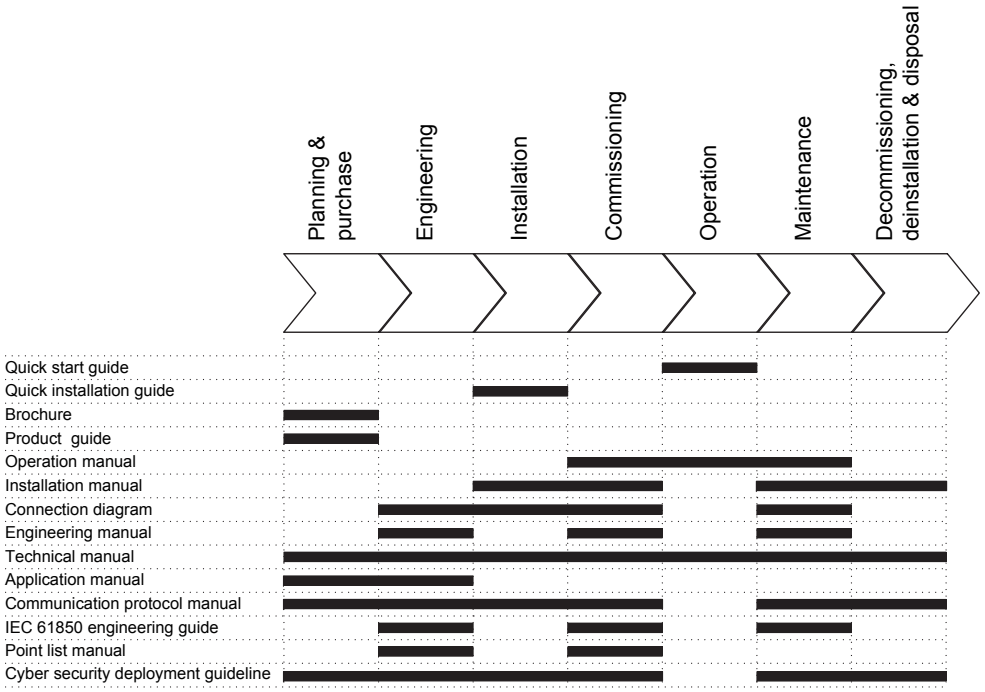



*Figure 1: The intended use of documents during the product life cycle*

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

## 1.3.2 Document revision history

| Document revision/date | Product version | History |
|---|---|---|
| A/2009-09-29 | 2.0 | First release |
| B/2010-07-02 | 3.0 | Content updated |
| C/2014-05-14 | 4.1 | Content updated to correspond to the product version |
| D/2019-04-30 | 5.0 FP1 | Content updated |

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

### 1.3.3 Related documentation

| Name of the document | Document ID |
|---|---|
| Modbus Communication Protocol Manual | 1MRS759002 |
| IEC 60870-5-103 Communication Protocol Manual | 1MRS759001 |
| IEC 61850 Engineering Guide | 1MRS759000 |
| Engineering Manual | 1MRS758999 |
| Installation Manual | 1MRS758997 |
| Operation Manual | 1MRS758998 |
| Technical Manual | 1YHT530004D05 |

## 1.4 Symbols and conventions

### 1.4.1 Symbols

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

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

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

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

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

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

## 1.4.2 Document conventions

A particular convention may not be used in this manual.

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

## 1.4.3 Functions, codes and symbols

*Table 1: RET615 functions, codes and symbols*

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| **Protection** | | | |
| Three-phase non-directional overcurrent protection, low stage | PHLPTOC1 | 3I> (1) | 51P-1 (1) |
| | PHLPTOC2 | 3I> (2) | 51P-1 (2) |
| Three-phase non-directional overcurrent protection, high stage | PHHPTOC1 | 3I>> (1) | 51P-2 (1) |
| | PHHPTOC2 | 3I>> (2) | 51P-2 (2) |
| Three-phase non-directional overcurrent protection, instantaneous stage | PHIPTOC1 | 3I>>> (1) | 50P/51P (1) |
| | PHIPTOC2 | 3I>>> (2) | 50P/51P (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) |
| Negative-sequence overcurrent protection | NSPTOC1 | I2> (1) | 46 (1) |
| | NSPTOC2 | I2> (2) | 46 (2) |
| Residual overvoltage protection | ROVPTOV1 | Uo> (1) | 59G (1) |
| | ROVPTOV2 | Uo> (2) | 59G (2) |
| Three-phase undervoltage protection | PHPTUV1 | 3U< (1) | 27 (1) |
| | PHPTUV2 | 3U< (2) | 27 (2) |

Table continues on next page

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Three-phase overvoltage protection | PHPTOV1 | 3U> (1) | 59 (1) |
| | PHPTOV2 | 3U> (2) | 59 (2) |
| Three-phase thermal overload protection, two time constants | T2PTTR1 | 3Ith>T/G/C (1) | 49T/G/C (1) |
| Stabilized and instantaneous differential protection for two-winding transformers | TR2PTDF1 | 3dI>T (1) | 87T (1) |
| Numerically stabilized low-impedance restricted earth-fault protection | LREFPNDF1 | dIoLo> (1) | 87NL (1) |
| High-impedance based restricted earth-fault protection | HREFPDIF1 | dIoHi> (1) | 87NH (1) |
| Circuit breaker failure protection | CCBRBRF1 | 3I>/Io>BF (1) | 51BF/51NBF (1) |
| Master trip | TRPPTRC1 | Master Trip (1) | 94/86 (1) |
| | TRPPTRC2 | Master Trip (2) | 94/86 (2) |
| | TRPPTRC3 | Master Trip (3) | 94/86 (3) |
| | TRPPTRC4 | Master Trip (4) | 94/86 (4) |
| | TRPPTRC5 | Master Trip (5) | 94/86 (5) |
| Arc protection | ARCSARC1 | ARC (1) | 50L/50NL (1) |
| | ARCSARC2 | ARC (2) | 50L/50NL (2) |
| | ARCSARC3 | ARC (3) | 50L/50NL (3) |
| Multipurpose protection | MAPGAPC1 | MAP (1) | MAP (1) |
| | MAPGAPC2 | MAP (2) | MAP (2) |
| | MAPGAPC3 | MAP (3) | MAP (3) |
| | MAPGAPC4 | MAP (4) | MAP (4) |
| | MAPGAPC5 | MAP (5) | MAP (5) |
| | MAPGAPC6 | MAP (6) | MAP (6) |
| | MAPGAPC7 | MAP (7) | MAP (7) |
| | MAPGAPC8 | MAP (8) | MAP (8) |
| | MAPGAPC9 | MAP (9) | MAP (9) |
| | MAPGAPC10 | MAP (10) | MAP (10) |
| | MAPGAPC11 | MAP (11) | MAP (11) |
| | MAPGAPC12 | MAP (12) | MAP (12) |
| | MAPGAPC13 | MAP (13) | MAP (13) |
| | MAPGAPC14 | MAP (14) | MAP (14) |
| | MAPGAPC15 | MAP (15) | MAP (15) |
| | MAPGAPC16 | MAP (16) | MAP (16) |
| | MAPGAPC17 | MAP (17) | MAP (17) |
| | MAPGAPC18 | MAP (18) | MAP (18) |
| **Control** | | | |
| Circuit-breaker control | CBXCBR1 | I <-> O CB (1) | I <-> O CB (1) |

Table continues on next page

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Disconnector control | DCXSWI1 | I <-> O DCC (1) | I <-> O DCC (1) |
| | DCXSWI2 | I <-> O DCC (2) | I <-> O DCC (2) |
| Earthing switch control | ESXSWI1 | I <-> O ESC (1) | I <-> O ESC (1) |
| Disconnector position indication | DCSXSWI1 | I <-> O DC (1) | I <-> O DC (1) |
| | DCSXSWI2 | I <-> O DC (2) | I <-> O DC (2) |
| | DCSXSWI3 | I <-> O DC (3) | I <-> O DC (3) |
| Earthing switch indication | ESSXSWI1 | I <-> O ES (1) | I <-> O ES (1) |
| | ESSXSWI2 | I <-> O ES (2) | I <-> O ES (2) |
| Tap changer position indication | TPOSYLTC1 | TPOSM (1) | 84M (1) |
| **Condition monitoring** | | | |
| Circuit-breaker condition monitoring | SSCBR1 | CBCM (1) | CBCM (1) |
| Trip circuit supervision | TCSSCBR1 | TCS (1) | TCM (1) |
| | TCSSCBR2 | TCS (2) | TCM (2) |
| Advanced current circuit supervision for transformers | CTSRCTF1 | MCS 3I,I2 (1) | MCS 3I,I2 (1) |
| Fuse failure supervision | SEQSPVC1 | FUSEF (1) | 60 (1) |
| Runtime counter for machines and devices | MDSOPT1 | OPTS (1) | OPTM (1) |
| **Measurement** | | | |
| Disturbance recorder | RDRE1 | DR (1) | DFR (1) |
| Load profile record | LDPRLRC1 | LOADPROF (1) | LOADPROF (1) |
| Fault record | FLTRFRC1 | FAULTREC (1) | FAULTREC (1) |
| Three-phase current measurement | CMMXU1 | 3I (1) | 3I (1) |
| | CMMXU2 | 3I (2) | 3I (2) |
| Sequence current measurement | CSMSQI1 | I1, I2, I0 (1) | I1, I2, I0 (1) |
| Residual current measurement | RESCMMXU1 | Io (1) | In (1) |
| | RESCMMXU2 | Io (2) | In (2) |
| Three-phase voltage measurement | VMMXU1 | 3U (1) | 3V (1) |
| Residual voltage measurement | RESVMMXU1 | Uo (1) | Vn (1) |
| Sequence voltage measurement | VSMSQI1 | U1, U2, U0 (1) | V1, V2, V0 (1) |
| Three-phase power and energy measurement | PEMMXU1 | P, E (1) | P, E (1) |
| RTD/mA measurement | XRGGIO130 | X130 (RTD) (1) | X130 (RTD) (1) |
| Frequency measurement | FMMXU1 | f (1) | f (1) |
| IEC 61850-9-2 LE sampled value sending | SMVSENDER | SMVSENDER | SMVSENDER |
| IEC 61850-9-2 LE sampled value receiving (voltage sharing) | SMVRECEIVER | SMVRECEIVER | SMVRECEIVER |
| **Other** | | | |

Table continues on next page

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

## 1.4.4 Functions, codes and symbols

*Table 2: REU615 functions, codes and symbols*

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| **Protection** | | | |
| Three-phase non-directional overcurrent protection, low stage | PHLPTOC1 | 3I> (1) | 51P-1 (1) |
| Three-phase non-directional overcurrent protection, high stage | PHHPTOC1 | 3I>> (1) | 51P-2 (1) |
| Table continues on next page | | | |

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Three-phase non-directional overcurrent protection, instantaneous stage | PHIPTOC1 | 3I>>> (1) | 50P/51P (1) |
| Residual overvoltage protection | ROVPTOV1 | Uo> (1) | 59G (1) |
| | ROVPTOV2 | Uo> (2) | 59G (2) |
| | ROVPTOV3 | Uo> (3) | 59G (3) |
| Three-phase undervoltage protection | PHPTUV1 | 3U< (1) | 27 (1) |
| | PHPTUV2 | 3U< (2) | 27 (2) |
| | PHPTUV3 | 3U< (3) | 27 (3) |
| Three-phase overvoltage protection | PHPTOV1 | 3U> (1) | 59 (1) |
| | PHPTOV2 | 3U> (2) | 59 (2) |
| | PHPTOV3 | 3U> (3) | 59 (3) |
| Positive-sequence undervoltage protection | PSPTUV1 | U1< (1) | 47U+ (1) |
| | PSPTUV2 | U1< (2) | 47U+ (2) |
| Negative-sequence overvoltage protection | NSPTOV1 | U2> (1) | 47O- (1) |
| | NSPTOV2 | U2> (2) | 47O- (2) |
| Frequency protection | FRPFRQ1 | f>/f<,df/dt (1) | 81 (1) |
| | FRPFRQ2 | f>/f<,df/dt (2) | 81 (2) |
| | FRPFRQ3 | f>/f<,df/dt (3) | 81 (3) |
| | FRPFRQ4 | f>/f<,df/dt (4) | 81 (4) |
| | FRPFRQ5 | f>/f<,df/dt (5) | 81 (5) |
| | FRPFRQ6 | f>/f<,df/dt (6) | 81 (6) |
| Three-phase thermal overload protection, two time constants | T2PTTR1 | 3Ith>T/G/C (1) | 49T/G/C (1) |
| Master trip | TRPPTRC1 | Master Trip (1) | 94/86 (1) |
| | TRPPTRC2 | Master Trip (2) | 94/86 (2) |
| Arc protection | ARCSARC1 | ARC (1) | 50L/50NL (1) |
| | ARCSARC2 | ARC (2) | 50L/50NL (2) |
| | ARCSARC3 | ARC (3) | 50L/50NL (3) |

Table continues on next page

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Multipurpose protection | MAPGAPC1 | MAP (1) | MAP (1) |
| | MAPGAPC2 | MAP (2) | MAP (2) |
| | MAPGAPC3 | MAP (3) | MAP (3) |
| | MAPGAPC4 | MAP (4) | MAP (4) |
| | MAPGAPC5 | MAP (5) | MAP (5) |
| | MAPGAPC6 | MAP (6) | MAP (6) |
| | MAPGAPC7 | MAP (7) | MAP (7) |
| | MAPGAPC8 | MAP (8) | MAP (8) |
| | MAPGAPC9 | MAP (9) | MAP (9) |
| | MAPGAPC10 | MAP (10) | MAP (10) |
| | MAPGAPC11 | MAP (11) | MAP (11) |
| | MAPGAPC12 | MAP (12) | MAP (12) |
| | MAPGAPC13 | MAP (13) | MAP (13) |
| | MAPGAPC14 | MAP (14) | MAP (14) |
| | MAPGAPC15 | MAP (15) | MAP (15) |
| | MAPGAPC16 | MAP (16) | MAP (16) |
| | MAPGAPC17 | MAP (17) | MAP (17) |
| | MAPGAPC18 | MAP (18) | MAP (18) |
| 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) |
| | LSHDPFRQ5 | UFLS/R (5) | 81LSH (5) |
| **Control** | | | |
| Circuit-breaker control | CBXCBR1 | I <-> O CB (1) | I <-> O CB (1) |
| Disconnector control | DCXSWI1 | I <-> O DCC (1) | I <-> O DCC (1) |
| | DCXSWI2 | I <-> O DCC (2) | I <-> O DCC (2) |
| Earthing switch control | ESXSWI1 | I <-> O ESC (1) | I <-> O ESC (1) |
| Disconnector position indication | DCSXSWI1 | I <-> O DC (1) | I <-> O DC (1) |
| | DCSXSWI2 | I <-> O DC (2) | I <-> O DC (2) |
| | DCSXSWI3 | I <-> O DC (3) | I <-> O DC (3) |
| Earthing switch indication | ESSXSWI1 | I <-> O ES (1) | I <-> O ES (1) |
| | ESSXSWI2 | I <-> O ES (2) | I <-> O ES (2) |
| Tap changer position indication | TPOSYLTC1 | TPOSM (1) | 84M (1) |
| Tap changer control with voltage regulator | OLATCC1 | COLTC (1) | 90V (1) |
| Synchronism and energizing check | SECRSYN1 | SYNC (1) | 25 (1) |
| **Condition monitoring** | | | |
| Trip circuit supervision | TCSSCBR1 | TCS (1) | TCM (1) |
| | TCSSCBR2 | TCS (2) | TCM (2) |

Table continues on next page

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Current circuit supervision | CCSPVC1 | MCS 3I (1) | MCS 3I (1) |
| Fuse failure supervision | SEQSPVC1 | FUSEF (1) | 60 (1) |
| Runtime counter for machines and devices | MDSOPT1 | OPTS (1) | OPTM (1) |
| **Measurement** | | | |
| Disturbance recorder | RDRE1 | DR (1) | DFR (1) |
| Load profile record | LDPRLRC1 | LOADPROF (1) | LOADPROF (1) |
| Fault record | FLTRFRC1 | FAULTREC (1) | FAULTREC (1) |
| Three-phase current measurement | CMMXU1 | 3I (1) | 3I (1) |
| Sequence current measurement | CSMSQI1 | I1, I2, I0 (1) | I1, I2, I0 (1) |
| Three-phase voltage measurement | VMMXU1 | 3U (1) | 3V (1) |
| | VMMXU2 | 3U (2) | 3V (2) |
| Residual voltage measurement | RESVMMXU1 | Uo (1) | Vn (1) |
| Sequence voltage measurement | VSMSQI1 | U1, U2, U0 (1) | V1, V2, V0 (1) |
| Three-phase power and energy measurement | PEMMXU1 | P, E (1) | P, E (1) |
| RTD/mA measurement | XRGGIO130 | X130 (RTD) (1) | X130 (RTD) (1) |
| Frequency measurement | FMMXU1 | f (1) | f (1) |
| IEC 61850-9-2 LE sampled value sending | SMVSENDER | SMVSENDER | SMVSENDER |
| IEC 61850-9-2 LE sampled value receiving (voltage sharing) | SMVRECEIVER | SMVRECEIVER | SMVRECEIVER |
| **Other** | | | |
| Minimum pulse timer (2 pcs) | TPGAPC1 | TP (1) | TP (1) |
| | TPGAPC2 | TP (2) | TP (2) |
| | TPGAPC3 | TP (3) | TP (3) |
| | TPGAPC4 | TP (4) | TP (4) |
| Minimum pulse timer (2 pcs, second resolution) | TPSGAPC1 | TPS (1) | TPS (1) |
| Minimum pulse timer (2 pcs, minute resolution) | TPMGAPC1 | TPM (1) | TPM (1) |
| Pulse timer (8 pcs) | PTGAPC1 | PT (1) | PT (1) |
| | PTGAPC2 | PT (2) | PT (2) |
| Time delay off (8 pcs) | TOFGAPC1 | TOF (1) | TOF (1) |
| | TOFGAPC2 | TOF (2) | TOF (2) |
| | TOFGAPC3 | TOF (3) | TOF (3) |
| | TOFGAPC4 | TOF (4) | TOF (4) |
| Time delay on (8 pcs) | TONGAPC1 | TON (1) | TON (1) |
| | TONGAPC2 | TON (2) | TON (2) |
| | TONGAPC3 | TON (3) | TON (3) |
| | TONGAPC4 | TON (4) | TON (4) |

Table continues on next page

| Function | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Set-reset (8 pcs) | SRGAPC1 | SR (1) | SR (1) |
| | SRGAPC2 | SR (2) | SR (2) |
| | SRGAPC3 | SR (3) | SR (3) |
| | SRGAPC4 | SR (4) | SR (4) |
| Move (8 pcs) | MVGAPC1 | MV (1) | MV (1) |
| | MVGAPC2 | MV (2) | MV (2) |
| Generic control point (16 pcs) | SPCGAPC1 | SPC (1) | SPC (1) |
| | SPCGAPC2 | SPC (2) | SPC (2) |
| Analog value scaling | SCA4GAPC1 | SCA4 (1) | SCA4 (1) |
| | SCA4GAPC2 | SCA4 (2) | SCA4 (2) |
| | SCA4GAPC3 | SCA4 (3) | SCA4 (3) |
| | SCA4GAPC4 | SCA4 (4) | SCA4 (4) |
| Integer value move | MVI4GAPC1 | MVI4 (1) | MVI4 (1) |

# Section 2 RET615 overview

## 2.1 Overview

RET615 is a dedicated transformer protection and control relay for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems. RET615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series relays are characterized by their compactness and withdrawable-unit design.

Re-engineered from the ground up, the 615 series has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices. Once the standard configuration relay has been given the application-specific settings, it can directly be put into service.

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, IEC 60870-5-103 and Modbus®. 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 |
| 3.0 | • New configurations E, F, G and H<br>• Additions to configuration A, B, C, D, J and K<br>• Application configurability support<br>• Analog GOOSE support<br>• Large display with single line diagram<br>• Enhanced mechanical design<br>• Increased maximum amount of events and fault records<br>• Frequency measurement and protection<br>• RTD/mA measurement and protection<br>• Voltage measurement and protection<br>• Fuse failure supervision<br>• Three-phase power and energy measurements<br>• Multi-port Ethernet option |

| Product version | Product history |
|---|---|
| 4.1 | • Additions/changes for configurations A-H<br>• Dual fibre optic Ethernet communication option (COM0032)<br>• Generic control point (SPCGGIO) function blocks<br>• Additional logic blocks<br>• Button object for SLD<br>• Controllable disconnector and earth switch objects for SLD<br>• Additional multi-purpose protection instances<br>• Increased maximum amount of events and fault records<br>• High-availability seamless redundancy (HSR) protocol<br>• Parallel redundancy protocol (PRP-1)<br>• Parallel use of IEC 61850 and IEC 60870-5-103 protocols<br>• Two selectable indication colors for LEDs (red or green)<br>• Online binary signal monitoring with PCM600 |
| 5.0 FP1 | • New configuration Z<br>• New layout in Application Configuration for all configurations<br>• Support for IEC 61850-9-2 LE<br>• IEEE 1588 v2 time synchronization<br>• Load profile recorder<br>• High-speed binary outputs<br>• Optional RTD/mA inputs for configurations A, B and Z<br>• Profibus adapter support<br>• Support for multiple SLD pages<br>• Import/export of settings via WHMI<br>• Setting usability improvements<br>• HMI event filtering tool<br>• IEC 61850 Edition 2<br>• Currents sending support with IEC 61850-9-2 LE<br>• Software closable Ethernet ports<br>• Report summary via WHMI<br>• Additional timer, set-reset and analog value scaling functions |

## 2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.9 Hotfix 1 or later
- RET615 Connectivity Package Ver.5.1 or later
  - Parameter Setting
  - Signal Monitoring
  - Event Viewer
  - Disturbance Handling
  - Application Configuration
  - Signal Matrix
  - Graphical Display Editor
  - Communication Management
  - IED User Management
  - IED Compare
  - Firmware Update
  - Fault Record tool
  - Load Record Profile
  - Lifecycle Traceability
  - Configuration Wizard
  - AR Sequence Visualizer

- Label Printing
- IEC 61850 Configuration
- Differential Characteristics Tool

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

## 2.2 Operation functionality

### 2.2.1 Optional functions

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- RTD/mA measurements and multipurpose protection (configurations A, B and Z only)
- IEC 61850-9-2 LE
- IEEE 1588 v2 time synchronization

## 2.3 Physical hardware

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

*Table 3: Plug-in unit and case*

| Main unit | Slot ID | Content options | |
|---|---|---|---|
| Plug-in unit | - | HMI | Small (5 lines, 20 characters)<br>Large (10 lines, 20 characters) with SLD |
| | | | Small Chinese (3 lines, 8 or more characters)<br>Large Chinese (7 lines, 8 or more characters) with SLD |
| | X100 | Auxiliary power/BO module | 48...250 V DC/100...240 V AC; or 24...60 V DC<br>2 normally-open PO contacts<br>1 change-over SO contact<br>1 normally-open SO contact<br>2 double-pole PO contacts with TCS<br>1 dedicated internal fault output contact |
| | X110 | BIO module | 8 binary inputs<br>4 SO contacts |
| | | | 8 binary inputs<br>3 HSO contacts |
| | X120 | AI module | 6 phase current inputs (1/5 A)<br>1 residual current input (1/5 A) |
| Case | X130 | AI/BI module | Only with configurations E and F:<br>3 phase voltage inputs (60...210 V)<br>1 residual voltage input (60...210 V)<br>4 binary inputs |
| | | AI/RTD/mA module | Only with configurations E and F:<br>3 phase voltage inputs (60...210 V)<br>1 residual voltage input (60...210 V)<br>1 generic mA input<br>2 RTD sensor inputs |
| | | Optional RTD/mA module | Optional for configurations A, B and Z:<br>2 generic mA inputs<br>6 RTD sensor inputs |
| | | Optional BIO module | Optional for configurations A, B and Z:<br>6 binary inputs<br>3 SO contacts |
| | X000 | Optional communication module | See the technical manual for details about different types of communication modules. |

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

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

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

*Table 4: Input/output overview*

| Std. conf. | Order code digit | | Analog channels | | Binary channels | | | |
|---|---|---|---|---|---|---|---|---|
| | 5-6 | 7-8 | CT | VT | BI | BO | RTD | mA |
| A<br>B | BA | BB | 7 | - | 14 | 4 PO + 9 SO | - | - |
| | | FF | 7 | - | 14 | 4 PO + 5 SO + 3 HSO | - | - |
| | BG | BA | 7 | - | 8 | 4 PO + 6 SO | 6 | 2 |
| | | FD | 7 | - | 8 | 4 PO + 2 SO + 3 HSO | 6 | 2 |
| E<br>F | BC | AD | 7 | 5 | 12 | 4 PO + 6 SO | - | - |
| | | FE | 7 | 5 | 12 | 4 PO + 2 SO + 3 HSO | - | - |
| | BE | BA | 7 | 5 | 8 | 4 PO + 6 SO | 2 | 1 |
| | | FD | 7 | 5 | 8 | 4 PO + 2 SO + 3 HSO | 2 | 1 |
| Z | BA | BB | 7 | - | 14 | 4 PO + 9 SO | - | - |
| | | BA | 7 | - | 8 | 4 PO + 6 SO | - | - |
| | BG | BA | 7 | - | 8 | 4 PO + 6 SO | 6 | 2 |

## 2.4 Local HMI

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

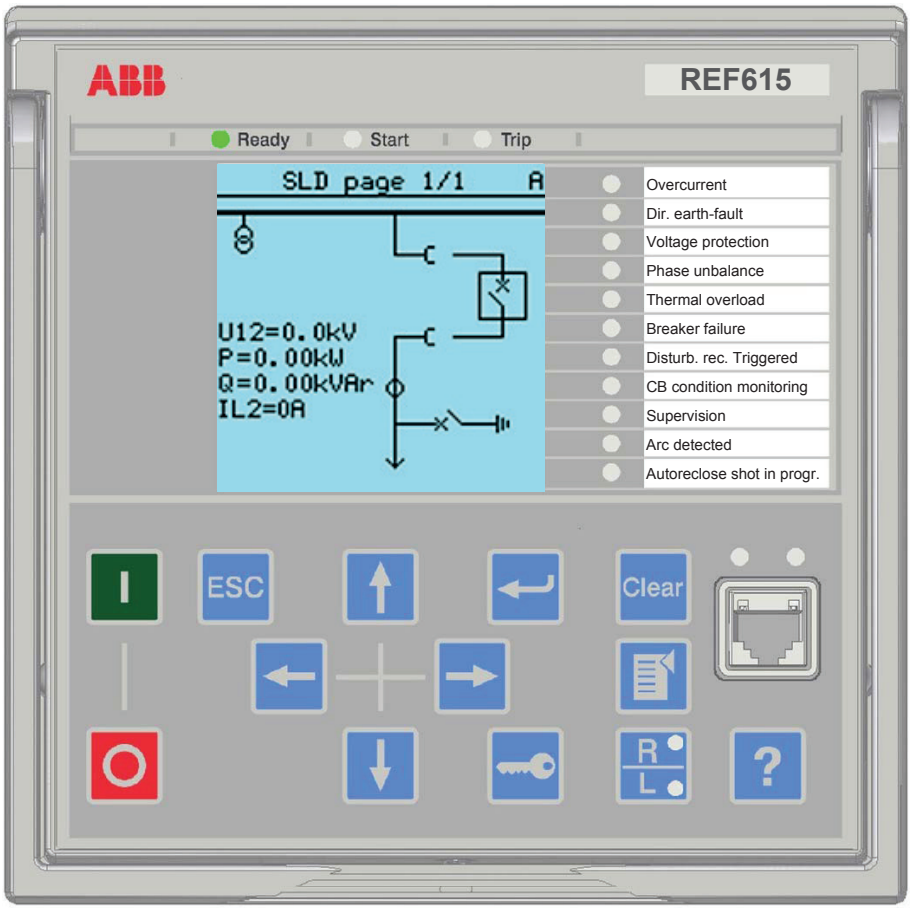



*Figure 2: Example of the LHMI*

## 2.4.1 Display

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

***Table 5: Small display***

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

1) Depending on the selected language

***Table 6: Large display***

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

1) Depending on the selected language

The display view is divided into four basic areas.

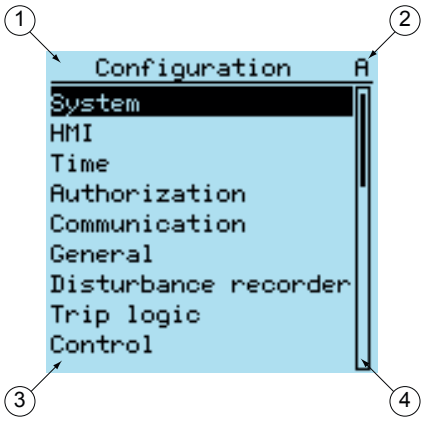



*Figure 3: Display layout*

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

## 2.4.2 LEDs

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

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

## 2.4.3 Keypad

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

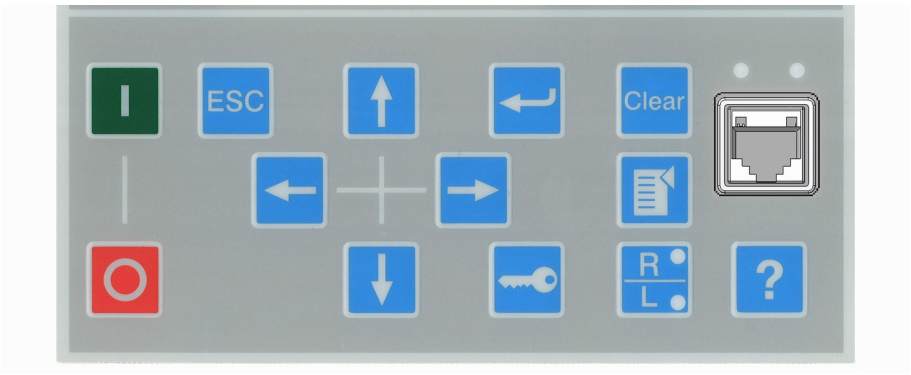



*Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port*

## 2.5 Web HMI

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

WHMI is disabled by default.

WHMI offers several functions.

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

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

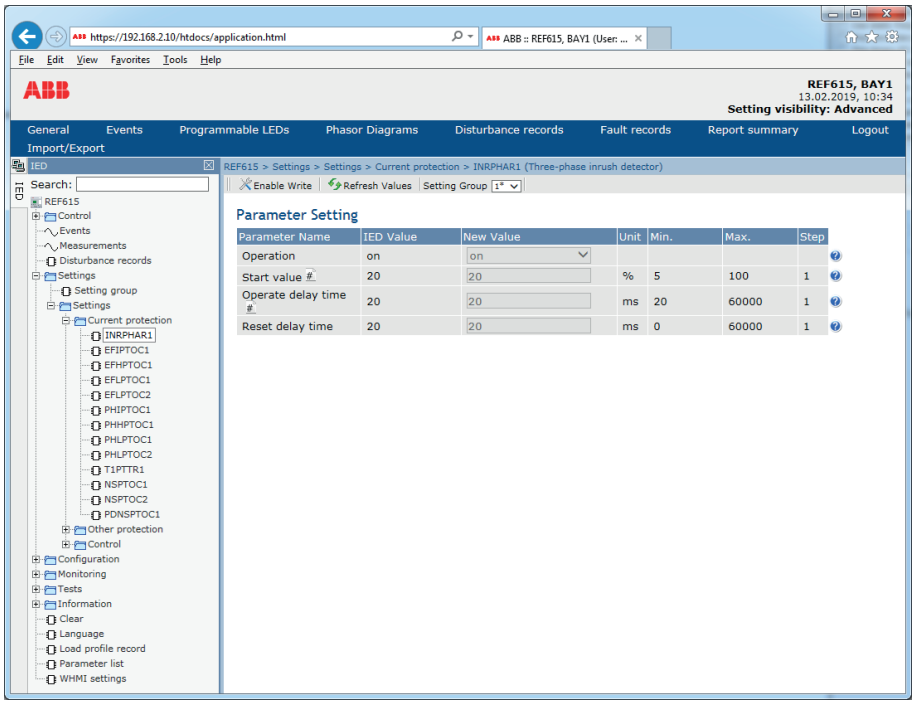



*Figure 5: Example view of the WHMI*

The WHMI can be accessed locally and remotely.

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

## 2.6 Authorization

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

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

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

*Table 7: Predefined user categories*

| Username | User rights |
|---|---|
| VIEWER | Read only access |
| OPERATOR | • Selecting remote or local state with (only locally)<br>• Changing setting groups<br>• Controlling<br>• Clearing indications |
| ENGINEER | • Changing settings<br>• Clearing event list<br>• Clearing disturbance records<br>• Changing system settings such as IP address, serial baud rate or disturbance recorder settings<br>• Setting the protection relay to test mode<br>• Selecting language |
| ADMINISTRATOR | • All listed above<br>• Changing password<br>• 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 8: Audit trail events*

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

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

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

*Table 9: Comparison of authority logging levels*

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

## 2.7 Communication

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

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices

(so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Furthermore, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard.

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

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

### 2.7.1 Self-healing Ethernet ring

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

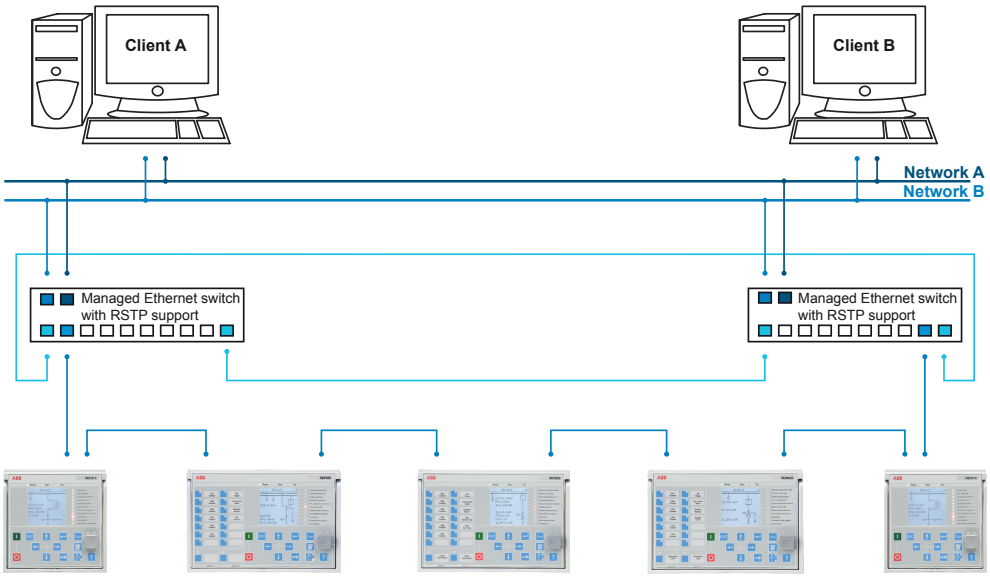



*Figure 6: Self-healing Ethernet ring solution*

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

## 2.7.2 Ethernet redundancy

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

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

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

## PRP

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

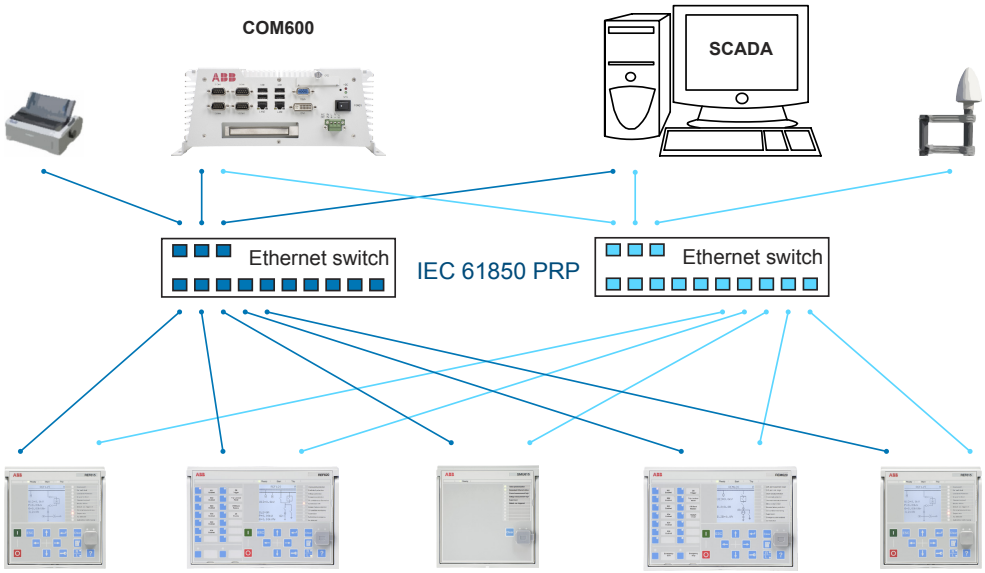



*Figure 7: PRP solution*

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

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

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

### HSR

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

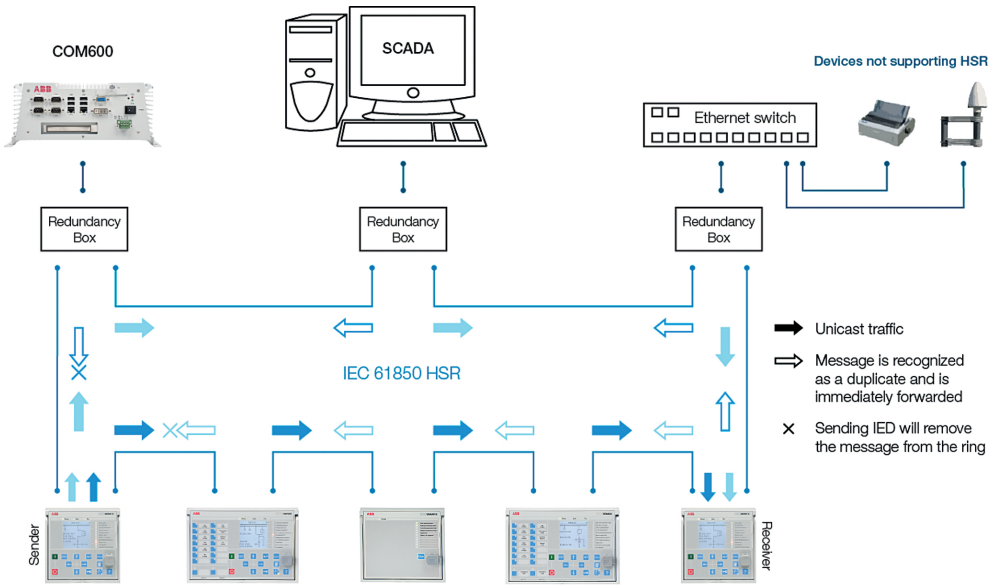



*Figure 8: HSR solution*

## 2.7.3 Process bus

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

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

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

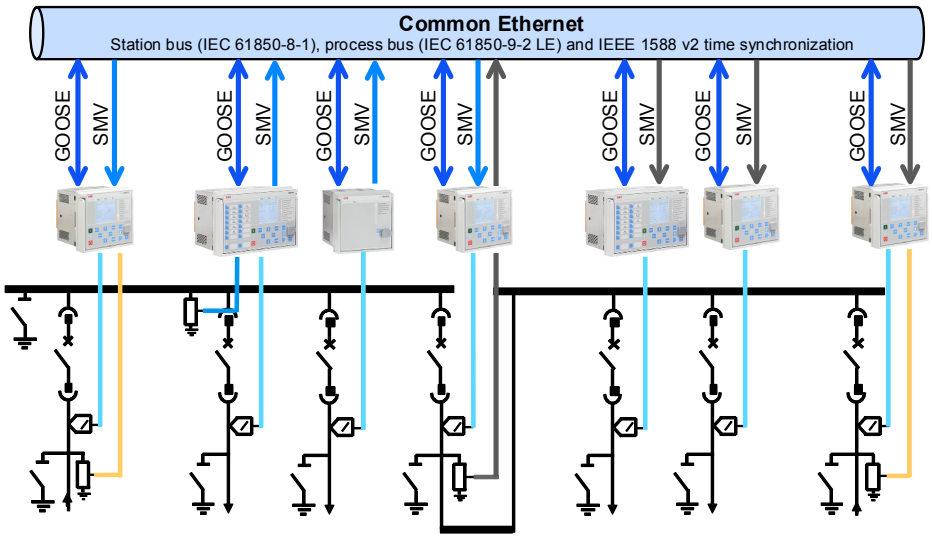



*Figure 9: Process bus application of voltage sharing and synchrocheck*

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

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

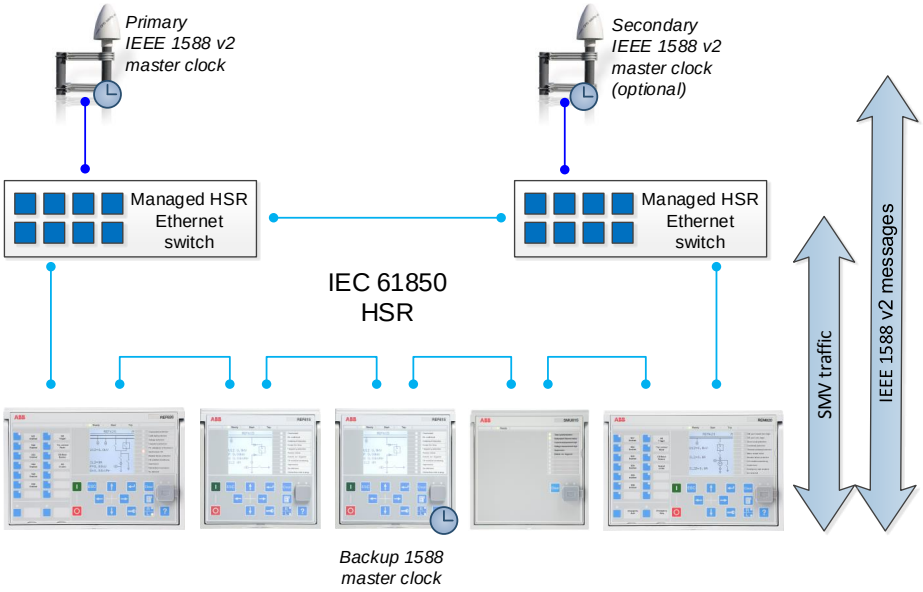



*Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization*

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

## 2.7.4 Secure communication

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

# Section 3 RET615 standard configurations

## 3.1 Standard configurations

RET615 is available with five alternative standard configurations. The standard signal configuration can be altered by means of the signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions utilizing various logical elements including timers and flip-flops. By combining protection functions with logic function blocks the relay configuration can be adapted to user specific application requirements.

The relay is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. Some of the supported functions in RET615 must be added with the Application Configuration tool to be available in the Signal Matrix tool and in the relay. The positive measuring direction of directional protection functions is towards the outgoing feeder.

*Table 10: Standard configurations*

| Description | Std. conf. |
|---|---|
| Transformer differential with low-impedance restricted earth-fault protection on the HV side | A |
| Transformer differential with low-impedance restricted earth-fault protection on the LV side | B |
| Transformer differential with voltage protection and measurements, and low-impedance restricted earth-fault protection on the HV side | E |
| Transformer differential with voltage protection and measurements, and low-impedance restricted earth-fault protection on the LV side | F |
| Transformer differential protection with advanced current circuit supervision for transformers | Z |

*Table 11: Supported functions*

| Function | IEC 61850 | A | B | E | F | Z |
|---|---|---|---|---|---|---|
| **Protection** | | | | | | |
| Three-phase non-directional overcurrent protection, low stage | PHLPTOC1 | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | |
| | PHLPTOC2 | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | |
| Three-phase non-directional overcurrent protection, high stage | PHHPTOC1 | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | |
| | PHHPTOC2 | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | |
| Table continues on next page | | | | | | |

| Function | IEC 61850 | A | B | E | F | Z |
|---|---|---|---|---|---|---|
| Three-phase non-directional overcurrent protection, instantaneous stage | PHIPTOC1 | 1[HV] | 1[HV] | 1[HV] | 1[HV] | |
| | PHIPTOC2 | 1[LV] | 1[LV] | 1[LV] | 1[LV] | |
| Non-directional earth-fault protection, low stage | EFLPTOC1 | 1[HV] | | 1[HV] | | |
| | EFLPTOC2 | | 1[LV] | | 1[LV] | |
| Non-directional earth-fault protection, high stage | EFHPTOC1 | 1[HV] | | 1[HV] | | |
| | EFHPTOC2 | | 1[LV] | | 1[LV] | |
| Negative-sequence overcurrent protection | NSPTOC1 | 1[HV] | 1[HV] | 1[HV] | 1[HV] | |
| | NSPTOC2 | 1[LV] | 1[LV] | 1[LV] | 1[LV] | |
| Residual overvoltage protection | ROVPTOV | | | 2[HV] | 2[HV] | |
| Three-phase undervoltage protection | PHPTUV | | | 2[HV] | 2[HV] | |
| Three-phase overvoltage protection | PHPTOV | | | 2[HV] | 2[HV] | |
| Three-phase thermal overload protection, two time constants | T2PTTR | 1[HV] | 1[HV] | 1[HV] | 1[HV] | |
| Stabilized and instantaneous differential protection for two-winding transformers | TR2PTDF | 1 | 1 | 1 | 1 | 1 |
| Numerically stabilized low-impedance restricted earth-fault protection | LREFPNDF | 1[HV] | 1[LV1)] | 1[HV] | 1[LV1)] | |
| High-impedance based restricted earth-fault protection | HREFPDIF | | | | | 1[HV] |
| Circuit breaker failure protection | CCBRBRF | 1[HV2)] | 1[HV2)] | 1[HV2)] | 1[HV2)] | 1[HV2)] |
| Master trip | TRPPTRC | 2 (3)[3)] | 2 (3)[3)] | 2 (3)[3)] | 2 (3)[3)] | 2 |
| Arc protection | ARCSARC | (3)[LV4)] | (3)[LV4)] | (3)[LV4)] | (3)[LV4)] | (3)[LV4)] |
| Multipurpose protection[5)] | MAPGAPC | 18 | 18 | 18 | 18 | 6 |
| **Control** | | | | | | |
| Circuit-breaker control | CBXCBR | 1[HV] | 1[HV] | 1[HV] | 1[HV] | 1[HV] |
| Disconnector control | DCXSWI | 2 | 2 | 2 | 2 | 2 |
| Earthing switch control | ESXSWI | 1 | 1 | 1 | 1 | 1 |
| Disconnector position indication | DCSXSWI | 3 | 3 | 3 | 3 | 3 |
| Earthing switch indication | ESSXSWI | 2 | 2 | 2 | 2 | 2 |
| Tap changer position indication | TPOSYLTC | 1 | 1 | 1 | 1 | 1 |
| **Condition monitoring** | | | | | | |
| Circuit-breaker condition monitoring | SSCBR | 1[HV] | 1[HV] | 1[HV] | 1[HV] | 1[HV] |
| Trip circuit supervision | TCSSCBR | 2 | 2 | 2 | 2 | 2 |
| Advanced current circuit supervision for transformers | CTSRCTF | | | | | 1 |
| Fuse failure supervision | SEQSPVC | | | 1 | 1 | |
| Runtime counter for machines and devices | MDSOPT | 1 | 1 | 1 | 1 | 1 |
| **Measurement** | | | | | | |
| Disturbance recorder | RDRE | 1 | 1 | 1 | 1 | 1 |
| Load profile record | LDPRLRC | 1 | 1 | 1 | 1 | 1 |
| Fault record | FLTRFRC | 1 | 1 | 1 | 1 | 1 |

Table continues on next page

| Function | IEC 61850 | A | B | E | F | Z |
|---|---|---|---|---|---|---|
| Three-phase current measurement | CMMXU1 | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ |
| | CMMXU2 | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ | $1^{LV}$ |
| Sequence current measurement | CSMSQI | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ | $1^{HV}$ |
| Residual current measurement | RESCMMXU1 | $1^{HV}$ | | $1^{HV}$ | | $1^{HV}$ |
| | RESCMMXU2 | | $1^{LV}$ | | $1^{LV}$ | |
| Three-phase voltage measurement | VMMXU | | | $1^{HV}$ | $1^{HV}$ | |
| Residual voltage measurement | RESVMMXU | | | $1^{HV}$ | $1^{HV}$ | |
| Sequence voltage measurement | VSMSQI | | | $1^{HV}$ | $1^{HV}$ | |
| Three-phase power and energy measurement | PEMMXU | | | $1^{HV}$ | $1^{HV}$ | |
| RTD/mA measurement | XRGGIO130 | (1) | (1) | (1) | (1) | (1) |
| Frequency measurement | FMMXU | | | 1 | 1 | |
| IEC 61850-9-2 LE sampled value sending[6)] | SMVSENDER | | | (1) | (1) | |
| IEC 61850-9-2 LE sampled value receiving (voltage sharing)[6)] | SMVRECEIVER | | | (1) | (1) | |
| **Other** | | | | | | |
| Minimum pulse timer (2 pcs) | TPGAPC | 4 | 4 | 4 | 4 | 4 |
| Minimum pulse timer (2 pcs, second resolution) | TPSGAPC | 1 | 1 | 1 | 1 | |
| Minimum pulse timer (2 pcs, minute resolution) | TPMGAPC | 1 | 1 | 1 | 1 | |
| Pulse timer (8 pcs) | PTGAPC | 2 | 2 | 2 | 2 | 2 |
| Time delay off (8 pcs) | TOFGAPC | 4 | 4 | 4 | 4 | 2 |
| Time delay on (8 pcs) | TONGAPC | 4 | 4 | 4 | 4 | 2 |
| Set-reset (8 pcs) | SRGAPC | 4 | 4 | 4 | 4 | 2 |
| Move (8 pcs) | MVGAPC | 2 | 2 | 2 | 2 | 2 |
| Generic control point (16 pcs) | SPCGAPC | 2 | 2 | 2 | 2 | 2 |
| Analog value scaling | SCA4GAPC | 4 | 4 | 4 | 4 | |
| Integer value move | MVI4GAPC | 1 | 1 | 1 | 1 | |

1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration.
() = optional
HV = The function block is to be used on the high-voltage side in the application.
LV = The function block is to be used on the low-voltage side in the application.

1) "IoB measured" and "3IB" are always used.
2) "Io calculated" is always used.
3) Master trip is included and connected to the corresponding HSO in the configuration only when the BIO0007 module is used. If, additionally, the ARC option is selected, ARCSARC is connected to the corresponding master trip input in the configuration.
4) "IoB calculated" and "3IB" are always used.
5) Used for RTD/mA based protection or analog GOOSE, for example
6) Available only with COM0031...0037

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

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

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

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

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

# 3.2 Connection diagrams

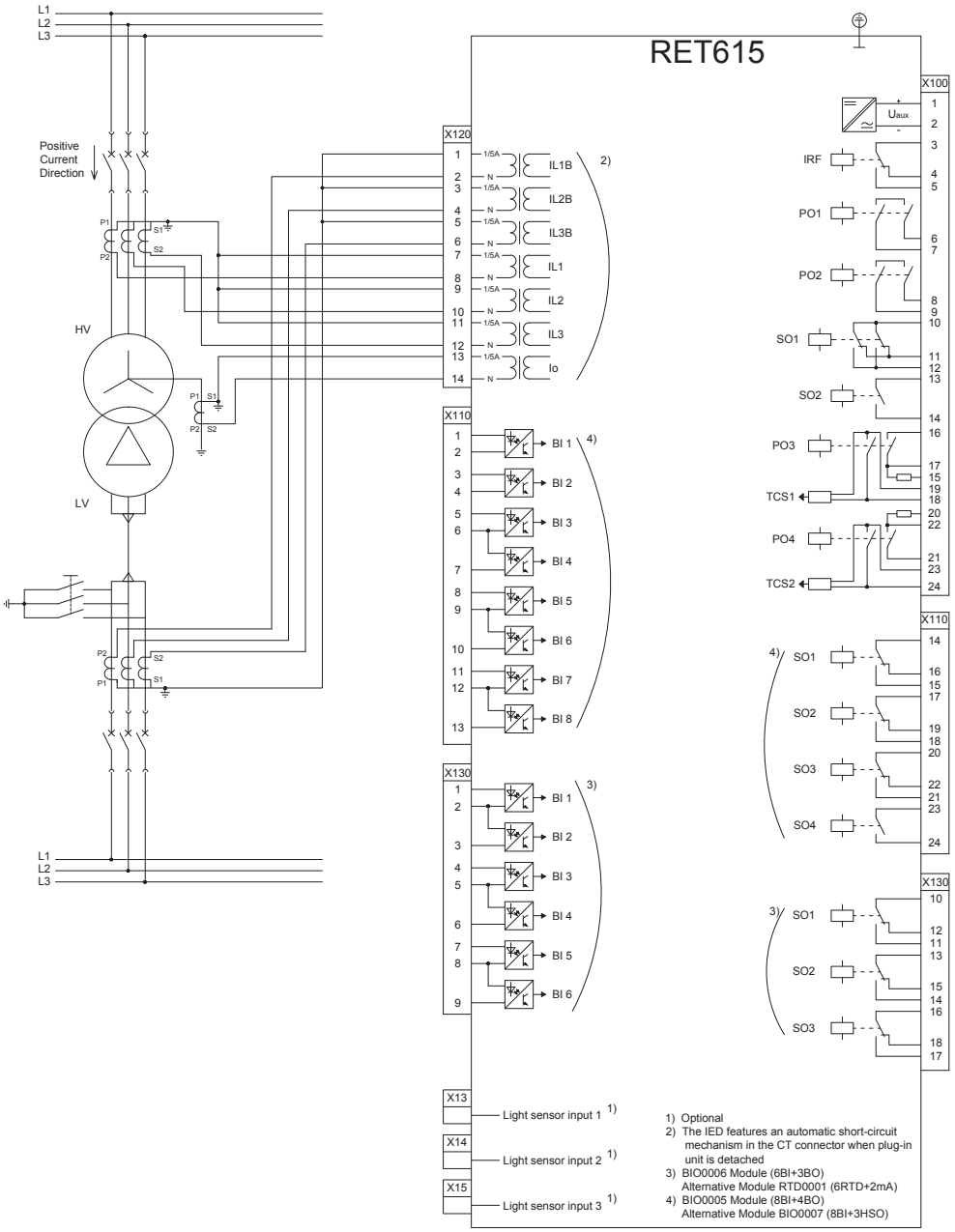



*Figure 11: Connection diagram for the A configuration*

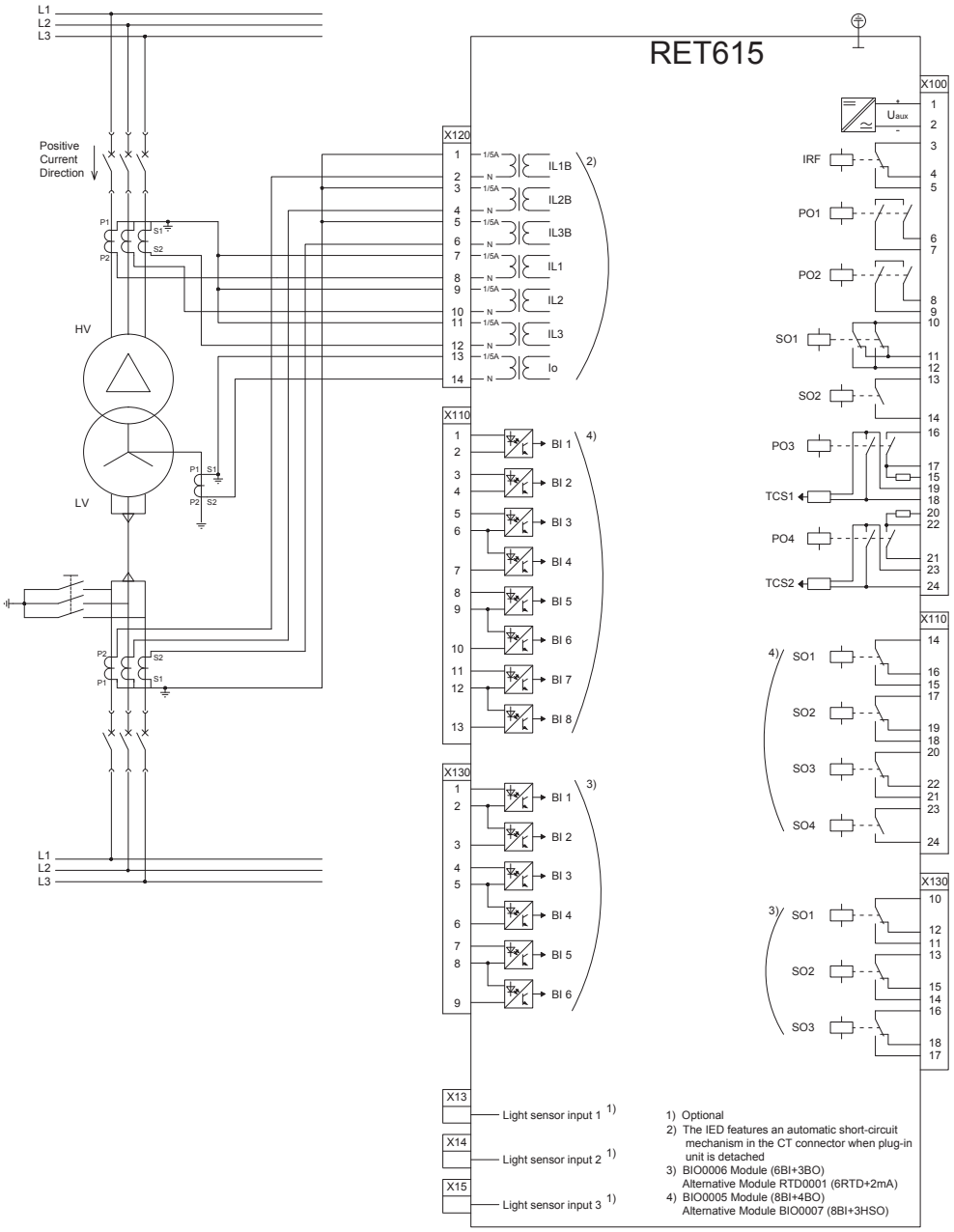



*Figure 12: Connection diagram for the B configuration*

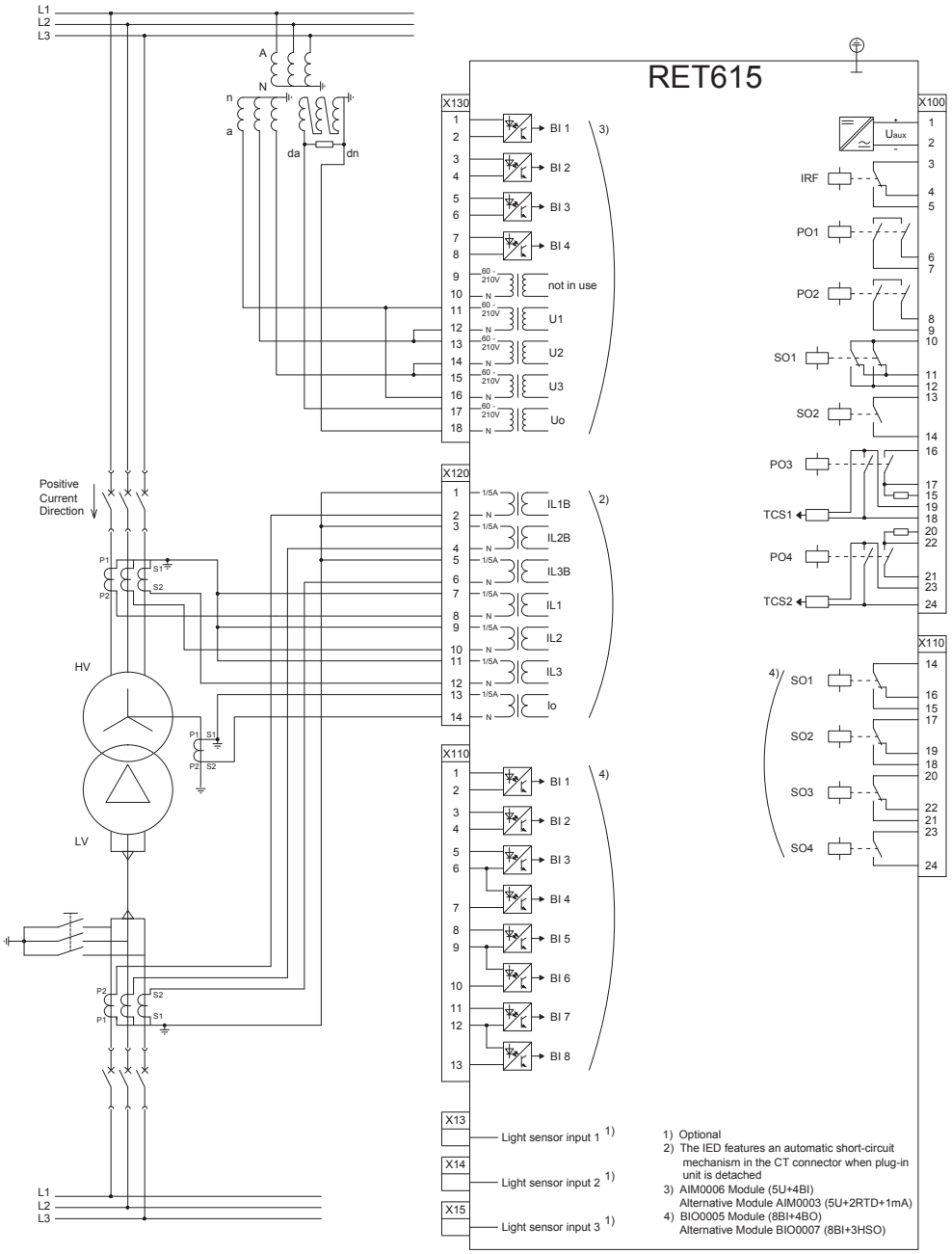



*Figure 13: Connection diagram for the E configuration*

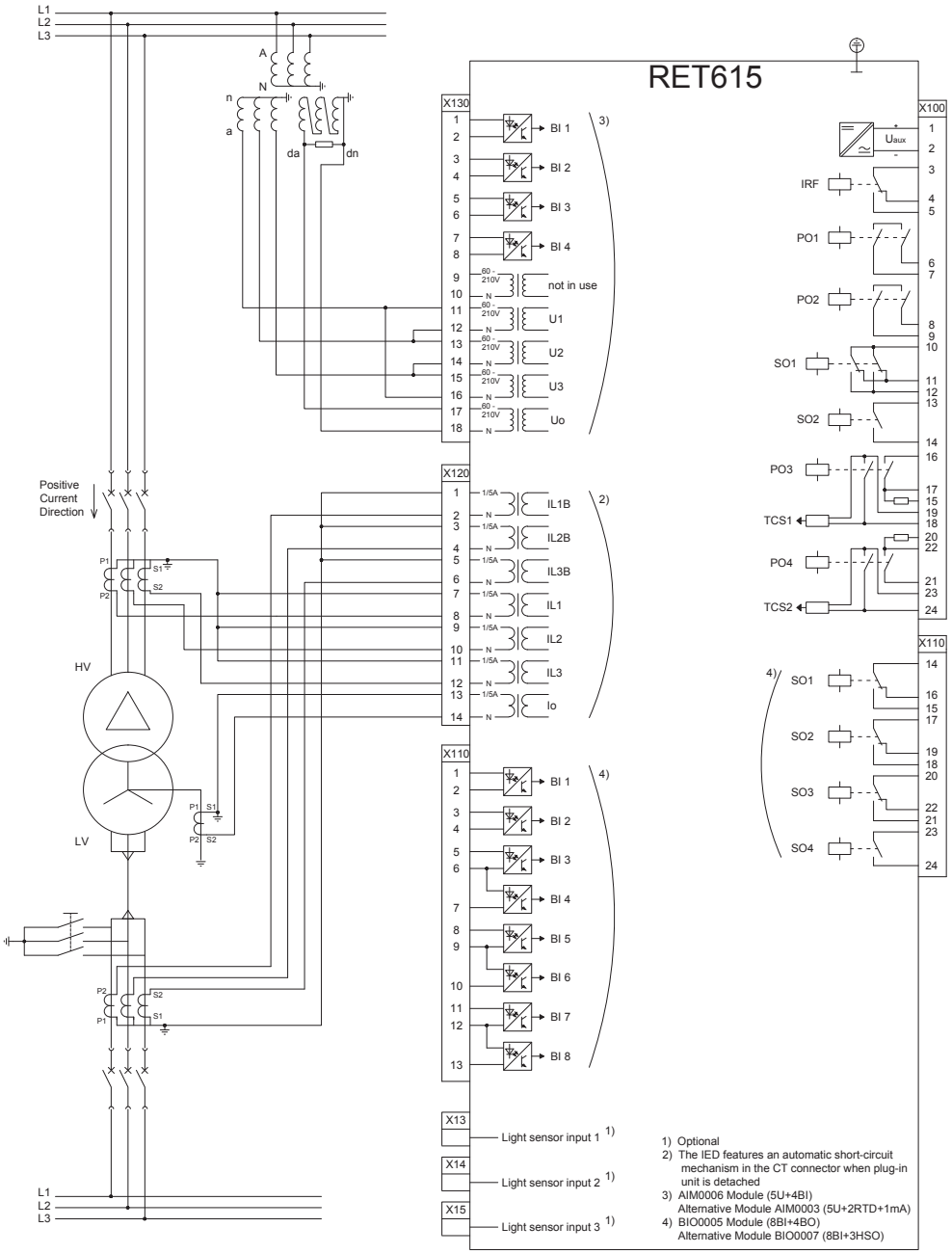



*Figure 14: Connection diagram for the F configuration*

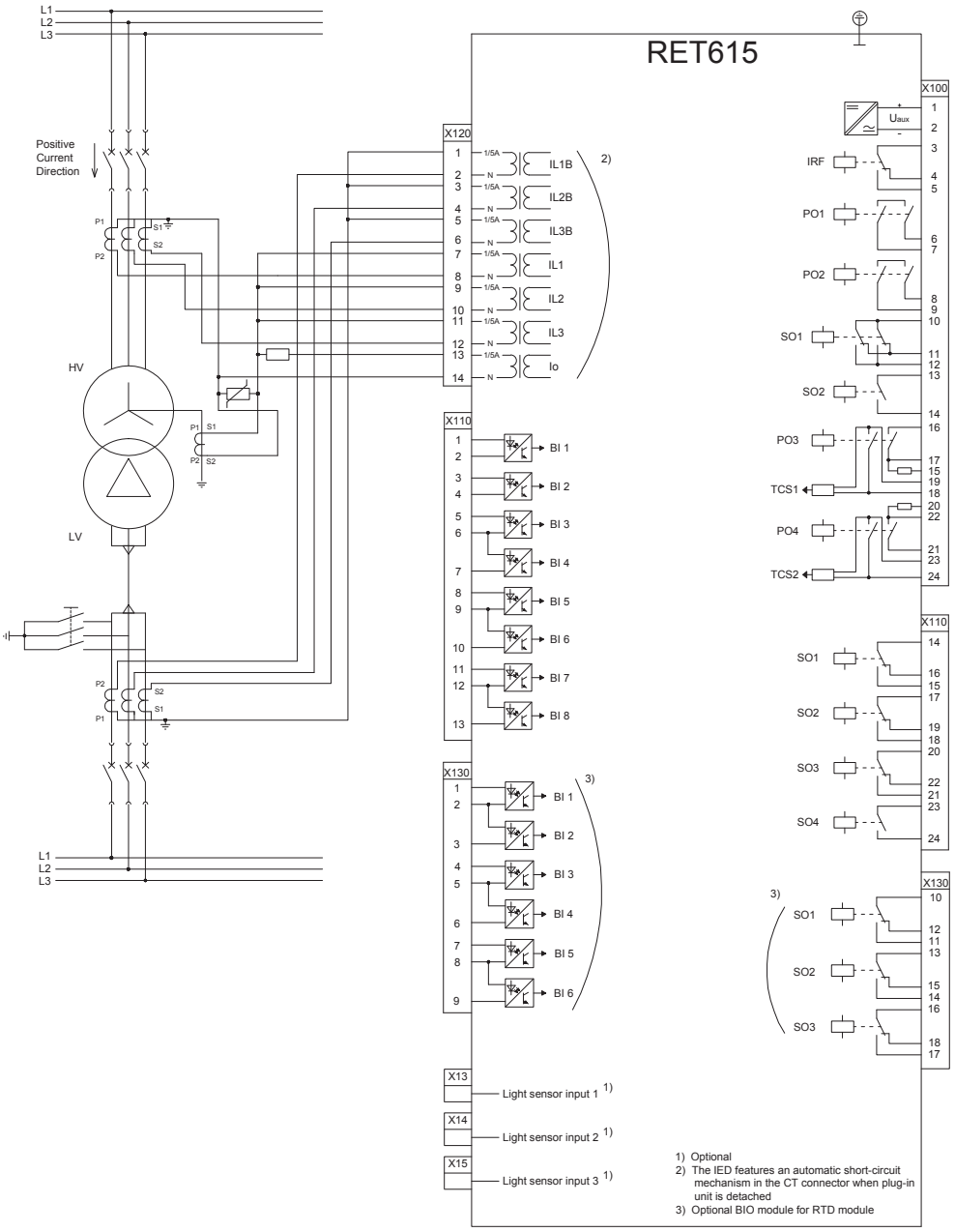



*Figure 15: Connection diagram for the Z configuration*

# 3.3 Standard configuration A

## 3.3.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and numerical restricted earth-fault protection for the

high-voltage (HV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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

## 3.3.2 Functions

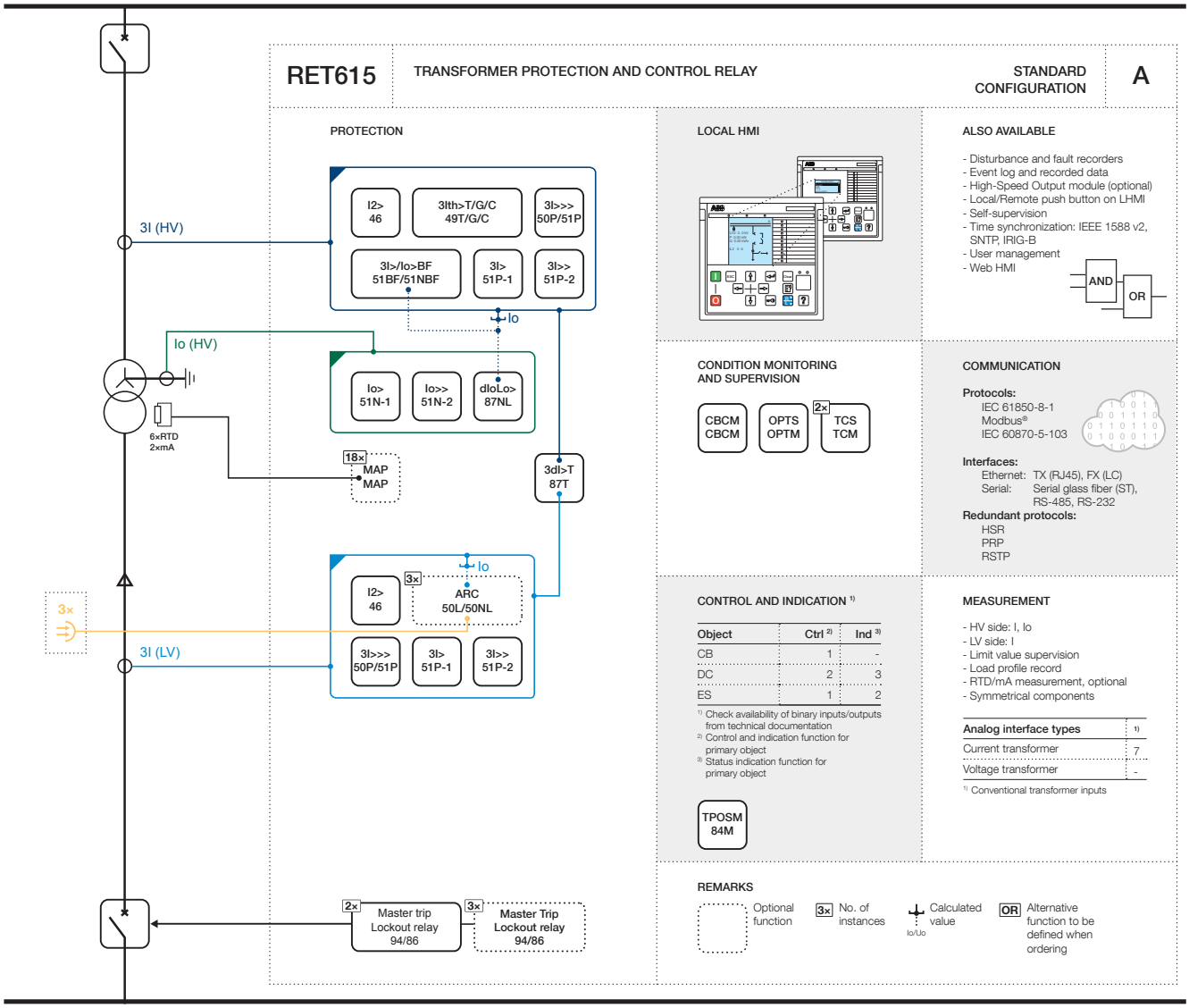



*Figure 16: Functionality overview for standard configuration A*

### 3.3.2.1 Default I/O connections

Connector pins for each input and output are presented in the Protection ralay's physical connections section.

*Table 12: Default connections for analog inputs*

| Analog input | Description | Connector pins |
|---|---|---|
| IL1B | Phase A current, LV side | X120:1-2 |
| IL2B | Phase B current, LV side | X120:3-4 |
| IL3B | Phase C current, LV side | X120:5-6 |
| IL1 | Phase A current, HV side | X120:7-8 |
| IL2 | Phase B current, HV side | X120:9-10 |
| IL3 | Phase C current, HV side | X120:11-12 |
| Io | Residual current | X120:13-14 |
| AI1 | Tap changer position | X130:1-2 |
| AI2 | - | X130:3-4 |
| AI3 | Ambient temperature | X130:5-6 |
| AI4 | - | X130:7-8 |
| AI5 | - | X130:9-10 |
| AI6 | - | X130:13-14 |
| AI7 | - | X130:15-16 |
| AI8 | - | X130:17-18 |

*Table 13: Default connections for binary inputs*

| Binary input | Description | Connector pins | |
|---|---|---|---|
| | | BIO0005 | BIO0007 |
| X110-BI1 | Blocking of overcurrent high state (high voltage) and instantaneous stage (medium voltage) | X110:1-2 | X110:1,5 |
| X110-BI2 | External protection trip | X110:3-4 | X110:2,5 |
| X110-BI3 | Circuit breaker low gas pressure indication | X110:5-6 | X110:3,5 |
| X110-BI4 | Circuit breaker spring charged indication | X110:7-6 | X110:4-5 |
| X110-BI5 | High-voltage side disconnector closed indication | X110:8-9 | X110:6,10 |
| X110-BI6 | High-voltage side disconnector open indication | X110:10-9 | X110:7,10 |
| X110-BI7 | High-voltage side circuit breaker closed indication | X110:11-12 | X110:8,10 |
| X110-BI8 | High-voltage side circuit breaker open indication | X110:13-12 | X110:9-10 |
| X130-BI1 | BCD sign bit (tap changer position) | X130:1-2 | |
| X130-BI2 | BCD bit 0 (LSB) | X130:3-2 | |
| X130-BI3 | BCD bit 1 | X130:4-5 | |
| X130-BI4 | BCD bit 2 | X130:6-5 | |
| X130-BI5 | BCD bit 3 | X130:7-8 | |
| X130-BI6 | BCD Bit 4 (MSB) | X130:9-8 | |

*Table 14: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close high-voltage circuit breaker | X100:6-7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker (Breaker 1 and 2) | 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 high-voltage | X100:15-19 |
| X100-PO4 | Open circuit breaker/trip coil 2 low-voltage | X100:20-24 |
| X110-SO1 | Overcurrent operate alarm | X110:14-16 |
| X110-SO2 | Differential protection operate alarm | X110:17-19 |
| X110-SO3 | Earth-fault operate alarm | X110:20-22 |
| X110-SO4 | Thermal overload and negative phase-sequence operate alarm | X110:23-24 |
| X110-HSO1 | Arc protection instance 1 trip activated | X110:15-16 |
| X110-HSO1 | Arc protection instance 2 trip activated | X110:19-20 |
| X110-HSO1 | Arc protection instance 3 trip activated | X110:23-24 |
| X130-SO1 | - | X130:10-12 |
| X130-SO2 | - | X130:13-15 |
| X130-SO3 | - | X130:16-18 |

*Table 15: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Transformer differential protection biased stage operate |
| 2 | Transformer differential protection instantaneous stage operate |
| 3 | Non-directional overcurrent protection operate |
| 4 | Restricted earth-fault protection operate |
| 5 | Earth-fault protection operate |
| 6 | Circuit failure protection backup operate |
| 7 | Negative sequence overcurrent or thermal overload protection operate |
| 8 | Disturbance recorder triggered |
| 9 | TCS, fuse failure, measuring circuit fault or circuit breaker supervision |
| 10 | Arc protection operate |
| 11 | Protection trip from external device |

### 3.3.2.2 Default disturbance recorder settings

*Table 16: Default disturbance recorder analog channels*

| Channel | Description[1)] |
|---|---|
| 1 | IL1 |
| 2 | IL2 |
| 3 | IL3 |
| 4 | IL1B |
| 5 | IL2B |
| 6 | IL3B |
| 7 | Io |
| 8 | - |
| 9 | - |
| 10 | - |
| 11 | - |
| 12 | - |

1) Text with “B” refers to measurement on low-voltage side of the transformer

*Table 17: Default disturbance recorder binary channels*

| Channel | ID text | Level trigger mode |
|---|---|---|
| 1 | PHIPTOC1 - start | Positive or Rising |
| 2 | PHHPTOC1 - start | Positive or Rising |
| 3 | PHLPTOC1 - start | Positive or Rising |
| 4 | PHIPTOC2 - start | Positive or Rising |
| 5 | PHHPTOC2 - start | Positive or Rising |
| 6 | PHLPTOC2 - start | Positive or Rising |
| 7 | EFHPTOC2 - start | Positive or Rising |
| 8 | EFLPTOC2 - start | Positive or Rising |
| 9 | NSPTOC1 - start | Positive or Rising |
| 10 | NSPTOC2 - start | Positive or Rising |
| 11 | LREFPNDF1 - start | Positive or Rising |
| 12 | T2PTTR1 - start | Positive or Rising |
| 13 | CCBRBRF1 - trret | Level trigger off |
| 14 | CCBRBRF1 - trbu | Level trigger off |
| 15 | PHIPTOC1 - operate | Level trigger off |
| | PHHPTOC1 - operate | |
| | PHLPTOC1 - operate | |
| 16 | PHIPTOC2 - operate | Level trigger off |
| | PHHPTOC2- operate | |
| | PHLPTOC2 - operate | |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 17 | EFLPTOC2 - operate | Level trigger off |
| | EFHPTOC2 - operate | |
| 18 | NSPTOC1 - operate | Level trigger off |
| | NSPTOC2 - operate | |
| 19 | TR2PTDF1 - operate | Positive or Rising |
| 20 | TR2PTDF1 - opr LS | Level trigger off |
| 21 | TR2PTDF1 - opr HS | Level trigger off |
| 22 | TR2PTDF1 - blkd2h | Level trigger off |
| 23 | TR2PTDF1 - blkd5h | Level trigger off |
| 24 | TR2PTDF1 - blkdwav | Level trigger off |
| 25 | LREFPNDF1 - operate | Level trigger off |
| 26 | T2PTTR1 - operate | Level trigger off |
| 27 | T2PTTR1 - alarm | Level trigger off |
| 28 | T2PTTR1 - blk close | Level trigger off |
| 29 | X110BI1 - ext OC blocking | Level trigger off |
| 30 | X110BI2 - ext operate | Positive or Rising |
| 31 | X110BI7 - HVCB closed | Level trigger off |
| 32 | X110BI8 - HVCB open | Level trigger off |
| 33 | MDSOPT1 - alarm | Level trigger off |
| 34 | ARCSARC1 - ARC flt det | Level trigger off |
| | ARCSARC2 - ARC flt det | |
| | ARCSARC3 - ARC flt det | |
| 35 | ARCSARC1 - operate | Positive or Rising |
| 36 | ARCSARC2 - operate | Positive or Rising |
| 37 | ARCSARC3 - operate | Positive or Rising |
| 38 | - | - |
| 39 | - | - |
| 40 | - | - |
| 41 | - | - |
| 42 | - | - |
| 43 | - | - |
| 44 | - | - |
| 45 | - | - |
| 46 | - | - |
| 47 | - | - |
| 48 | - | - |
| 49 | - | - |
| 50 | - | - |
| 51 | - | - |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 52 | - | - |
| 53 | - | - |
| 54 | - | - |
| 55 | - | - |
| 56 | - | - |
| 57 | - | - |
| 58 | - | - |
| 59 | - | - |
| 60 | - | - |
| 61 | - | - |
| 62 | - | - |
| 63 | - | - |
| 64 | - | - |

## 3.3.3 Functional diagrams

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

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

The high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

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

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

### 3.3.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The protection relay compares the phase currents on both sides of the object to be protected. If the differential current of the

phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

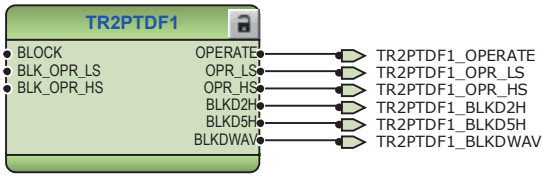



*Figure 17: Differential protection*

Three non-directional overcurrent stages are offered for each overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

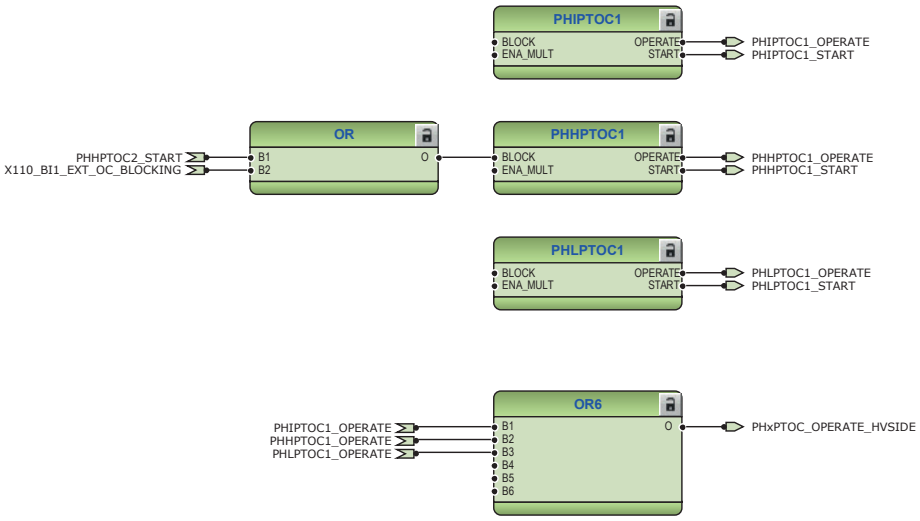



*Figure 18: High-voltage side overcurrent protection function*

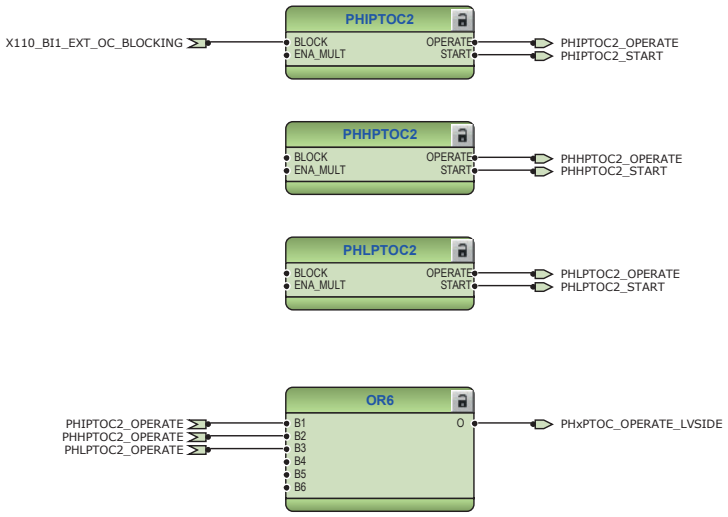



*Figure 19: Low-voltage side overcurrent protection function*

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from high-voltage side.

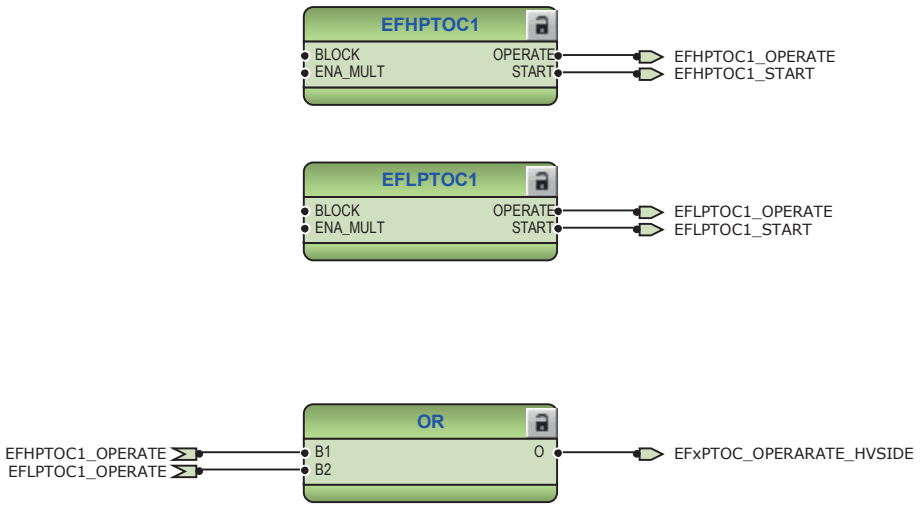



*Figure 20: High-voltage side earth-fault protection*

The configuration includes numerically stabilized low-impedance restricted earth-fault protection LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

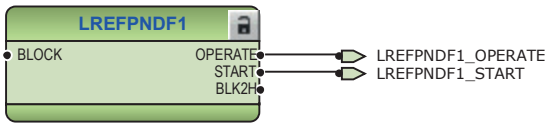



*Figure 21: Restricted low-impedance earth-fault protection function*

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

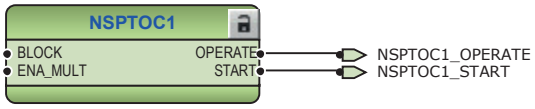



*Figure 22: High-voltage side negative-sequence overcurrent protection function*

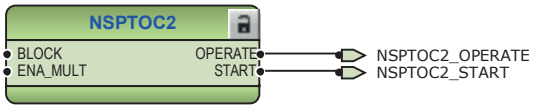



*Figure 23: Low-voltage side negative-sequence overcurrent protection function*

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overload conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. The disturbance recorder is connected in the configuration. If the protection relay is ordered with optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

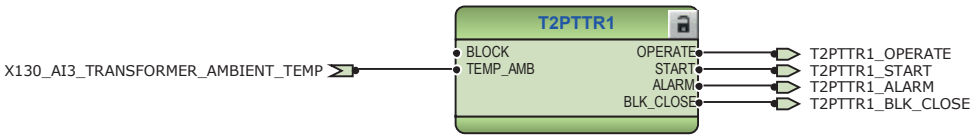



*Figure 24: Thermal overcurrent protection function*

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the protection relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

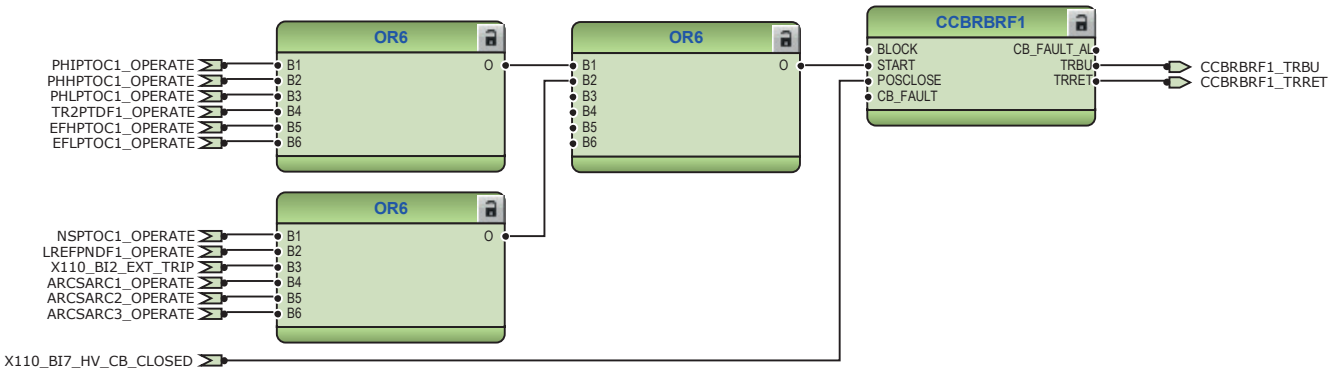



*Figure 25: Circuit breaker failure protection function*

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

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

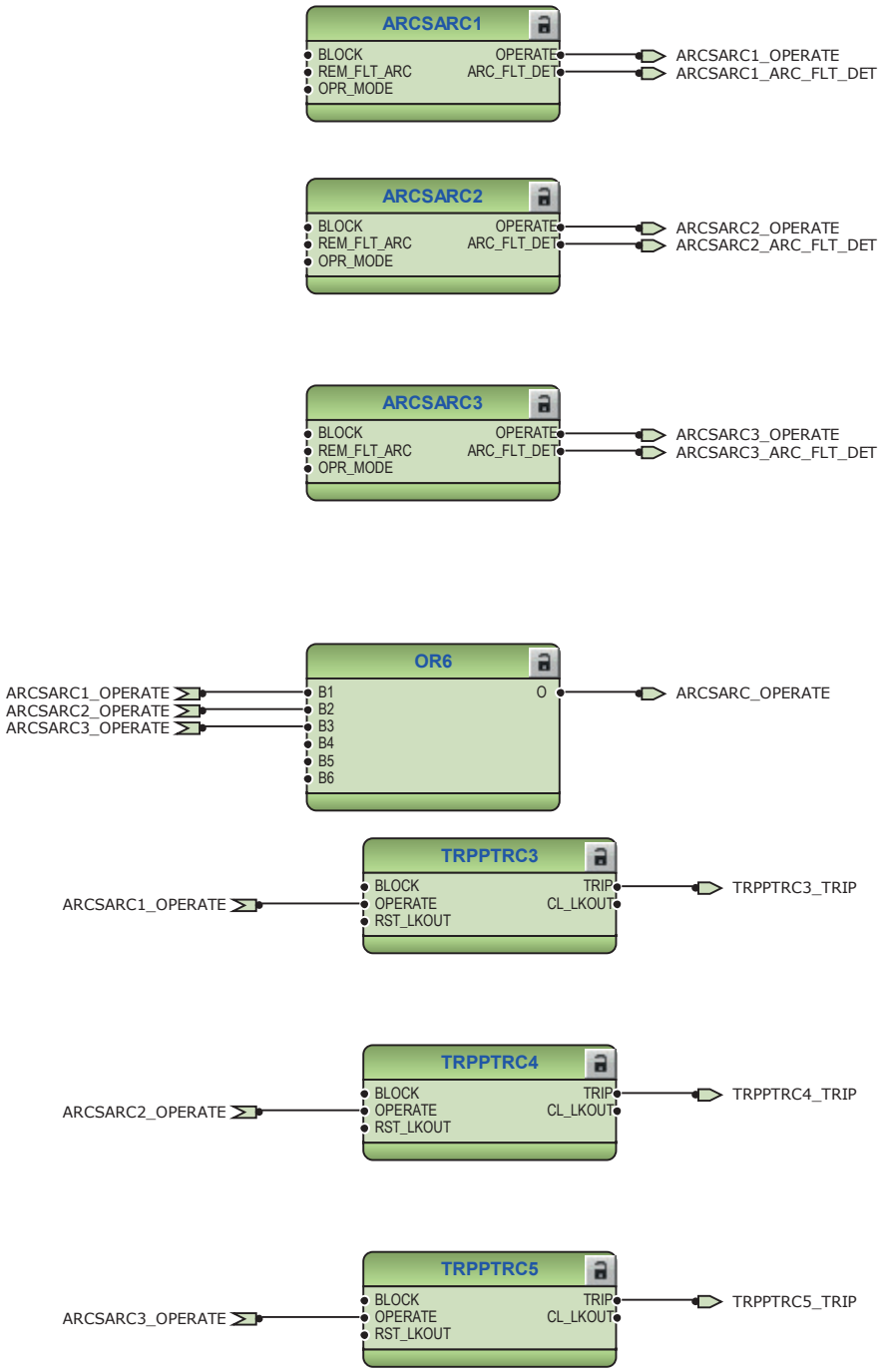



*Figure 26: Arc protection with dedicated HSO*

The generic operation time counter MDSOPT1 accumulates the operation time of the transformer.

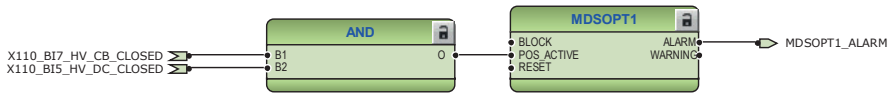



*Figure 27: Operation time counter*

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

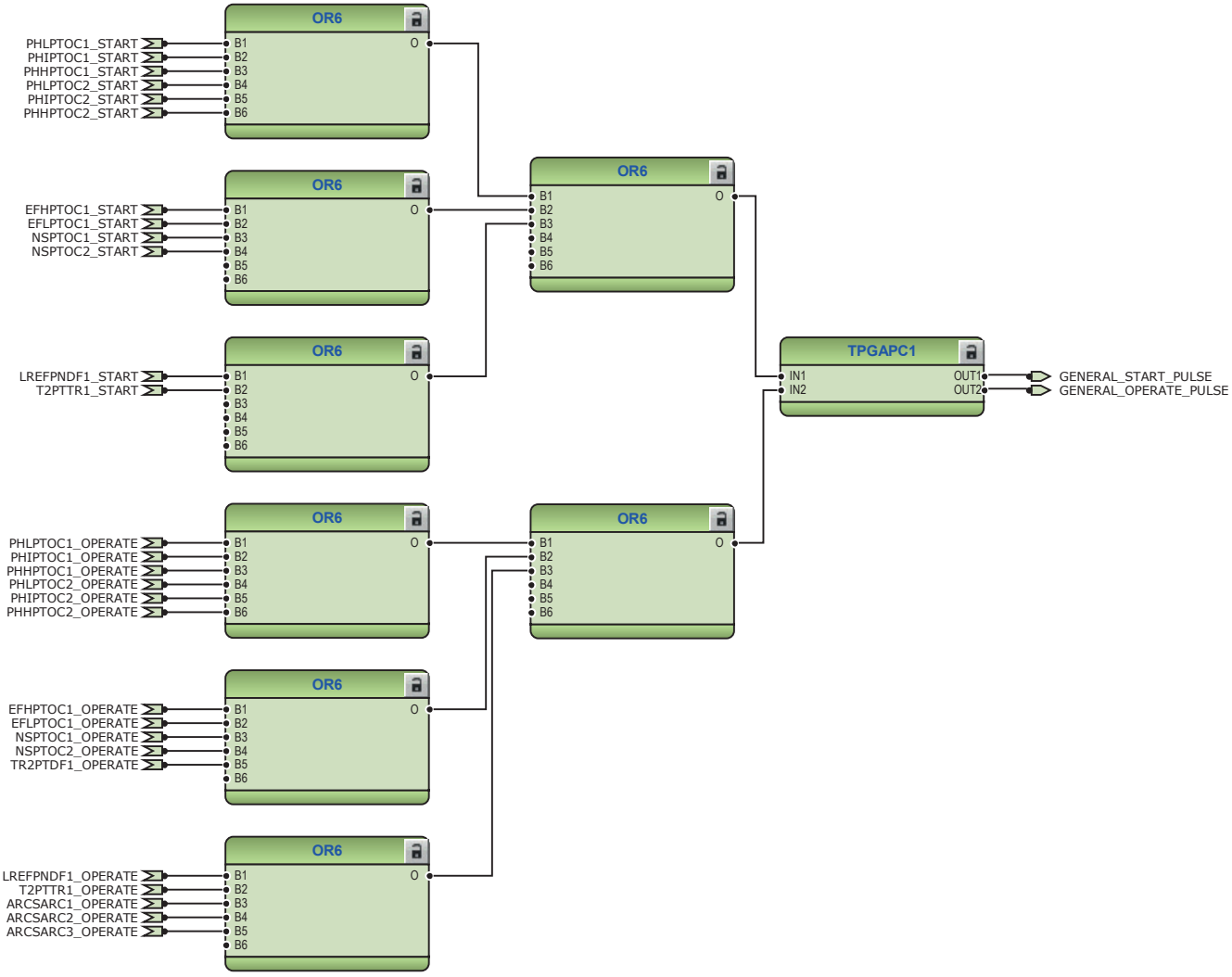



*Figure 28: General start and operate signals*

The operate signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open the circuit breaker on the high and low voltage sides respectively.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is

selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5 are also available if protection relay is ordered with high speed binary outputs options.

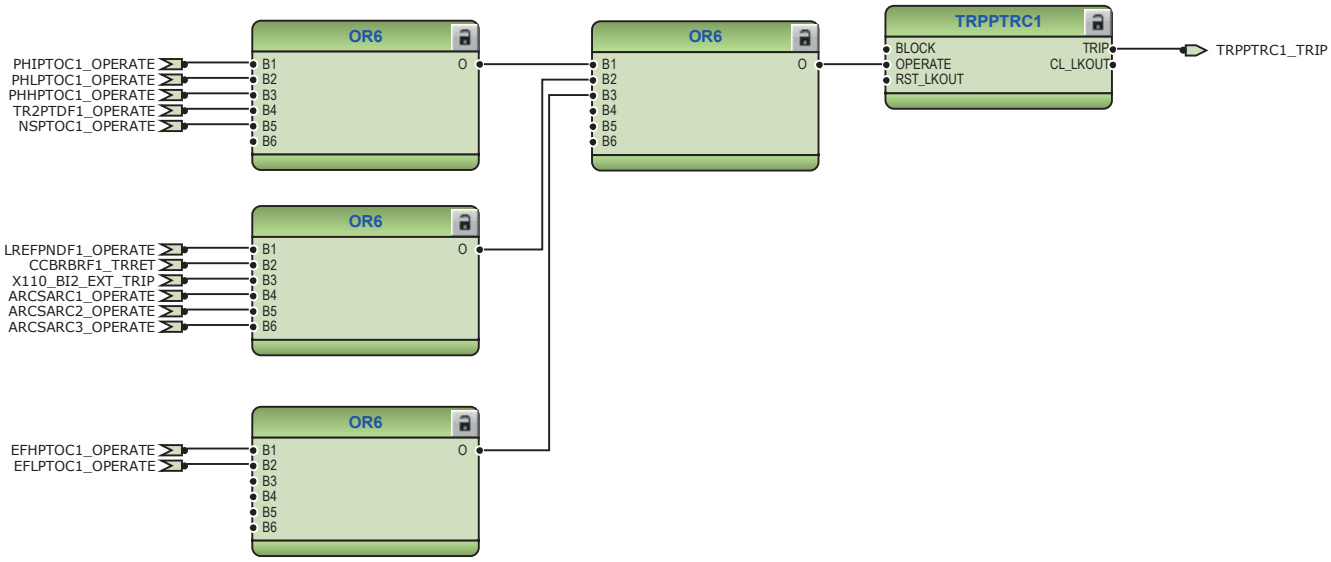



*Figure 29: Trip logic TRPPTRC1*

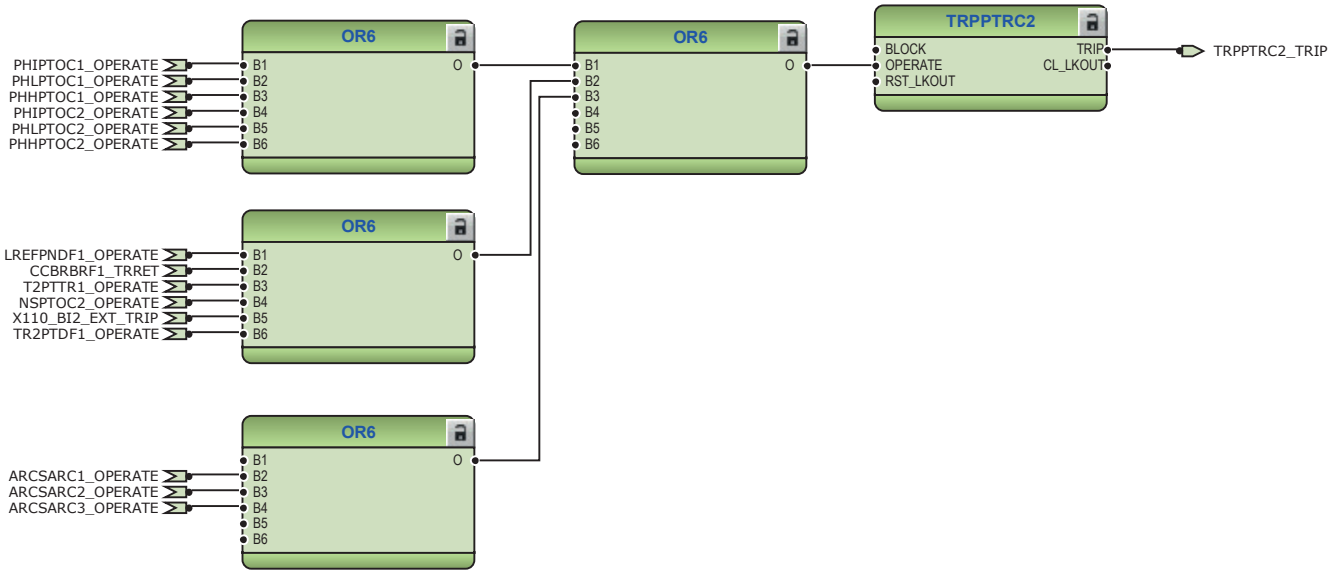



*Figure 30: Trip logic TRPPTRC2*

### 3.3.3.2 Functional diagrams for disturbance recorder

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

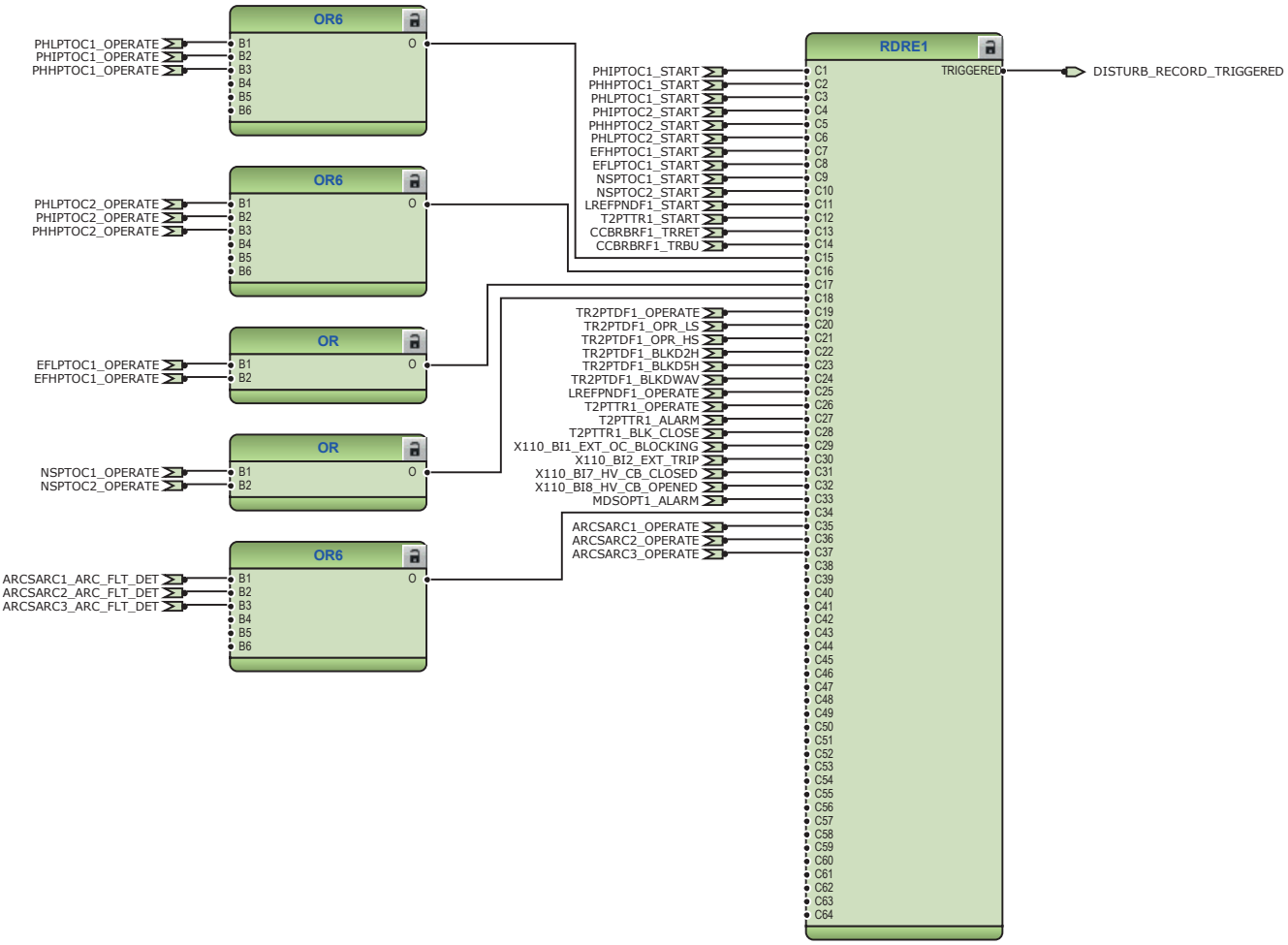



*Figure 31: Disturbance recorder*

### 3.3.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

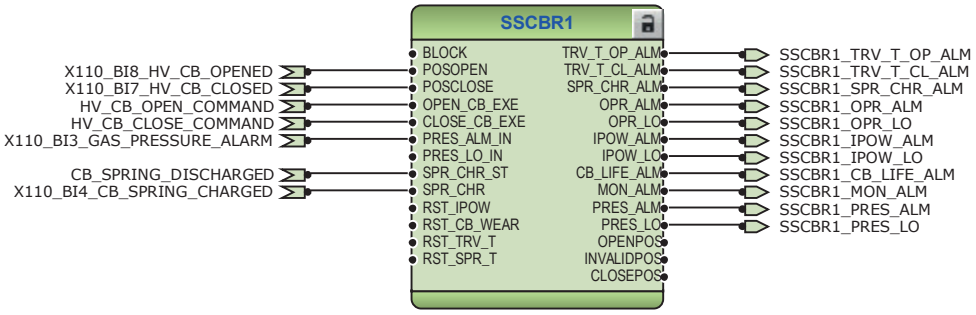



*Figure 32: Circuit breaker condition monitoring function*

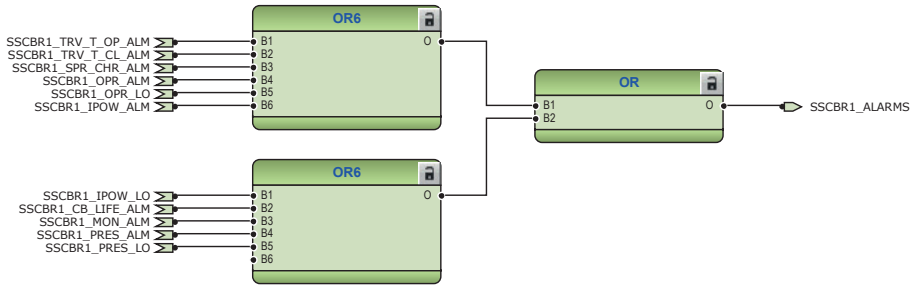



*Figure 33: Logic for circuit-breaker monitoring alarm*


*Figure 34: Logic for start of circuit-breaker spring charging*

Two separate trip circuit supervision functions are included, TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and the HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

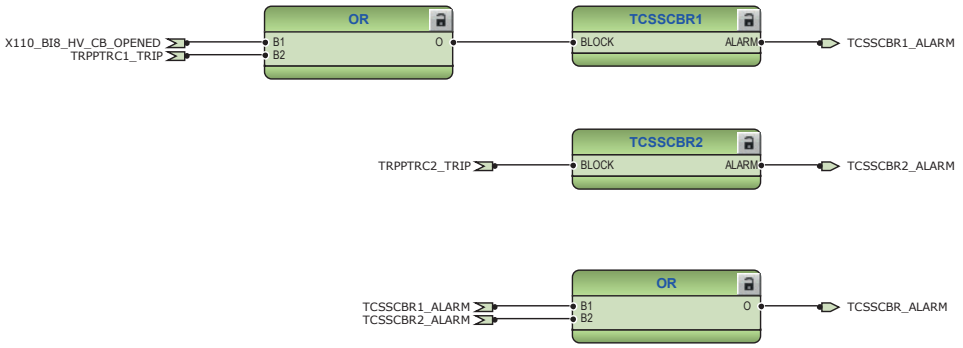



*Figure 35: Trip circuit supervision function*

### 3.3.3.4 Functional diagrams for control and interlocking

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

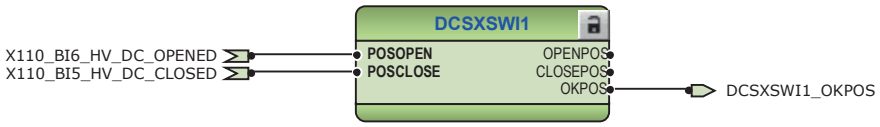



*Figure 36: Disconnector control logic*

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

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

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

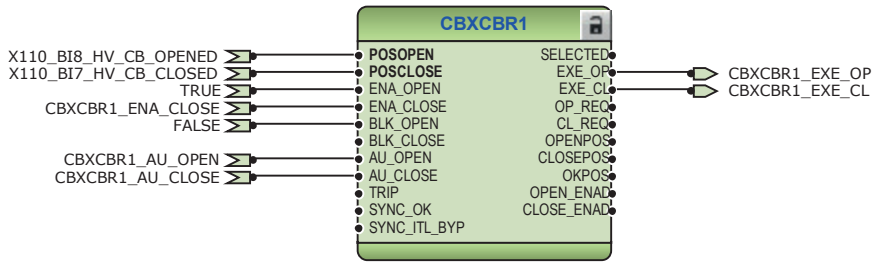



*Figure 37: High-voltage side circuit breaker control logic: Circuit breaker 1*

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


*Figure 38: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker*


*Figure 39: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker*

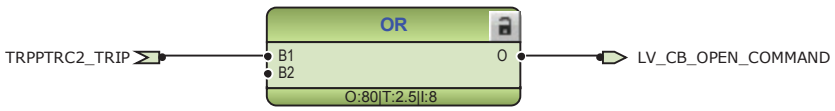



*Figure 40: Circuit breaker control logic: Signals for opening coil of low-voltage side circuit breaker*

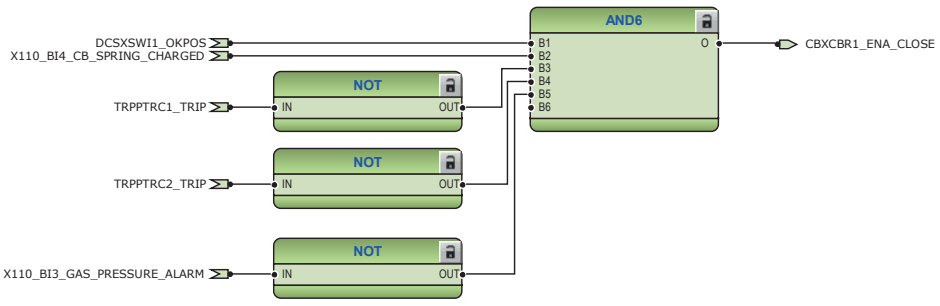



*Figure 41: High-voltage side circuit breaker close enable logic*

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

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

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

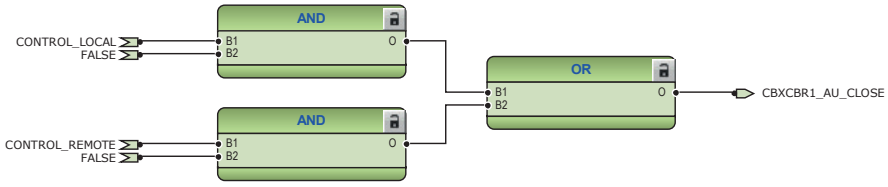



*Figure 42: External closing command for circuit breaker*

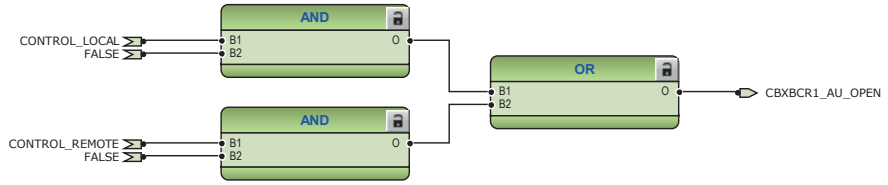



*Figure 43: External opening command for circuit breaker*

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the protection relay via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used, TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters for TPOSYLTC1 properly.

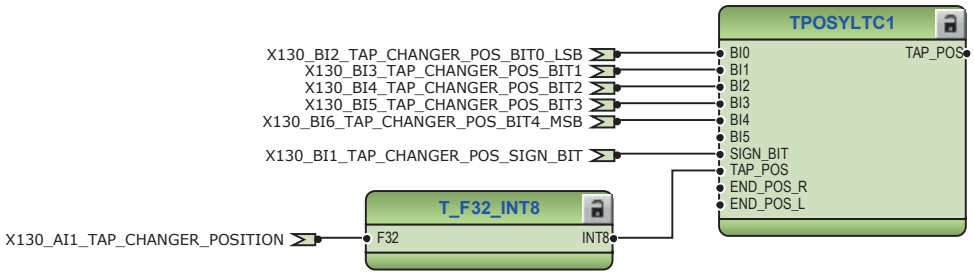



*Figure 44: Tap changer position indicator*

### 3.3.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the protection relay are measured by three-phase current measurement CMMXU1 and CMMXU2. 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 from high-voltage side.

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

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

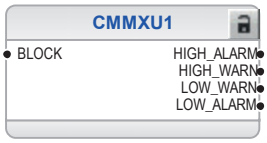



*Figure 45: Current measurement: Three-phase current measurement (HV side)*

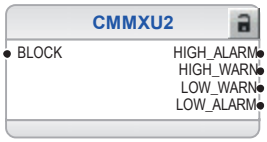



*Figure 46: Current measurement: Three-phase current measurement (LV side)*


*Figure 47: Current measurement: Sequence current measurement (HV side)*


*Figure 48: Current measurement: Residual current measurement (HV side)*


*Figure 49: Other measurement: Data monitoring*


*Figure 50: Other measurement: Load profile record*

### 3.3.3.6 Functional diagrams for I/O and alarm LEDs

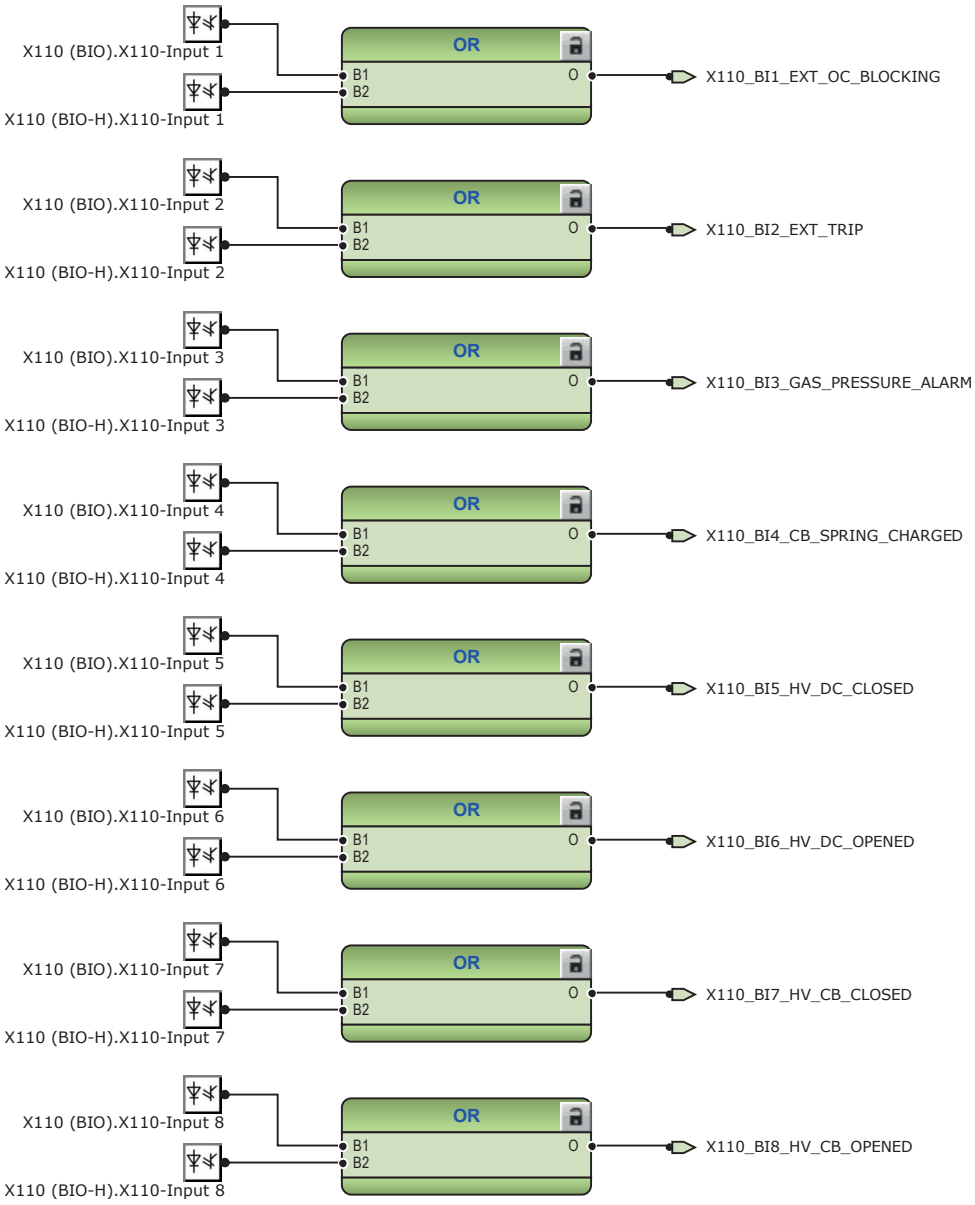



*Figure 51: Binary inputs - X110 terminal block*

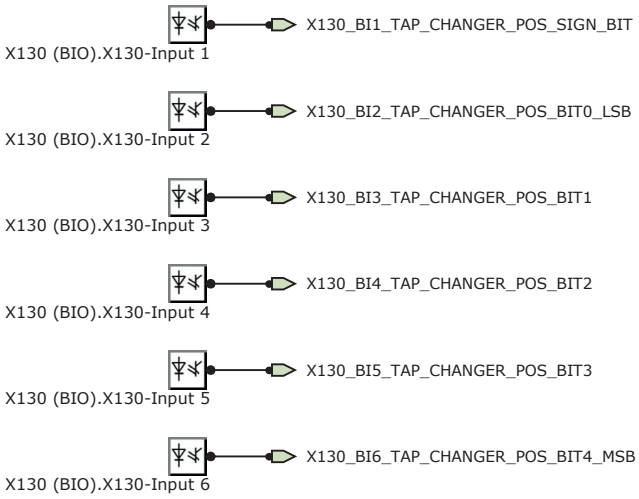



*Figure 52: Binary inputs - X130 terminal block*

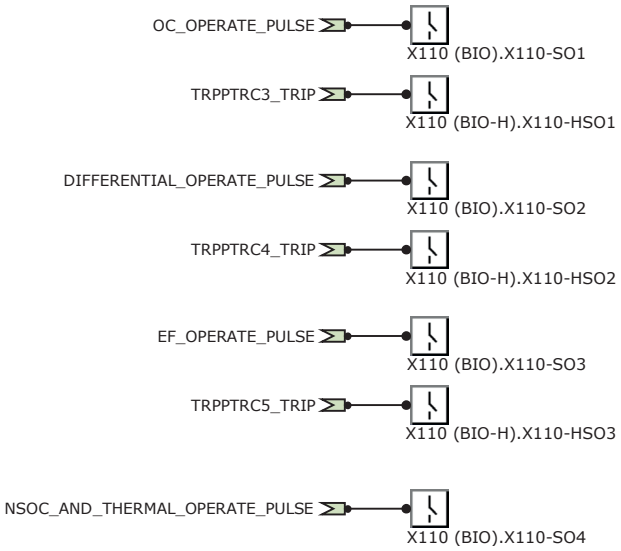



*Figure 53: Binary outputs - X110 terminal block*

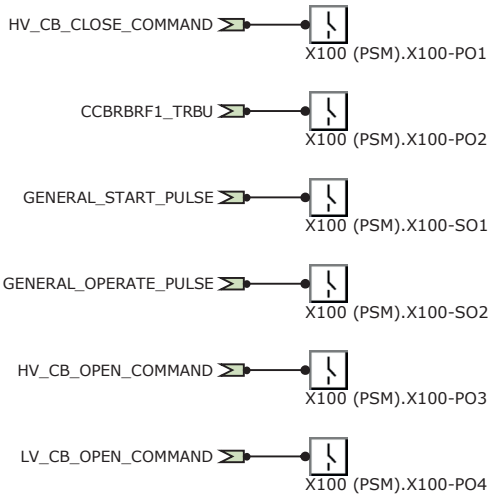



*Figure 54: Binary outputs - X100 terminal block*

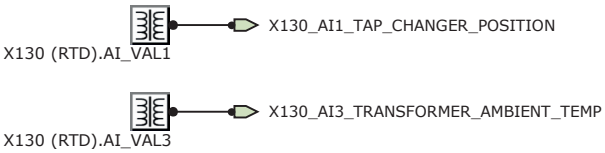



*Figure 55: Default mA/RTD inputs X130*

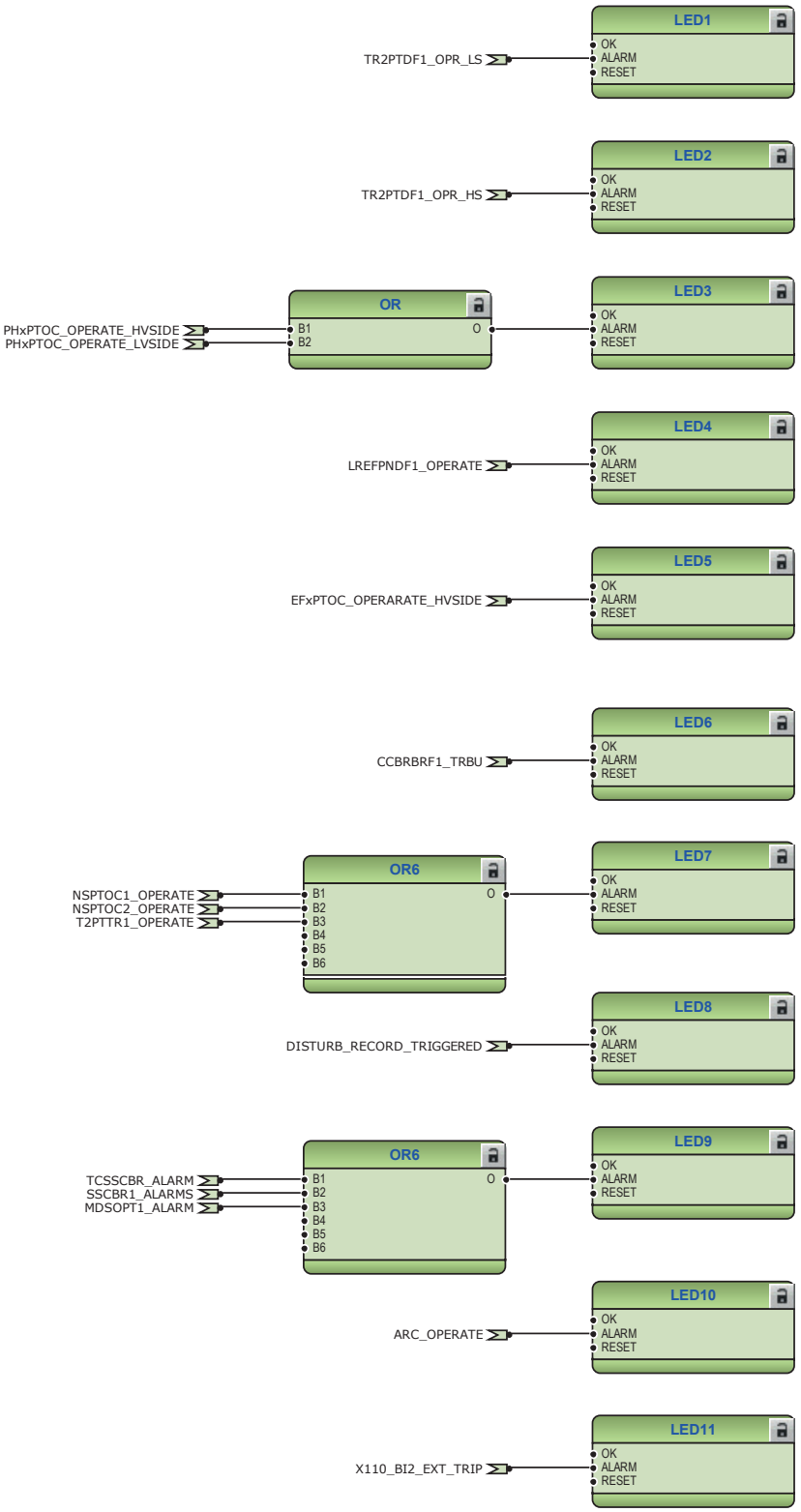



*Figure 56: Default LED connection*

### 3.3.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, differential operate, earth-fault operate and combined negative-sequence and thermal overload operate logic. The operate logics are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

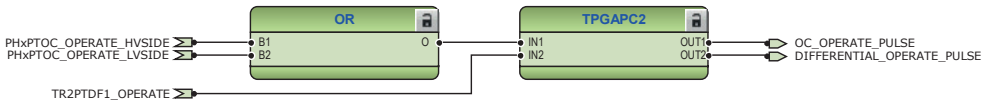



*Figure 57: Timer logic for overcurrent and differential operate pulse*

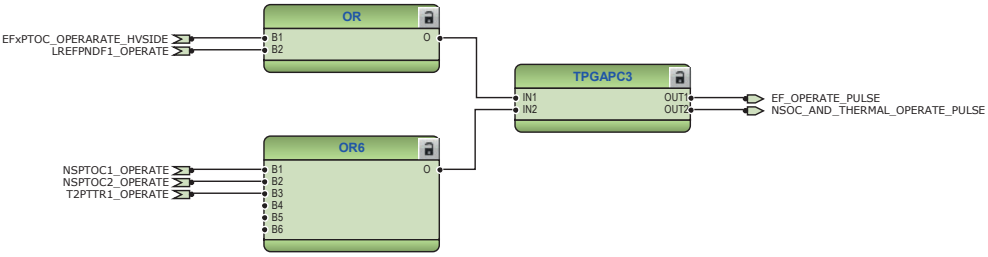



*Figure 58: Timer logic for earth-fault and negative-sequence with thermal overload protection operate alarm*

### 3.3.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

## 3.4 Standard configuration B

### 3.4.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and numerical restricted earth-fault protection for the low-voltage (LV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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

## 3.4.2 Functions

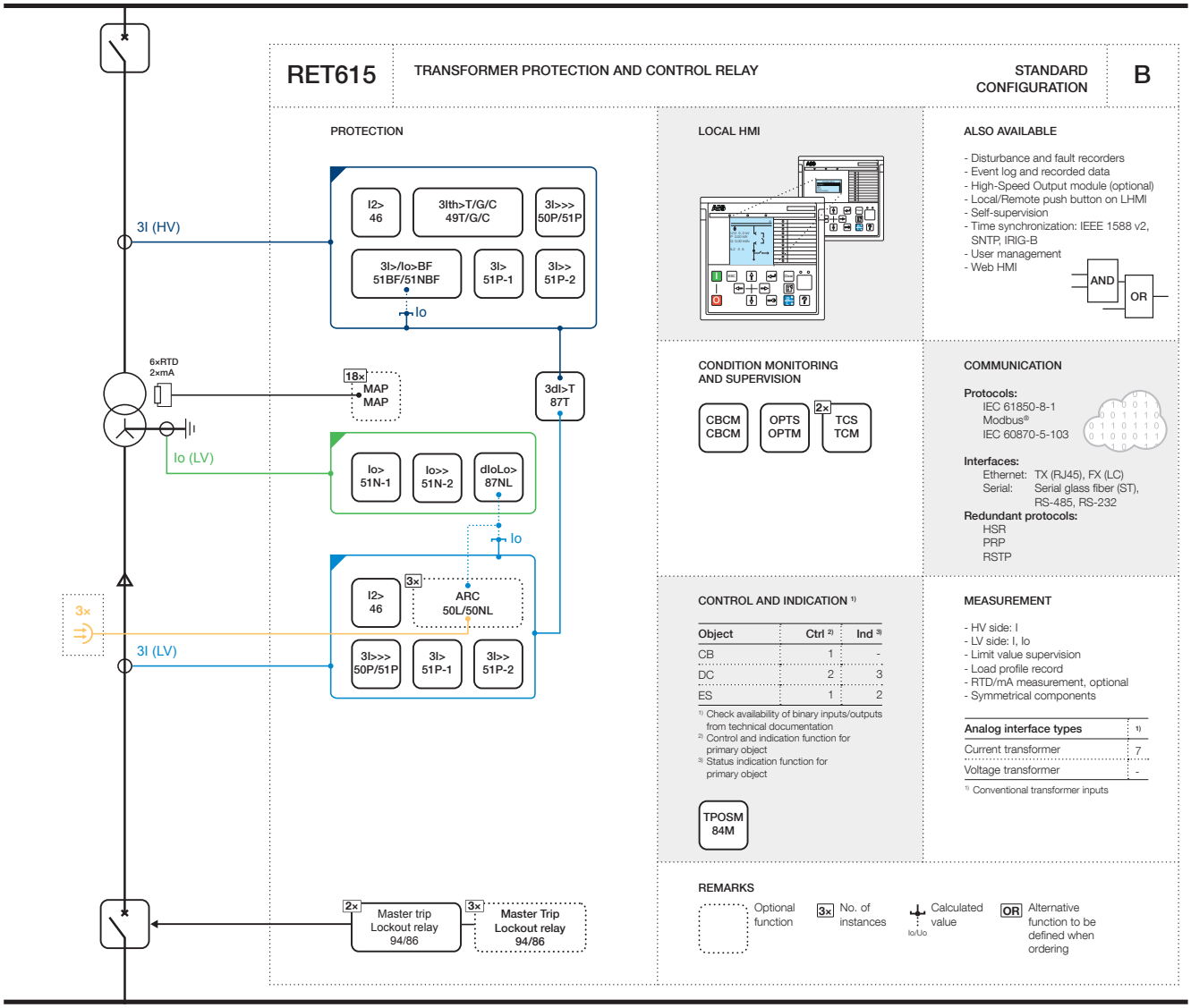



*Figure 59: Functionality overview for standard configuration B*

### 3.4.2.1 Default I/O connections

Connector pins for each input and output are presented in the Protection relay's physical connections section.

*Table 18: Default connections for analog inputs*

| Analog input | Description | Connector pins |
|---|---|---|
| IL1B | Phase A current, LV side | X120:1-2 |
| IL2B | Phase B current, LV side | X120:3-4 |
| IL3B | Phase C current, LV side | X120:5-6 |
| IL1 | Phase A current, HV side | X120:7-8 |
| IL2 | Phase B current, HV side | X120:9-10 |
| IL3 | Phase C current, HV side | X120:11-12 |
| Io | Residual current | X120:13-14 |
| AI1 | Tap changer position | X130:1-2 |
| AI2 | - | X130:3-4 |
| AI3 | Ambient temperature | X130:5-6 |
| AI4 | - | X130:7-8 |
| AI5 | - | X130:9-10 |
| AI6 | - | X130:13-14 |
| AI7 | - | X130:15-16 |
| AI8 | - | X130:17-18 |

*Table 19: Default connections for binary inputs*

| Binary input | Description | Connector pins | |
|---|---|---|---|
| | | BIO0005 | BIO0007 |
| X110-BI1 | Blocking of overcurrent high state (high voltage) and instantaneous stage (medium voltage) | X110:1-2 | X110:1,5 |
| X110-BI2 | External protection trip | X110:3-4 | X110:2,5 |
| X110-BI3 | Circuit breaker low gas pressure indication | X110:5-6 | X110:3,5 |
| X110-BI4 | Circuit breaker spring charged indication | X110:7-6 | X110:4-5 |
| X110-BI5 | High-voltage side disconnector closed indication | X110:8-9 | X110:6,10 |
| X110-BI6 | High-voltage side disconnector open indication | X110:10-9 | X110:7,10 |
| X110-BI7 | High-voltage side circuit breaker closed indication | X110:11-12 | X110:8,10 |
| X110-BI8 | High-voltage side circuit breaker open indication | X110:13-12 | X110:9-10 |
| X130-BI1 | BCD sign bit (tap changer position) | X130:1-2 | |
| X130-BI2 | BCD bit 0 (LSB) | X130:3-2 | |
| X130-BI3 | BCD bit 1 | X130:4-5 | |
| X130-BI4 | BCD bit 2 | X130:6-5 | |
| X130-BI5 | BCD bit 3 | X130:7-8 | |
| X130-BI6 | BCD Bit 4 (MSB) | X130:9-8 | |

*Table 20: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close high-voltage circuit breaker | X100:6-7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker (Breaker 1 and 2) | 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 high-voltage | X100:15-19 |
| X100-PO4 | Open circuit breaker/trip coil 2 low-voltage | X100:20-24 |
| X110-SO1 | Overcurrent operate alarm | X110:14-16 |
| X110-SO2 | Differential protection operate alarm | X110:17-19 |
| X110-SO3 | Earth-fault operate alarm | X110:20-22 |
| X110-SO4 | Thermal overload and negative phase-sequence operate alarm | X110:23-24 |
| X110-HSO1 | Arc protection instance 1 trip activated | X110:15-16 |
| X110-HSO1 | Arc protection instance 2 trip activated | X110:19-20 |
| X110-HSO1 | Arc protection instance 3 trip activated | X110:23-24 |
| X130-SO1 | - | X130:10-12 |
| X130-SO2 | - | X130:13-15 |
| X130-SO3 | - | X130:16-18 |

*Table 21: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Transformer differential protection biased stage operate |
| 2 | Transformer differential protection instantaneous stage operate |
| 3 | Non-directional overcurrent protection operate |
| 4 | Restricted earth-fault protection operate |
| 5 | Earth-fault protection operate |
| 6 | Circuit failure protection backup operate |
| 7 | Negative sequence overcurrent or thermal overload protection operate |
| 8 | Disturbance recorder triggered |
| 9 | TCS, fuse failure, measuring circuit fault or circuit breaker supervision |
| 10 | Arc protection operate |
| 11 | Protection trip from external device |

### 3.4.2.2 Default disturbance recorder settings

*Table 22: Default disturbance recorder analog channels*

| Channel | Description[1)] |
|---|---|
| 1 | IL1 |
| 2 | IL2 |
| 3 | IL3 |
| 4 | IL1B |
| 5 | IL2B |
| 6 | IL3B |
| 7 | IoB |
| 8 | - |
| 9 | - |
| 10 | - |
| 11 | - |
| 12 | - |

1) Text with “B” refers to measurement on low-voltage side of the transformer

*Table 23: Default disturbance recorder binary channels*

| Channel | ID text | Level trigger mode |
|---|---|---|
| 1 | PHIPTOC1 - start | Positive or Rising |
| 2 | PHHPTOC1 - start | Positive or Rising |
| 3 | PHLPTOC1 - start | Positive or Rising |
| 4 | PHIPTOC2 - start | Positive or Rising |
| 5 | PHHPTOC2 - start | Positive or Rising |
| 6 | PHLPTOC2 - start | Positive or Rising |
| 7 | EFHPTOC2 - start | Positive or Rising |
| 8 | EFLPTOC2 - start | Positive or Rising |
| 9 | NSPTOC1 - start | Positive or Rising |
| 10 | NSPTOC2 - start | Positive or Rising |
| 11 | LREFPNDF1 - start | Positive or Rising |
| 12 | T2PTTR1 - start | Positive or Rising |
| 13 | CCBRBRF1 - trret | Level trigger off |
| 14 | CCBRBRF1 - trbu | Level trigger off |
| 15 | PHIPTOC1 - operate | Level trigger off |
| | PHHPTOC1 - operate | |
| | PHLPTOC1 - operate | |
| 16 | PHIPTOC2 - operate | Level trigger off |
| | PHHPTOC2- operate | |
| | PHLPTOC2 - operate | |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 17 | EFLPTOC2 - operate | Level trigger off |
| | EFHPTOC2 - operate | |
| 18 | NSPTOC1 - operate | Level trigger off |
| | NSPTOC2 - operate | |
| 19 | TR2PTDF1 - operate | Positive or Rising |
| 20 | TR2PTDF1 - opr LS | Level trigger off |
| 21 | TR2PTDF1 - opr HS | Level trigger off |
| 22 | TR2PTDF1 - blkd2h | Level trigger off |
| 23 | TR2PTDF1 - blkd5h | Level trigger off |
| 24 | TR2PTDF1 - blkdwav | Level trigger off |
| 25 | LREFPNDF1 - operate | Level trigger off |
| 26 | T2PTTR1 - operate | Level trigger off |
| 27 | T2PTTR1 - alarm | Level trigger off |
| 28 | T2PTTR1 - blk close | Level trigger off |
| 29 | X110BI1 - ext OC blocking | Level trigger off |
| 30 | X110BI2 - ext operate | Positive or Rising |
| 31 | X110BI7 - HVCB closed | Level trigger off |
| 32 | X110BI8 - HVCB open | Level trigger off |
| 33 | MDSOPT1 - alarm | Level trigger off |
| 34 | ARCSARC1 - ARC flt det | Level trigger off |
| | ARCSARC2 - ARC flt det | |
| | ARCSARC3 - ARC flt det | |
| 35 | ARCSARC1 - operate | Positive or Rising |
| 36 | ARCSARC2 - operate | Positive or Rising |
| 37 | ARCSARC3 - operate | Positive or Rising |
| 38 | - | - |
| 39 | - | - |
| 40 | - | - |
| 41 | - | - |
| 42 | - | - |
| 43 | - | - |
| 44 | - | - |
| 45 | - | - |
| 46 | - | - |
| 47 | - | - |
| 48 | - | - |
| 49 | - | - |
| 50 | - | - |
| 51 | - | - |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 52 | - | - |
| 53 | - | - |
| 54 | - | - |
| 55 | - | - |
| 56 | - | - |
| 57 | - | - |
| 58 | - | - |
| 59 | - | - |
| 60 | - | - |
| 61 | - | - |
| 62 | - | - |
| 63 | - | - |
| 64 | - | - |

## 3.4.3 Functional diagrams

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

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

The high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

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

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

### 3.4.3.1 Functional diagrams for protection

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

The stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The protection relay compares the phase currents on both sides of the object to be protected. If the differential current of the

phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

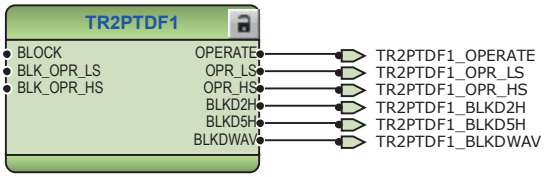



*Figure 60: Transformer differential protection function*

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

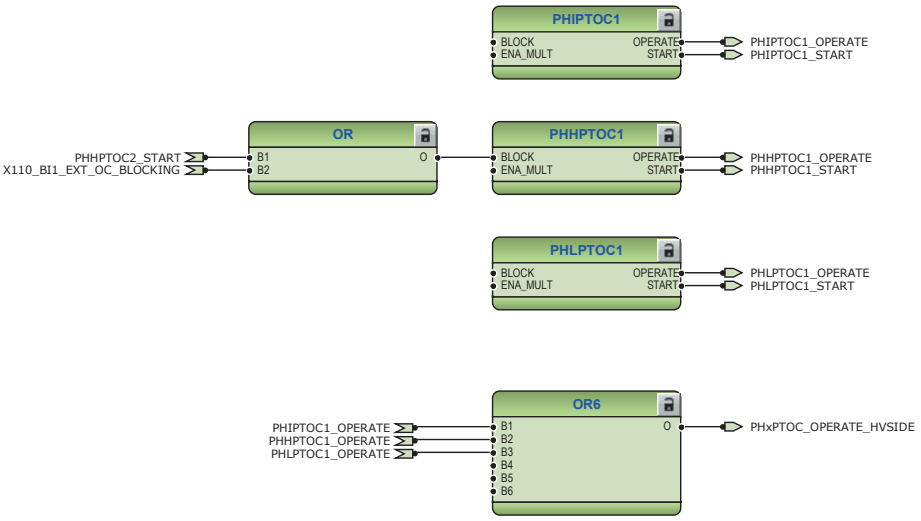



*Figure 61: High-voltage side overcurrent protection function*

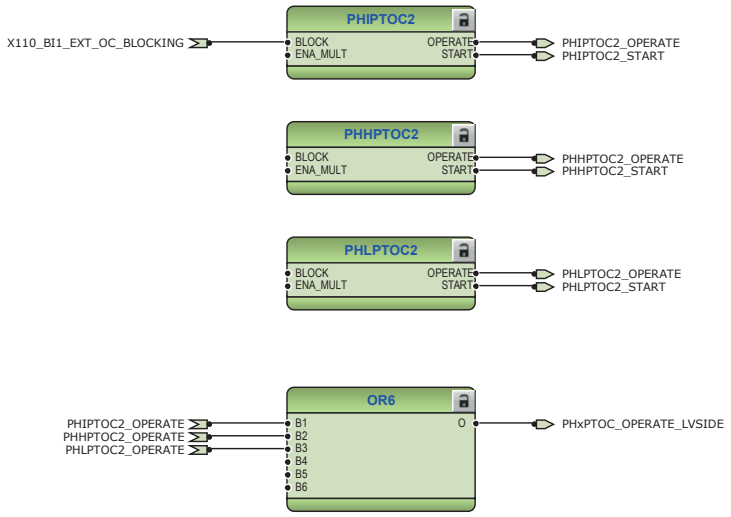



*Figure 62: Low-voltage side overcurrent protection function*

Two stages are offered for non-directional earth-fault protection and this measures the neutral current from low-voltage side.

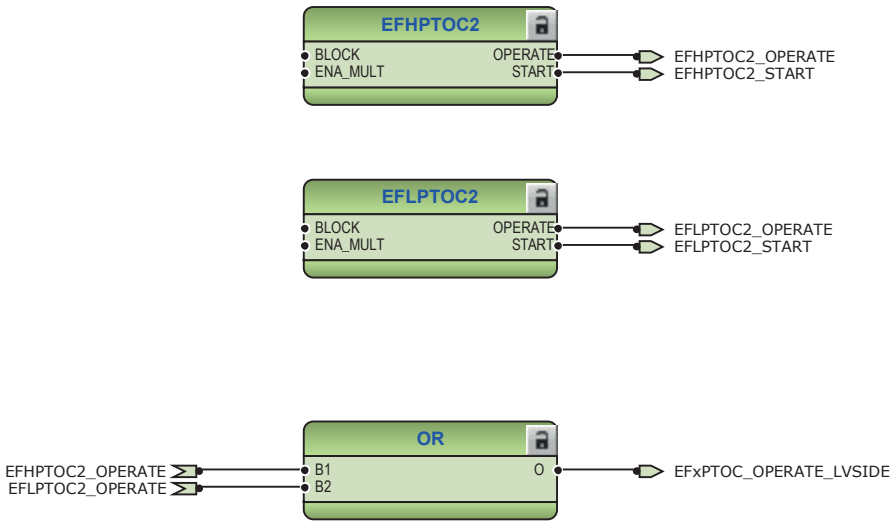



*Figure 63: Low-voltage side earth-fault protection function*

The configuration includes numerically stabilized low-impedance restricted earth-fault protection function for low-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

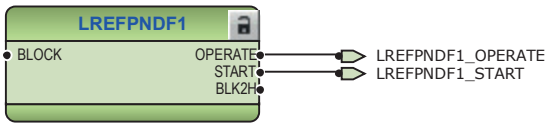



*Figure 64: Restricted low-impedance earth-fault protection*

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

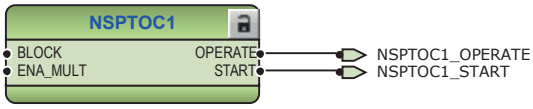



*Figure 65: High-voltage side negative-sequence overcurrent protection function*

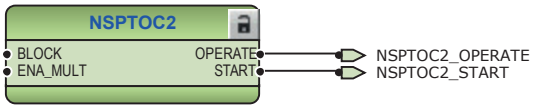



*Figure 66: Low-voltage side negative-sequence overcurrent protection function*

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the protection relay is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

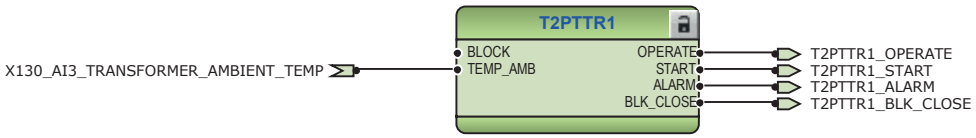



*Figure 67: Thermal overcurrent protection function*

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the protection relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

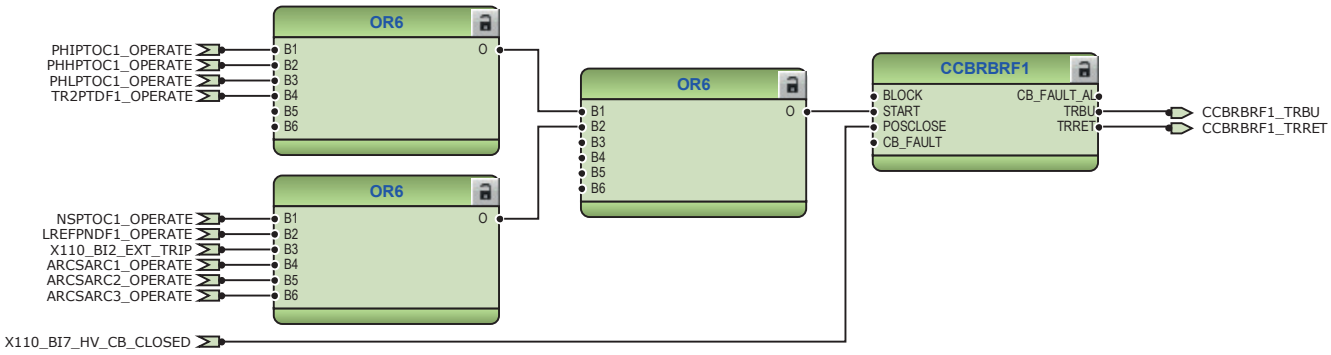



*Figure 68: Circuit breaker failure protection function*

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

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

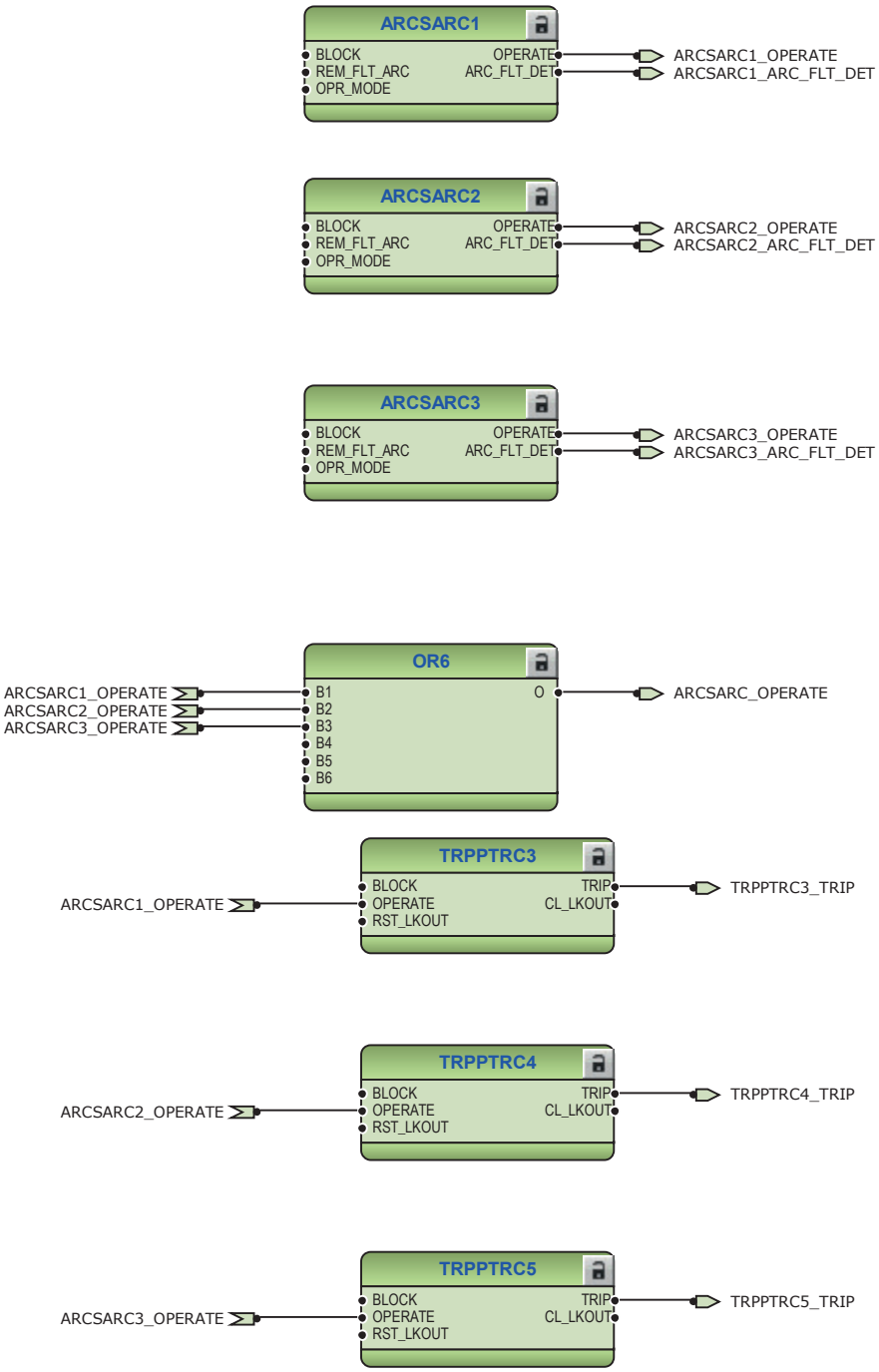



*Figure 69: Arc protection with dedicated HSO*

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

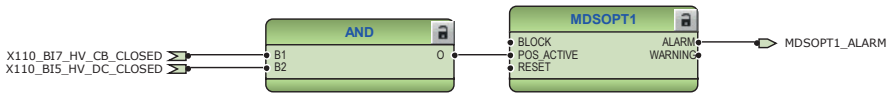



*Figure 70: Transformer operation time counter*

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

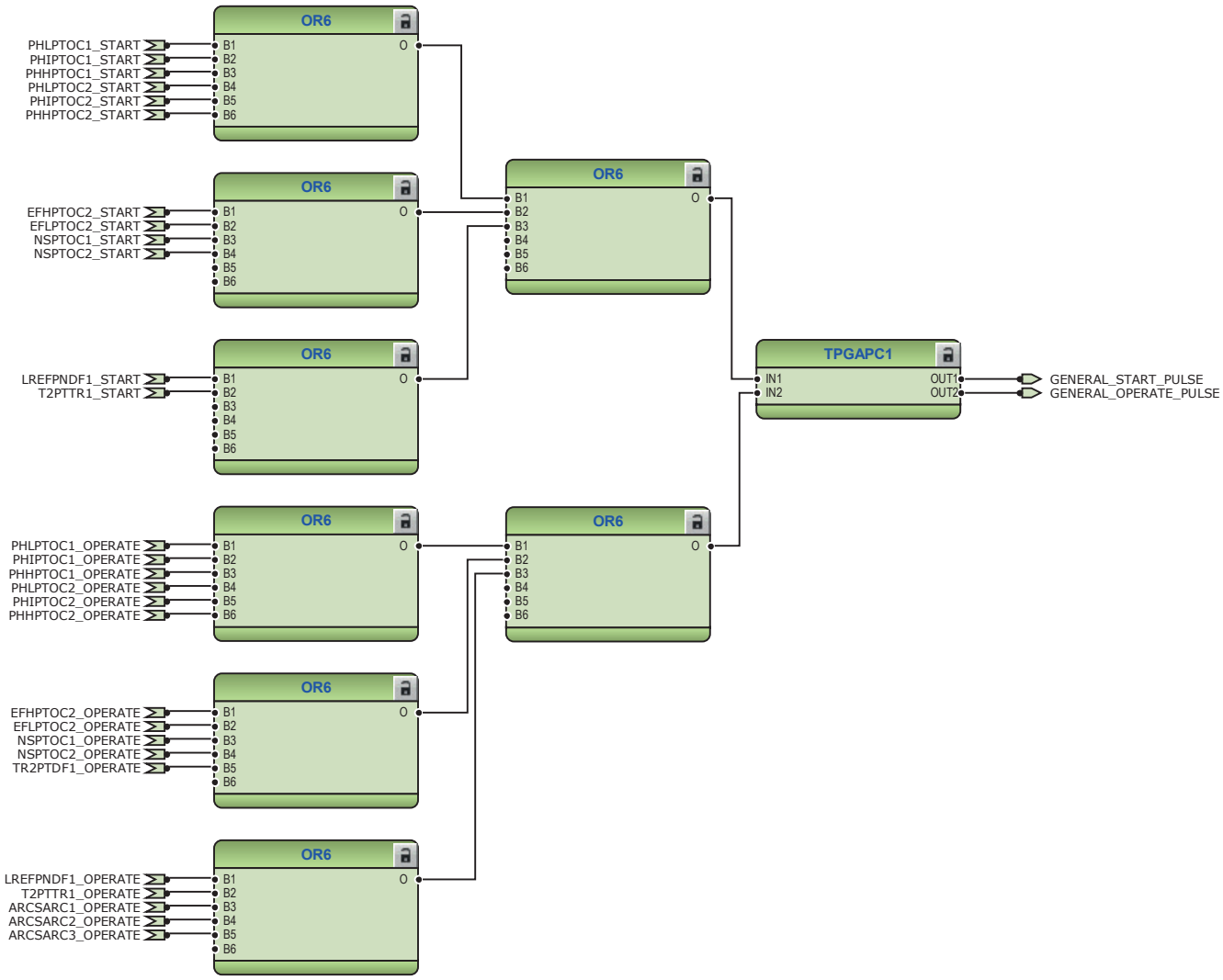



*Figure 71: General start and operate signals*

The operate signals from the protection are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which is further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

Other three trip logics TRPPTRC3...5 are also available if the protection relay is ordered with high speed binary outputs options.

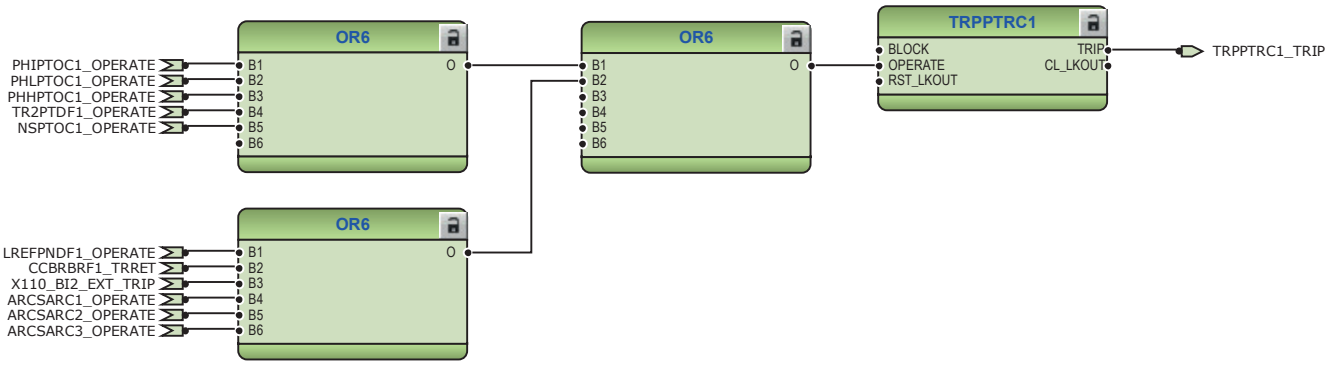



*Figure 72: Trip logic TRPPTRC1*

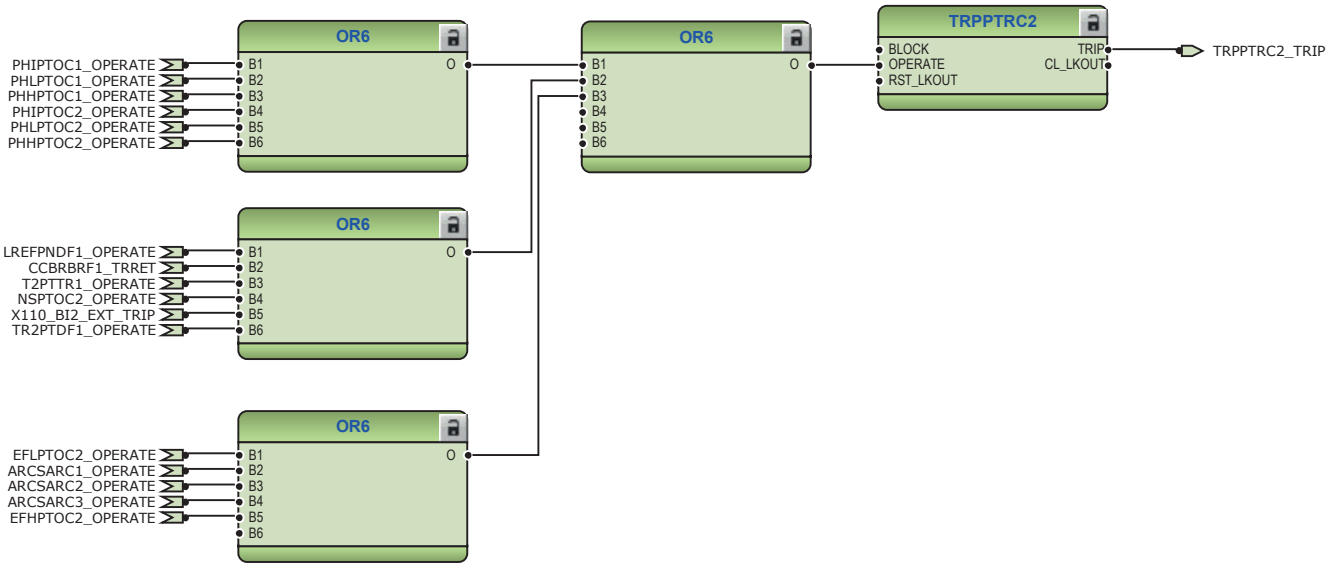



*Figure 73: Trip logic TRPPTRC2*

### 3.4.3.2 Functional diagrams for disturbance recorder

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

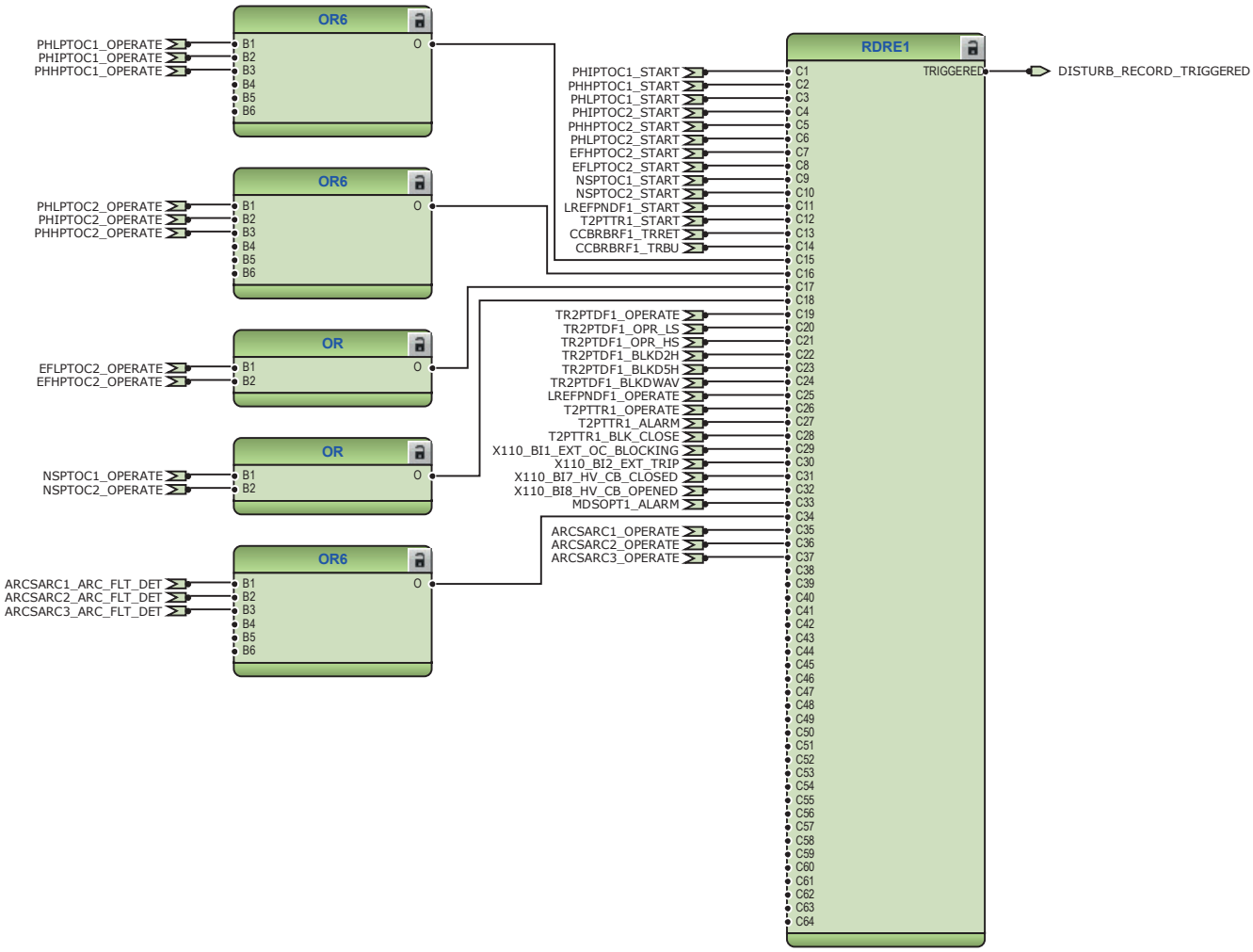



*Figure 74: Disturbance recorder*

### 3.4.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

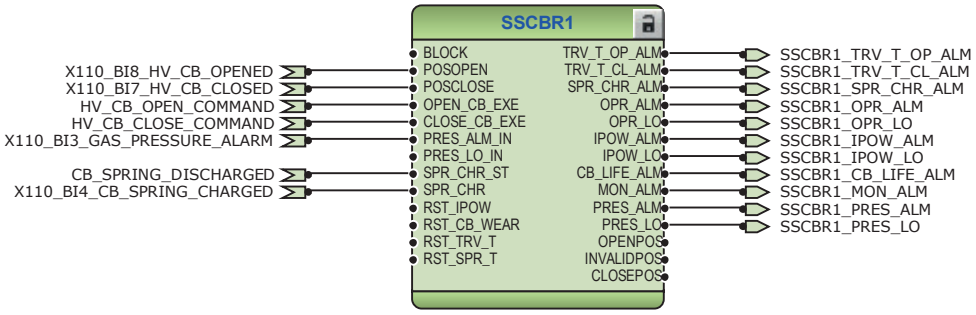



*Figure 75: Circuit-breaker condition monitoring function*

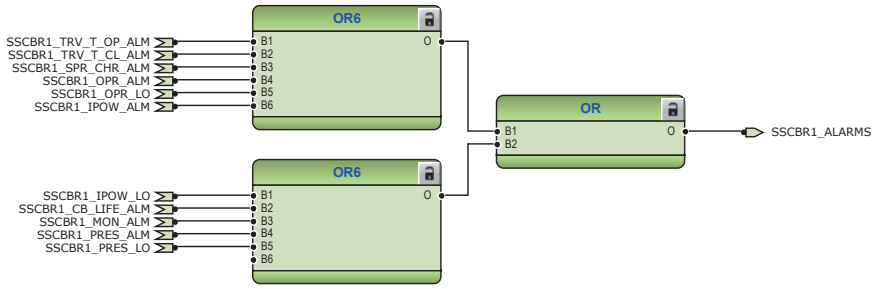



*Figure 76: Logic for circuit-breaker monitoring alarm*


*Figure 77: Logic for start of circuit-breaker spring charging*

Two separate trip circuit supervision functions are included, TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and the HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

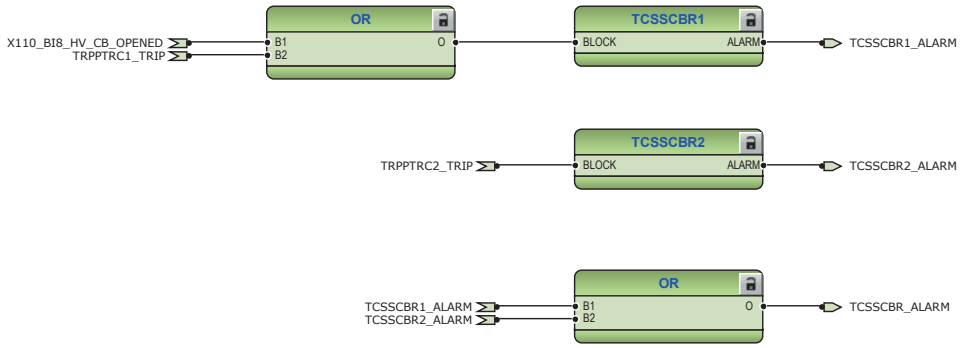



*Figure 78: Trip circuit supervision function*

### 3.4.3.4 Functional diagrams for control and interlocking

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

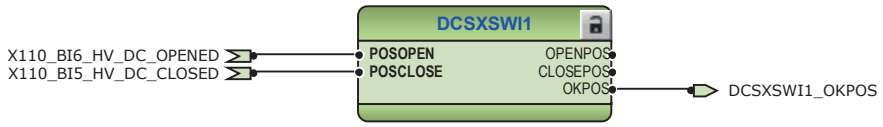



*Figure 79: Disconnector control logic*

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

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

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

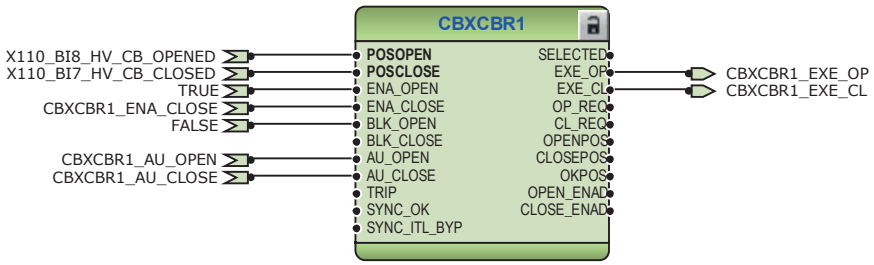



*Figure 80: High-voltage side circuit breaker control logic: Circuit breaker 1*

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


*Figure 81: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker*


*Figure 82: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker*

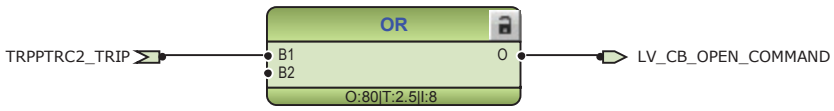



*Figure 83: Circuit breaker control logic: Signals for opening coil of low-voltage side circuit breaker*

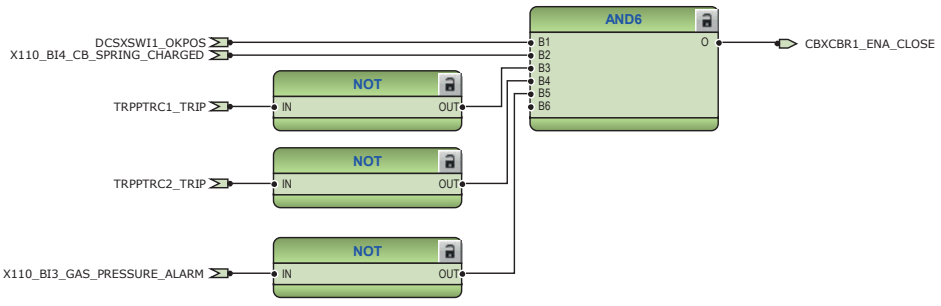



*Figure 84: High-voltage side circuit breaker close enable logic*

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

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

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

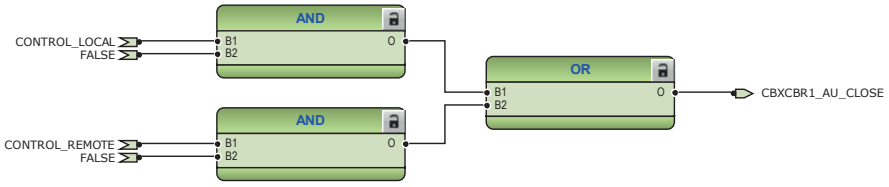



*Figure 85: External closing command for circuit breaker*

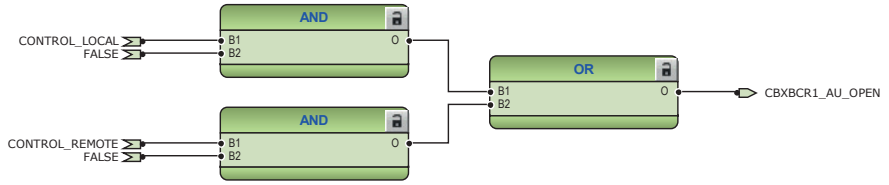



*Figure 86: External opening command for circuit breaker*

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the protection relay via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used, TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters TPOSYLTC1 properly

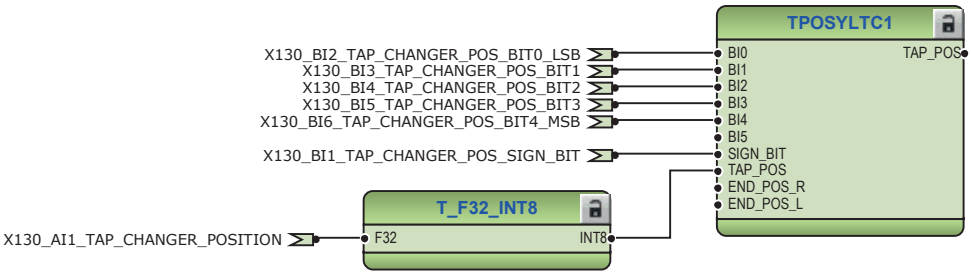



*Figure 87: Tap changer position indicator*

### 3.4.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the protection relay are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. The sequence current measurement function CSMSQI1 measures the sequence current from high-voltage side and the residual current measurement function RESCMMXU2 measures the residual current from low-voltage side.

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

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

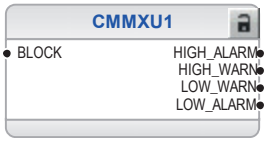



*Figure 88: Current measurement: Three-phase current measurement (HV side)*

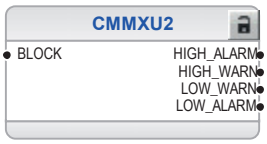



*Figure 89: Current measurement: Three-phase current measurement (LV side)*


*Figure 90: Current measurement: Sequence current measurement (HV side)*


*Figure 91: Current measurement: Residual current measurement (LV side)*


*Figure 92: Other measurement: Data monitoring*


*Figure 93: Other measurement: Load profile record*

### 3.4.3.6 Functional diagrams for I/O and alarms LEDs

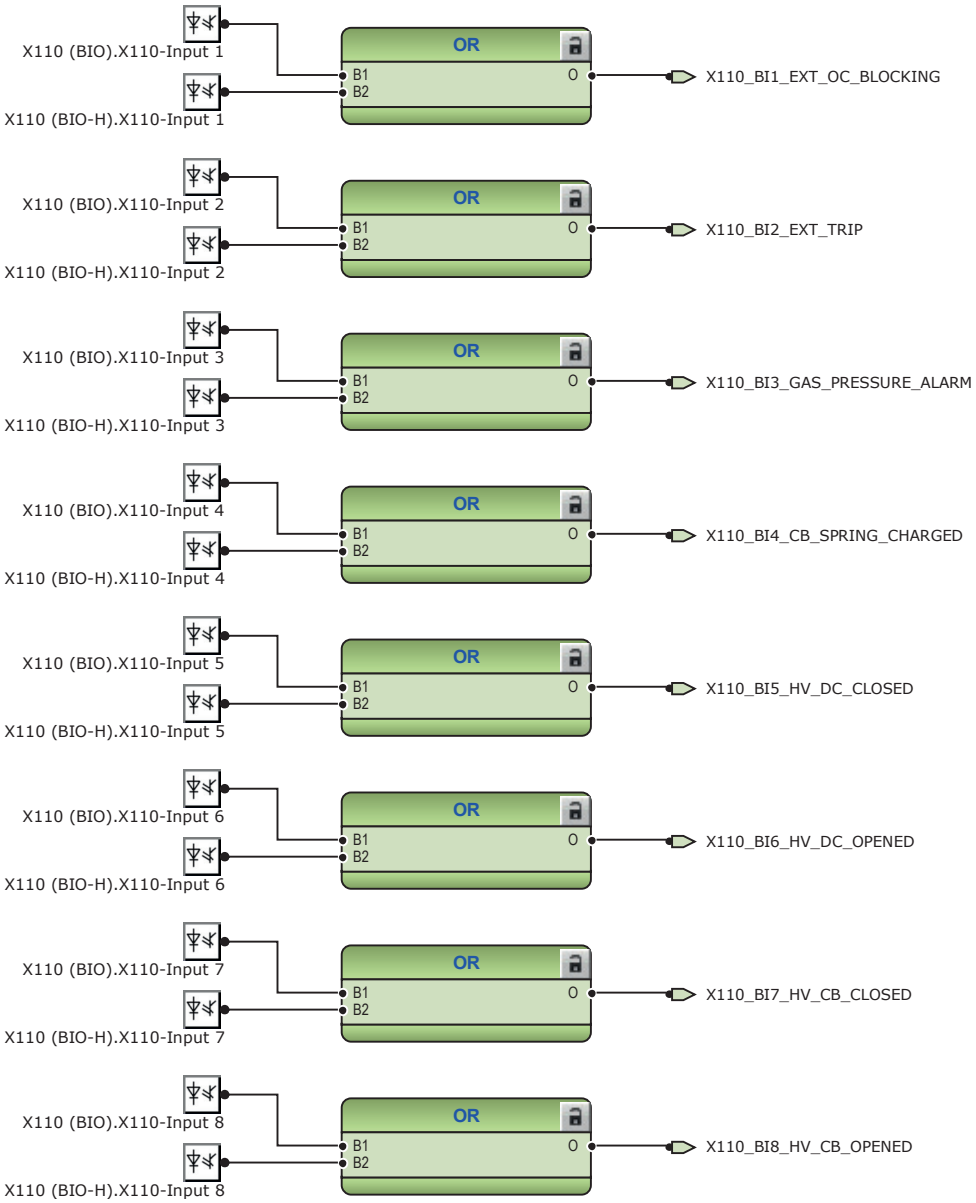



*Figure 94: Binary inputs - X110 terminal block*

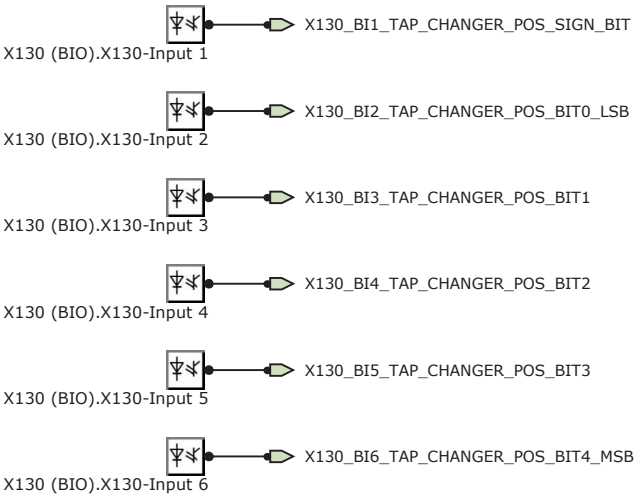



*Figure 95: Binary inputs - X130 terminal block*

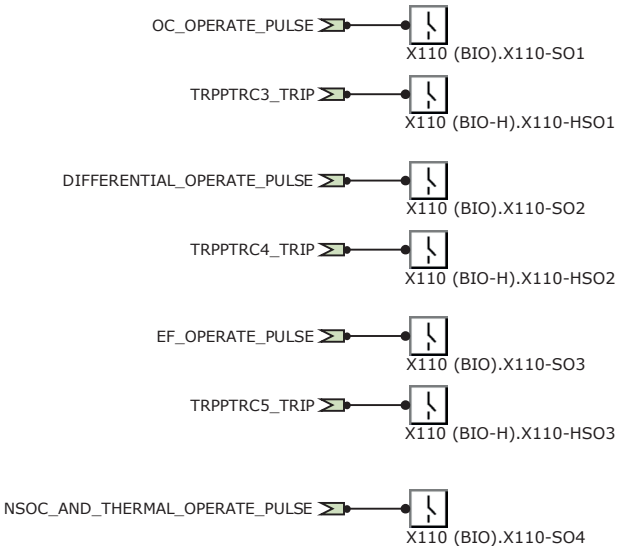



*Figure 96: Binary outputs - X110 terminal block*

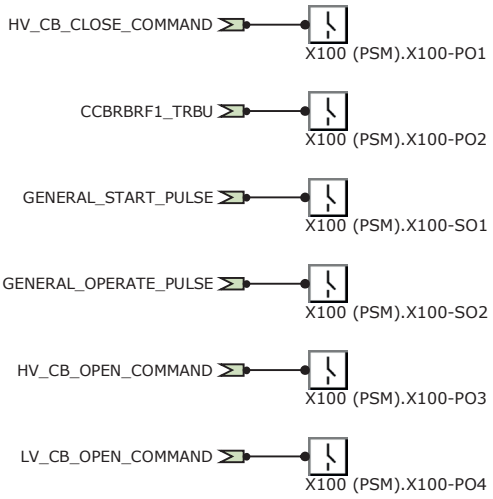



*Figure 97: Binary outputs - X100 terminal block*

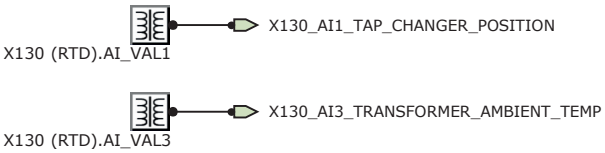
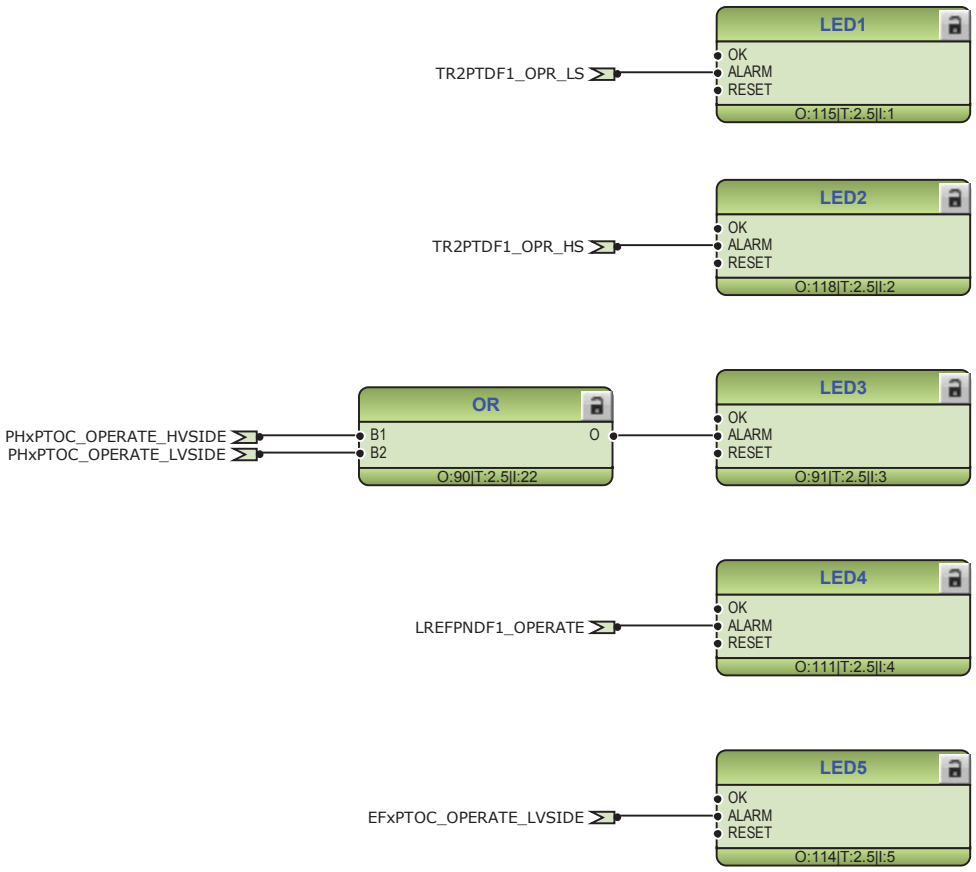



*Figure 98: Default mA/RTD inputs X130*


LED1
OK
ALARM
RESET
O:115|T:2.5|I:1
TR2PTDF1_OPR_LS
LED2
OK
ALARM
RESET
O:118|T:2.5|I:2
TR2PTDF1_OPR_HS
OR
B1
B2
O
O:90|T:2.5|I:22
PHxPTOC_OPERATE_HVSIDE
PHxPTOC_OPERATE_LVSIDE
LED3
OK
ALARM
RESET
O:91|T:2.5|I:3
LED4
OK
ALARM
RESET
O:111|T:2.5|I:4
LREFPNDF1_OPERATE
LED5
OK
ALARM
RESET
O:114|T:2.5|I:5
EFxPTOC_OPERATE_LVSIDE

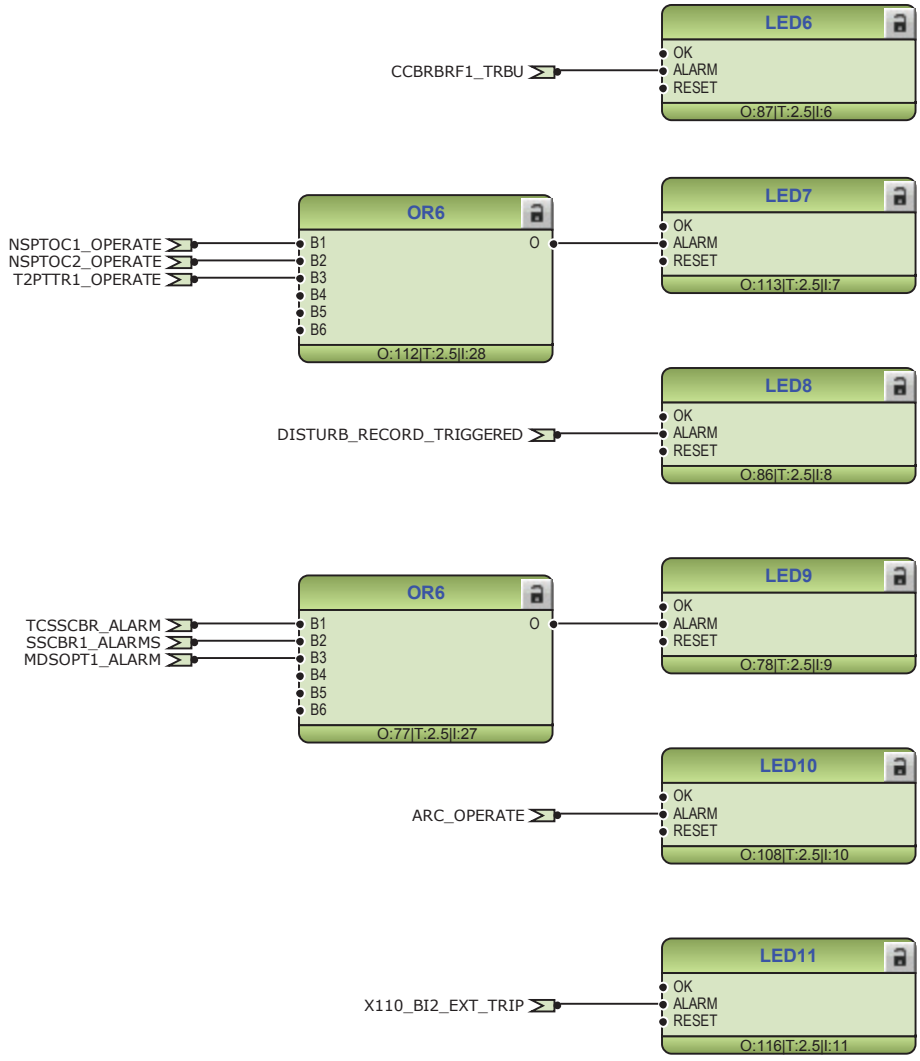



*Figure 99: Default LED connection*

## 3.4.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, differential operate, earth-fault operate and combined negative-sequence and thermal overload operate logic. The operate logics are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

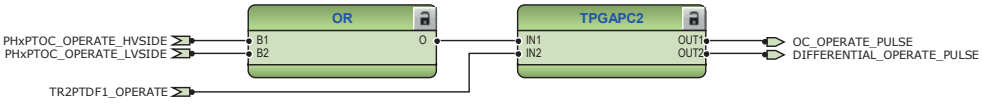



*Figure 100: Timer logic for overcurrent and differential operate pulse*

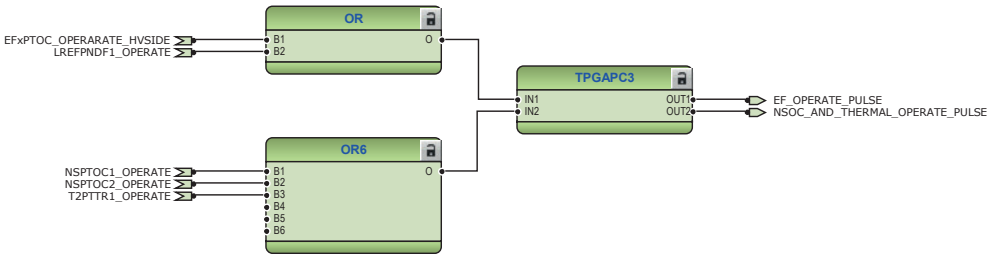



*Figure 101: Timer logic for earth-fault and negative sequence with thermal overload protection operate alarm*

### 3.4.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

## 3.5 Standard configuration E

### 3.5.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the high-voltage (HV) side, high voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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

## 3.5.2 Functions

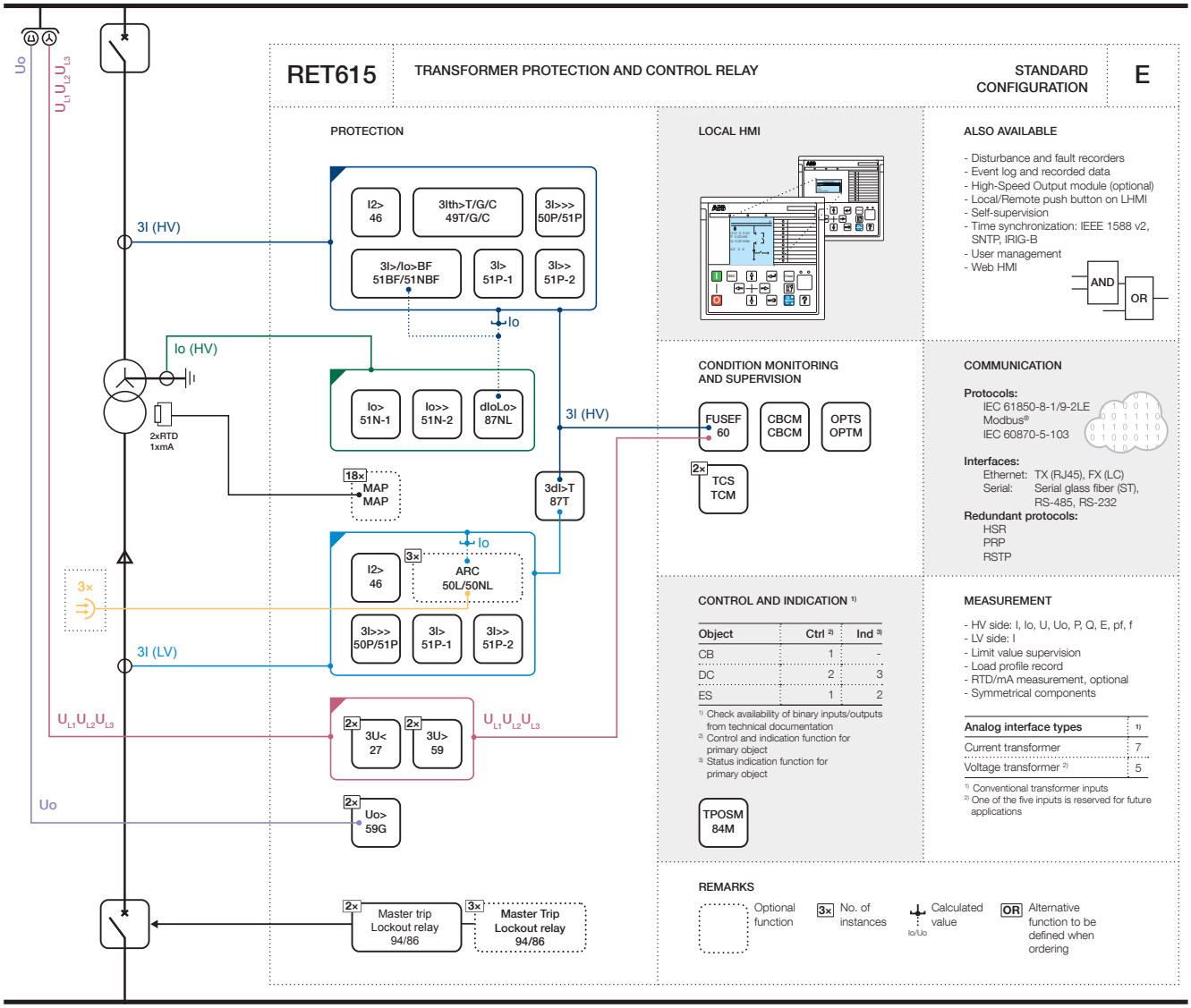



*Figure 102: Functionality overview for standard configuration E*

### 3.5.2.1 Default I/O connections

Connector pins for each input and output are presented in the Protection relay's physical connections section.

*Table 24: Default connections for analog inputs*

| Analog input | Description | Connector pins |
|---|---|---|
| IL1B | Phase A current, LV side | X120:1-2 |
| IL2B | Phase B current, LV side | X120:3-4 |
| IL3B | Phase C current, LV side | X120:5-6 |
| IL1 | Phase A current, HV side | X120:7-8 |
| IL2 | Phase B current, HV side | X120:9-10 |
| IL3 | Phase C current, HV side | X120:11-12 |
| Io | Residual current | X120:13-14 |
| U1 | Phase voltage U1 | X130:11-12 |
| U2 | Phase voltage U2 | X130:13-14 |
| U3 | Phase voltage U3 | X130:15-16 |
| Uo | Residual voltage | X130:17-18 |
| mA1 | - | X130:1-2 |
| RTD1 | - | X130:3-4 |
| RTD2 | - | X130:6-7 |
| AI1 | Tap changer position | X130:1-2 |
| AI2 | - | X130:3-4 |
| AI3 | Ambient temperature | X130:5-6 |
| AI4 | - | X130:7-8 |
| AI5 | - | X130:9-10 |
| AI6 | - | X130:13-14 |
| AI7 | - | X130:15-16 |
| AI8 | - | X130:17-18 |

*Table 25: Default connections for binary inputs*

| Binary input | Description | Connector pins | |
|---|---|---|---|
| | | BIO0005 | BIO0007 |
| X110-BI1 | Blocking of overcurrent high state (high voltage) and instantaneous stage (medium voltage) | X110:1-2 | X110:1,5 |
| X110-BI2 | External protection trip | X110:3-4 | X110:2,5 |
| X110-BI3 | Circuit breaker low gas pressure indication | X110:5-6 | X110:3,5 |
| X110-BI4 | Circuit breaker spring charged indication | X110:7-6 | X110:4-5 |
| X110-BI5 | High-voltage side disconnector closed indication | X110:8-9 | X110:6,10 |
| X110-BI6 | High-voltage side disconnector open indication | X110:10-9 | X110:7,10 |
| X110-BI7 | High-voltage side circuit breaker closed indication | X110:11-12 | X110:8,10 |
| X110-BI8 | High-voltage side circuit breaker open indication | X110:13-12 | X110:9-10 |
| X130-BI1 | Voltage transformer secondary MCB open | X130:1-2 | |
| X130-BI2 | - | X130:3-4 | |
| X130-BI3 | - | X130:5-6 | |
| X130-BI4 | - | X130:7-8 | |

*Table 26: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close high-voltage circuit breaker | X100:6-7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker (Breaker 1 and 2) | 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 high-voltage | X100:15-19 |
| X100-PO4 | Open circuit breaker/trip coil 2 low-voltage | X100:20-24 |
| X110-SO1 | Overcurrent operate alarm | X110:14-16 |
| X110-SO2 | Differential protection operate alarm | X110:17-19 |
| X110-SO3 | Earth-fault operate alarm | X110:20-22 |
| X110-SO4 | Thermal overload and negative phase-sequence operate alarm | X110:23-24 |
| X110-HSO1 | Arc protection instance 1 trip activated | X110:15-16 |
| X110-HSO1 | Arc protection instance 2 trip activated | X110:19-20 |
| X110-HSO1 | Arc protection instance 3 trip activated | X110:23-24 |

*Table 27: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Transformer differential protection biased stage operate |
| 2 | Transformer differential protection instantaneous stage operate |
| 3 | Overcurrent or earth-fault protection operate |
| 4 | Restricted earth-fault protection operate |
| 5 | Voltage protection operate |
| 6 | Circuit failure protection backup operate |
| 7 | Negative sequence overcurrent or thermal overload protection operate |
| 8 | Disturbance recorder triggered |
| 9 | TCS, fuse failure, measuring circuit fault or circuit breaker supervision |
| 10 | Arc protection operate |
| 11 | Protection trip from external device |

### 3.5.2.2 Default disturbance recorder settings

*Table 28: Default disturbance recorder analog channels*

| Channel | Description[1)] |
|---|---|
| 1 | IL1 |
| 2 | IL2 |
| 3 | IL3 |
| 4 | IL1B |

Table continues on next page

| Channel | Description[1)] |
|---|---|
| 5 | IL2B |
| 6 | IL3B |
| 7 | Io |
| 8Uo | Uo |
| 9 | U1 |
| 10 | U2 |
| 11 | U3 |
| 12 | - |

1) Text with “B” refers to measurement on low-voltage side of the transformer

*Table 29: Default disturbance recorder binary channels*

| Channel | ID text | Level trigger mode |
|---|---|---|
| 1 | PHIPTOC1 - start | Positive or Rising |
| 2 | PHHPTOC1 - start | Positive or Rising |
| 3 | PHLPTOC1 - start | Positive or Rising |
| 4 | PHIPTOC2 - start | Positive or Rising |
| 5 | PHHPTOC2 - start | Positive or Rising |
| 6 | PHLPTOC2 - start | Positive or Rising |
| 7 | EFHPTOC2 - start | Positive or Rising |
| 8 | EFLPTOC2 - start | Positive or Rising |
| 9 | NSPTOC1 - start | Positive or Rising |
| 10 | NSPTOC2 - start | Positive or Rising |
| 11 | LREFPNDF1 - start | Positive or Rising |
| 12 | T2PTTR1 - start | Positive or Rising |
| 13 | ROVPTOV1 - start | Positive or Rising |
| 14 | ROVPTOV2 - start | Positive or Rising |
| 15 | PHPTOV1 - start | Positive or Rising |
| 16 | PHPTOV2 - start | Positive or Rising |
| 17 | PHPTUV1 - start | Positive or Rising |
| 18 | PHPTUV2 - start | Positive or Rising |
| 19 | CCBRBRF1 - trret | Level trigger off |
| 20 | CCBRBRF1 - trbu | Level trigger off |
| 21 | PHIPTOC1 - operate | Level trigger off |
| | PHHPTOC1 - operate | |
| | PHLPTOC1 - operate | |
| 22 | PHIPTOC2 - operate | Level trigger off |
| | PHHPTOC2- operate | |
| | PHLPTOC2 - operate | |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 23 | EFLPTOC2 - operate | Level trigger off |
| | EFHPTOC2 - operate | |
| 24 | NSPTOC1 - operate | Level trigger off |
| | NSPTOC2 - operate | |
| 25 | TR2PTDF1 - operate | Positive or Rising |
| 26 | TR2PTDF1 - opr LS | Level trigger off |
| 27 | TR2PTDF1 - opr HS | Level trigger off |
| 28 | TR2PTDF1 - blkd2h | Level trigger off |
| 29 | TR2PTDF1 - blkd5h | Level trigger off |
| 30 | TR2PTDF1 - blkdwav | Level trigger off |
| 31 | LREFPNDF1 - operate | Level trigger off |
| 32 | T2PTTR1 - operate | Level trigger off |
| 33 | T2PTTR1 - alarm | Level trigger off |
| 34 | T2PTTR1 - blk close | Level trigger off |
| 35 | SEQSPVC1 - fusef3ph | Level trigger off |
| 36 | SEQSPVC1 - fusefu | Level trigger off |
| 37 | ROVPTOV1 - operate | Level trigger off |
| | ROVPTOV2 - operate | |
| 38 | PHPTOV1 - operate | Level trigger off |
| | PHPTOV2 - operate | |
| 39 | PHPTUV1 - operate | Level trigger off |
| | PHPTUV2 - operate | |
| 40 | X110BI1 - ext OC blocking | Level trigger off |
| 41 | X110BI2 - ext operate | Positive or Rising |
| 42 | X110BI7 - HVCB closed | Level trigger off |
| 43 | X110BI8 - HVCB open | Level trigger off |
| 44 | MDSOPT1 - alarm | Level trigger off |
| 45 | ARCSARC1 - ARC flt det | Level trigger off |
| | ARCSARC2 - ARC flt det | |
| | ARCSARC3 - ARC flt det | |
| 46 | ARCSARC1 - operate | Positive or Rising |
| 47 | ARCSARC2 - operate | Positive or Rising |
| 48 | ARCSARC3 - operate | Positive or Rising |
| 49 | - | - |
| 50 | - | - |
| 51 | - | - |
| 52 | - | - |
| 53 | - | - |
| 54 | - | - |

Table continues on next page

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

## 3.5.3 Functional diagrams

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

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

The high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

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

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

### 3.5.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The protection relay compares the phase currents on both sides of the object to be protected. If the differential current of the

phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to the master trips as well as to alarm LEDs

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

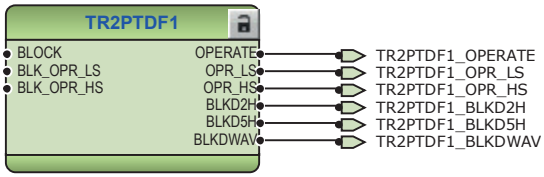



*Figure 103: Transformer differential protection function*

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

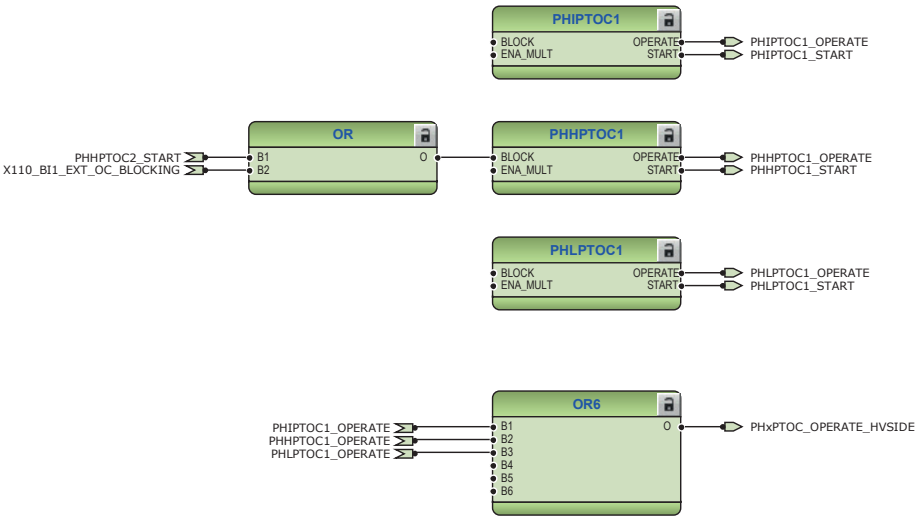



*Figure 104: High-voltage side overcurrent protection function*

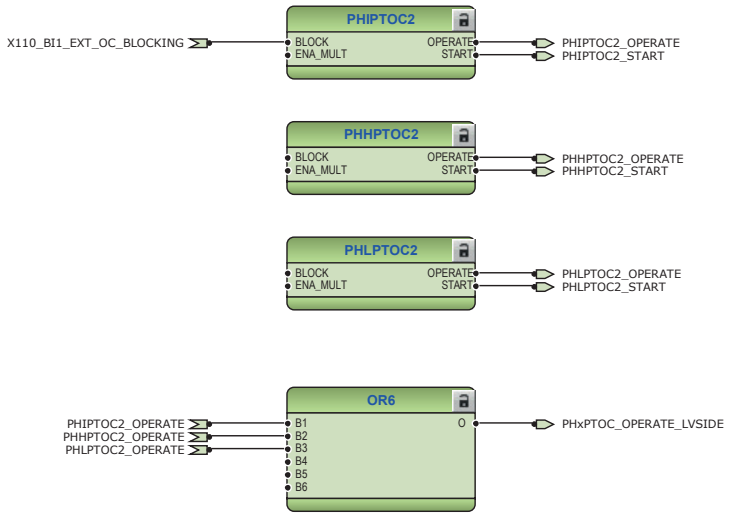



*Figure 105: Low-voltage side overcurrent protection function*

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from high-voltage side.

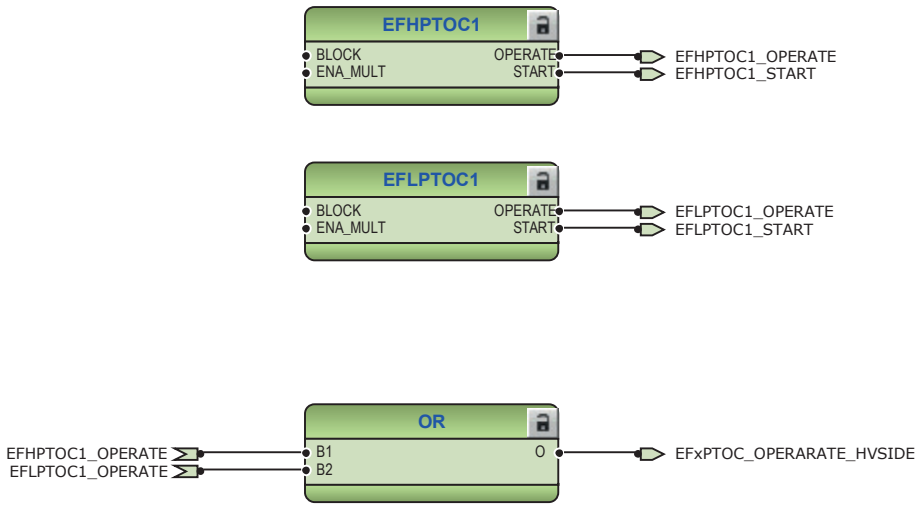



*Figure 106: High-voltage side earth-fault protection function*

Configuration also includes numerically stabilized low-impedance restricted earth-fault protection for high-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

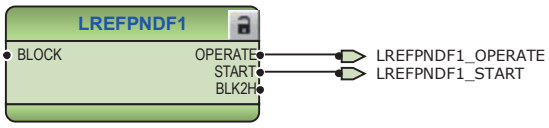



*Figure 107: Restricted low-impedance earth-fault protection*

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

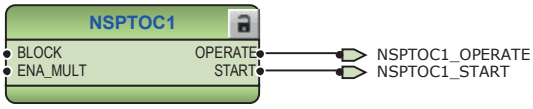



*Figure 108: High-voltage side negative-sequence overcurrent protection function*

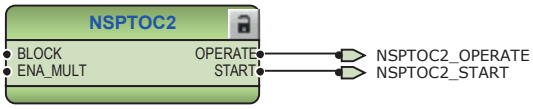



*Figure 109: Low-voltage side negative-sequence overcurrent protection function*

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the protection relay is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

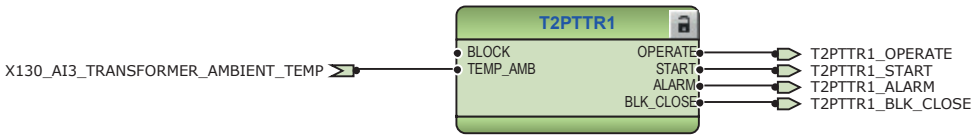



*Figure 110: Thermal overcurrent protection function*

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the protection relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output (X100:PO2).

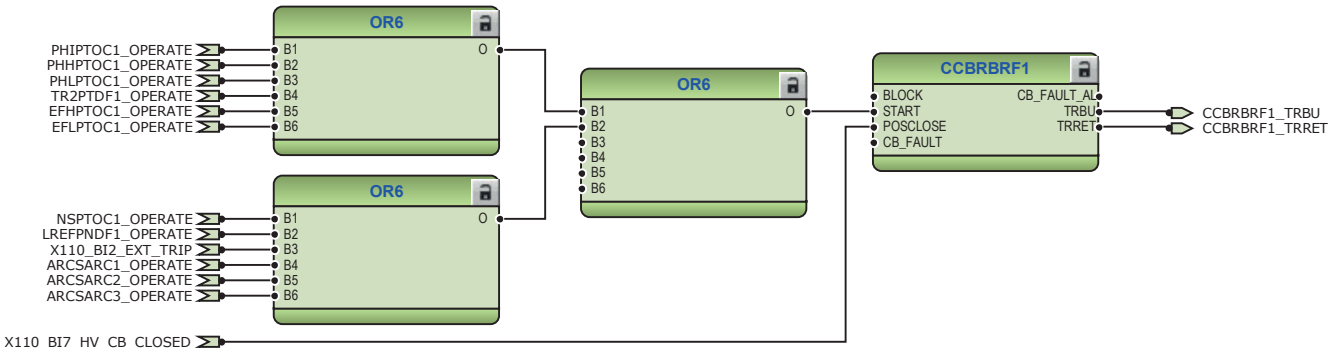



*Figure 111: Circuit breaker failure protection function*

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

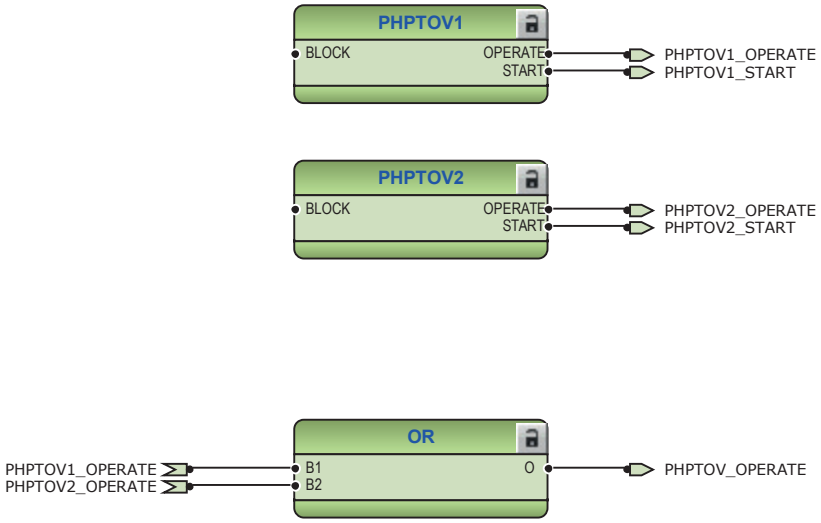



*Figure 112: High-voltage side phase overvoltage protection function*

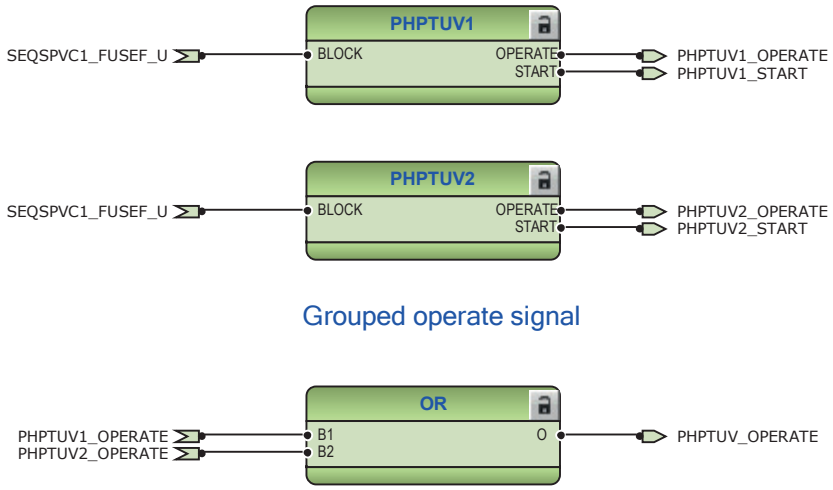



*Figure 113: High-voltage side phase undervoltage protection function*

High-voltage side phase undervoltage protection function

Residual overvoltage protection ROVPTOV provides earth-fault protection by detecting abnormal level of residual voltage.

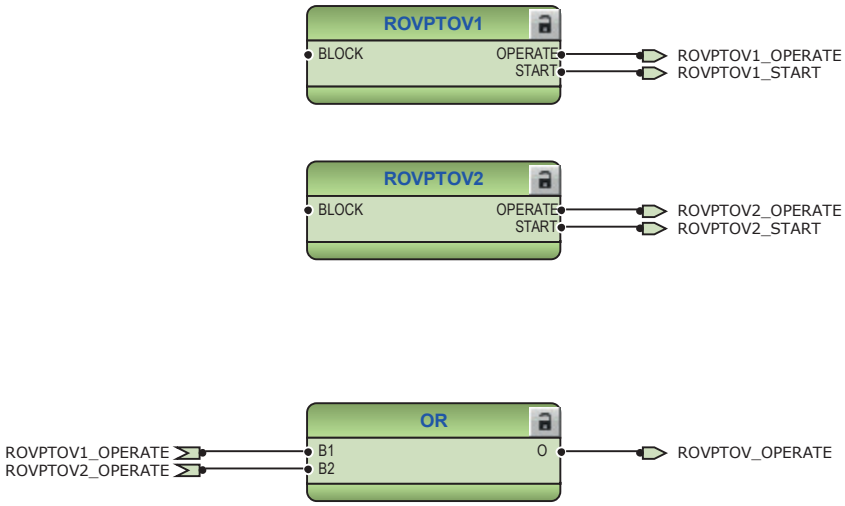



*Figure 114: High-voltage side residual voltage protection function*

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

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

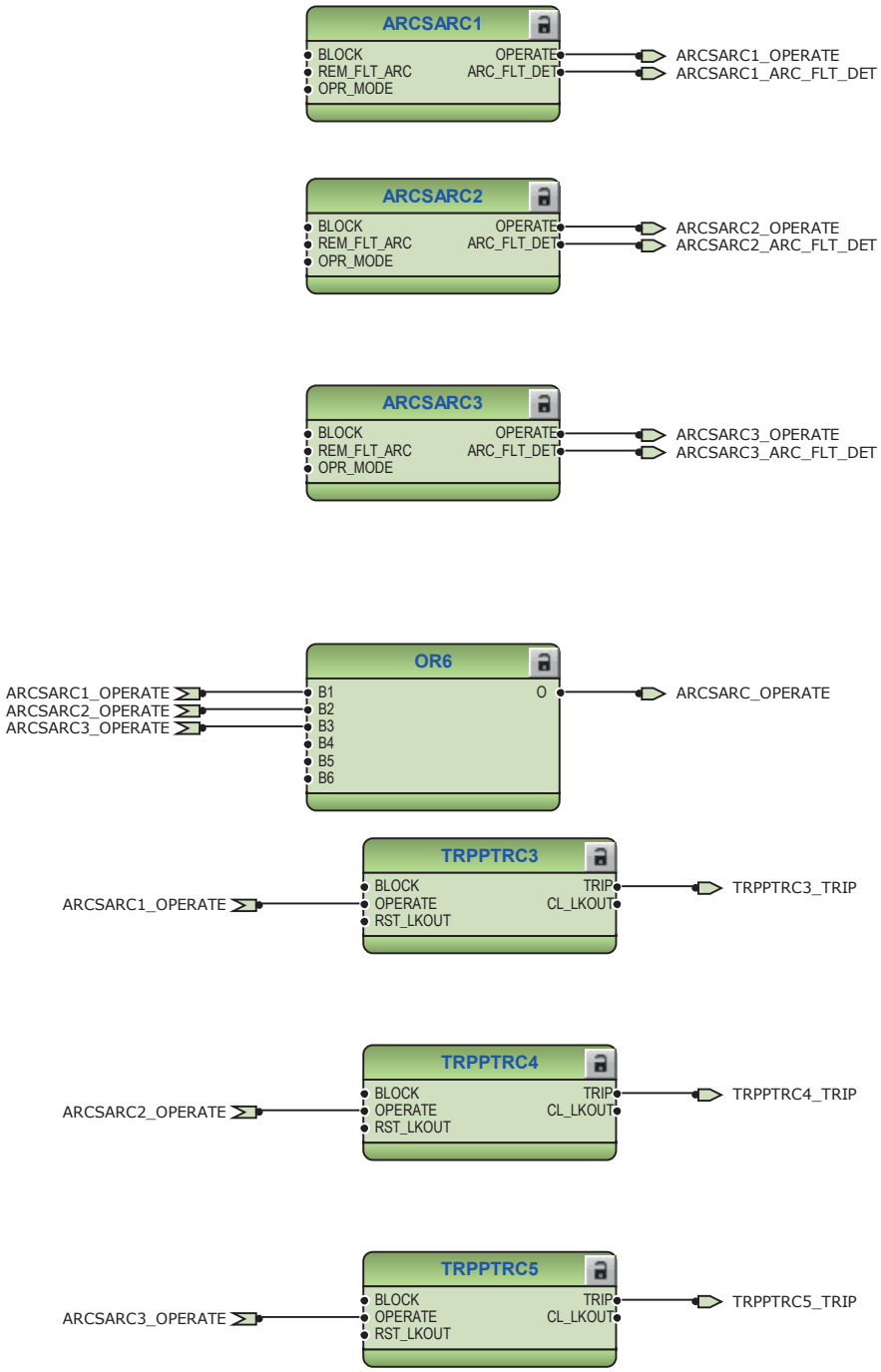



*Figure 115: Arc protection with dedicated HSO*

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

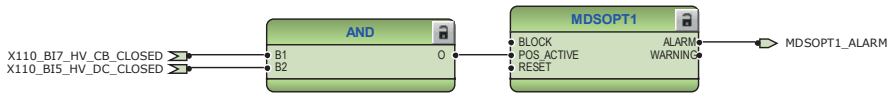



*Figure 116: Transformer operation time counter*

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

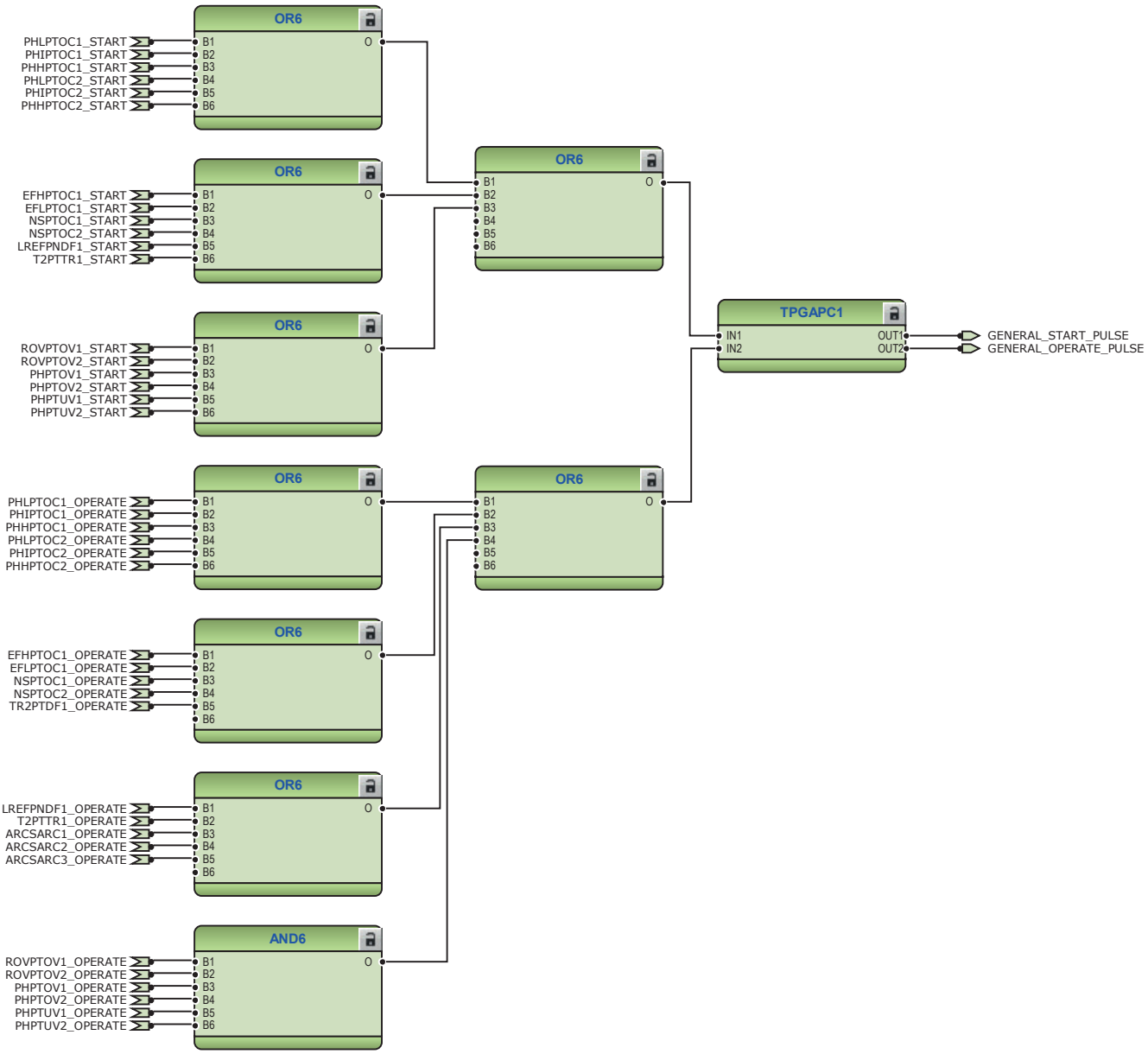



*Figure 117: General start and operate signals*

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at

binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of the trip logic to enable external reset with a push button.

Other three trip logics TRPPTRC3...5 are also available if the protection relay is ordered with high speed binary outputs options.

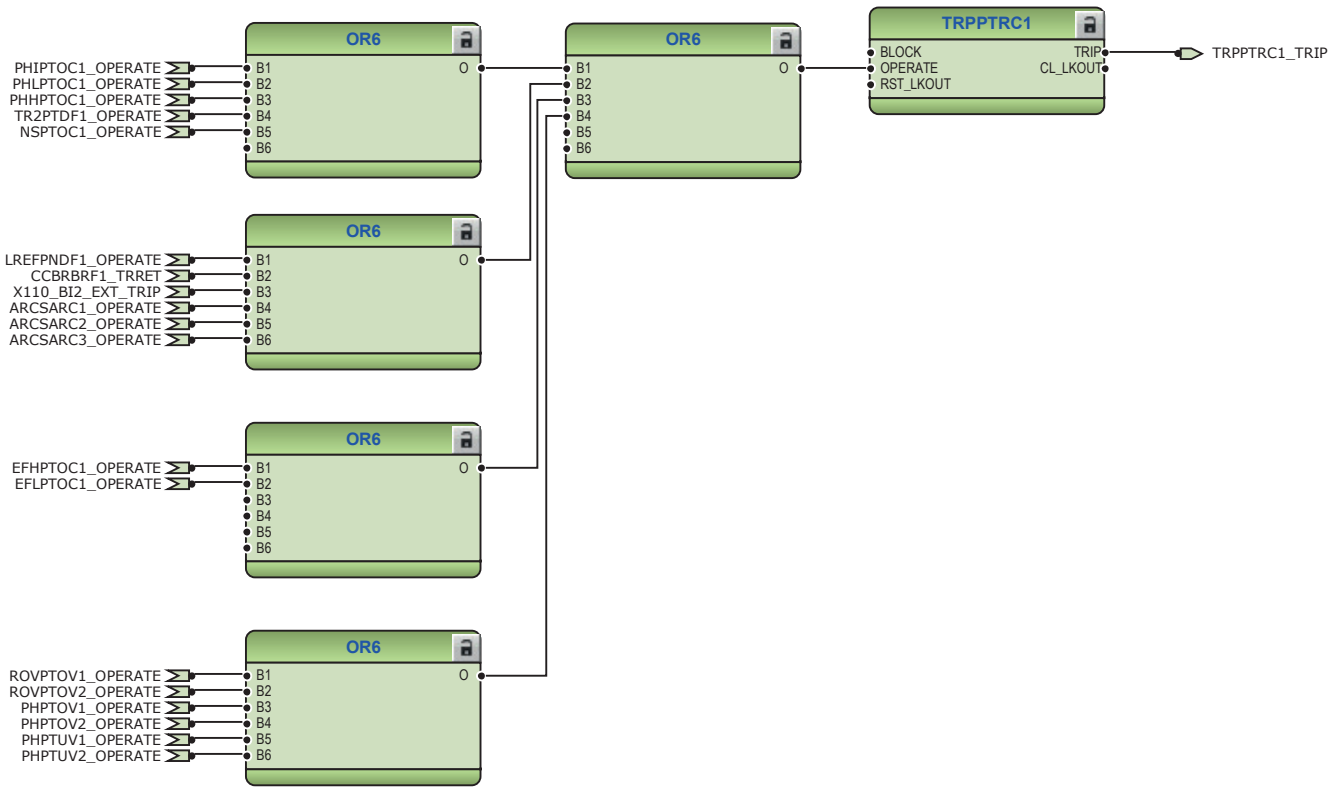



*Figure 118: Trip logic TRPPTRC1*

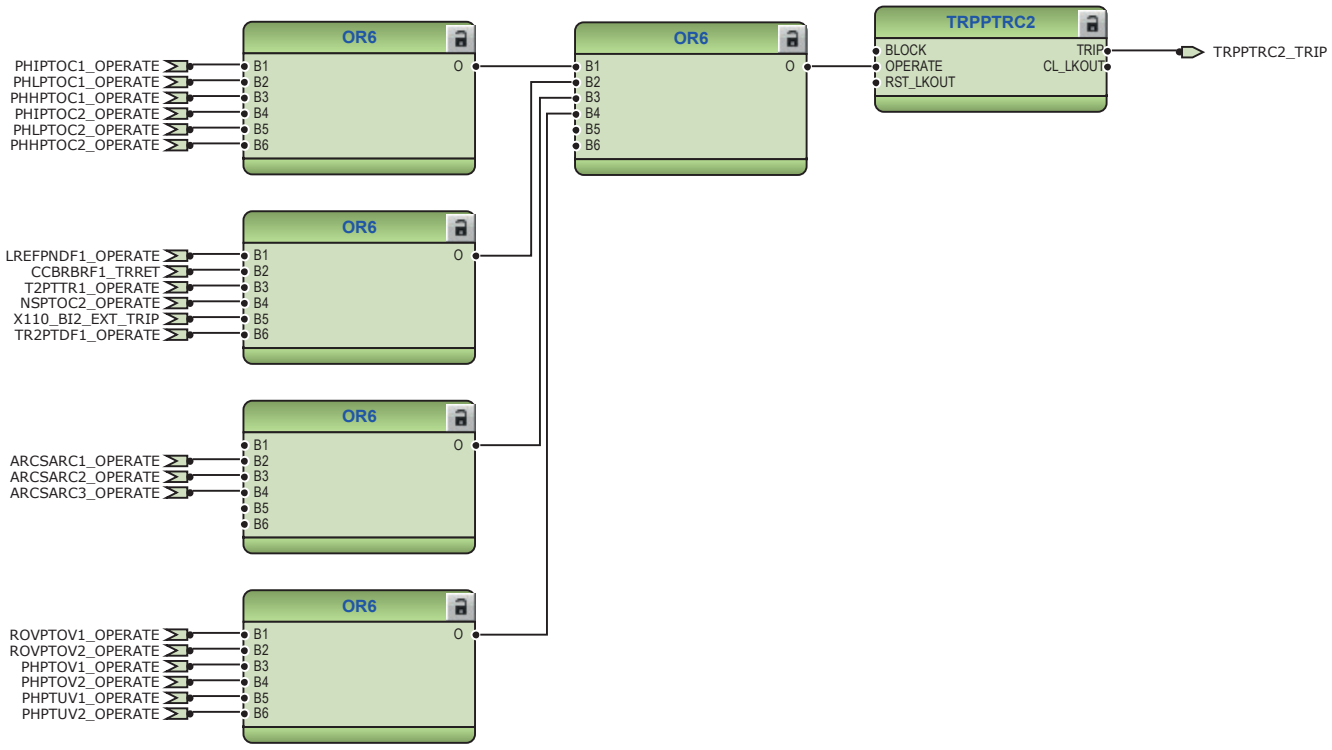



*Figure 119: Trip logic TRPPTRC2*

### 3.5.3.2 Functional diagrams for disturbance recorder

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

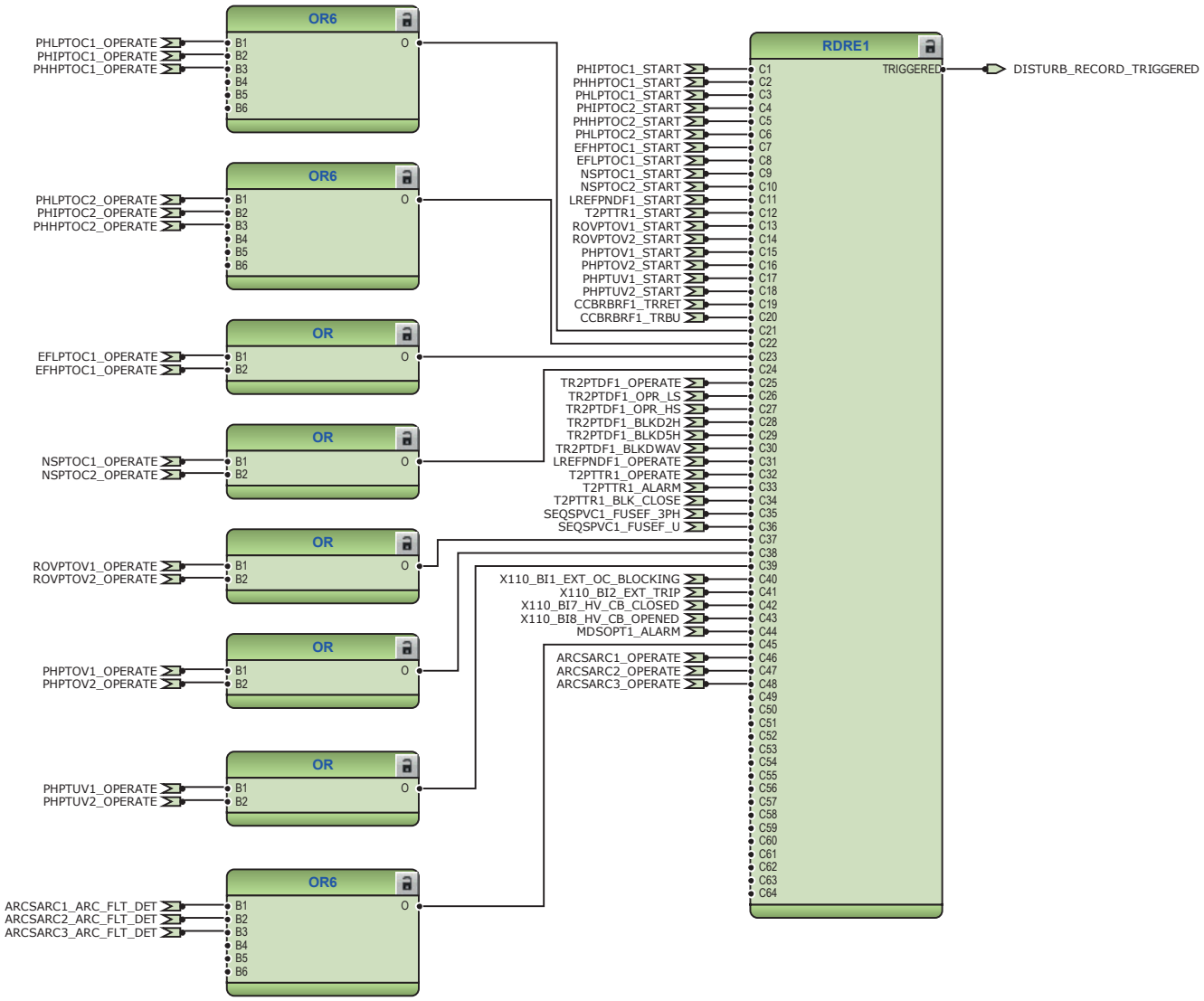



*Figure 120: Disturbance recorder*

### 3.5.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

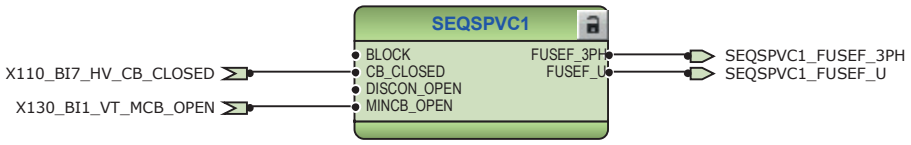



*Figure 121: Fuse failure supervision function*

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

Set the parameters for SSCBR1 properly.

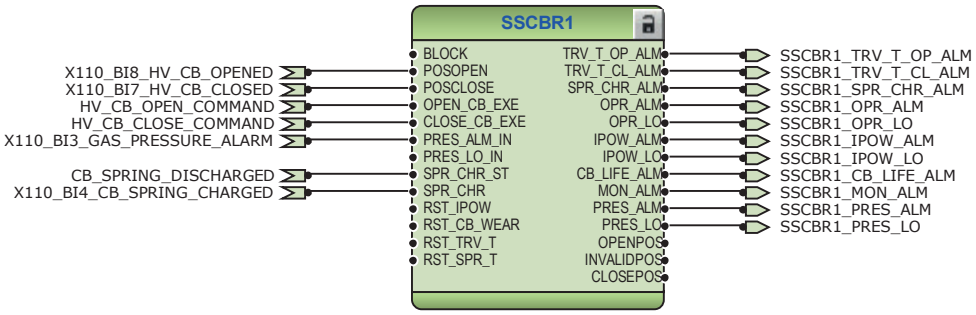



*Figure 122: Circuit-breaker condition monitoring function*

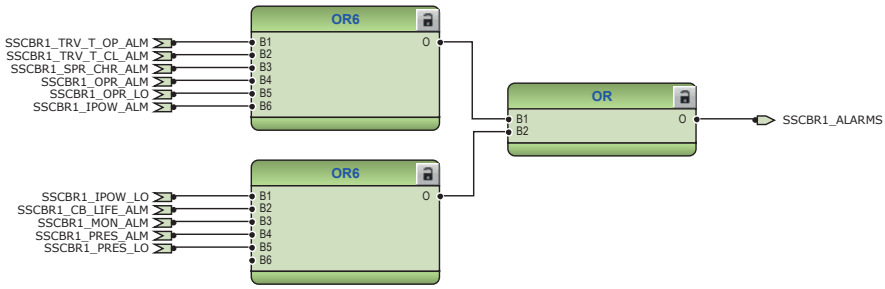



*Figure 123: Logic for circuit-breaker monitoring alarm*


*Figure 124: Logic for start of circuit-breaker spring charging*

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

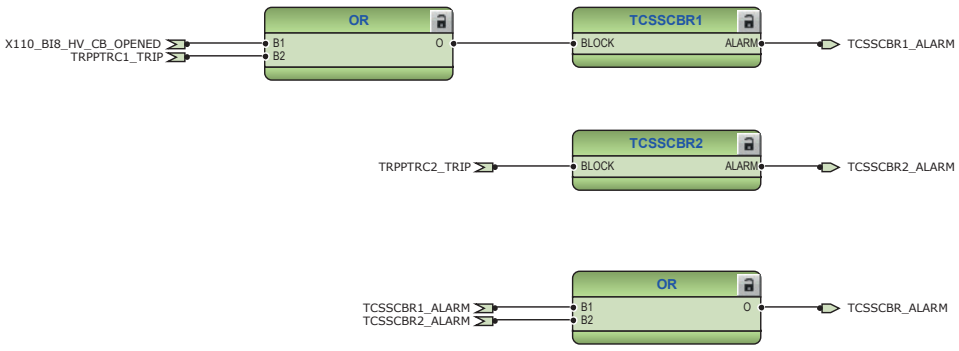



*Figure 125: Trip circuit supervision function*

### 3.5.3.4 Functional diagrams for control and interlocking

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

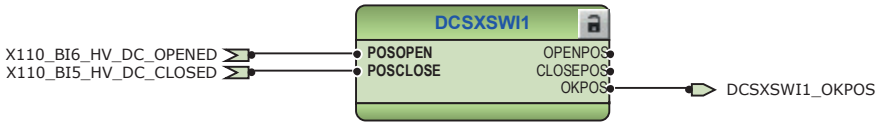



*Figure 126: High voltage side disconnector 1*

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

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

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

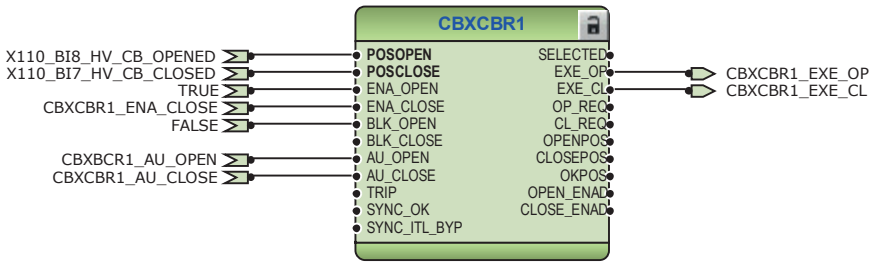



*Figure 127: High-voltage side circuit breaker 1*

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


*Figure 128: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker*


*Figure 129: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker*

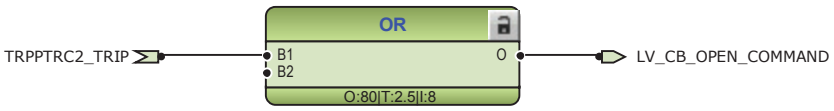



*Figure 130: Circuit breaker control logic: Signals for opening coil of low-voltage side circuit breaker*

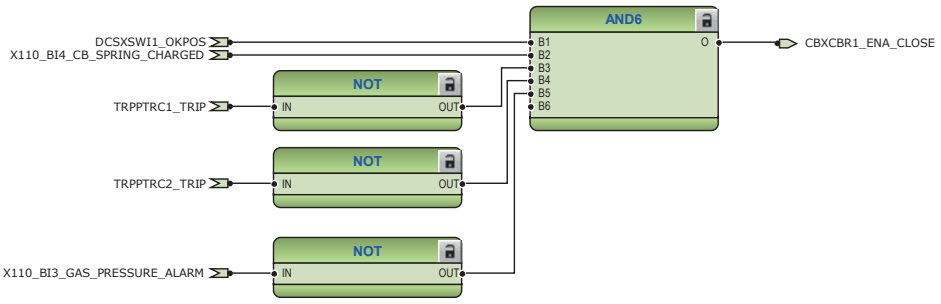



*Figure 131: High-voltage side circuit breaker 1 close enable logic*

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

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

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

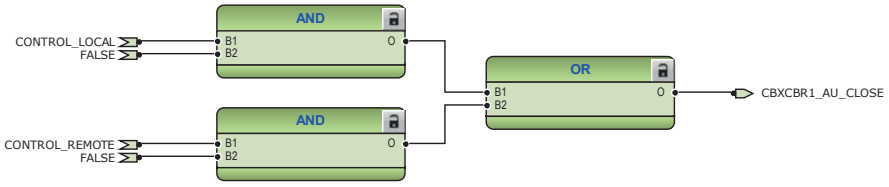



*Figure 132: External closing command for circuit breaker 1*

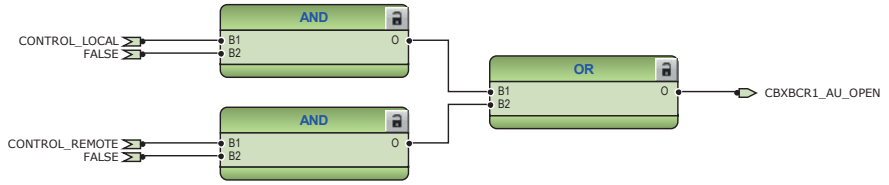



*Figure 133: External opening command for circuit breaker 1*

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the protection relay via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters TPOSYLTC1 properly.

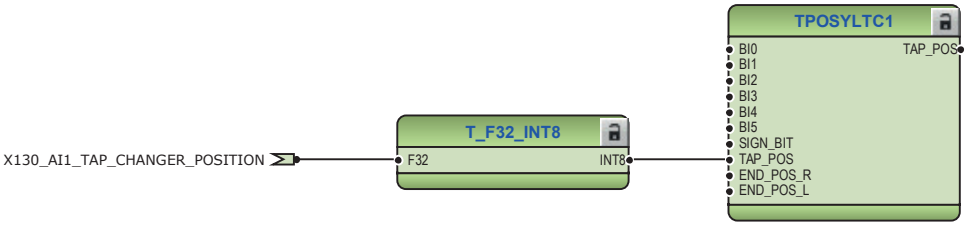



*Figure 134: Tap changer position indicator*

### 3.5.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the protection relay are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current and residual current measurement RESCMMXU1 measures the residual current from high-voltage side.

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

The measurements can be seen in the LHMI and they are available by using 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

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

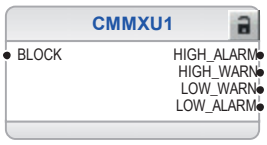



*Figure 135: Current measurement: Three-phase current measurement (HV side)*

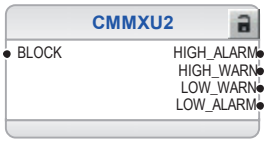



*Figure 136: Current measurement: Three-phase current measurement (LV side)*


*Figure 137: Current measurement: Sequence current measurement (HV side)*


*Figure 138: Current measurement: Residual current measurement (HV side)*

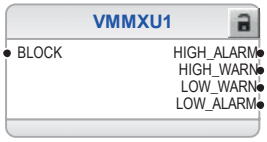



*Figure 139: Voltage measurement: Three-phase voltage measurement (HV side)*


*Figure 140: Voltage measurement: Sequence voltage measurement (HV side)*

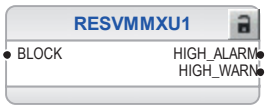



*Figure 141: Voltage measurement: Residual voltage measurement (HV side)*


*Figure 142: Other measurement: Frequency measurement*


*Figure 143: Other measurement: Three-phase power and energy measurement*


*Figure 144: Other measurement: Data monitoring*


*Figure 145: Other measurement: Load profile record*

### 3.5.3.6 Functional diagrams for I/O and alarms LEDs

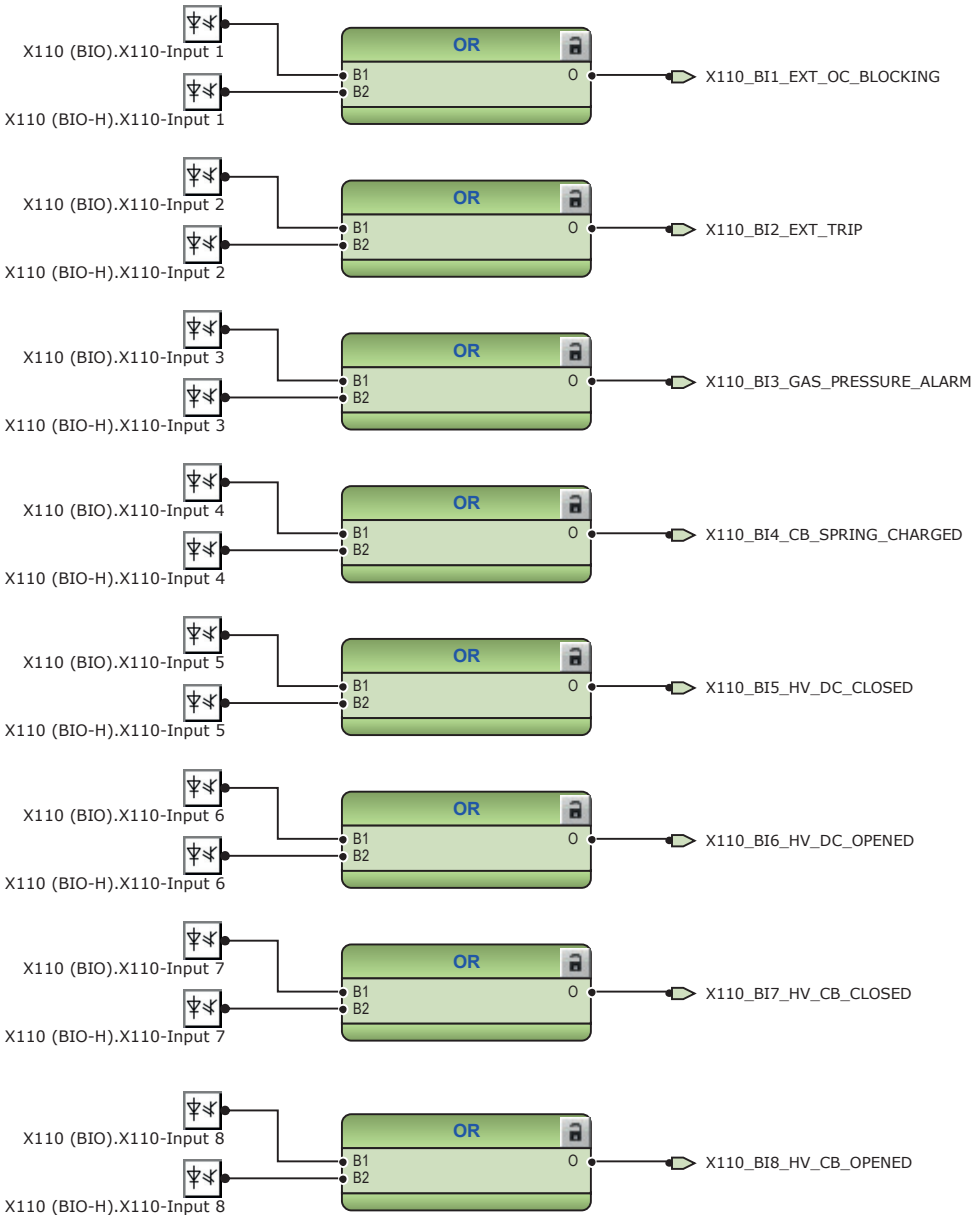



*Figure 146: Binary inputs - X110 terminal block*

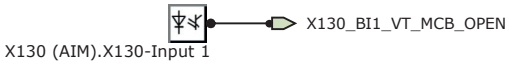



*Figure 147: Binary inputs - X130 terminal block*

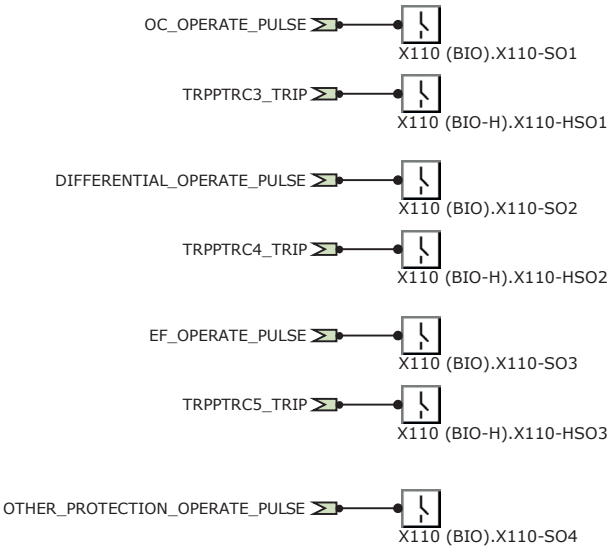



*Figure 148: Binary outputs - X110 terminal block*

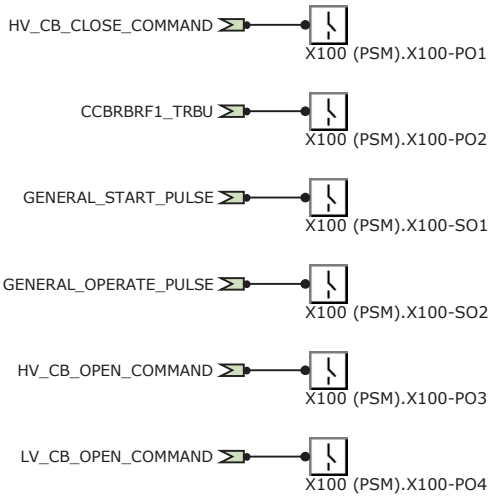



*Figure 149: Binary outputs - X100 terminal block*

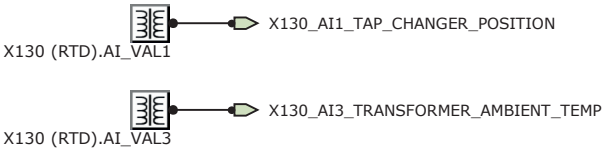



*Figure 150: Default mA/RTD inputs X130*

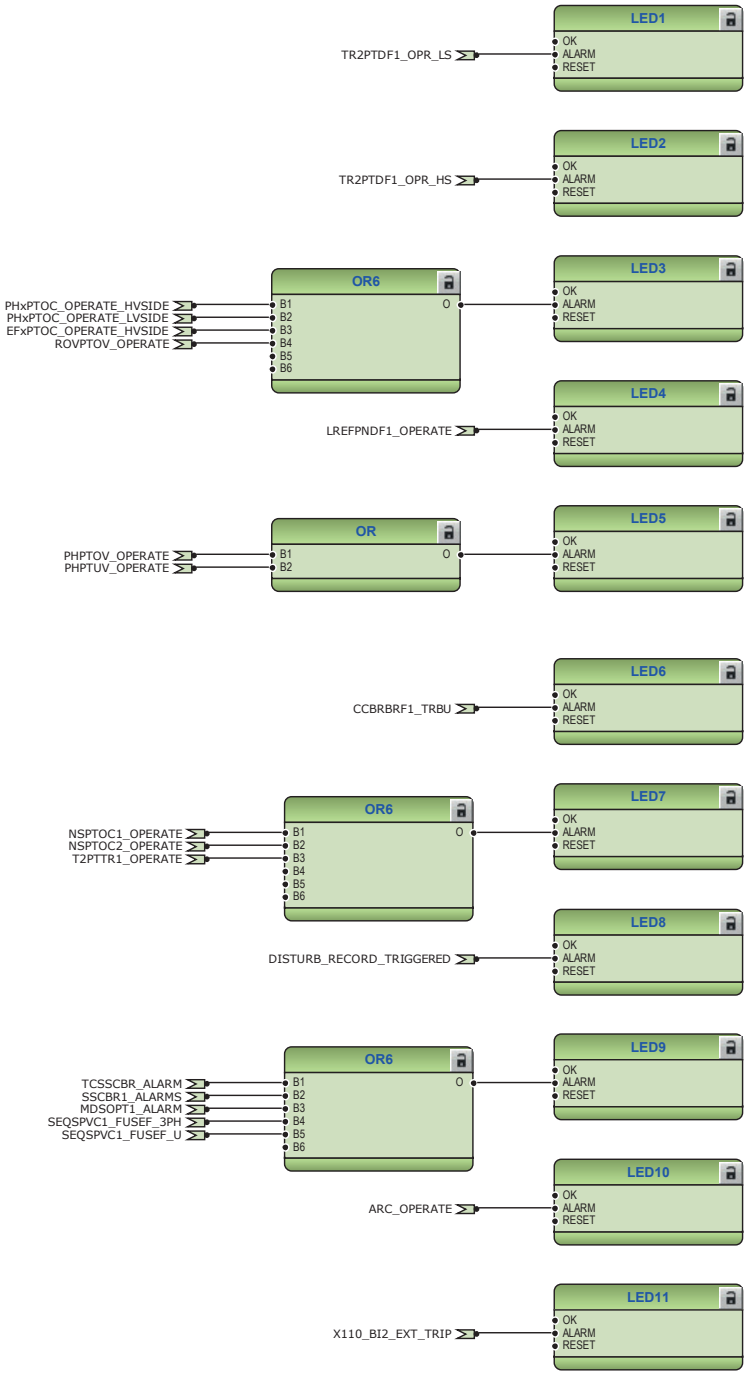



*Figure 151: Default LED connection*

## 3.5.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). The operate logics

are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

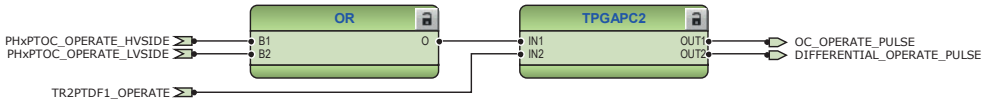



*Figure 152: Timer logic for overcurrent and differential operate pulse*

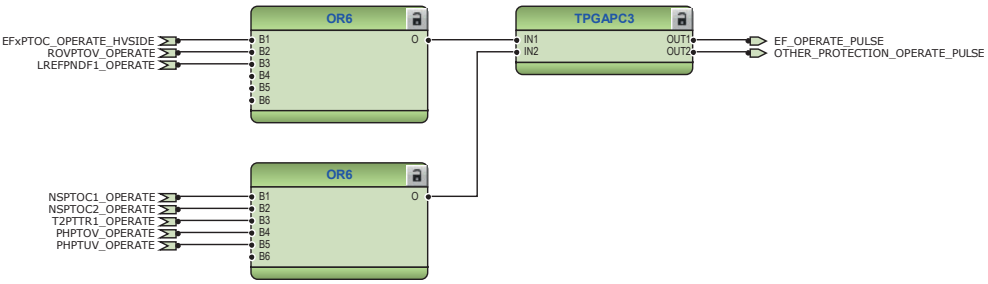



*Figure 153: Timer logic for earth-fault and combined other operate pulse*

### 3.5.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but can be added based on the system requirements.

## 3.6 Standard configuration F

### 3.6.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the low-voltage (LV) side, high voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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

## 3.6.2 Functions

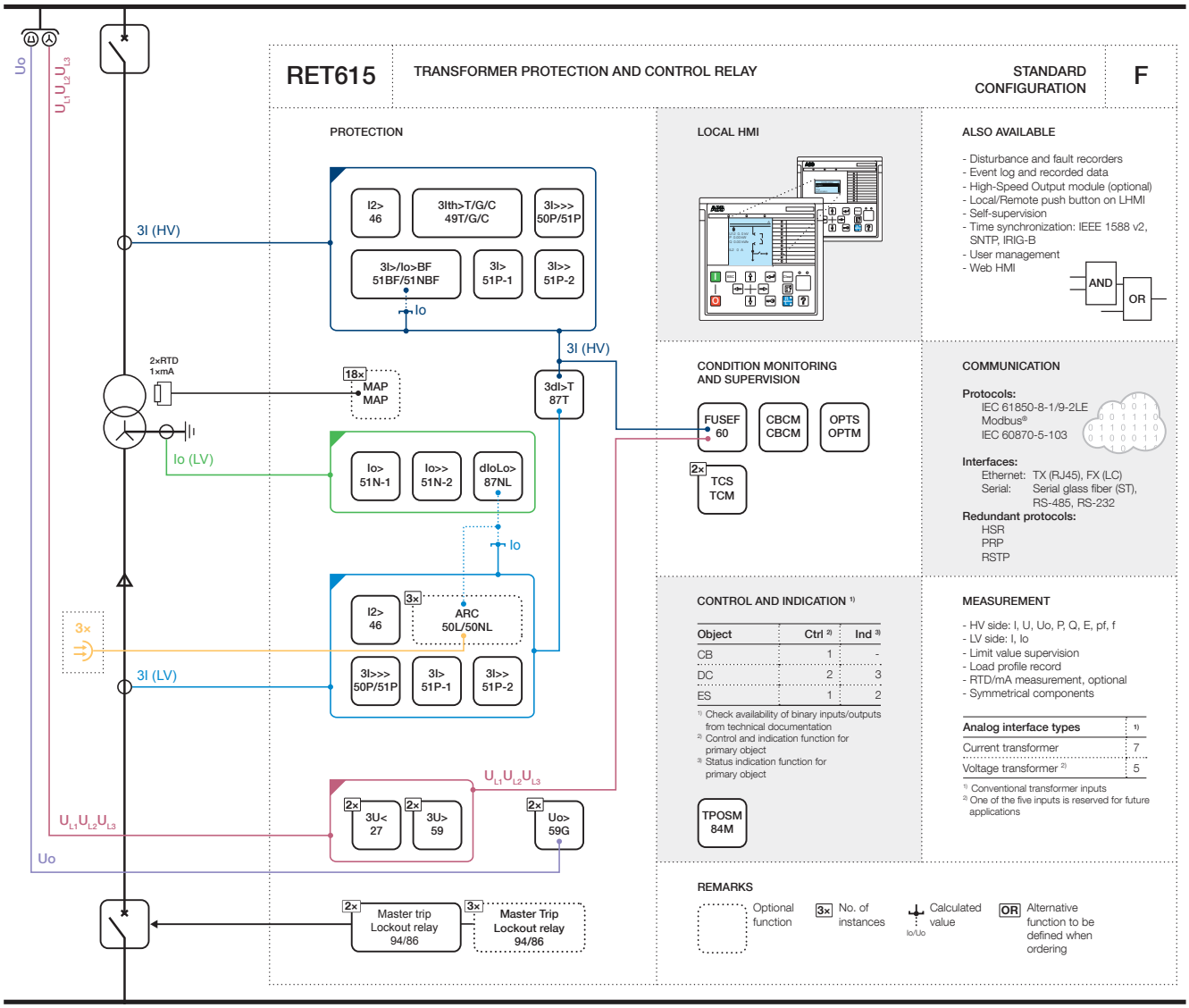



*Figure 154: Functionality overview for standard configuration F*

### 3.6.2.1 Default I/O connections

Connector pins for each input and output are presented in the Protection relay's physical connections section.

*Table 30: Default connections for analog inputs*

| Analog input | Description | Connector pins |
|---|---|---|
| IL1B | Phase A current, LV side | X120:1-2 |
| IL2B | Phase B current, LV side | X120:3-4 |
| IL3B | Phase C current, LV side | X120:5-6 |
| IL1 | Phase A current, HV side | X120:7-8 |
| IL2 | Phase B current, HV side | X120:9-10 |
| IL3 | Phase C current, HV side | X120:11-12 |
| Io | Residual current | X120:13-14 |
| U1 | Phase voltage U1 | X130:11-12 |
| U2 | Phase voltage U2 | X130:13-14 |
| U3 | Phase voltage U3 | X130:15-16 |
| Uo | Residual voltage | X130:17-18 |
| mA1 | - | X130:1-2 |
| RTD1 | - | X130:3-4 |
| RTD2 | - | X130:6-7 |
| AI1 | Tap changer position | X130:1-2 |
| AI2 | - | X130:3-4 |
| AI3 | Ambient temperature | X130:5-6 |
| AI4 | - | X130:7-8 |
| AI5 | - | X130:9-10 |
| AI6 | - | X130:13-14 |
| AI7 | - | X130:15-16 |
| AI8 | - | X130:17-18 |

*Table 31: Default connections for binary inputs*

| Binary input | Description | Connector pins | |
|---|---|---|---|
| | | BIO0005 | BIO0007 |
| X110-BI1 | Blocking of overcurrent high state (high voltage) and instantaneous stage (medium voltage) | X110:1-2 | X110:1,5 |
| X110-BI2 | External protection trip | X110:3-4 | X110:2,5 |
| X110-BI3 | Circuit breaker low gas pressure indication | X110:5-6 | X110:3,5 |
| X110-BI4 | Circuit breaker spring charged indication | X110:7-6 | X110:4-5 |
| X110-BI5 | High-voltage side disconnector closed indication | X110:8-9 | X110:6,10 |
| X110-BI6 | High-voltage side disconnector open indication | X110:10-9 | X110:7,10 |
| X110-BI7 | High-voltage side circuit breaker closed indication | X110:11-12 | X110:8,10 |
| X110-BI8 | High-voltage side circuit breaker open indication | X110:13-12 | X110:9-10 |
| X130-BI1 | Voltage transformer secondary MCB open | X130:1-2 | |
| X130-BI2 | - | X130:3-4 | |
| X130-BI3 | - | X130:5-6 | |
| X130-BI4 | - | X130:7-8 | |

*Table 32: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close high-voltage circuit breaker | X100:6-7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker (Breaker 1 and 2) | 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 high-voltage | X100:15-19 |
| X100-PO4 | Open circuit breaker/trip coil 2 low-voltage | X100:20-24 |
| X110-SO1 | Overcurrent operate alarm | X110:14-16 |
| X110-SO2 | Differential protection operate alarm | X110:17-19 |
| X110-SO3 | Earth-fault operate alarm | X110:20-22 |
| X110-SO4 | Thermal overload and negative phase-sequence operate alarm | X110:23-24 |
| X110-HSO1 | Arc protection instance 1 trip activated | X110:15-16 |
| X110-HSO1 | Arc protection instance 2 trip activated | X110:19-20 |
| X110-HSO1 | Arc protection instance 3 trip activated | X110:23-24 |

*Table 33: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Transformer differential protection biased stage operate |
| 2 | Transformer differential protection instantaneous stage operate |
| 3 | Overcurrent or earth-fault protection operate |
| 4 | Restricted earth-fault protection operate |
| 5 | Voltage protection operate |
| 6 | Circuit failure protection backup operate |
| 7 | Negative sequence overcurrent or thermal overload protection operate |
| 8 | Disturbance recorder triggered |
| 9 | TCS, fuse failure, measuring circuit fault or circuit breaker supervision |
| 10 | Arc protection operate |
| 11 | Protection trip from external device |

### 3.6.2.2 Default disturbance recorder settings

*Table 34: Default disturbance recorder analog channels*

| Channel | Description[1)] |
|---|---|
| 1 | IL1 |
| 2 | IL2 |
| 3 | IL3 |
| 4 | IL1B |
| Table continues on next page | |

| Channel | Description[1)] |
|---|---|
| 5 | IL2B |
| 6 | IL3B |
| 7 | IoB |
| 8 | Uo |
| 9 | U1 |
| 10 | U2 |
| 11 | U3 |
| 12 | - |

1) Text with “B” refers to measurement on low-voltage side of the transformer

*Table 35: Default disturbance recorder binary channels*

| Channel | ID text | Level trigger mode |
|---|---|---|
| 1 | PHIPTOC1 - start | Positive or Rising |
| 2 | PHHPTOC1 - start | Positive or Rising |
| 3 | PHLPTOC1 - start | Positive or Rising |
| 4 | PHIPTOC2 - start | Positive or Rising |
| 5 | PHHPTOC2 - start | Positive or Rising |
| 6 | PHLPTOC2 - start | Positive or Rising |
| 7 | EFHPTOC2 - start | Positive or Rising |
| 8 | EFLPTOC2 - start | Positive or Rising |
| 9 | NSPTOC1 - start | Positive or Rising |
| 10 | NSPTOC2 - start | Positive or Rising |
| 11 | LREFPNDF1 - start | Positive or Rising |
| 12 | T2PTTR1 - start | Positive or Rising |
| 13 | ROVPTOV1 - start | Positive or Rising |
| 14 | ROVPTOV2 - start | Positive or Rising |
| 15 | PHPTOV1 - start | Positive or Rising |
| 16 | PHPTOV2 - start | Positive or Rising |
| 17 | PHPTUV1 - start | Positive or Rising |
| 18 | PHPTUV2 - start | Positive or Rising |
| 19 | CCBRBRF1 - trret | Level trigger off |
| 20 | CCBRBRF1 - trbu | Level trigger off |
| 21 | PHIPTOC1 - operate | Level trigger off |
| | PHHPTOC1 - operate | |
| | PHLPTOC1 - operate | |
| 22 | PHIPTOC2 - operate | Level trigger off |
| | PHHPTOC2- operate | |
| | PHLPTOC2 - operate | |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 23 | EFLPTOC2 - operate | Level trigger off |
| | EFHPTOC2 - operate | |
| 24 | NSPTOC1 - operate | Level trigger off |
| | NSPTOC2 - operate | |
| 25 | TR2PTDF1 - operate | Positive or Rising |
| 26 | TR2PTDF1 - opr LS | Level trigger off |
| 27 | TR2PTDF1 - opr HS | Level trigger off |
| 28 | TR2PTDF1 - blkd2h | Level trigger off |
| 29 | TR2PTDF1 - blkd5h | Level trigger off |
| 30 | TR2PTDF1 - blkdwav | Level trigger off |
| 31 | LREFPNDF1 - operate | Level trigger off |
| 32 | T2PTTR1 - operate | Level trigger off |
| 33 | T2PTTR1 - alarm | Level trigger off |
| 34 | T2PTTR1 - blk close | Level trigger off |
| 35 | SEQSPVC1 - fusef3ph | Level trigger off |
| 36 | SEQSPVC1 - fusefu | Level trigger off |
| 37 | ROVPTOV1 - operate | Level trigger off |
| | ROVPTOV2 - operate | |
| 38 | PHPTOV1 - operate | Level trigger off |
| | PHPTOV2 - operate | |
| 39 | PHPTUV1 - operate | Level trigger off |
| | PHPTUV2 - operate | |
| 40 | X110BI1 - ext OC blocking | Level trigger off |
| 41 | X110BI2 - ext operate | Positive or Rising |
| 42 | X110BI7 - HVCB closed | Level trigger off |
| 43 | X110BI8 - HVCB open | Level trigger off |
| 44 | MDSOPT1 - alarm | Level trigger off |
| 45 | ARCSARC1 - ARC flt det | Level trigger off |
| | ARCSARC2 - ARC flt det | |
| | ARCSARC3 - ARC flt det | |
| 46 | ARCSARC1 - operate | Positive or Rising |
| 47 | ARCSARC2 - operate | Positive or Rising |
| 48 | ARCSARC3 - operate | Positive or Rising |
| 49 | - | - |
| 50 | - | - |
| 51 | - | - |
| 52 | - | - |
| 53 | - | - |
| 54 | - | - |

Table continues on next page

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

## 3.6.3 Functional diagrams

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

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

The high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

The high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

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

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

### 3.6.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The protection relay compares the phase currents on both sides of the object to be protected. If the differential current of the

phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

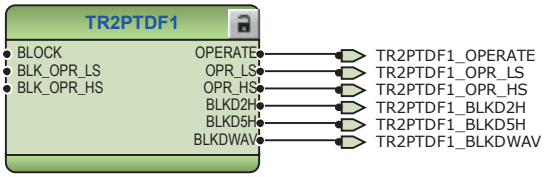



*Figure 155: Transformer differential protection function*

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110: BI1. In addition high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

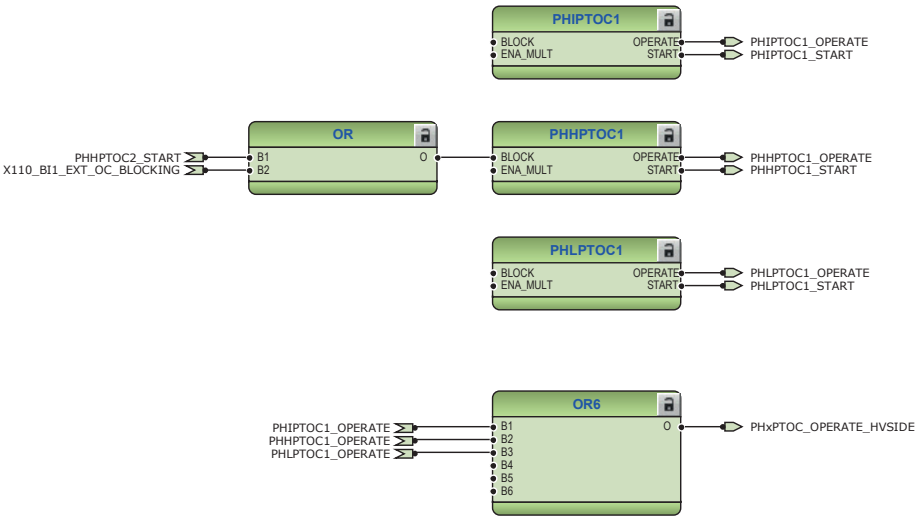



*Figure 156: High-voltage side overcurrent protection function*

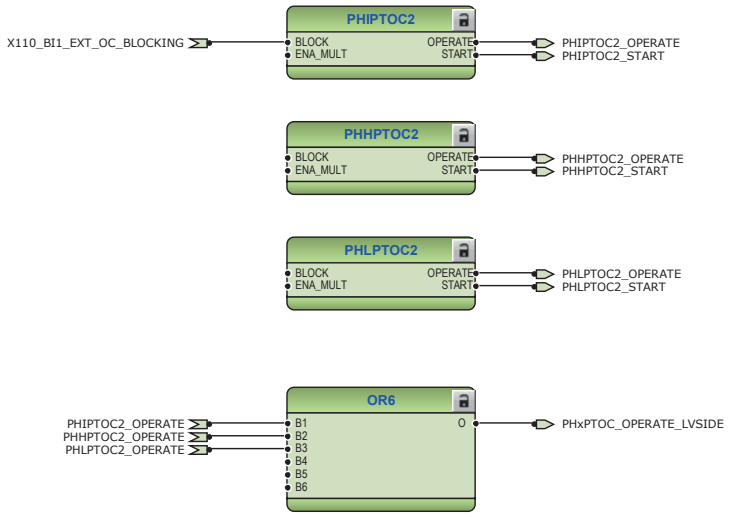



*Figure 157: Low-voltage side overcurrent protection function*

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from low-voltage side.

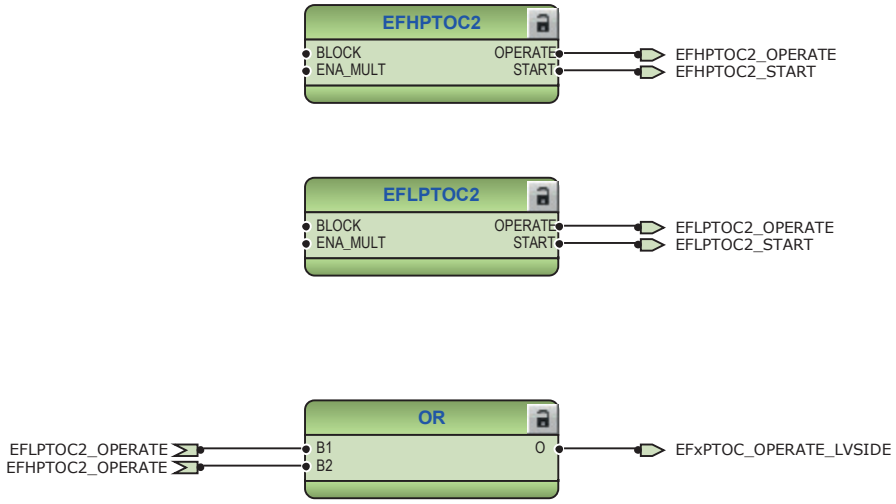



*Figure 158: Low-voltage side earth-fault protection function*

The configuration includes numerically stabilized low-impedance restricted earth-fault protection for low-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

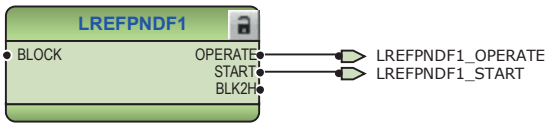



*Figure 159: Restricted low-impedance earth-fault protection*

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

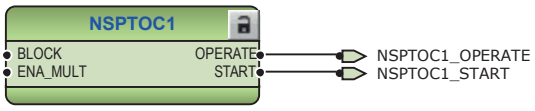



*Figure 160: High-voltage side negative-sequence overcurrent protection function*

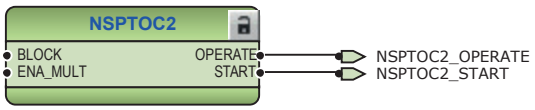



*Figure 161: Low-voltage side negative-sequence overcurrent protection function*

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the protection relay is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

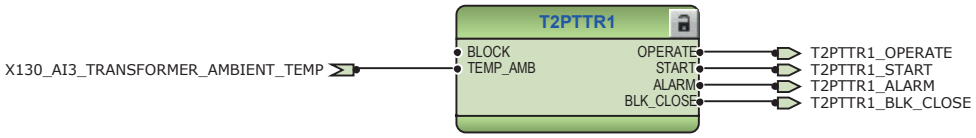



*Figure 162: Transformer thermal overcurrent protection function*

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the protection relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2

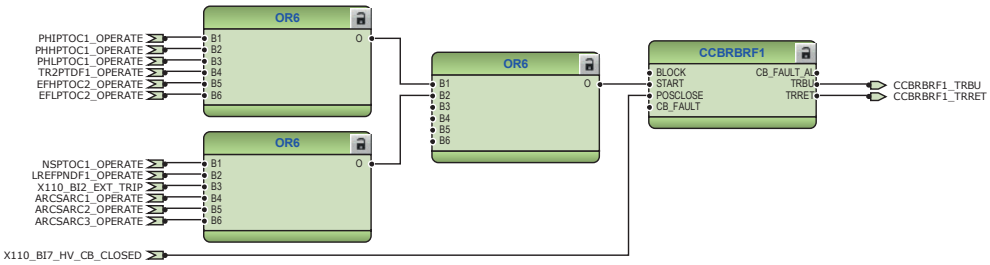



*Figure 163: Circuit breaker failure protection function*

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

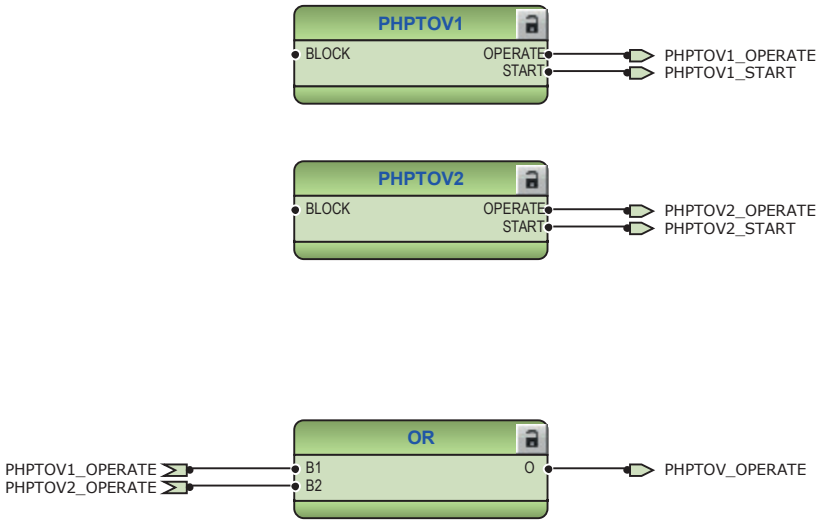



*Figure 164: High-voltage side phase overvoltage protection function*

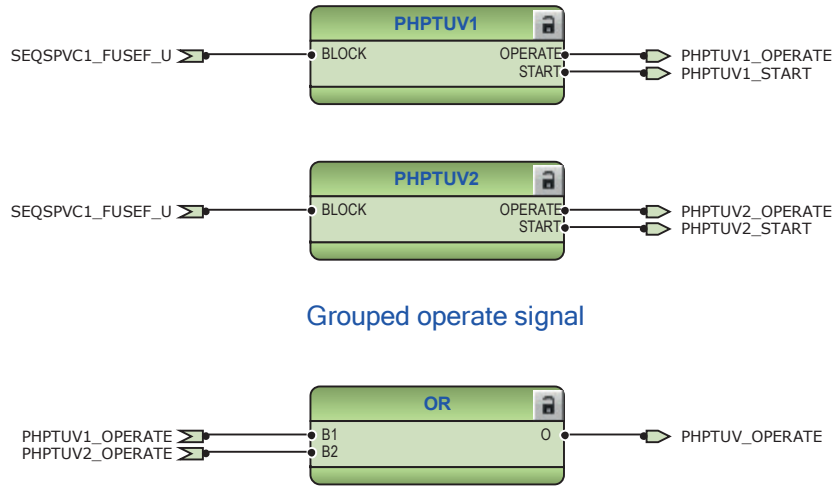



*Figure 165: High-voltage side phase undervoltage protection function*

Residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage.

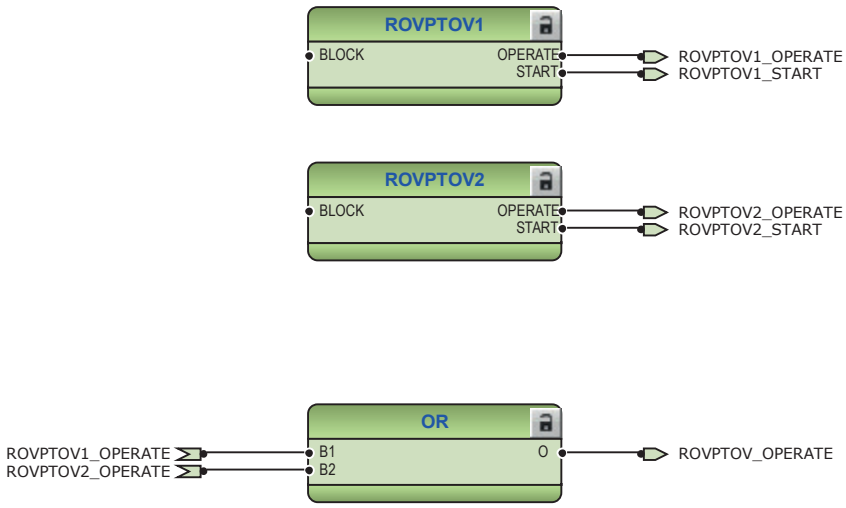



*Figure 166: Residual voltage protection function*

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

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

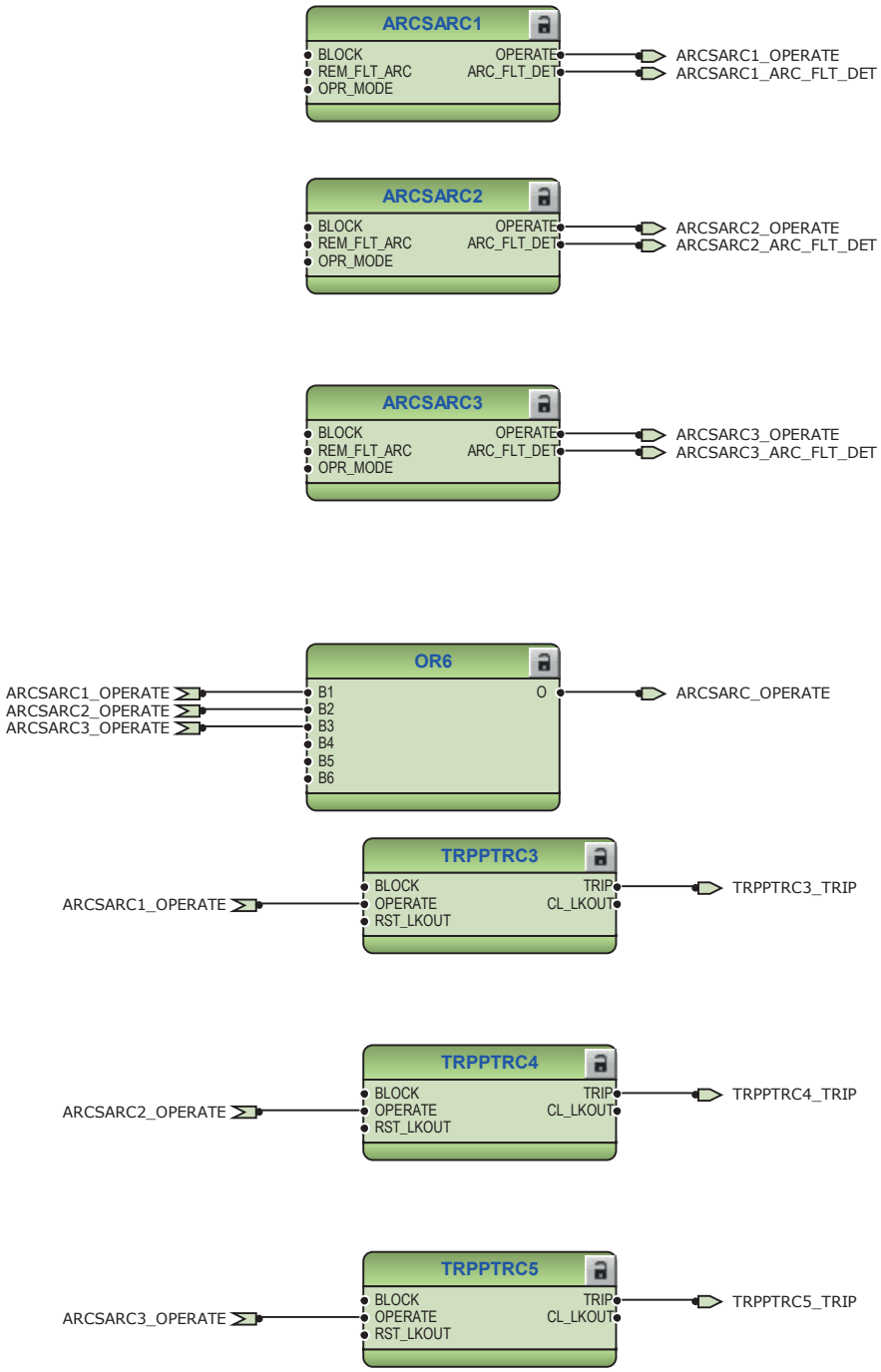



*Figure 167: Arc protection with dedicated HSO*

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

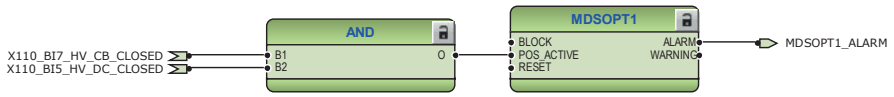



*Figure 168: Transformer operation time counter*

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

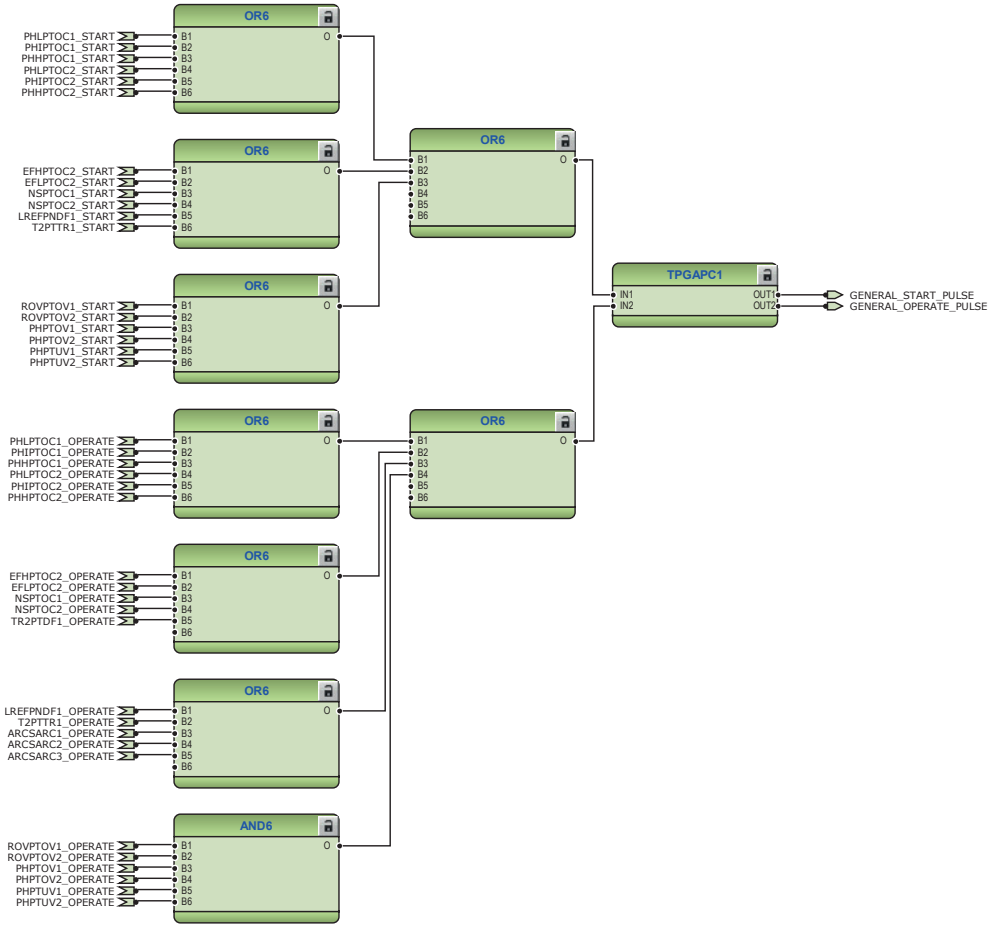



*Figure 169: General start and operate signals*

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Other three trip logics TRPPTRC3...5 are also available if the protection relay is ordered with high speed binary outputs options.

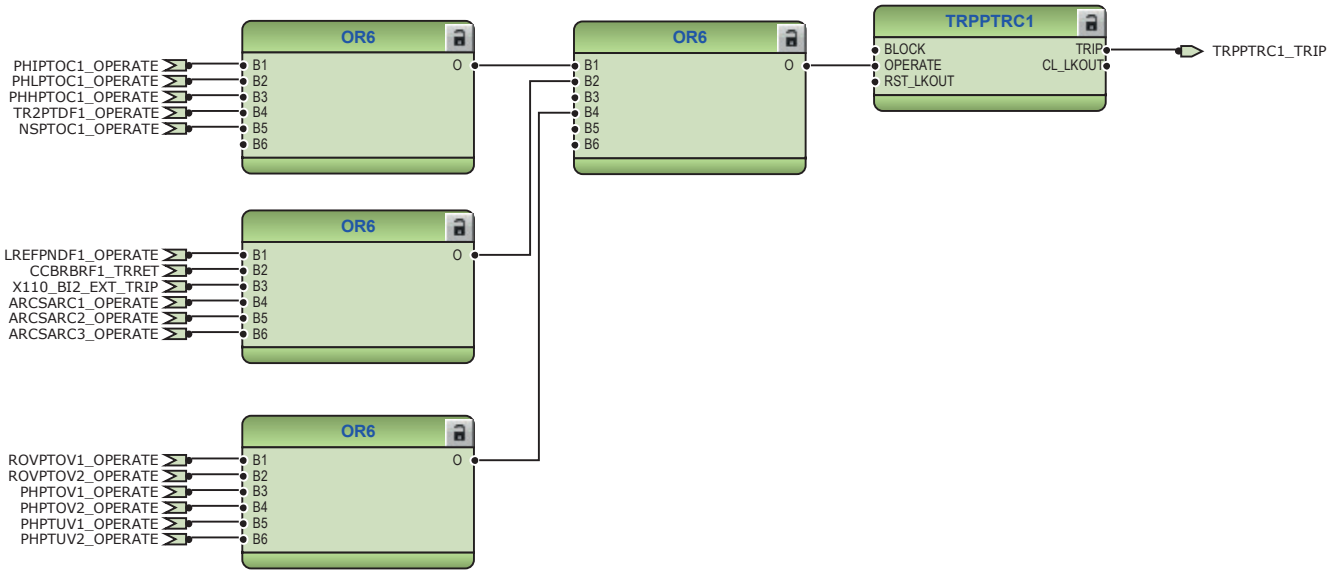



*Figure 170: Trip logic TRPPTRC1*

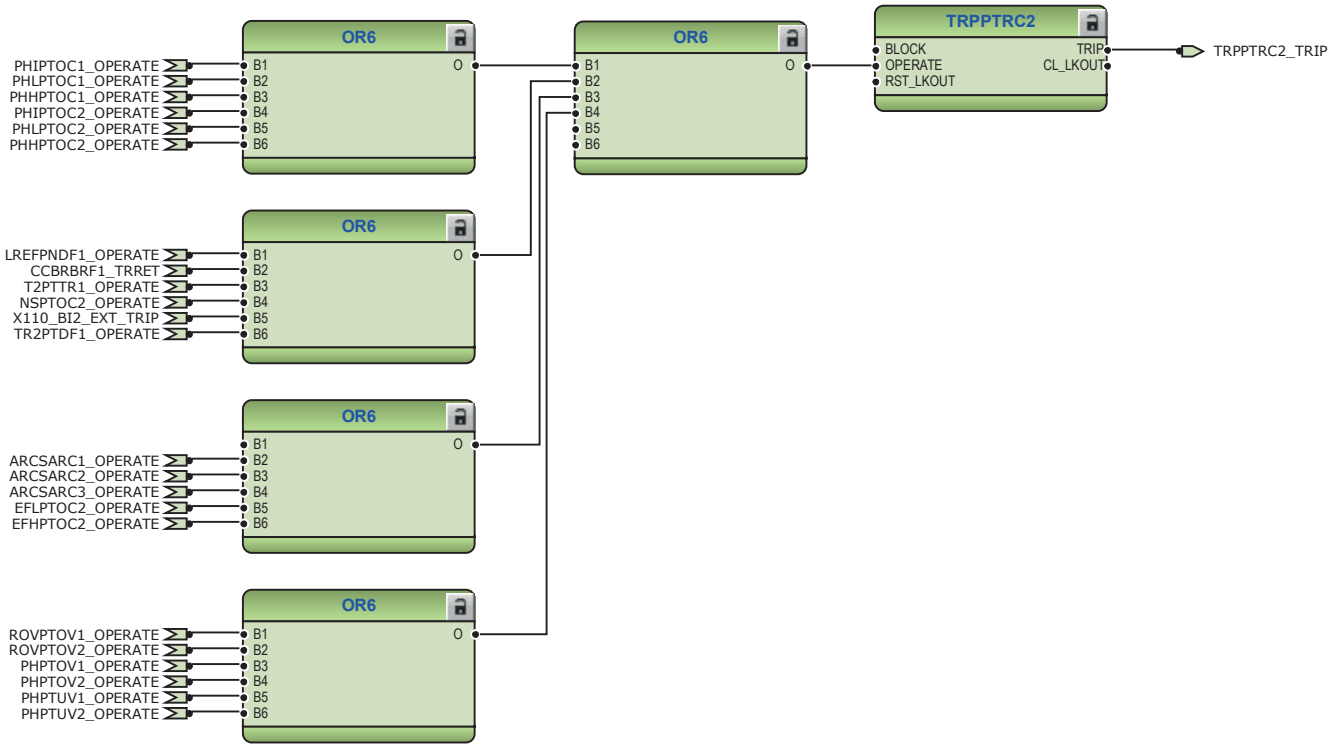



*Figure 171: Trip logic TRPPTRC2*

### 3.6.3.2 Functional diagrams for disturbance recorder

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

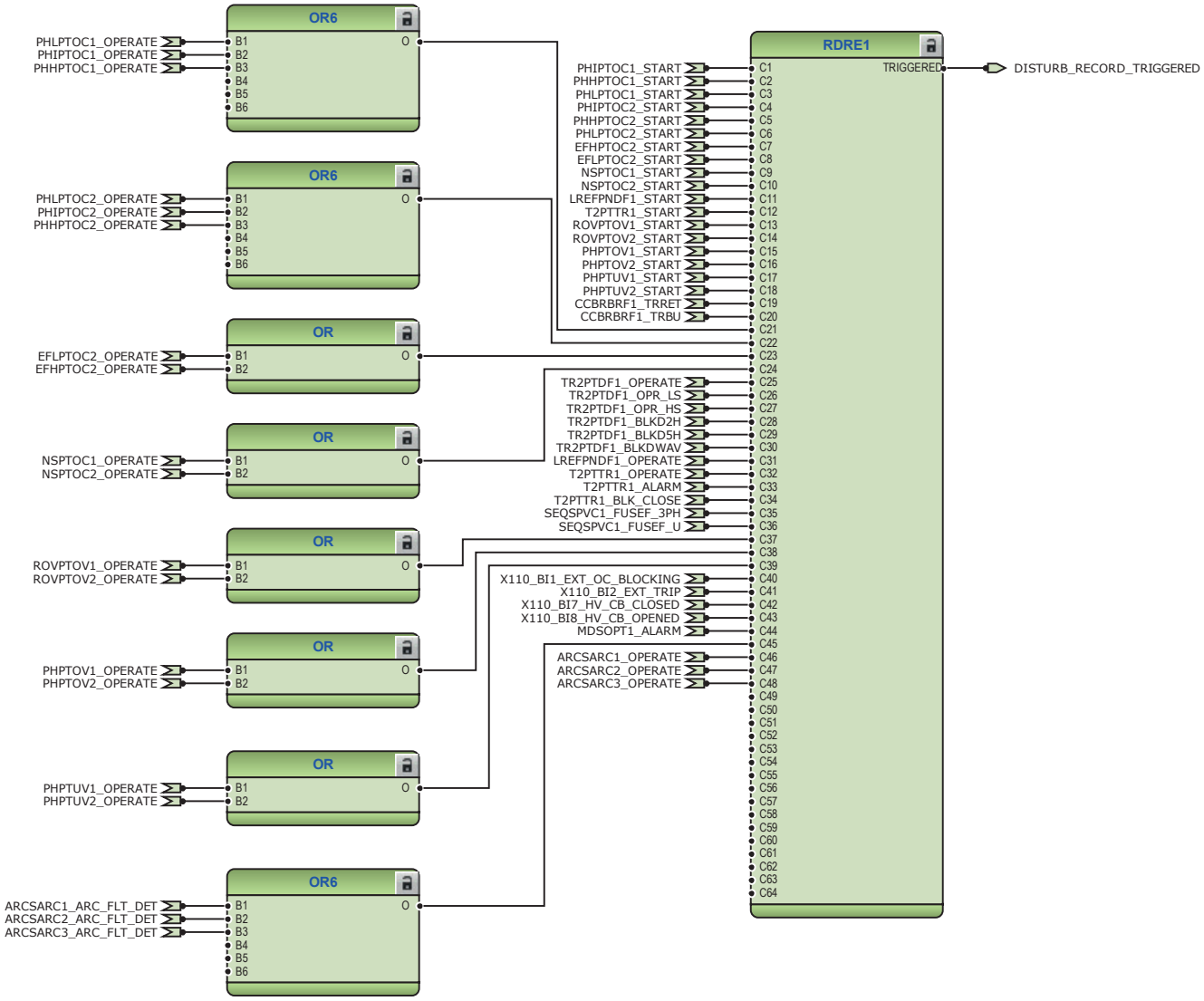



*Figure 172: Disturbance recorder*

### 3.6.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

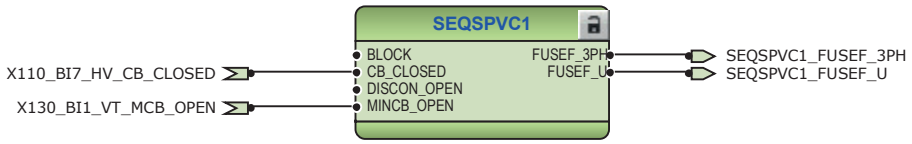



*Figure 173: High-voltage fuse failure supervision function*

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

Set the parameters for SSCBR1 properly.

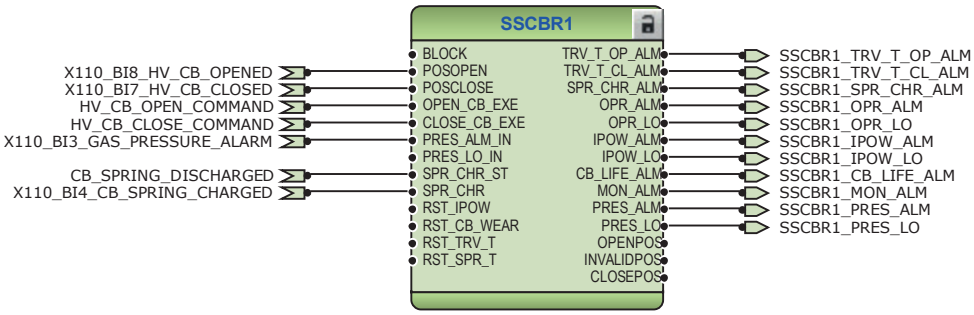



*Figure 174: Circuit-breaker condition monitoring alarm*

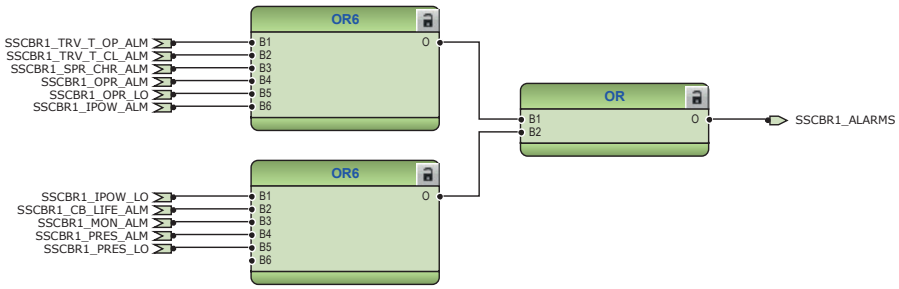



*Figure 175: Logic for circuit-breaker monitoring alarm*


*Figure 176: Logic for start of circuit-breaker spring charging*

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

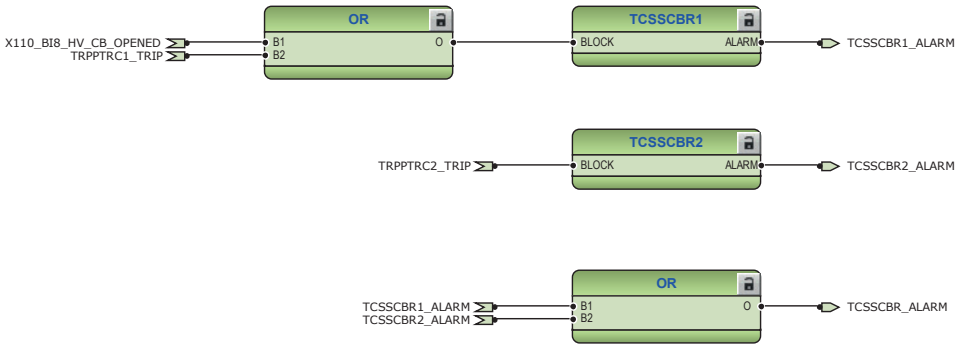



*Figure 177: Trip circuit supervision function*

### 3.6.3.4 Functional diagrams for control and interlocking

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

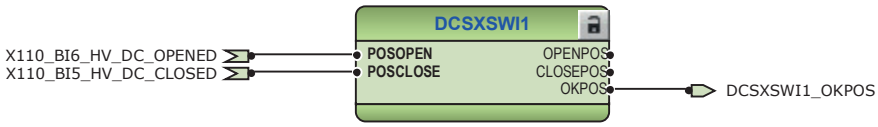



*Figure 178: High-voltage side disconnector 1*

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

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

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

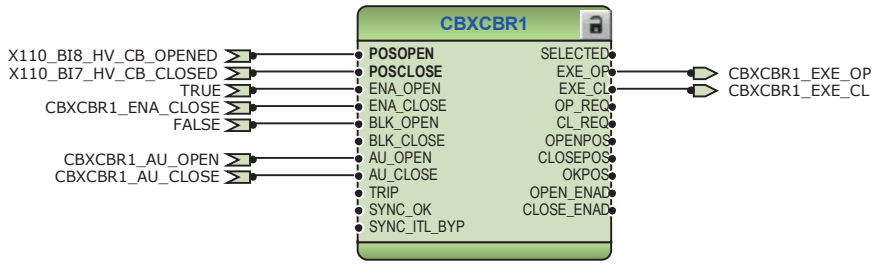



*Figure 179: High-voltage side circuit breaker*

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


*Figure 180: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker*

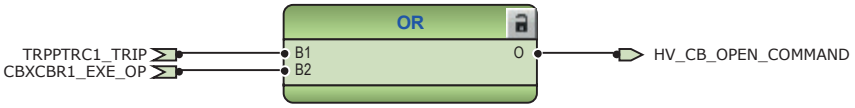



*Figure 181: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker*

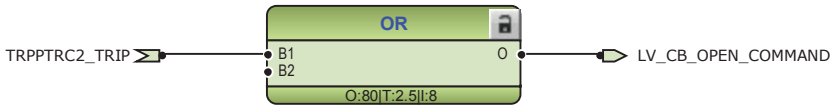



*Figure 182: Circuit breaker control logic: Signals for opening coil of low-voltage side circuit breaker*

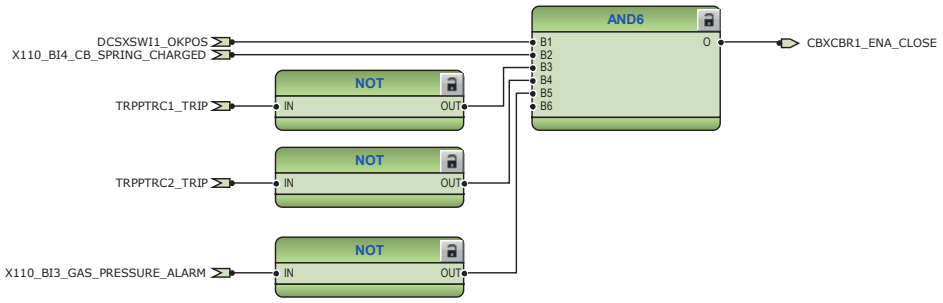



*Figure 183: High-voltage side circuit breaker 1 close enable logic*

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

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

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

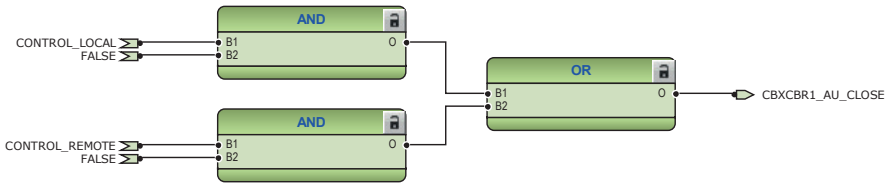



*Figure 184: External closing command for circuit breaker 1*

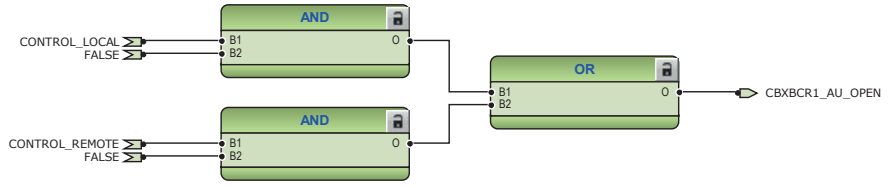



*Figure 185: External opening command for circuit breaker 1*

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the protection relay via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters for TPOSYLTC1 properly.

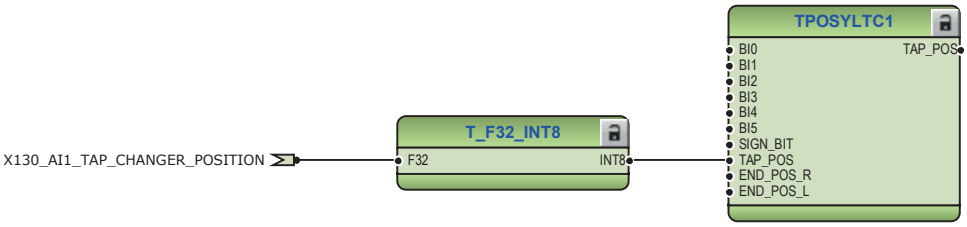



*Figure 186: Tap changer position indicator*

### 3.6.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the protection relay are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement function CSMSQI1 measures the sequence current from high-voltage side and residual current measurement RESCMMXU2 measures the residual current and low-voltage side.

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

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

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

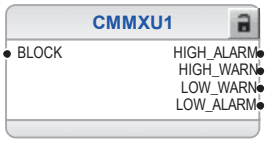



*Figure 187: Current measurement: Three-phase current measurement (HV side)*

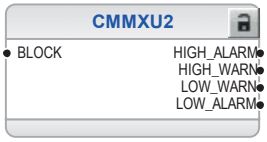



*Figure 188: Current measurement: Three-phase current measurement (LV side)*


*Figure 189: Current measurement: Sequence current measurement (HV side)*

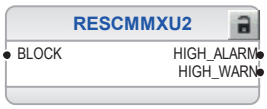



*Figure 190: Current measurement: Residual current measurement (LV side)*

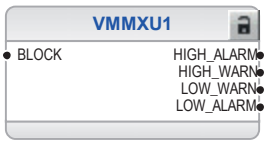



*Figure 191: Voltage measurement: Three-phase voltage measurement (HV side)*

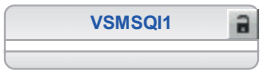



*Figure 192: Voltage measurement: Sequence voltage measurement (HV side)*


*Figure 193: Voltage measurement: Residual voltage measurement (HV side)*


*Figure 194: Other measurement: Frequency measurement*

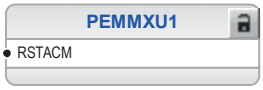



*Figure 195: Other measurement: Three-phase power and energy measurement*


*Figure 196: Other measurement: Data monitoring*


*Figure 197: Other measurement: Load profile record*

### 3.6.3.6 Functional diagrams for I/O and alarms LEDs

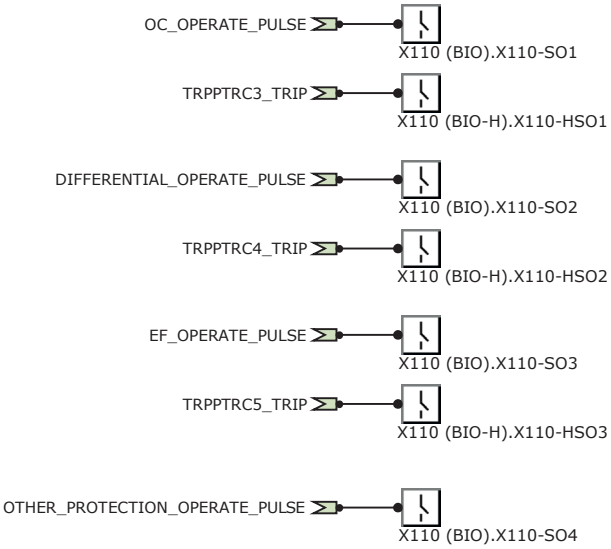



*Figure 198: Binary inputs - X110 terminal block*

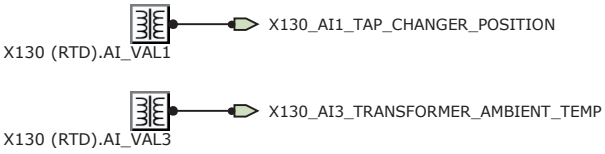



*Figure 199: Binary inputs - X130 terminal block*

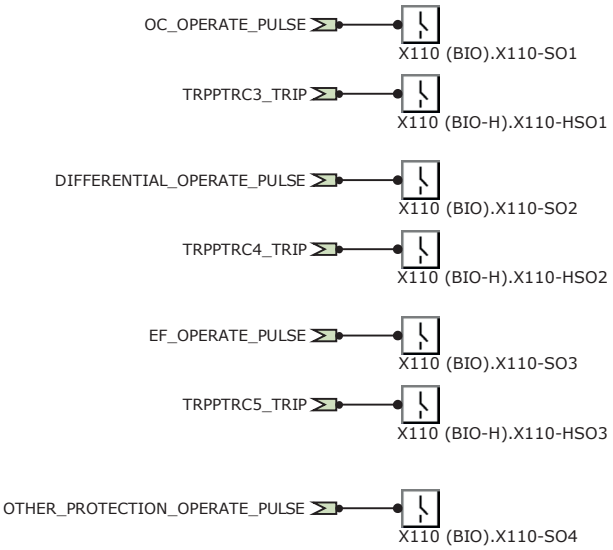



*Figure 200: Binary outputs - X110 terminal block*

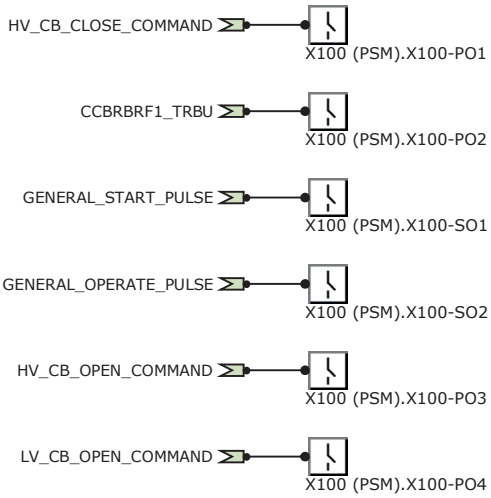



*Figure 201: Binary outputs - X100 terminal block*

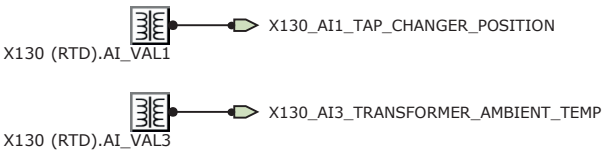



*Figure 202: Default mA/RTD inputs X130*

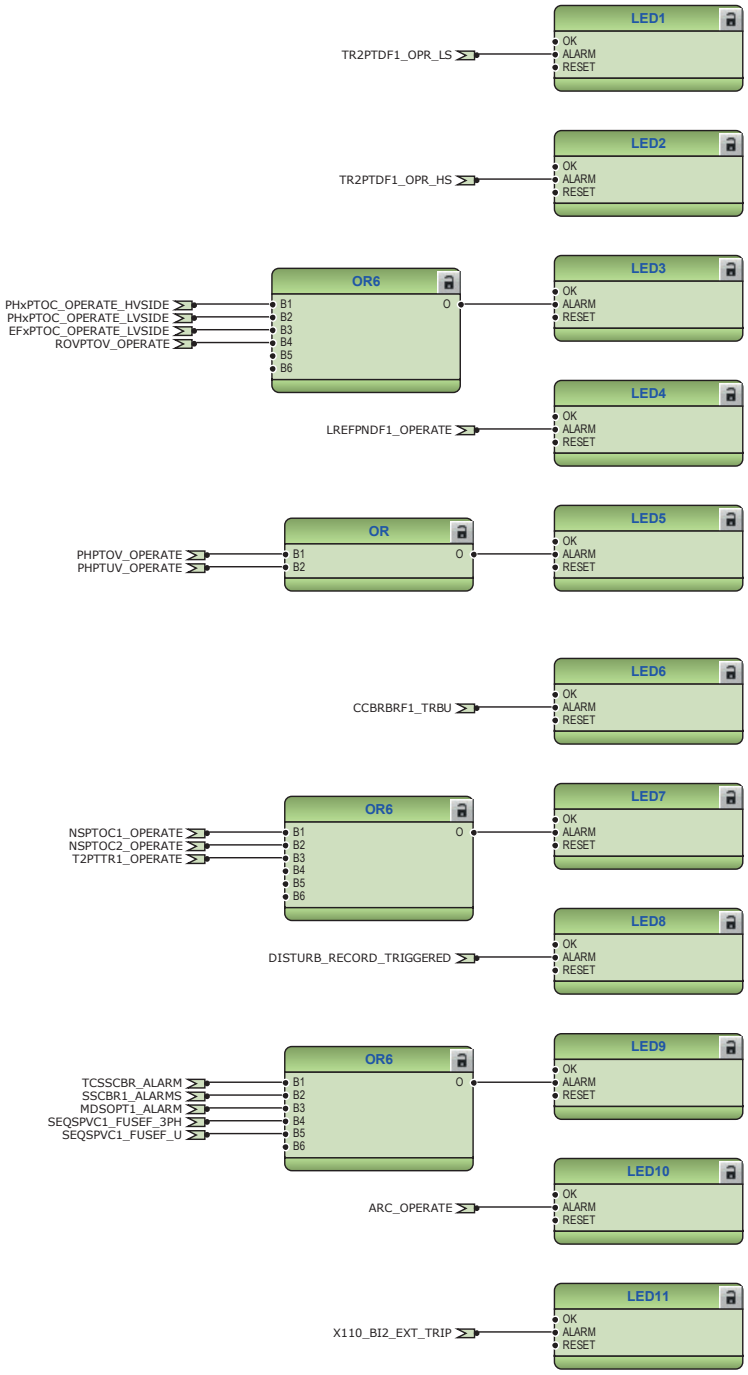



*Figure 203: Default LED connection*

### 3.6.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). The operate logics

are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

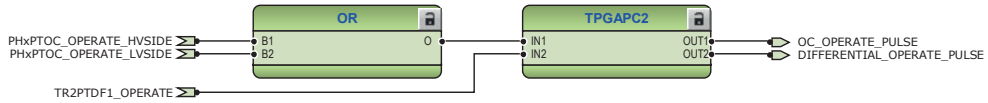



*Figure 204: Timer logic for overcurrent and differential operate pulse*

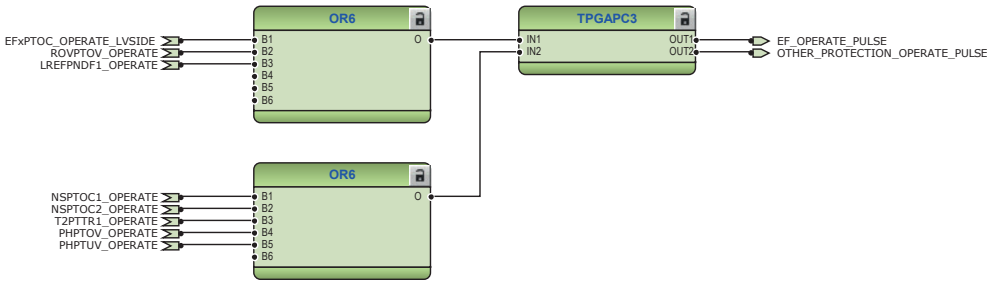



*Figure 205: Timer logic for earth-fault and combined other operate pulse*

### 3.6.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

## 3.7 Standard configuration Z

### 3.7.1 Applications

The standard configuration Z provides mainly three-phase differential protection and non-electrical protection for power transformer feeders. The standard configuration is mainly intended for protection of the power transformer between current transformers.

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

## 3.7.2 Functions

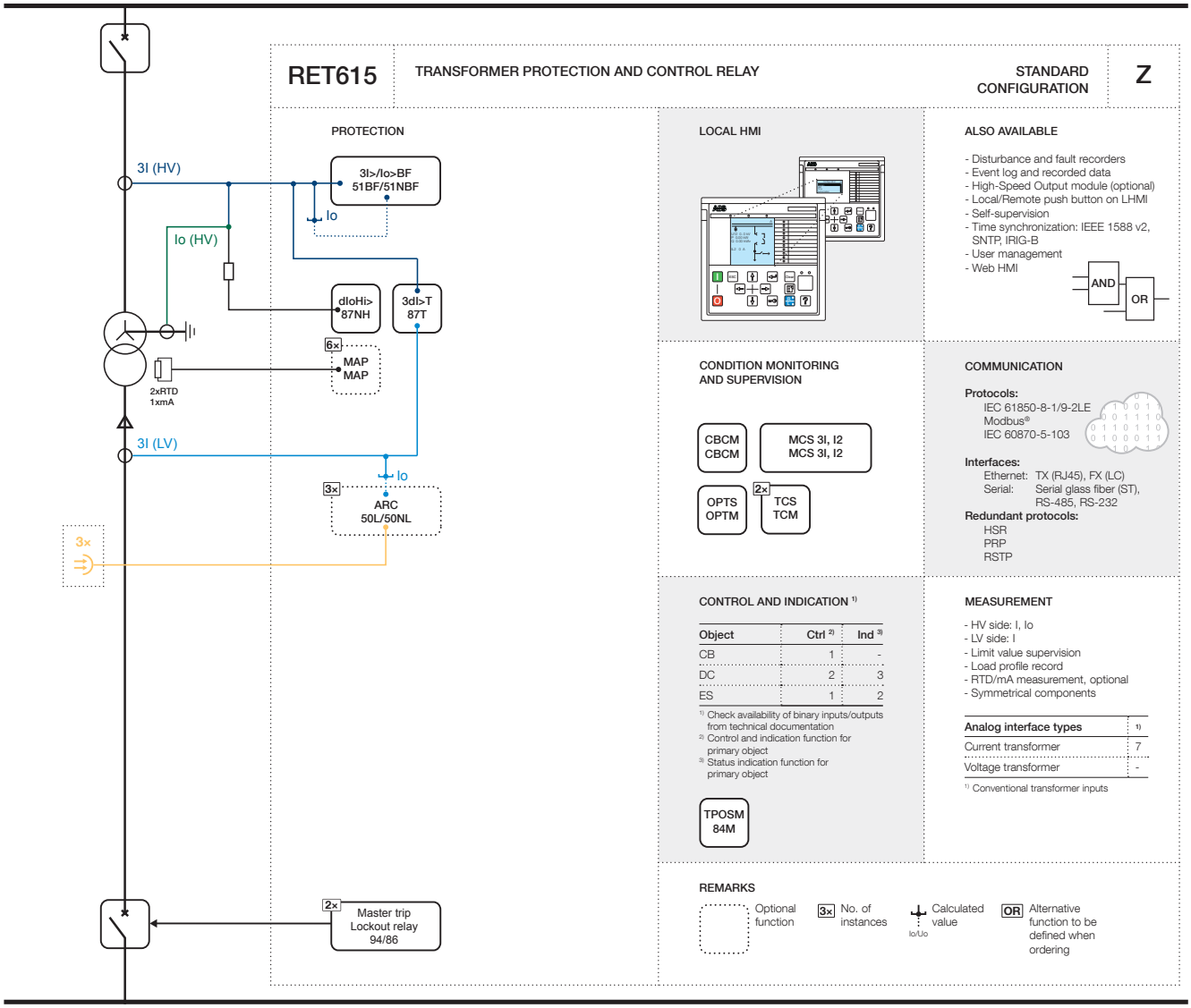



*Figure 206: Functionality overview for standard configuration Z*

### 3.7.2.1 Default I/O connections

Connector pins for each input and output are presented in the Protection relay's physical connections section.

*Table 36: Default connections for analog inputs*

| Analog input | Description | Connector pins |
|---|---|---|
| IL1B | Phase A current, LV side | X120:1-2 |
| IL2B | Phase B current, LV side | X120:3-4 |
| IL3B | Phase C current, LV side | X120:5-6 |
| IL1 | Phase A current, HV side | X120:7-8 |
| IL2 | Phase B current, HV side | X120:9-10 |
| IL3 | Phase C current, HV side | X120:11-12 |
| Io | Residual current | X120:13-14 |
| AI1 | Tap changer position | X130:1-2 |
| AI2 | - | X130:3-4 |
| AI3 | Ambient temperature | X130:5-6 |
| AI4 | - | X130:7-8 |
| AI5 | - | X130:9-10 |
| AI6 | - | X130:13-14 |
| AI7 | - | X130:15-16 |
| AI8 | - | X130:17-18 |

*Table 37: Default connections for binary inputs*

| Binary input | Description | Connector pins |
|---|---|---|
| X110-BI1 | External trip 1 | X110:1-2 |
| X110-BI2 | External trip 2 | X110:3-4 |
| X110-BI3 | Low-voltage side circuit breaker closed indication | X110:5-6 |
| X110-BI4 | Circuit breaker spring charged indication | X110:7-6 |
| X110-BI5 | External alarm 1 | X110:8-9 |
| X110-BI6 | External alarm 2 | X110:10-9 |
| X110-BI7 | High-voltage side circuit breaker closed indication | X110:11-12 |
| X110-BI8 | High-voltage side circuit breaker open indication | X110:13-12 |
| X130-BI1 | BCD sign bit (tap changer position) | X130:1-2 |
| X130-BI2 | BCD bit 0 (LSB) | X130:3-2 |
| X130-BI3 | BCD bit 1 | X130:4-5 |
| X130-BI4 | BCD bit 2 | X130:6-5 |
| X130-BI5 | BCD bit 3 | X130:7-8 |
| X130-BI6 | BCD Bit 4 (MSB) | X130:9-8 |

*Table 38: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close high-voltage circuit breaker | X100:6-7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker (Breaker 1 and 2) | 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 high-voltage | X100:15-19 |
| X100-PO4 | Open circuit breaker/trip coil 2 low-voltage | X100:20-24 |
| X110-SO1 | Differential protection operate alarm | X110:14-16 |
| X110-SO2 | Restricted earth-fault protection operate | X110:17-19 |
| X110-SO3 | External protection trip | X110:20-22 |
| X110-SO4 | External protection alarm | X110:23-24 |
| X130-SO1 | - | X130:10-12 |
| X130-SO2 | - | X130:13-15 |
| X130-SO3 | - | X130:16-18 |

*Table 39: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Transformer differential protection biased stage operate |
| 2 | Transformer differential protection instantaneous stage operate |
| 3 | Restricted earth-fault protection operate |
| 4 | External trip 1 |
| 5 | External trip 2 |
| 6 | Circuit failure protection backup operate |
| 7 | Arc protection operate |
| 8 | Disturbance recorder triggered |
| 9 | TCS, fuse failure, measuring circuit fault or circuit breaker supervision |
| 10 | External alarm 1 |
| 11 | External alarm 2 |

### 3.7.2.2 Default disturbance recorder settings

*Table 40: Default disturbance recorder analog channels*

| Channel | Description[1)] |
|---|---|
| 1 | IL1 |
| 2 | IL2 |
| 3 | IL3 |
| 4 | IL1B |
| 5 | IL2B |

Table continues on next page

| Channel | Description[1)] |
|---|---|
| 6 | IL3B |
| 7 | Io |
| 8 | - |
| 9 | - |
| 10 | - |
| 11 | - |
| 12 | - |

1) Text with “B” refers to measurement on low-voltage side of the transformer

*Table 41: Default disturbance recorder binary channels*

| Channel | ID text | Level trigger mode |
|---|---|---|
| 1 | HREFPDIF1 - start | Positive or Rising |
| 2 | CCBRBRF1 - trret | Level trigger off |
| 3 | CCBRBRF1 - trbu | Level trigger off |
| 4 | HREFPDIF1 - operate | Level trigger off |
| 5 | TR2PTDF1 - operate | Positive or Rising |
| 6 | TR2PTDF1 - opr LS | Level trigger off |
| 7 | TR2PTDF1 - opr HS | Level trigger off |
| 8 | TR2PTDF1 - blkd2h | Level trigger off |
| 9 | TR2PTDF1 - blkd5h | Level trigger off |
| 10 | TR2PTDF1 - blkdwav | Level trigger off |
| 11 | ARCSARC1 - ARC flt det | Level trigger off |
| | ARCSARC2 - ARC flt det | |
| | ARCSARC3 - ARC flt det | |
| 12 | ARCSARC1 - operate | Positive or Rising |
| 13 | ARCSARC2 - operate | Positive or Rising |
| 14 | ARCSARC3 - operate | Positive or Rising |
| 15 | X110BI3 - LVCB closed | Level trigger off |
| 16 | X110BI7 - HVCB closed | Level trigger off |
| 17 | X110BI8 - HVCB open | Level trigger off |
| 18 | X110BI1 - external trip 1 | Positive or Rising |
| 19 | X110BI2 - external trip 2 | Positive or Rising |
| 20 | X110BI5 - external alarm 1 | Positive or Rising |
| 21 | X110BI6 - external alarm 2 | Positive or Rising |
| 22 | CTSCRCTF1 - fail | Level trigger off |
| 23 | CTSCRCTF1 - alarm | Level trigger off |
| 24 | - | - |
| 25 | - | - |
| 26 | - | - |

Table continues on next page

| Channel | ID text | Level trigger mode |
|---|---|---|
| 27 | - | - |
| 28 | - | - |
| 29 | - | - |
| 30 | - | - |
| 31 | - | - |
| 32 | - | - |
| 33 | - | - |
| 34 | - | - |
| 35 | - | - |
| 36 | - | - |
| 37 | - | - |
| 38 | - | - |
| 39 | - | - |
| 40 | - | - |
| 41 | - | - |
| 42 | - | - |
| 43 | - | - |
| 44 | - | - |
| 45 | - | - |
| 46 | - | - |
| 47 | - | - |
| 48 | - | - |
| 49 | - | - |
| 50 | - | - |
| 51 | - | - |
| 52 | - | - |
| 53 | - | - |
| 54 | - | - |
| 55 | - | - |
| 56 | - | - |
| 57 | - | - |
| 58 | - | - |
| 59 | - | - |
| 60 | - | - |
| 61 | - | - |
| 62 | - | - |
| 63 | - | - |
| 64 | - | - |

## 3.7.3 Functional diagrams

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

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

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

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

### 3.7.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The protection relay compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal.

All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

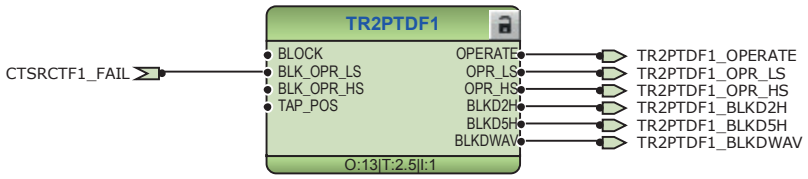



*Figure 207: Transformer differential protection function*

The configuration includes restricted high-impedance earth-fault protection HREFPDIF1. The restricted earth-fault current and the numerical differential current stage operate exclusively on earth faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth fault in this area

appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

High-impedance based restricted earth-fault protection needs a dedicated differential current measurement channel, so when it is used, it is not possible to choose other functions which need measured Io.

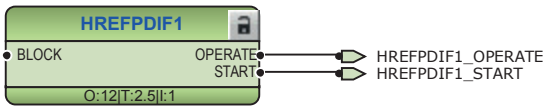



*Figure 208: Restricted earth-fault protection function*

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the protection relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

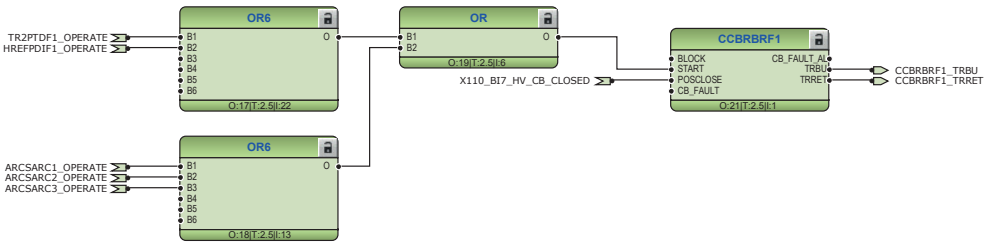



*Figure 209: Circuit breaker failure protection function*

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

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

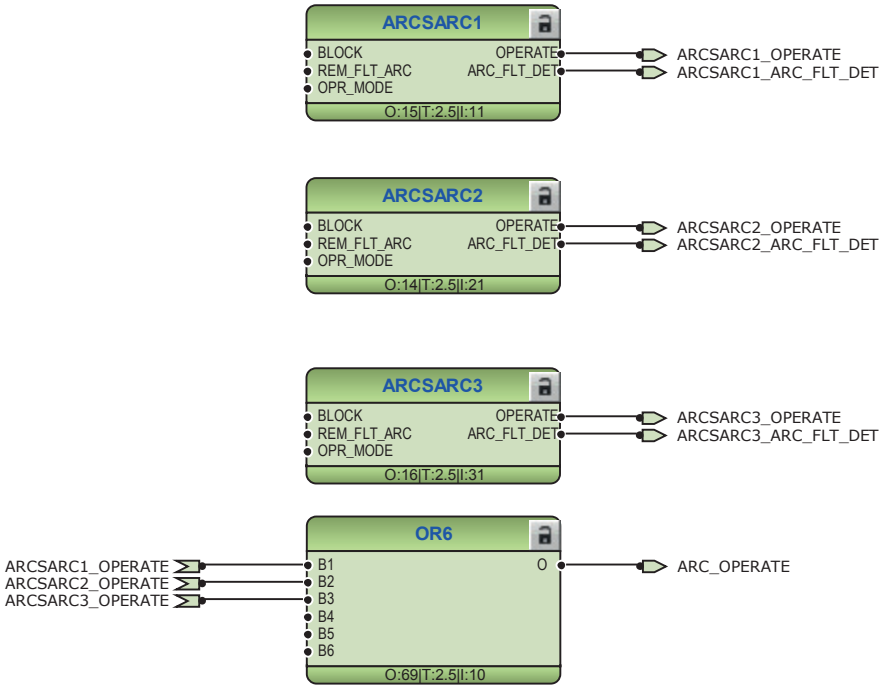



*Figure 210: Arc protection*

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

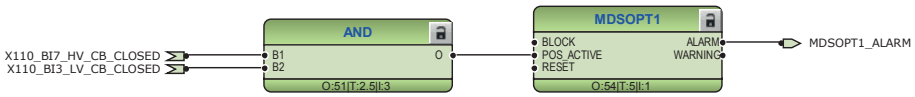



*Figure 211: Transformer operation time counter*

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

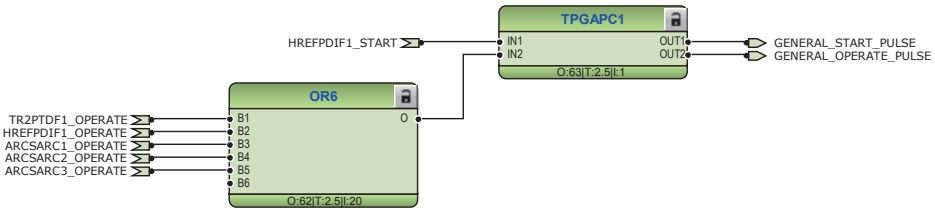



*Figure 212: General start and operate signals*

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

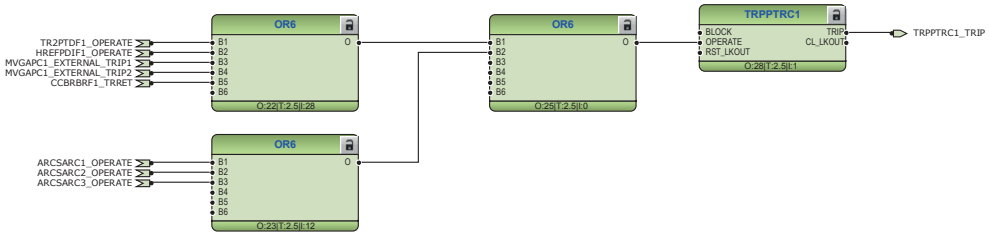



*Figure 213: Trip logic TRPPTRC1*

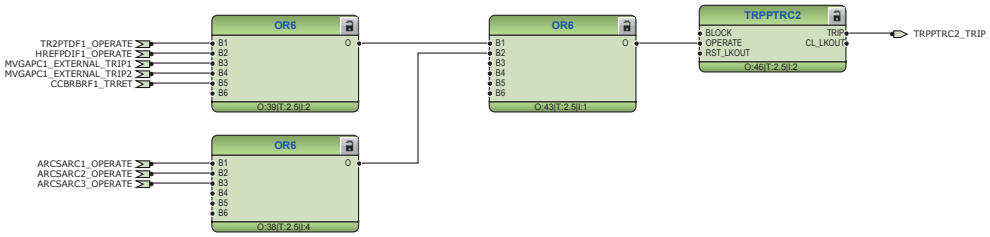



*Figure 214: Trip logic TRPPTRC2*

### 3.7.3.2 Functional diagrams for disturbance recorder

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

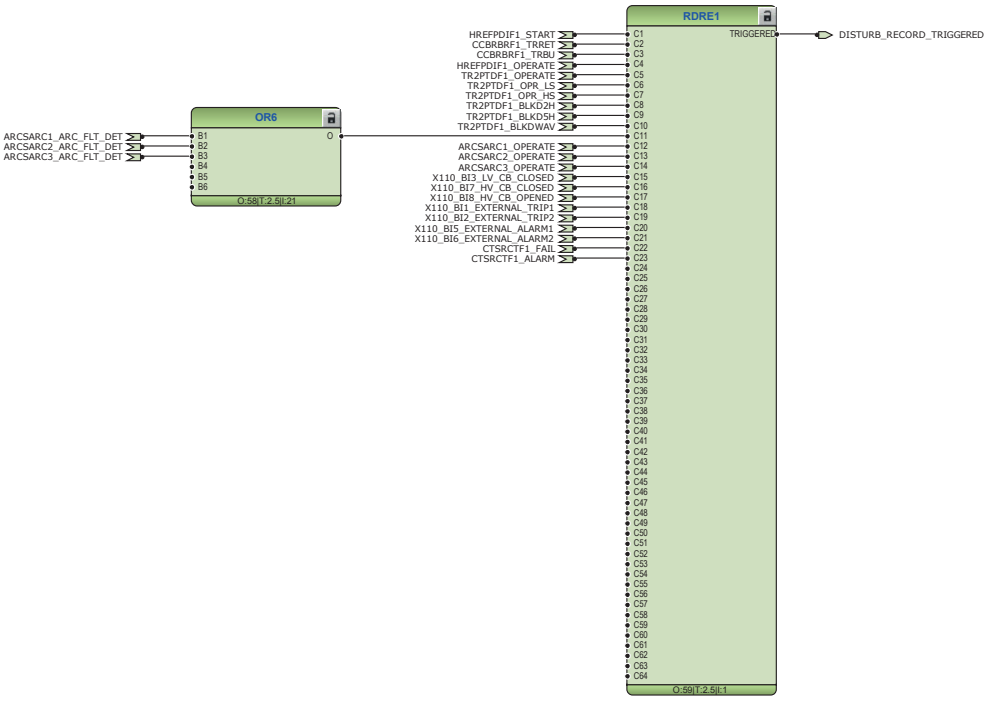



*Figure 215: Disturbance recorder*

### 3.7.3.3 Functional diagrams for condition monitoring

CTSRCTF1 is used for monitoring the current transformer secondary circuit where a separate reference current transformer input for comparison is not available or where a separate voltage channel for calculating or measuring the zero-sequence voltage is not available.

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

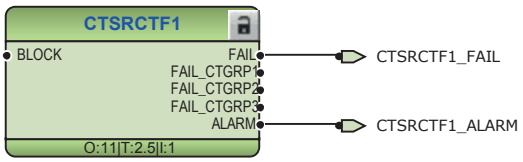



*Figure 216: Current circuit supervision function*

Set the parameters for SSCBR1 properly.

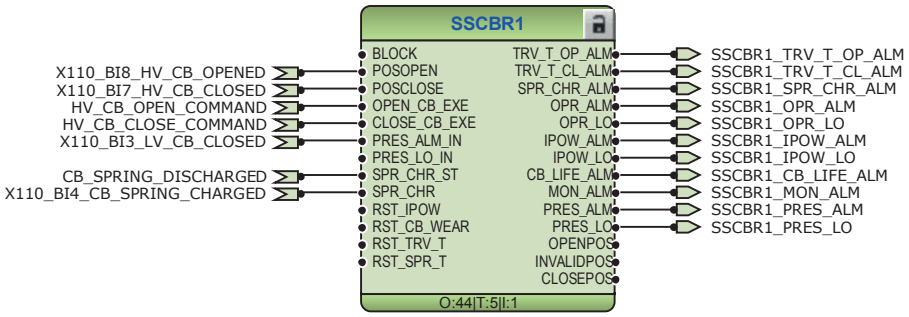



*Figure 217: Circuit-breaker condition monitoring alarm*

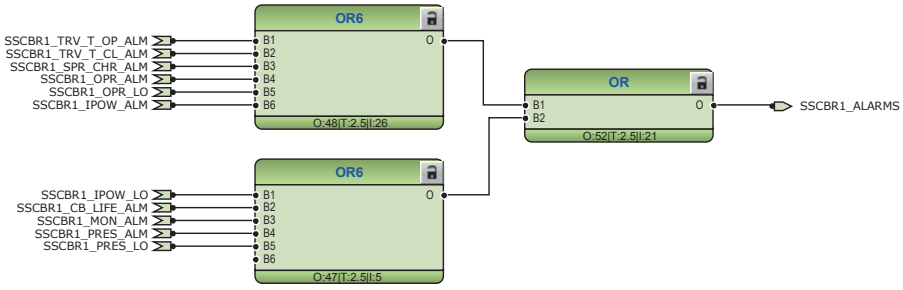



*Figure 218: Logic for circuit-breaker monitoring alarm*

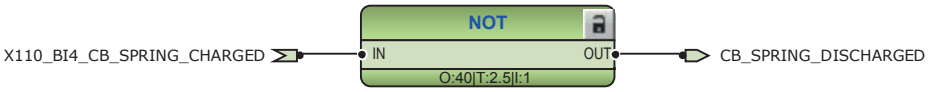



*Figure 219: Logic for start of circuit-breaker spring charging*

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

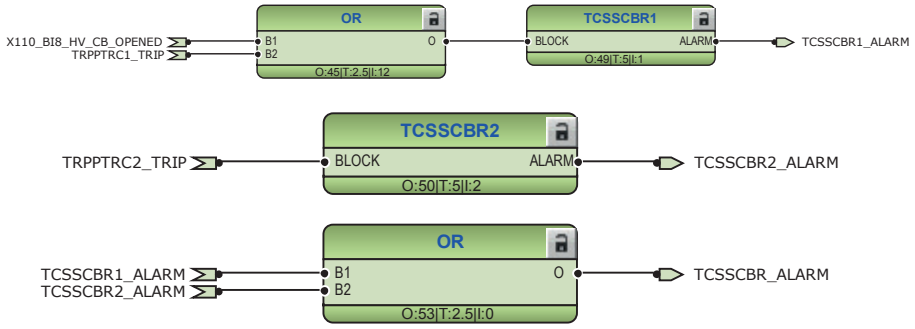



*Figure 220: Trip circuit supervision function*

### 3.7.3.4 Functional diagrams for control and interlocking

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

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

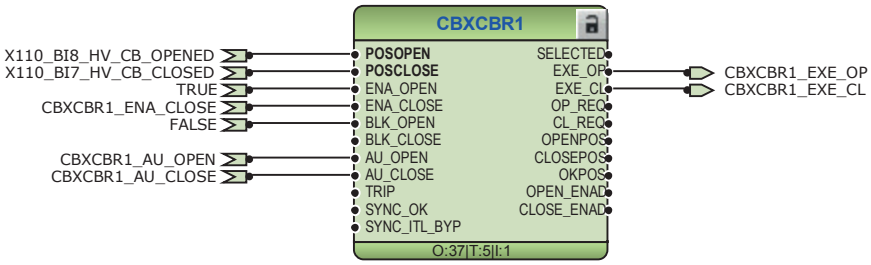



*Figure 221: High-voltage side circuit breaker*

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

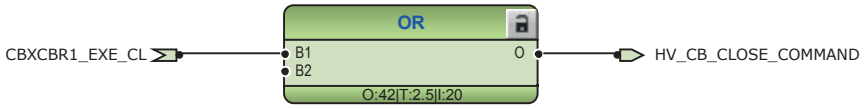



*Figure 222: Signals for closing coil of circuit breaker 1*

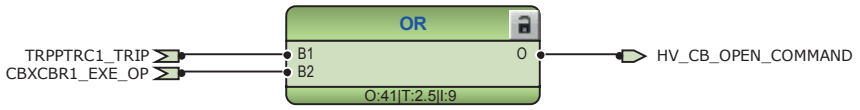



*Figure 223: Signals for opening coil of circuit breaker 1*

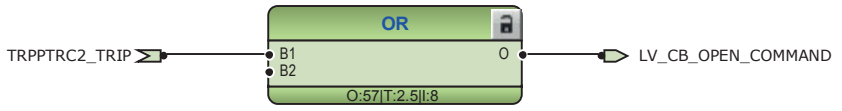



*Figure 224: Signals for opening coil of circuit breaker 2*

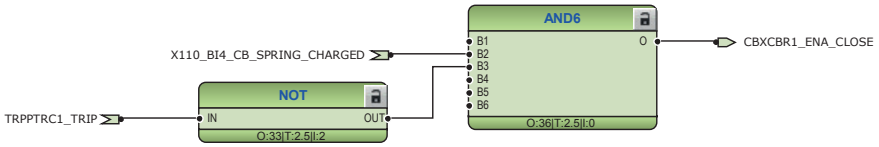



*Figure 225: High-voltage side circuit breaker 1 close enable logic*

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

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

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

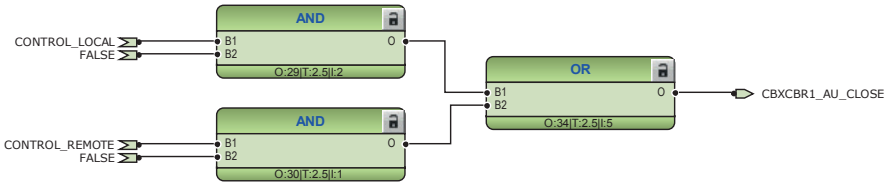



*Figure 226: External closing command for circuit breaker 1*

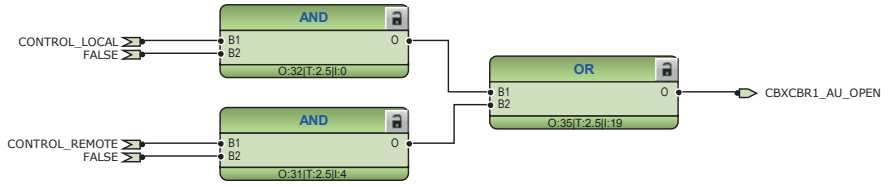



*Figure 227: External opening command for circuit breaker 1*

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the relay via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or, alternatively, by the mA input of the RTD card. In the configuration the information is available via the mA input.

Set the parameters for TPOSYLTC1 properly.

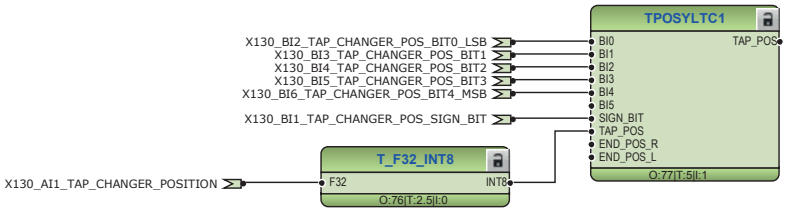



*Figure 228: Tap changer position indicator*

### 3.7.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the relay are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement function CSMSQI1 measures the sequence current from high-voltage side and residual current measurement RESCMMXU1 measures the residual current and high-voltage side.

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

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

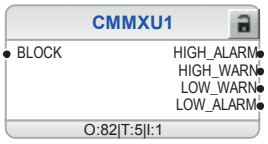



*Figure 229: Current measurement: Three-phase current measurement (HV side)*

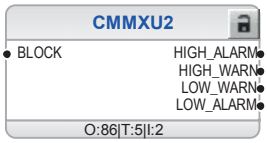



*Figure 230: Current measurement: Three-phase current measurement (LV side)*

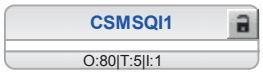



*Figure 231: Current measurement: Sequence current measurement (HV side)*


*Figure 232: Current measurement: Residual current measurement (HV side)*


*Figure 233: Other measurement: Data monitoring*


*Figure 234: Other measurement: Load profile record*

### 3.7.3.6 Functional diagrams for I/O and alarms LEDs

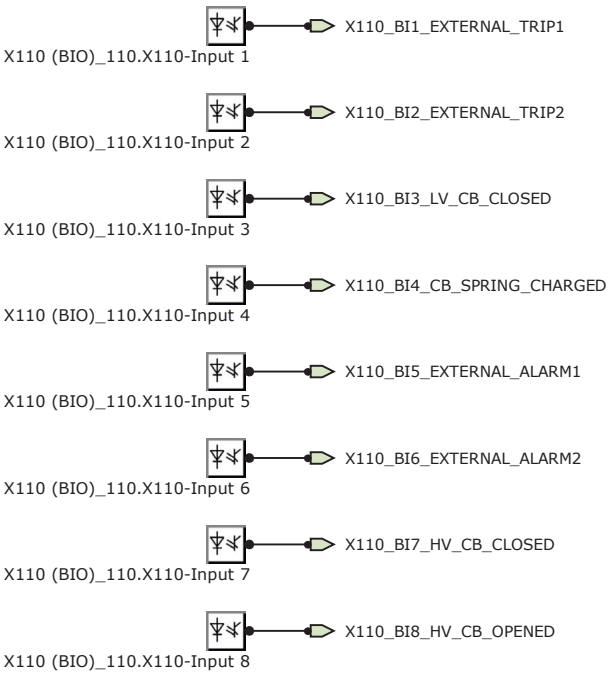



*Figure 235: Binary inputs - X110 terminal block*

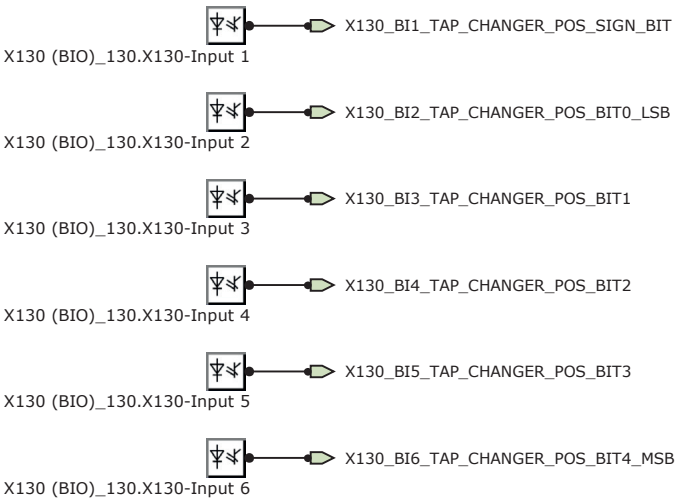



*Figure 236: Binary inputs - X130 terminal block*

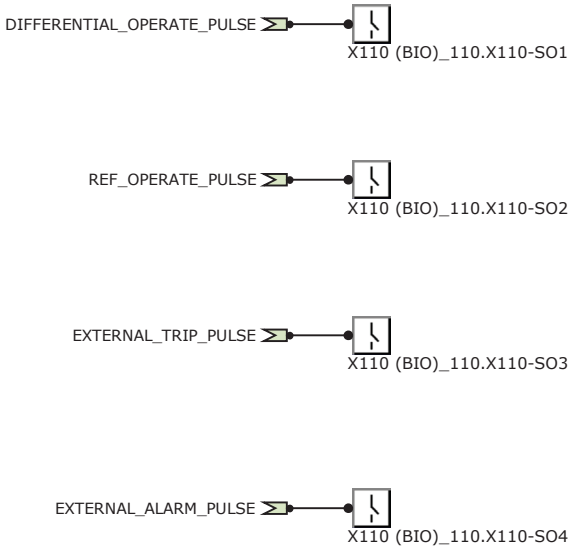



*Figure 237: Binary outputs - X110 terminal block*

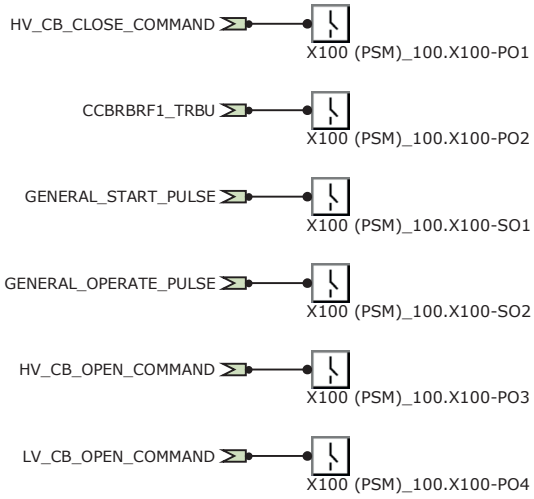



*Figure 238: Binary outputs - X100 terminal block*

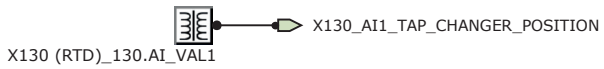



*Figure 239: Default mA/RTD inputs X130*

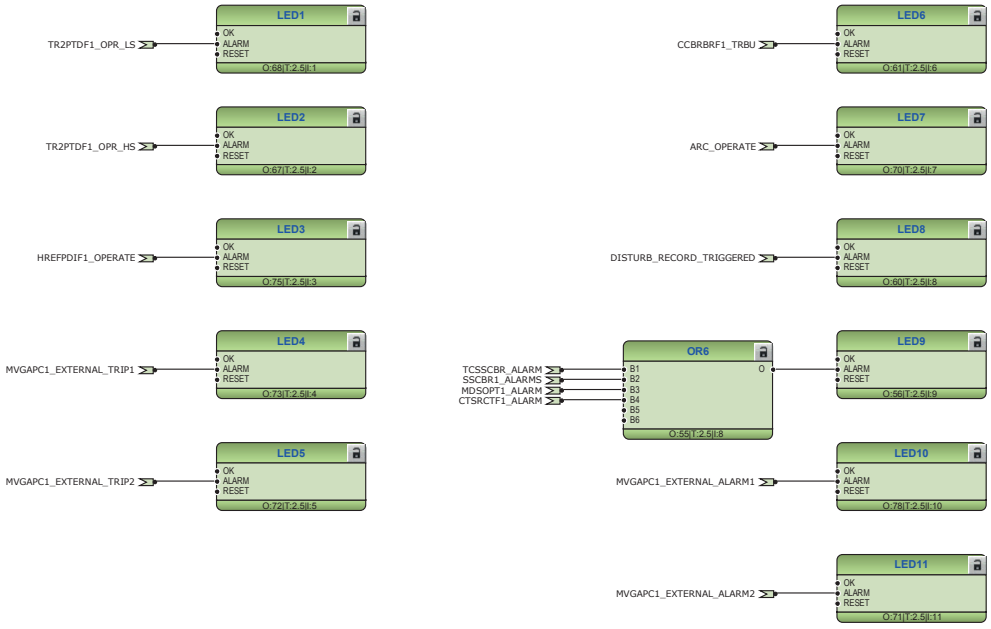



*Figure 240: Default LED connection*

## 3.7.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). The operate logics are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

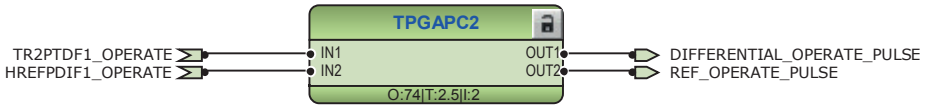



*Figure 241: Timer logic for differential operate and high-impedance based restricted earth-fault operate*

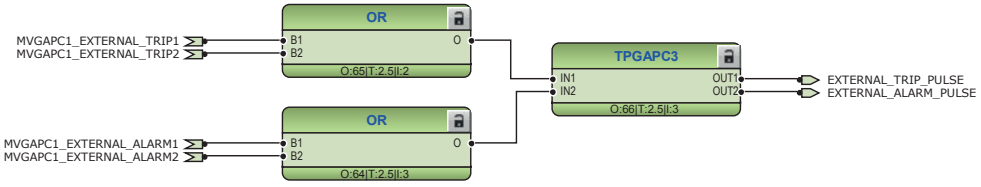



*Figure 242: Timer logic for earth-fault and combined other operate pulse*

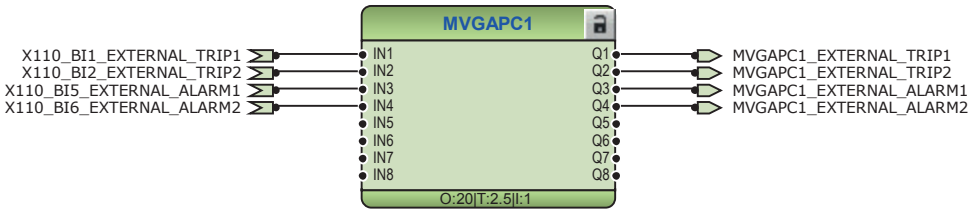



*Figure 243: Move for creating events*

### 3.7.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

# Section 4 Requirements for measurement transformers

## 4.1 Current transformers

### 4.1.1 Current transformer requirements for overcurrent protection

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

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

#### 4.1.1.1 Current transformer accuracy class and accuracy limit factor

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

*Table 42: Limits of errors according to IEC 60044-1 for protective current transformers*

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

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

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current

of the CT is distorted and it might have severe effects on the performance of the protection relay.

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

The actual accuracy limit factor is calculated using the formula:

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

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

### 4.1.1.2 Non-directional overcurrent protection

#### The current transformer selection

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

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

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

$I_{kmax}$ is the highest fault current.

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

#### Recommended start current settings

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

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

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

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

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

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

#### Delay in operation caused by saturation of current transformers

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

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

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

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

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

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

### 4.1.1.3 Example for non-directional overcurrent protection

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

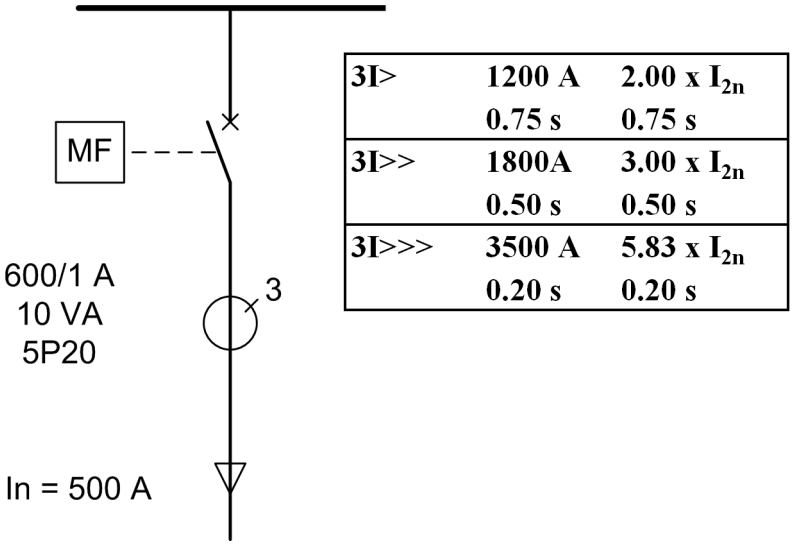



*Figure 244: Example of three-stage overcurrent protection*

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 244). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 244.

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

# Section 5 Protection relay's physical connections

## 5.1 Inputs

### 5.1.1 Energizing inputs

#### 5.1.1.1 Phase currents

*Table 43: Phase current inputs*

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

#### 5.1.1.2 Residual current

*Table 44: Residual current input*

| Terminal | Description |
|---|---|
| X120:13-14 | Io |

#### 5.1.1.3 Phase voltages

*Table 45: Phase voltage inputs included in configurations E and F*

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

#### 5.1.1.4 Residual voltage

*Table 46: Residual voltage input included in configurations E and F*

| Terminal | Description |
|---|---|
| X130:17-18 | Uo |

## 5.1.2 Auxiliary supply voltage input

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

*Table 47: Auxiliary voltage supply*

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

## 5.1.3 Binary inputs

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

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

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

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

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

Table continues on next page

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

Binary inputs of slot X130 are optional for configurations A and B.

*Table 50: Binary input terminals X130:1-9 with BIO0006 module*

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

Binary inputs of slot X130 are available with configurations E and F.

*Table 51: Binary input terminals X130:1-8 with AIM0006 module*

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

Table continues on next page

| Terminal | Description |
|---|---|
| X130:6 | BI3, - |
| X130:7 | BI4, + |
| X130:8 | BI4, - |

## 5.1.4 Optional light sensor inputs

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

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

*Table 52: Light sensor input connectors*

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

## 5.1.5 RTD/mA inputs

It is possible to connect mA and RTD based measurement sensors to the protection relay if the protection relay is provided with an optional RTD0001 module in standard configurations A, B and Z or with an AIM0003 module in standard configurations E, F and Z.

*Table 53: Optional RTD/mA inputs for standard configurations A, B and Z*

| Terminal | Description |
|---|---|
| X130:1 | mA1 (AI1), + |
| X130:2 | mA1 (AI1), - |
| X130:3 | mA2 (AI2), + |
| X130:4 | mA2 (AI2), - |
| X130:5 | RTD1 (AI3), + |
| X130:6 | RTD1 (AI3), - |
| X130:7 | RTD2 (AI4), + |
| X130:8 | RTD2 (AI4), - |
| X130:9 | RTD3 (AI5), + |

Table continues on next page

| Terminal | Description |
|---|---|
| X130:10 | RTD3 (AI5), - |
| X130:11 | Common[1)] |
| X130:12 | Common[2)] |
| X130:13 | RTD4 (AI6), + |
| X130:14 | RTD4 (AI6), - |
| X130:15 | RTD5 (AI7), + |
| X130:16 | RTD5 (AI7), - |
| X130:17 | RTD6 (AI8), + |
| X130:18 | RTD6 (AI8), - |

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

*Table 54: Optional RTD/mA inputs for standard configurations E and F*

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

# 5.2 Outputs

## 5.2.1 Outputs for tripping and controlling

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

*Table 55: Output contacts*

| Terminal | Description |
|---|---|
| X100:6 | PO1, NO |
| X100:7 | PO1, NO |
| X100:8 | PO2, NO |
| X100:9 | PO2, NO |
| X100:15 | PO3, NO (TCS resistor) |
| X100:16 | PO3, NO |

Table continues on next page

| Terminal | Description |
|---|---|
| X100:17 | PO3, NO |
| X100:18 | PO3 (TCS1 input), NO |
| X100:19 | PO3 (TCS1 input), NO |
| X100:20 | PO4, NO (TCS resistor) |
| X100:21 | PO4, NO |
| X100:22 | PO4, NO |
| X100:23 | PO4 (TCS2 input), NO |
| X100:24 | PO4 (TCS2 input), NO |

## 5.2.2 Outputs for signalling

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

*Table 56: Output contacts X100:10-14*

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

*Table 57: Output contacts X110:14-24 with BIO0005*

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

Output contacts of slot X130 are available in the optional BIO module (BIOB02A).

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

*Table 58: Output contacts X130:10-18 with BIO0006 module*

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

## 5.2.3 IRF

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

*Table 59: IRF contact*

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

# Section 6 Glossary

| | |
|---|---|
| 100BASE-FX | A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling |
| 100BASE-TX | A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors |
| 615 series | Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment |
| AC | Alternating current |
| AI | Analog input |
| ASCII | American Standard Code for Information Interchange |
| BCD | Binary coded decimal |
| BI | Binary input |
| BIO | Binary input and output |
| BO | Binary output |
| CB | Circuit breaker |
| CT | Current transformer |
| DAN | Doubly attached node |
| DC | 1. Direct current<br>2. Disconnector<br>3. Double command |
| 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 |
| HV | High voltage |
| I/O | Input/output |
| IEC | International Electrotechnical Commission |
| IEC 60870-5-103 | 1. Communication standard for protective equipment<br>2. A serial master/slave protocol for point-to-point communication |
| IEC 61850 | International standard for substation communication and modeling |
| IEC 61850-8-1 | A communication protocol based on the IEC 61850 standard series |
| IEC 61850-9-2 | A communication protocol based on the IEC 61850 standard series |
| IEC 61850-9-2 LE | Lite Edition of IEC 61850-9-2 offering process bus interface |
| IEEE 1686 | Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities |
| IP address | A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol. |
| IRIG-B | Inter-Range Instrumentation Group's time code format B |
| LAN | Local area network |
| 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 |
| LSB | Least significant bit |
| LV | Low voltage |
| MAC | Media access control |
| MCB | Miniature circuit breaker |
| MMS | 1. Manufacturing message specification<br>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 |
| **MSB** | Most significant bit |
| **NC** | Normally closed |
| **NO** | Normally open |
| **PCM600** | Protection and Control IED Manager |
| **PO** | Power output |
| **PRP** | Parallel redundancy protocol |
| **PTP** | Precision Time Protocol |
| **RET615** | Transformer protection and control relay |
| **RIO600** | Remote I/O unit |
| **RJ-45** | Galvanic connector type |
| **RSTP** | Rapid spanning tree protocol |
| **RTD** | Resistance temperature detector |
| **RTU** | Remote terminal unit |
| **SAN** | Single attached node |
| **Single-line diagram** | Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented. |
| **SLD** | Single-line diagram |
| **SMV** | Sampled measured values |
| **SNTP** | Simple Network Time Protocol |
| **SO** | Signal output |
| **TCS** | Trip-circuit supervision |
| **WAN** | Wide area network |
| **WHMI** | Web human-machine interface |

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