Relion® 650 SERIES

Transformer protection RET650 Version 1.3 ANSI

Product guide

Contents

1. 650 series overview

Protection for a wide range of applications, control of switching devices with interlocking, and monitoring can be provided in one IED.

The 650 series IEDs provide both customized and configured solutions. With the customized IEDs you have the freedom to completely adapt the functionality according to your needs.

The 650 series IEDs provide optimum 'off-the-shelf', ready-to-use solutions. It is configured with complete protection functionality and default parameters to meet the needs of a wide range of applications for generation, transmission and sub-transmission grids.

The 650 series IEDs include:

- Customized versions providing the possibility to adapt the functionality to the application needs for protection and control in one IED.
- Configured versions solutions are completely ready to use and optimized for a wide range of applications for generation, transmission and sub-transmission grids.
- Support for user-defined names in the local language for signal and function engineering.
- Minimized rule based parameter settings based on default values and ABB's global base value concept. You only need to set those parameters specific to your own installed and activated application.
- GOOSE messaging for horizontal communication on bumpless redundant station bus following IEC62439–3 ed2 PRP.
- Extended HMI functionality with 15 dynamic three-color-indication LEDs per page, on up to three pages, and configurable push-button shortcuts for different actions.
- Programmable LED text-based labels.
- Settable 1A/5A -rated current inputs.
- Role based access control with independent passwords and FTPS encrypted communication. Managed authentication and accounting of all user activities.

2. Application

RET650 provides fast and selective protection, monitoring and control for two- and three-winding transformers, autotransformers, generator-transformer units and shunt reactors. The IED is designed to operate correctly over a wide frequency range in order to accommodate power system frequency variations during disturbances and generator start-up and shut-down. Apparatus control for up to 8 apparatuses with interlocking can be included in one IED by function block engineering.

A very fast differential protection function with built-in transformer ratio matching and phase shift compensation makes this IED the ideal solution even for the most demanding applications. The differential protection function is provided with 2nd harmonic and wave-block restraint features to avoid tripping for magnetizing inrush current, and 5th harmonic restraint to avoid tripping during overexcitation conditions.

The differential function offers a high sensitivity for low-level internal faults. The unique and innovative sensitive differential protection feature of the RET650 provides the best possible coverage for winding internal turn-to-turn faults, based on the theory of symmetrical components .

A low impedance restricted ground-fault protection function is available as a complimentary sensitive and fast main protection against winding ground faults. This function includes a directional zero-sequence current criterion for additional security.

Tripping from pressure relief/Buchholz and temperature devices can be implemented through the RET650, where trip signal conditioning can be performed (pulsing, lockout, additional logics, etc). The binary inputs are thoroughly stabilized against disturbances in order to prevent incorrect operations due to for example DC system capacitive discharges or DC ground faults.

Versatile phase, ground, negative and zero sequence overcurrent functions with directional capability provide further alternative backup protections. Thermal overload with two time-constants, overexcitation (volts per hertz) and over/under voltage protection functions are also available.

A built-in disturbance and event recorder provides valuable data to the user about status and operation for post-fault disturbance analysis.

An included breaker failure protection function allows high speed back-up tripping of surrounding breakers.

Three packages have been defined for the following applications:

- Two-winding transformer in single breaker arrangements (A01A)
- Three-winding transformer in single breaker arrangements (A05A)
- One or two transformer tap changer control (A07A)

The packages are preconfigured and ready for direct use. Analog and tripping IO has been pre-defined for basic use. Other signals need to be applied as required for each application.

The graphical configuration tool ensures simple and fast testing and commissioning.

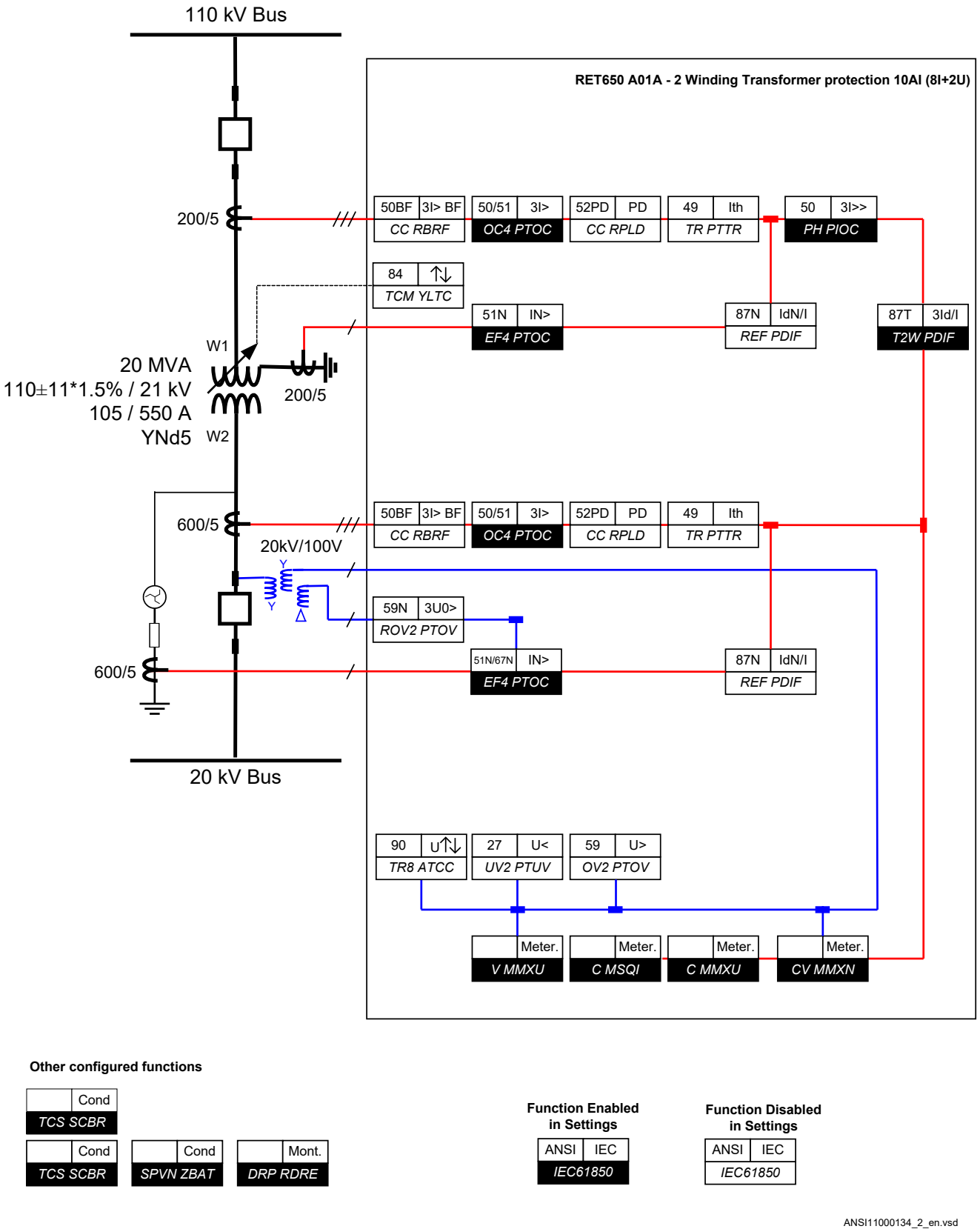


Figure 1. A typical protection application for a two-winding transformer in single breaker arrangement

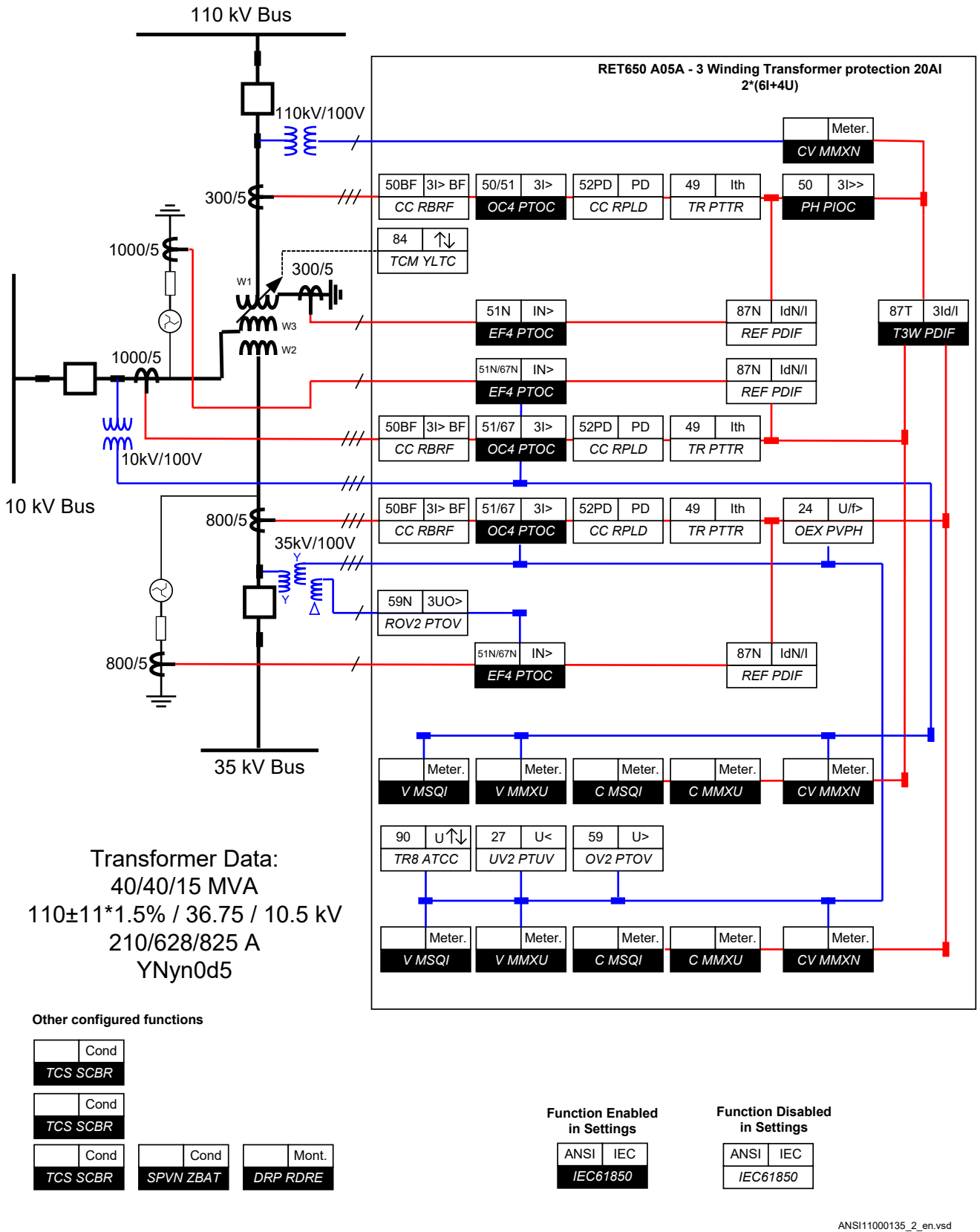


Figure 2. A typical protection application for a three-winding transformer in single breaker arrangement

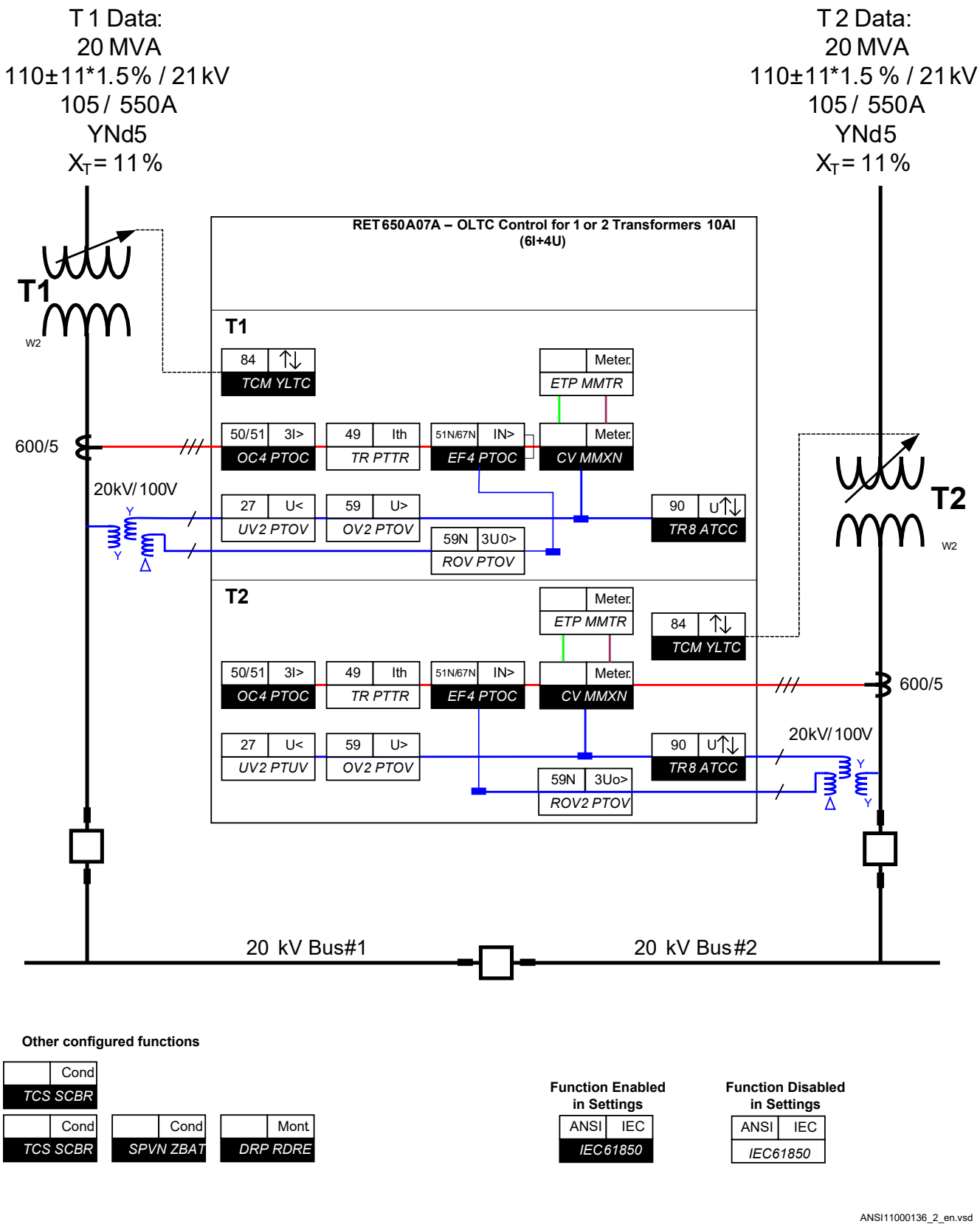


Figure 3. A typical tap changer control application for one or two transformers

3. Available functions

Main protection functions

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
Differential protection						
T2WPDIF	87T	Transformer differential protection, two winding	0–1	1		
T3WPDIF	87T	Transformer differential protection, three winding	0–1		1	
REFPDIF	87N	Restricted earth fault protection, low impedance	0–3	2	3	
HZPDIF	87	1Ph High impedance differential protection	0–2	2	2	
Impedance protection						
ZMRPSB	68	Power swing detection	0–1			
ZGCPDIS	21G	Underimpedance protection for generators and transformers	0–1			
LEPDIS		Load encroachment	0–1			

Back-up protection functions

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
Current protection						
PHPIOC	50	Instantaneous phase overcurrent protection, 3–phase output	0–3	2	3	
OC4PTOC	51/67	Four step phase overcurrent protection, 3-phase output	0–3	2	3	2
EFPIOC	50N	Instantaneous residual overcurrent protection	0–3	2	3	
EF4PTOC	51N/67N	Four step residual overcurrent protection, zero/negative sequence direction	0–3	2	3	2
TRPTTR	49	Thermal overload protection, two time constants	0–3	2	3	2
CCRBRF	50BF	Breaker failure protection, 3–phase activation and output	0–3	2	3	
CCRPLD	52PD	Pole discordance protection	0–3	2	3	
GUPPDUP	37	Directional underpower protection	0–2	1	1	2
GOPPDOP	32	Directional overpower protection	0–2	1	1	2
DNSPTOC	46	Negative sequence based overcurrent function	0–2	1	2	
Voltage protection						
UV2PTUV	27	Two step undervoltage protection	0–2	1	1	2
OV2PTOV	59	Two step overvoltage protection	0–2	1	1	2
ROV2PTOV	59N	Two step residual overvoltage protection	0–2	1	1	2
OEXPVPH	24	Overexcitation protection	0–1	1	1	
Frequency protection						
SAPTUF	81	Underfrequency function	0–4	4	4	4
SAPTOF	81	Overfrequency function	0–4	4	4	4
SAPFRC	81	Rate-of-change frequency protection	0–4	2	2	4

Control and monitoring functions

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
Control						
TR8ATCC	90	Automatic voltage control for tap changer, parallel control	0–2	1	1	2
TCMYLTC	84	Tap changer control and supervision, 6 binary inputs	0–2	1	1	2
SLGGIO		Logic Rotating Switch for function selection and LHMI presentation	15	15	15	15
VSGGIO		Selector mini switch	20	20	20	20
DPGGIO		IEC 61850 generic communication I/O functions double point	16	16	16	16
SPC8GGIO		Single point generic control 8 signals	5	5	5	5
AUTOBITS		AutomationBits, command function for DNP3.0	3	3	3	3
I103CMD		Function commands for IEC60870-5-103	1	1	1	1
I103IEDCMD		IED commands for IEC60870-5-103	1	1	1	1
I103USRCMD		Function commands user defined for IEC60870-5-103	4	4	4	4
I103GENCMD		Function commands generic for IEC60870-5-103	50	50	50	50
I103POSCMD		IED commands with position and select for IEC60870-5-103	50	50	50	50
Apparatus control and Interlocking						
APC8		Apparatus control for single bay, max 8 app. (1CB) incl. interlocking	0–1			
QCBAY		Bay control	1	1	1	1
LOCREM		Handling of LR-switch positions	1	1	1	1
LOCREMCTRL		LHMI control of Permitted Source To Operate (PSTO)	1	1	1	1
CBC2		Circuit breaker control for 2CB	0–1	1		
CBC3		Circuit breaker control for 3CB	0–1		1	
CBC4		Circuit breaker control for 4CB	0–1			1
Secondary system supervision						
SDDRFUF		Fuse failure supervision	0–1			
TCSSCBR		Breaker close/trip circuit monitoring	3	3	3	3
Logic						
SMPPTRC	94	Tripping logic, common 3–phase output	1–3	2	3	2
TMAGGIO		Trip matrix logic	12	12	12	12
OR		Configurable logic blocks	283	283	283	283
INVERTER		Configurable logic blocks	140	140	140	140

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
PULSETIMER		Configurable logic blocks	40	40	40	40
GATE		Configurable logic blocks	40	40	40	40
XOR		Configurable logic blocks	40	40	40	40
LOOPDELAY		Configurable logic blocks	40	40	40	40
TIMERSET		Configurable logic blocks	40	40	40	40
AND		Configurable logic blocks	280	280	280	280
SRMEMORY		Configurable logic blocks	40	40	40	40
RSMEMORY		Configurable logic blocks	40	40	40	40
Q/T		Configurable logic blocks Q/T	0–1			
ANDQT		Configurable logic blocks Q/T	0–120			
ORQT		Configurable logic blocks Q/T	0–120			
INVERTERQT		Configurable logic blocks Q/T	0–120			
XORQT		Configurable logic blocks Q/T	0–40			
SRMEMORYQT		Configurable logic blocks Q/T	0–40			
RSMEMORYQT		Configurable logic blocks Q/T	0–40			
TIMERSETQT		Configurable logic blocks Q/T	0–40			
PULSETIMERQT		Configurable logic blocks Q/T	0–40			
INVALIDQT		Configurable logic blocks Q/T	0–12			
INDCOMBSPQT		Configurable logic blocks Q/T	0–20			
INDEXTSPQT		Configurable logic blocks Q/T	0–20			
FXDSIGN		Fixed signal function block	1	1	1	1
B16I		Boolean 16 to Integer conversion	16	16	16	16
B16IFCVI		Boolean 16 to Integer conversion with logic node representation	16	16	16	16
IB16A		Integer to Boolean 16 conversion	16	16	16	16
IB16FCVB		Integer to Boolean 16 conversion with logic node representation	16	16	16	16
TEIGGIO		Elapsed time integrator with limit transgression and overflow supervision	12	12	12	12
Monitoring						
CVMMXN		Measurements	6	6	6	6
CMMXU		Phase current measurement	10	10	10	10

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
VMMXU		Phase-phase voltage measurement	6	6	6	6
CMSQI		Current sequence component measurement	6	6	6	6
VMSQI		Voltage sequence measurement	6	6	6	6
VNMMXU		Phase-neutral voltage measurement	6	6	6	6
AISVBAS		Function block for service values presentation of the analog inputs	1	1	1	1
TM_P_P2		Function block for service values presentation of primary analog inputs 600TRM	1	1	1	1
AM_P_P4		Function block for service values presentation of primary analog inputs 600AIM	1	1	1	1
TM_S_P2		Function block for service values presentation of secondary analog inputs 600TRM	1	1	1	1
AM_S_P4		Function block for service values presentation of secondary analog inputs 600AIM	1	1	1	1
CNTGGIO		Event counter	5	5	5	5
L4UFCNT		Event counter with limit supervision	12	12	12	12
DRPRDRE		Disturbance report	1	1	1	1
AnRADR		Analog input signals	4	4	4	4
BnRBDR		Binary input signals	6	6	6	6
SPGGIO		IEC 61850 generic communication I/O functions	64	64	64	64
SP16GGIO		IEC 61850 generic communication I/O functions 16 inputs	16	16	16	16
MVGGIO		IEC 61850 generic communication I/O functions	16	16	16	16
MVEXP		Measured value expander block	66	66	66	66
SPVNZBAT		Station battery supervision	0–1	1	1	1
SSIMG	63	Insulation gas monitoring function	0–2	2	2	2
SSIML	71	Insulation liquid monitoring function	0–2	2	2	2
SSCBR		Circuit breaker condition monitoring	0–3	2	3	2
I103MEAS		Measurands for IEC60870-5-103	1	1	1	1
I103MEASUSR		Measurands user defined signals for IEC60870-5-103	3	3	3	3
I103AR		Function status auto-recloser for IEC60870-5-103	1	1	1	1
I103EF		Function status ground-fault for IEC60870-5-103	1	1	1	1
I103FLTPROT		Function status fault protection for IEC60870-5-103	1	1	1	1
I103IED		IED status for IEC60870-5-103	1	1	1	1

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
I103SUPERV		Supervison status for IEC60870-5-103	1	1	1	1
I103USRDEF		Status for user defined signals for IEC60870-5-103	20	20	20	20
Metering						
PCGGIO		Pulse counter	16	16	16	16
ETPMMTR		Function for energy calculation and demand handling	3	3	3	3

Station communication

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
Station communication						
IEC61850-8-1		IEC 61850 communication protocol	1	1	1	1
DNPGEN		DNP3.0 communication general protocol	1	1	1	1
RS485DNP		DNP3.0 for RS-485 communication protocol	1	1	1	1
CH1TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
CH2TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
CH3TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
CH4TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
OPTICALDNP		DNP3.0 for optical RS-232 communication protocol	1	1	1	1
MSTSERIAL		DNP3.0 for serial communication protocol	1	1	1	1
MST1TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
MST2TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
MST3TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
MST4TCP		DNP3.0 for TCP/IP communication protocol	1	1	1	1
RS485GEN		RS485	1	1	1	1
OPTICALPROT		Operation selection for optical serial	1	1	1	1
RS485PROT		Operation selection for RS485	1	1	1	1
DNPFREC		DNP3.0 fault records for TCP/IP communication protocol	1	1	1	1
OPTICAL103		IEC60870-5-103 Optical serial communication	1	1	1	1
RS485103		IEC60870-5-103 serial communication for RS485	1	1	1	1
GOOSEINTLKRCV		Horizontal communication via GOOSE for interlocking	59	59	59	59
GOOSEBINRCV		GOOSE binary receive	4	4	4	4
GOOSEVCTRCONF		GOOSE VCTR configuration for send and receive	1	1	1	1
VCTRSEND		Voltage control sending block for GOOSE	1	1	1	1
GOOSEVCTRRCV		Voltage control receiving block for GOOSE	3	3	3	3
ETHFRNT ETHLAN1 GATEWAY		Ethernet configuration of front port, LAN1 port and gateway	1	1	1	1
ETHLAN1_AB		Ethernet configuration of LAN1 port	1			
PRPSTATUS		System component for parallell redundancy protocol	1			
CONFPROT		IED Configuration Protocol	1	1	1	1

IEC 61850 or Function name	ANSI	Function description	Transformer			
			RET650	RET650 (A01A) 2W/1CB	RET650 (A05A) 3W/1CB	RET650 (A07A) OLTC
ACTIVLOG		Activity logging parameters	1	1	1	1
SECALARM		Component for mapping security events on protocols such as DNP3 and IEC103	1	1	1	1
AGSAL		Generic security application component	1	1	1	1
GOOSEDPRCV		GOOSE function block to receive a double point value	32	32	32	32
GOOSEINTRCV		GOOSE function block to receive an integer value	32	32	32	32
GOOSEMVRCV		GOOSE function block to receive a measurand value	16	16	16	16
GOOSESPRCV		GOOSE function block to receive a single point value	64	64	64	64

Basic IED functions

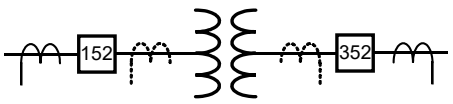
IEC 61850/Function block name	Function description	
Basic functions included in all products		
INTERRSIG	Self supervision with internal event list	1
SELFSUPEVLST	Self supervision with internal event list	1
TIMESYNCHGEN	Time synchronization	1
SNTP	Time synchronization	1
DTSBEGIN, DTSEND, TIMEZONE	Time synchronization, daylight saving	1
IRIG-B	Time synchronization	1
SETGRPS	Setting group handling	1
ACTVGRP	Parameter setting groups	1
TESTMODE	Test mode functionality	1
CHNGLCK	Change lock function	1
PRIMVAL	Primary system values	1
SMAI_20_1 - SMAI_20_12	Signal matrix for analog inputs	2
3PHSUM	Summation block 3 phase	12
GBASVAL	Global base values for settings	6
ATHSTAT	Authority status	1
ATHCHCK	Authority check	1
AUTHMAN	Authority management	1
FTPACCS	FTPS access with password	1
DOSFRNT	Denial of service, frame rate control for front port	1
DOSLAN1	Denial of service, frame rate control for LAN1A and LAN1B ports	1
DOSSCKT	Denial of service, socket flow control	1

4. Differential protection

Transformer differential protection T3WPDIF (87T)

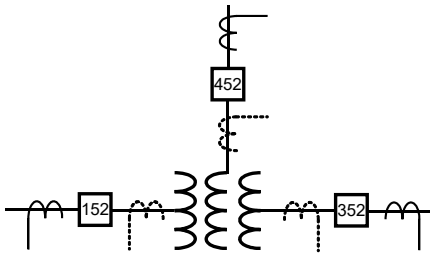
The function can be provided with two or three three-phase sets of current inputs. All current inputs are provided with percentage bias restraint features, making the IED suitable for two- or three-winding transformer arrangements.

Two-winding applications



xx05000048_ansi.vsd

Three-winding applications



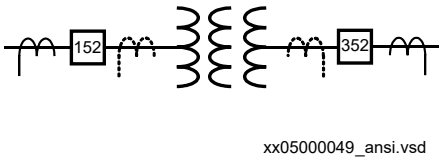


Figure 4. CT group arrangement for differential protection and other protections

The available settings of this function allow the RET650 to cover various differential protection applications such as power transformers and auto-transformers with or without load tap changer as well as for shunt reactors including local feeders within the station. An adaptive stabilizing feature is included to avoid misoperations during for heavy through-faults.

Harmonic restraint is included for inrush and overexcitation currents respectively, cross-blocking is also available. Adaptive harmonic restraint is also included for system recovery inrush and CT saturation during external faults. A high set unrestrained differential current protection element is included for a very high speed tripping at a high internal fault currents.

Included is an innovative sensitive differential protection element based on the theory of symmetrical components. This element offers the best possible coverage of power transformer windings turn to turn faults.

Restricted earth fault protection REFPDIF

Restricted earth-fault protection, low impedance REFPDIF (87N)

Restricted fault protection, low-impedance function REFPDIF (87N)can be used on all solidly or low-impedance grounded windings. The REFPDIF (87N) function provides high sensitivity and high speed tripping as it protects each winding separately and thus does not need inrush stabilization.

The low-impedance function is a percentage biased function with an additional zero sequence current directional comparison criterion. This gives excellent sensitivity and stability during through faults. The function allows the use of different CT ratios and magnetizing characteristics on the phase and neutral CT cores. Unlike high impedance restricted ground fault it allows for mixing with other functions and protection IEDs on the same CT cores.

1Ph High impedance differential protection HZPDIF (87)

The 1Ph High impedance differential protection HZPDIF (87) functions can be used when the involved CTs have the same turns ratio and similar magnetizing characteristics. Each utilizes an external summation of the currents in the interconnected CTs, a series resistor, and a voltage dependent resistor which are mounted externally connected to the IED.

The external resistor unit shall be ordered under accessories.

HZPDIF (87) can be used as high impedance REF protection.

5. Impedance protection

Power swing detection ZMRPSB (68)

Power swings may occur after disconnection of heavy loads, upon severe fault clearing or after tripping of big generation plants.

Power swing detection function ZMRPSB (68) is used to detect power swings and initiate block of all distance protection zones. Occurrence of ground-fault currents during a power swing inhibits the ZMRPSB (68) function to allow fault clearance.

Underimpedance protection for generators and transformers ZGCPDIS (21)

The underimpedance protection for generators and transformers ZGCPDIS(21G), has the offset mho characteristic as a three zone back-up protection for detection of phase-to-phase short circuits in transformers and generators. The full scheme three zones have independent measuring phase-to-phase loops and settings that gives high flexibility for all types of applications.

All three zones can be individually definite time delayed.

A load encroachment characteristic is available for the third zone as shown in figure 5.

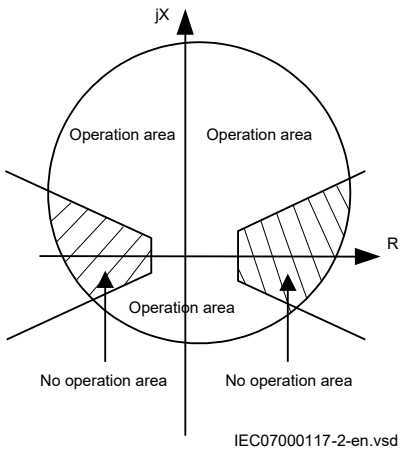


Figure 5. Load encroachment influence on the offset mho Z3 characteristic

Load encroachment LEPDIS

Heavy load transfer is common in many power networks and may make fault resistance coverage difficult to achieve. In such a case, Load encroachment LEPDIS function can be used to prevent operation of the of the underimpedance measuring zones during heavy loads.

Each of the three measuring phase-to-phase loops has its own load encroachment characteristic.

6. Current protection

Instantaneous phase overcurrent protection, 3-phase output PHPIOC (50)

The instantaneous three phase overcurrent function has a low transient overreach and short tripping time to allow use as a high set short-circuit protection function.

Four step phase overcurrent protection, 3-phase output OC4PTOC (51/67)

The four step phase overcurrent protection function OC4PTOC (51/67) has independent inverse time delay settings for step 1 and 4. Step 2 and 3 are always definite time delayed.

All IEC and ANSI inverse time characteristics are available.

The directional function is voltage polarized with memory. The function can be set to be directional or non-directional independently for each of the steps.

Second harmonic blocking level can be set for the function and can be used to block each step individually

Instantaneous residual overcurrent protection EFPIOC (50N)

The Instantaneous residual overcurrent protection EFPIOC (50N) has a low transient overreach and short tripping times to allow use for instantaneous ground-fault protection, with the reach limited to less than typical eighty percent of the transformer impedance at minimum source impedance. EFPIOC (50N) can be configured to measure the residual current from the three-phase current inputs or the current from a separate current input. EFPIOC (50N) can be blocked by activating the input BLOCK.

Four step residual overcurrent protection, zero sequence and negative sequence direction EF4PTOC (51N_67N)

The four step residual overcurrent protection, zero or negative sequence direction (EF4PTOC, 51N/67N) has independent inverse time delay settings for step 1 and 4. Step 2 and 3 are always definite time delayed.

All IEC and ANSI inverse time characteristics are available.

EF4PTOC (51N/67N) can be set directional or non-directional independently for each of the steps.

The directional part of the function can be set to operate on following combinations:

- Directional current (I3PDir) versus Polarizing voltage (V3PPol)
- Directional current (I3PDir) versus Polarizing current (I3PPol)
- Directional current (I3PDir) versus Dual polarizing (VPol +ZPol x IPol) where ZPol = RPol + jXPol

IDir, VPol and IPol can be independently selected to be either zero sequence or negative sequence.

Second harmonic blocking level can be set for the function and can be used to block each step individually.

Thermal overload protection, two time constant TRPTTR (49)

If a power transformer or generator reaches very high temperatures the equipment might be damaged. The insulation within the transformer/generator will have forced ageing. As a consequence of this the risk of internal phase-to-phase or phase-to-ground faults will increase. High temperature will degrade the quality of the transformer/generator insulation.

The thermal overload protection estimates the internal heat content of the transformer/generator (temperature)

continuously. This estimation is made by using a thermal model of the transformer/generator with two time constants, which is based on current measurement.

Two warning pickup levels are available. This enables actions in the power system to be done before dangerous temperatures are reached. If the temperature continues to increase to the trip value, the protection initiates a trip of the protected transformer/generator.

Estimated time to trip before operation is presented.

Breaker failure protection CCRBRF, 3-phase activation and output (50BF)
CCRBRF (50BF) can be current based, contact based, or an adaptive combination of these two conditions.

Breaker failure protection (CCRBRF, 50BF) ensures fast back-up tripping of surrounding breakers in case the protected breaker fails to open. CCRBRF (50BF) can be current based, contact based, or an adaptive combination of these two conditions.

Current check with extremely short reset time is used as check criterion to achieve high security against inadvertent operation.

Contact check criteria can be used where the fault current through the breaker is small.

Breaker failure protection, 3-phase activation and output (CCRBRF, 50BF) current criteria can be fulfilled by one or two phase currents the residual current, or one phase current plus residual current. When those currents exceed the user defined settings, the function is triggered. These conditions increase the security of the back-up trip command.

CCRBRF (50BF) function can be programmed to give a three-phase re-trip of the protected breaker to avoid inadvertent tripping of surrounding breakers.

Pole discordance protection CCRPLD (52PD)
Circuit breakers and disconnectors can end up with their phases in different positions (close-open), due to electrical or mechanical failures. An open phase can cause negative and zero sequence currents which cause thermal stress on rotating machines and can cause unwanted operation of zero sequence or negative sequence current functions.

Normally the affected breaker is tripped to correct such a situation. If the situation warrants the surrounding breakers should be tripped to clear the unsymmetrical load situation.

The pole discrepancy function operates based on information from the circuit breaker logic with additional criteria from phase selective current unsymmetry.

Directional over/underpower protection GOPPDOP/ GUPPDUP (32/37)
The directional over-/under-power protection GOPPDOP (32)/GUPPDUP (37) can be used wherever a high/low active, reactive or apparent power protection or alarming is required. The functions can alternatively be used to check the direction of active or reactive power flow in the power system. There are a number of applications where such functionality is needed. Some of them are:

- detection of reversed active power flow
- detection of high reactive power flow

Each function has two steps with definite time delay.

Negative sequence based overcurrent function DNSPTOC (46)
Negative sequence based overcurrent function DNSPTOC (46) may be used in power line applications where the reverse zero sequence source is weak or open, the forward source impedance is strong and it is desired to detect forward ground faults.

Additionally, it is applied in applications on cables, where zero sequence impedance depends on the fault current return paths, but the cable negative sequence impedance is practically constant.

The directional function is current and voltage polarized. The function can be set to forward, reverse or non-directional independently for each step. Both steps are provided with a settable definite time delay.

DNSPTOC (46) protects against all unbalanced faults including phase-to-phase faults. The minimum pickup current of the function must be set to above the normal system unbalance level in order to avoid inadvertent tripping.

7. Voltage protection

Two step undervoltage protection UV2PTUV (27)
Undervoltages can occur in the power system during faults or abnormal conditions. Two step undervoltage protection (UV2PTUV, 27) function can be used to open circuit breakers to prepare for system restoration at power outages or as long-time delayed back-up to primary protection.

UV2PTUV (27) has two voltage steps, where step 1 is settable as inverse or definite time delayed. Step 2 is always definite time delayed.

UV2PTUV (27) has a high reset ratio to allow settings close to system service voltage.

Two step overvoltage protection OV2PTOV (59)
Overvoltages may occur in the power system during abnormal conditions such as sudden power loss, tap changer regulating failures, and open line ends on long lines.

Two step overvoltage protection (OV2PTOV, 59) function can be used to detect open line ends, normally then combined with a directional reactive over-power function to supervise the system voltage. When triggered, the function will cause an alarm, switch in reactors, or switch out capacitor banks.

OV2PTOV (59) has two voltage steps, where step 1 can be set as inverse or definite time delayed. Step 2 is always definite time delayed.

OV2PTOV (59) has a high reset ratio to allow settings close to system service voltage.

Two step residual overvoltage protection ROV2PTOV (59N)
Residual voltages may occur in the power system during ground faults.

Two step residual overvoltage protection ROV2PTOV (59N) function calculates the residual voltage from the three-phase voltage input transformers or measures it from a single voltage input transformer fed from a broken delta or neutral point voltage transformer.

ROV2PTOV (59N) has two voltage steps, where step 1 can be set as inverse or definite time delayed. Step 2 is always definite time delayed.

Overexcitation protection OEXPVPH (24)
When the laminated core of a power transformer or generator is subjected to a magnetic flux density beyond its design limits, stray flux will flow into non-laminated components that are not designed to carry flux. This will cause eddy currents to flow. These eddy currents can cause excessive heating and severe damage to insulation and adjacent parts in a relatively short time. The function has settable inverse operating curves and independent alarm stages.

8. Frequency protection

Underfrequency protection SAPTUF (81)
Underfrequency occurs as a result of a lack of sufficient generation in the network.

Underfrequency protection SAPTUF (81) measures frequency with high accuracy, and is used for load shedding systems, remedial action schemes, gas turbine startup and so on. Separate definite time delays are provided for operate and restore.

SAPTUF (81) is provided with undervoltage blocking.

Overfrequency protection SAPTOF (81)
Overfrequency protection function SAPTOF (81) is applicable in all situations, where reliable detection of high fundamental power system frequency is needed.

Overfrequency occurs because of sudden load drops or shunt faults in the power network. Close to the generating plant, generator governor problems can also cause over frequency.

SAPTOF (81) measures frequency with high accuracy, and is used mainly for generation shedding and remedial action schemes. It is also used as a frequency stage initiating load restoring. A definite time delay is provided for operate.

SAPTOF (81) is provided with an undervoltage blocking.

Rate-of-change frequency protection SAPFRC (81)
The rate-of-change frequency protection function SAPFRC (81) gives an early indication of a main disturbance in the system. SAPFRC (81) measures frequency with high accuracy, and can be used for generation shedding, load shedding and remedial action schemes. SAPFRC (81) can discriminate between a positive or negative change of frequency. A definite time delay is provided for operate.

SAPFRC (81) is provided with an undervoltage blocking.

9. Secondary system supervision

Fuse failure supervision SDDRFUF
The aim of the fuse failure supervision function SDDRFUF is to block voltage measuring functions at failures in the secondary circuits between the voltage transformer and the IED in order to avoid inadvertent operations that otherwise might occur.

The fuse failure supervision function basically has three different detection methods, negative sequence and zero sequence based detection and an additional delta voltage and delta current detection.

The negative sequence detection is recommended for IEDs used in isolated or high-impedance grounded networks. It is based on the negative-sequence measuring quantities, a high value of negative sequence voltage $3V_2$ without the presence of the negative-sequence current $3I_2$.

The zero sequence detection is recommended for IEDs used in directly or low impedance grounded networks. It is based on the zero sequence measuring quantities, a high value of zero sequence voltage $3V_0$ without the presence of the zero sequence current $3I_0$.

For better adaptation to system requirements, an operation mode setting has been introduced which makes it possible to select the operating conditions for negative sequence and zero sequence based function. The selection of different operation modes makes it possible to choose different interaction possibilities between the negative sequence and zero sequence based detection.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.

Breaker close/trip circuit monitoring TCSSCBR
The trip circuit supervision function TCSSCBR is designed to supervise the control circuit of the circuit breaker. The trip circuit supervision generates a current of approximately 1 mA through the supervised control circuit. The validity supervision of a control circuit is provided for power output contacts T1, T2 and T3.

The function picks up and trips when TCSSCBR detects a trip circuit failure. The trip time characteristic for the function is of definite time (DT) type. The function trips after a predefined operating time and resets when the fault disappears.

10. Control

Apparatus control APC
The apparatus control function APC8 for up to 8 apparatuses is used for control and supervision of circuit breakers, disconnectors and grounding switches within a bay. Permission to operate is given after evaluation of conditions from other functions such as interlocking, synchronism check, operator place selection and external or internal blockings.

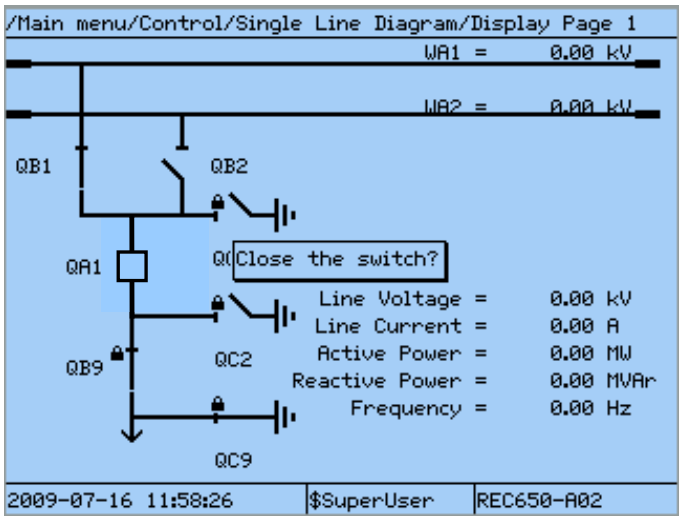
Apparatus control features:
- Select-Execute principle to give high reliability
- Selection function to prevent simultaneous operation
- Selection and supervision of operator place
- Command supervision
- Block/deblock of operation
- Block/deblock of updating of position indications
- Substitution of position indications
- Overriding of interlocking functions
- Overriding of synchrocheck
- Operation counter
- Suppression of Mid position

Two types of command models can be used:
- Direct with normal security
- SBO (Select-Before-Operate) with enhanced security

Direct commands are received with no prior select command. SBO commands are received with a select command first and on successful selection, a proceeding operate command.

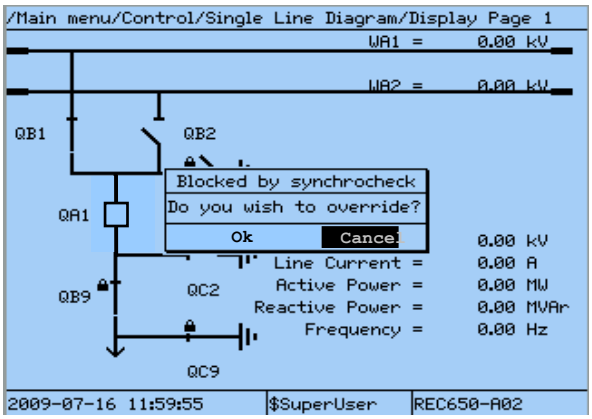
In normal security, the command is processed and the resulting position is not supervised. However with enhanced security, the command is processed and the resulting position is supervised.

Control operation can be performed from the local HMI under authority control if so defined.



ANSI09000668-1-en.vsd

Figure 6. Select before operation with confirmation of command



ANSI09000669-1-en.vsd

Figure 7. Overriding of synchrocheck

The switch controller SCSWI initializes and supervises all functions to properly select and operate switching primary apparatuses. Each of the 8 switch controllers SCSWI may handle and operate on one three-phase apparatus.

Each of the 3 circuit breaker controllers SXCBR provides the actual position status and pass the commands to the primary circuit breaker and supervises the switching operation and positions.

Each of the 7 circuit switch controllers SXSWI provides the actual position status and pass the commands to the primary disconnectors and earthing switches and supervises the switching operation and positions.

Interlocking

The interlocking functionality blocks the possibility to operate high-voltage switching devices, for instance when a disconnector is under load, in order to prevent material damage and/or accidental human injury.

Each control IED has interlocking functions for different switchyard arrangements, each handling the interlocking of one bay. The interlocking functionality in each IED is not dependent on any central function. For the station-wide interlocking, the IEDs communicate via the station bus or by using hard wired binary inputs/outputs.

The interlocking conditions depend on the primary bus configuration and status of any breaker or switch at any given time.

Bay control QCBAY

The Bay control QCBAY function is used together with Local remote and local remote control functions to handle the selection of the operator place per bay. QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay.

Local remote LOCREM /Local remote control LOCREMCTRL

The signals from the local HMI or from an external local/remote switch are applied via the function blocks LOCREM and LOCREMCTRL to the Bay control QCBAY function block. A parameter in function block LOCREM is set to choose if the switch signals are coming from the local HMI or from an external hardware switch connected via binary inputs.

Voltage control TR8ATCC (90) and TCMYLTC (84)

Automatic voltage control for tap changer TR8ATCC (90) and Tap changer control and supervision, 6 binary inputs TCMYLTC (84) are used for control of power transformers with a on-load tap changer. The functions provide automatic regulation of the voltage on the secondary side of transformers or alternatively on a load point further out in the network.

Control of a single transformer, as well as control of up to two transformers within a single RET650, or parallel control of up to four transformers in two or even four separate RET650 is possible. Note that the last alternative is achieved by using the GOOSE interbay communication on the IEC 61850-8-1 protocol. For parallel control of power transformers, three alternative methods are available, the master-follower method, the circulating current method and the reverse reactance method.

In RET650 a local HMI page with voltage control status and manual control possibilities is available. Manual control is under authority control if so defined.

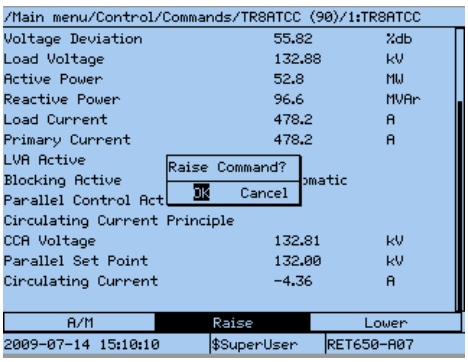


Figure 8. Manual control via local HMI

Voltage control includes many extra features such as possibility of to avoid simultaneous tapping of parallel transformers, extensive tap changer monitoring including contact wear and hunting detection, monitoring of the power flow in the transformer so that for example, the voltage control can be blocked if the power reverses etc.

In manual operating mode it is possible to give raise- or lower-commands to the load tap changer from the local HMI. Such facilities are pre-defined in the factory.

Circuit breaker control for circuit breakers, CBC2, CBC3 and CBC4

The CBC2, CBC 3 and CBC4 consists of 3 functions each:

- **SCILO** - The Logical node for interlocking. SCILO function contains the logic to enable a switching operation, and provides the information to SCSWI wether it is permitted to operate due to actual switchyard topology. The interlocking conditions are generated in separate function blocks containing the interlocking logic.
- **SCSWI** - The Switch controller initializes and supervises all functions to properly select and operate switching primary apparatuses. The Switch controller may handle and operate on one three-phase device.
- **SXCBR** - The circuit breaker controller SXCBR provides the actual position status and pass the commands to the primary circuit breaker and supervises the switching operation and positions.

Logic rotating switch for function selection and LHMI presentation SLGGIO

The logic rotating switch for function selection and LHMI presentation SLGGIO (or the selector switch function block) is used to get an enhanced selector switch functionality compared to the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and an extended purchase portfolio. The logic selector switches eliminate all these problems.

Selector mini switch VSGGIO

The Selector mini switch VSGGIO function block is a multipurpose function used for a variety of applications, as a general purpose switch.

VSGGIO can be controlled from the menu or from a symbol on the single line diagram (SLD) on the local HMI.

IEC 61850 generic communication I/O functions DPGGIO

The IEC 61850 generic communication I/O functions DPGGIO function block is used to send double indications to other systems or equipment in the substation using IEC61850. It is especially used in the interlocking and reservation station-wide logics.

Single point generic control 8 signals SPC8GGIO

The Single point generic control 8 signals SPC8GGIO function block is a collection of 8 single point commands, designed to bring in commands from REMOTE (SCADA) to those parts of the logic configuration that do not need extensive command receiving functionality (for example, SCSWI). In this way, simple commands can be sent directly to the IED outputs, without confirmation. The commands can be pulsed or steady with a settable pulse time.

AutomationBits AUTOBITS

The Automation bits function AUTOBITS is used to configure the DNP3 protocol command handling. Each of the 3 AUTOBITS available has 32 individual outputs available, each can be mapped as a binary output point in DNP3.

Function commands for IEC60870-5-103, I103CMD, I103IEDCMD, I103URSCMD, I103GENCMD, I103POSCMD

IEC60870–5–103 function and command logic blocks are available for configuration of the IED. The output signals are predefined or user defined depending on selected function block.

11. Logic

Tripping logic common 3-phase output SMPPTRC (94)

A function block for protection tripping is provided for each circuit breaker involved in the tripping of the fault. It provides a settable pulse prolongation to ensure a three-phase trip pulse of sufficient length, as well as all functionality necessary for correct co-operation with autoreclosing functions.

The trip function block also includes a settable latch functionality for breaker lock-out.

Trip matrix logic TMAGGIO

The 12 Trip matrix logic TMAGGIO function each with 32 inputs are used to route trip signals and other logical output signals to the tripping logics SMPPTRC and SPTPTRC or to different output contacts on the IED.

TMAGGIO 3 output signals and the physical outputs allows the user to adapt the signals to the physical tripping outputs according to the specific application needs for settable pulse or steady output.

Configurable logic blocks

A number of logic blocks and timers are available for the user to adapt the configuration to the specific application needs.

- **OR** function block. Each block has 6 inputs and two outputs where one is inverted.
- **INVERTER** function blocks that inverts the input signal.
- **PULSETIMER** function block can be used, for example, for pulse extensions or limiting of operation of outputs, settable pulse time.
- **GATE** function block is used for whether or not a signal should be able to pass from the input to the output.
- **XOR** function block. Each block has two outputs where one is inverted.
- **LOOPDELAY** function block used to delay the output signal one execution cycle.
- **TIMERSET** function has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay and must be Enabled for the input signal to activate the output with the appropriate time delay.
- **AND** function block. Each block has four inputs and two outputs where one is inverted
- **SRMEMORY** function block is a flip-flop that can set or reset an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block's output should reset or return to the state it was, after a power interruption. The SET input has priority if both SET and RESET inputs are operated simultaneously.
- **RSMEMORY** function block is a flip-flop that can reset or set an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block's output should reset or return to the state it was, after a power interruption. The RESET input has priority if both SET and RESET are operated simultaneously.

Configurable logic Q/T

A number of logic blocks and timers, with the capability to propagate timestamp and quality of the input signals, are available. The function blocks assist the user to adapt the IEDs configuration to the specific application needs.

- **ORQT** OR function block that also propagates timestamp and quality of input signals. Each block has six inputs and two outputs where one is inverted.
- **INVERTERQT** function block that inverts the input signal and propagates timestamp and quality of input signal.
- **PULSETIMERQT** Pulse timer function block can be used, for example, for pulse extensions or limiting of operation of outputs. The function also propagates timestamp and quality of input signal.
- **XORQT** XOR function block. The function also propagates timestamp and quality of input signals. Each block has two outputs where one is inverted.
- **TIMERSETQT** function has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay. The function also propagates timestamp and quality of input signal.
- **ANDQT** AND function block. The function also propagates timestamp and quality of input signals. Each block has four inputs and two outputs where one is inverted.
- **SRMEMORYQT** function block is a flip-flop that can set or reset an output from two inputs respectively. Each block has two outputs where one is inverted. The

memory setting controls if the block after a power interruption should return to the state before the interruption, or be reset. The function also propagates timestamp and quality of input signal.

- **RSMEMORYQT** function block is a flip-flop that can reset or set an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block after a power interruption should return to the state before the interruption, or be reset. The function also propagates timestamp and quality of input signal.
- **INVALIDQT** function which sets quality invalid of outputs according to a "valid" input. Inputs are copied to outputs. If input VALID is 0, or if its quality invalid bit is set, all outputs invalid quality bit will be set to invalid. The timestamp of an output will be set to the latest timestamp of INPUT and VALID inputs.
- **INDCOMBSPQT** combines single input signals to group signal. Single position input is copied to value part of SP_OUT output. TIME input is copied to time part of SP_OUT output. Quality input bits are copied to the corresponding quality part of SP_OUT output.
- **INDEXTSPQT** extracts individual signals from a group signal input. Value part of single position input is copied to SI_OUT output. Time part of single position input is copied to TIME output. Quality bits in common part and indication part of inputs signal is copied to the corresponding quality output.

Fixed signal function block

The Fixed signals function FXDSIGN generates nine pre-set (fixed) signals that can be used in the configuration of an IED, either for forcing the unused inputs in other function blocks to a certain level/value, or for creating certain logic. Boolean, integer, floating point, string types of signals are available.

Boolean 16 to Integer conversion B16I

Boolean 16 to integer conversion function B16I is used to transform a set of 16 binary (logical) signals into an integer.

Boolean 16 to Integer conversion with logic node representation B16IFCVI

Boolean 16 to integer conversion with logic node representation function B16IFCVI is used to transform a set of 16 binary (logical) signals into an integer. The block input will freeze the output at the last value.

Integer to Boolean 16 conversion IB16A

Integer to boolean 16 conversion function IB16A is used to transform an integer into a set of 16 binary (logical) signals.

Integer to Boolean 16 conversion with logic node representation IB16FCVB

Integer to boolean conversion with logic node representation function IB16FCVB is used to transform an integer to 16 binary (logic) signals.

IB16FCVB function can receive remote values over IEC61850 when the operator position input PSTO is in position remote. The block input will freeze the output at the last value.

Elapsed time integrator with limit transgression and overflow supervision TEIGGIO

The function TEIGGIO is used for user defined logics and it can also be used for different purposes internally in the IED . An application example is the integration of elapsed time during the measurement of neutral point voltage or neutral current at earth fault conditions.

Settable time limits for warning and alarm are provided. The time limit for overflow indication is fixed.

12. Monitoring

IEC61850 generic communication I/O function SPGGIO

IEC61850 generic communication I/O functions SPGGIO is used to send one single logical signal to other systems or equipment in the substation.

IEC61850 generic communication I/O function 16 inputs SP16GGIO

IEC 61850 generic communication I/O functions 16 inputs SP16GGIO function is used to send up to 16 logical signals to other systems or equipment in the substation.

Measurements CVMMXN, CMMXU, VNMMXU, VMMXU, CMSQI, VMSQI

The measurement functions are used to get on-line information from the IED. These service values make it possible to display on-line information on the local HMI and on the Substation automation system about:

- measured voltages, currents, frequency, active, reactive and apparent power and power factor
- primary and secondary phasors
- current sequence components
- voltage sequence components

Event counter CNTGGIO
Event counter CNTGGIO has six counters which are used for storing the number of times each counter input has been activated.

Event counter with limit supervison L4UFCNT
The 12 Up limit counter L4UFCNT provides a settable counter with four independent limits where the number of positive and/or negative flanks on the input signal are counted against the setting values for limits. The output for each limit is activated when the counted value reaches that limit.

Overflow indication is included for each up-counter.

Disturbance report DRPRDRE
Complete and reliable information about disturbances in the primary and/or in the secondary system together with continuous event-logging is accomplished by the disturbance report functionality.

Disturbance report DRPRDRE, always included in the IED, acquires sampled data of all selected analog input and binary signals connected to the function block with a, maximum of 40 analog and 96 binary signals.

The Disturbance report functionality is a common name for several functions:

- Sequential of events
- Indications
- Event recorder
- Trip value recorder
- Disturbance recorder

The Disturbance report function is characterized by great flexibility regarding configuration, initiating conditions, recording times, and large storage capacity.

A disturbance is defined as an activation of an input to the AnRADR or BnRBDR function blocks, which are set to trigger the disturbance recorder. All connected signals from start of pre-fault time to the end of post-fault time will be included in the recording.

Every disturbance report recording is saved in the IED in the standard Comtrade format as a reader file HDR, a configuration file CFG, and a data file DAT. The same applies to all events, which are continuously saved in a FIFO-buffer. The local HMI is used to get information about the recordings. The disturbance report files may be uploaded to PCM600 for further analysis using the disturbance handling tool.

Sequential of events DRPRDRE
Continuous event-logging is useful for monitoring the system from an overview perspective and is a complement to specific disturbance recorder functions.

The sequential of events logs all binary input signals connected to the Disturbance recorder function. The list may contain up to 1000 time-tagged events stored in a FIFO-buffer.

Indications DRPRDRE
To get fast, condensed and reliable information about disturbances in the primary and/or in the secondary system it is important to know, for example binary signals that have changed status during a disturbance. This information is used in the short perspective to get information via the local HMI in a straightforward way.

There are three LEDs on the local HMI (green, yellow and red), which will display status information about the IED and the Disturbance recorder function (triggered).

The Indication list function shows all selected binary input signals connected to the Disturbance recorder function that have changed status during a disturbance.

Event recorder DRPRDRE
Quick, complete and reliable information about disturbances in the primary and/or in the secondary system is vital, for example, time-tagged events logged during disturbances. This information is used for different purposes in the short term (for example corrective actions) and in the long term (for example functional analysis).

The event recorder logs all selected binary input signals connected to the Disturbance recorder function. Each recording can contain up to 150 time-tagged events.

The event recorder information is available for the disturbances locally in the IED.

The event recording information is an integrated part of the disturbance record (Comtrade file).

Trip value recorder DRPRDRE
Information about the pre-fault and fault values for currents and voltages are vital for the disturbance evaluation.

The Trip value recorder calculates the values of all selected analog input signals connected to the Disturbance recorder function. The result is magnitude and phase

angle before and during the fault for each analog input signal.

The trip value recorder information is available for the disturbances locally in the IED.

The trip value recorder information is an integrated part of the disturbance record (Comtrade file).

Disturbance recorder DRPRDRE

The Disturbance recorder function supplies fast, complete and reliable information about disturbances in the power system. It facilitates understanding system behavior and related primary and secondary equipment during and after a disturbance. Recorded information is used for different purposes in the short perspective (for example corrective actions) and long perspective (for example functional analysis).

The Disturbance recorder acquires sampled data from selected analog- and binary signals connected to the Disturbance recorder function (maximum 40 analog and 96 binary signals). The binary signals available are the same as for the event recorder function.

The function is characterized by great flexibility and is not dependent on the operation of protection functions. It can record disturbances not detected by protection functions. Up to 9,9 seconds of data before the trigger instant can be saved in the disturbance file.

The disturbance recorder information for up to 100 disturbances are saved in the IED and the local HMI is used to view the list of recordings.

Measured value expander block MVEXP

The current and voltage measurements functions (CVMMXN, CMMXU, VMMXU and VNMMXU), current and voltage sequence measurement functions (CMSQI and VMSQI) and IEC 61850 generic communication I/O functions (MVGGIO) are provided with measurement supervision functionality. All measured values can be supervised with four settable limits: low-low limit, low limit, high limit and high-high limit. The measure value expander block MVEXP has been introduced to enable translating the integer output signal from the measuring functions to 5 binary signals: below low-low limit, below low limit, normal, above high limit or above high-high limit. The output signals can be used as conditions in the configurable logic or for alarming purpose.

Station battery supervision SPVNZBAT

The station battery supervision function SPVNZBAT is used for monitoring battery terminal voltage.

SPVNZBAT activates the start and alarm outputs when the battery terminal voltage exceeds the set upper limit or drops below the set lower limit. A time delay for the overvoltage and undervoltage alarms can be set according to definite time characteristics.

SPVNZBAT operates after a settable operate time and resets when the battery undervoltage or overvoltage condition disappears after settable reset time.

Insulation gas monitoring function SSIMG

Insulation gas monitoring function SSIMG (63) is used for monitoring the circuit breaker condition. Binary information based on the gas pressure in the circuit breaker is used as input signals to the function. In addition, the function generates alarms based on received information.

Insulation liquid monitoring function SSIML

Insulation liquid monitoring function SSIML (71) is used for monitoring the circuit breaker condition. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition, the function generates alarms based on received information.

Circuit breaker monitoring SSCBR

The circuit breaker condition monitoring function SSCBR is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. For proper functioning of the circuit breaker, it is essential to monitor the circuit breaker operation, spring charge indication, breaker wear, travel time, number of operation cycles and accumulated energy. The energy is calculated from the measured input currents as a sum of I^2 t values. Alarms are generated when the calculated values exceed the threshold settings.

The function contains a block alarm functionality.

The supervised and presented breaker functions include

- breaker open and close travel time
- spring charging time
- number of breaker operations
- accumulated $I^Y t$ per phase with alarm and lockout
- remaining breaker life per phase
- breaker inactivity

13. Metering

Pulse counter logic PCGGIO

Pulse counter (PCGGIO) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the BIO (binary input/output) module and then read by the PCGGIO function. A scaled service value is available over the station bus.

Function for energy calculation and demand handling ETPMMTR

Outputs from the Measurements (CVMMXN) function can be used to calculate energy consumption. Active as well as reactive values are calculated in import and export direction. Values can be read or generated as pulses. Maximum demand power values are also calculated by the function.

14. Human Machine interface

Local HMI

Figure 9. Local human-machine interface

The LHMI of the IED contains the following elements:

- Display (LCD)
- Buttons
- LED indicators
- Communication port for PCM600

The LHMI is used for setting, monitoring and controlling.

The Local human machine interface, LHMI includes a graphical monochrome LCD with a resolution of 320x240 pixels. The character size may vary depending on selected language. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

The LHMI is simple and easy to understand. The whole front plate is divided into zones, each with a well-defined functionality:

- Status indication LEDs
- Alarm indication LEDs which can indicate three states with the colors green, yellow and red, with user defined and also printable label. All LEDs are configurable from the PCM600 tool
- Liquid crystal display (LCD)
- Keypad with push buttons for control and navigation purposes, switch for selection between local and remote control and reset
- Five user programmable function buttons
- An isolated RJ45 communication port for PCM600

15. Basic IED functions

Self supervision with internal event list

The Self supervision with internal event list INTERRSIG and SELFSUPEVLST function reacts to internal system events generated by the different built-in self-supervision elements. The internal events are saved in an internal event list presented on the LHMI and in PCM600 event viewer tool.

Time synchronization

Use a common global source for example GPS time synchronization inside each substation as well as inside the area of the utility responsibility to achieve a common time base for the IEDs in a protection and control system. This makes comparison and analysis of events and disturbance data between all IEDs in the power system possible.

Time-tagging of internal events and disturbances are an excellent help when evaluating faults. Without time synchronization, only the events within the IED can be compared to one another. With time synchronization, events and disturbances within the entire station, and even between line ends, can be compared during evaluation.

In the IED, the internal time can be synchronized from a number of sources:

- SNTP
- IRIG-B
- DNP
- IEC60870-5-103

Parameter setting groups ACTVGRP

Use the four different groups of settings to optimize the IED operation for different power system conditions. Creating and switching between fine-tuned setting sets, either from the local HMI or configurable binary inputs, results in a highly adaptable IED that can be applied to a variety of power system scenarios.

Test mode functionality TESTMODE

The protection and control IEDs may have many included functions. To make the testing procedure easier, the IEDs include the feature that allows individual blocking of all functions except the function(s) the shall be tested.

There are two ways of entering the test mode:

- By configuration, activating an input signal of the function block TESTMODE
- By setting the IED in test mode in the local HMI

While the IED is in test mode, all protection functions are blocked.

Any function can be unblocked individually regarding functionality and event signaling. This enables the user to follow the operation of one or several related functions to check functionality and to check parts of the configuration, and so on.

Forcing of binary outputs, wether from the LHMI or from the PCM600 is only possible when the IED is in test mode.

Change lock function CHNGLCK

Change lock function CHNGLCK is used to block further changes to the IED configuration and settings once the commissioning is complete. The purpose is to block inadvertent IED configuration changes beyond a certain point in time.

The change lock function activation is normally connected to a binary input.

Authorization

The user categories and roles with user rights as defined by IEC 62359–8 for role based access control are pre-defined in the IED.

The IED users can be created, deleted and edited only with PCM600.

Password policies are set in the PCM600 IED user management tool.

At delivery, the IED user has full access as SuperUser until users are created with PCM600.

Authority status ATHSTAT

Authority status ATHSTAT function is an indication function block for user log-on activity.

User denied attempt to log-on and user successful log-on are reported.

Authority check ATHCHCK

To safeguard the interests of our customers, both the IED and the tools that are accessing the IED are protected, by means of authorization handling. The authorization handling of the IED and the PCM600 is implemented at both access points to the IED:

- local, through the local HMI
- remote, through the communication ports

The IED users can be created, deleted and edited only with PCM600 IED user management tool.

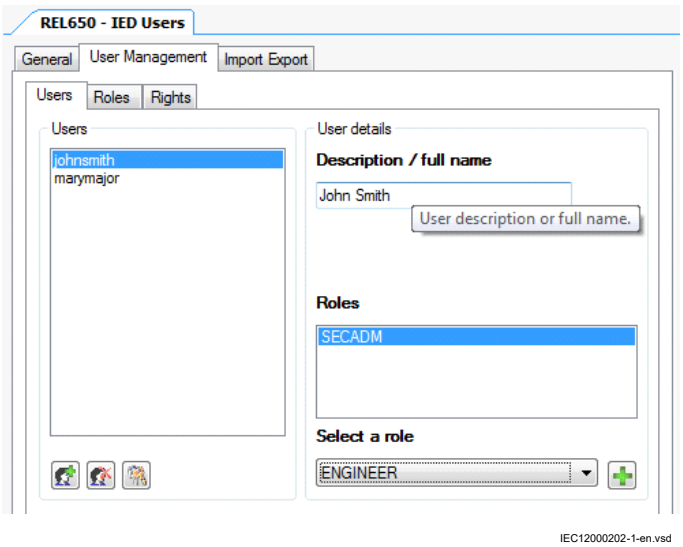


Figure 10. PCM600 user management tool

AUTHMAN

This function enables/disables the maintenance menu. It also controls the maintenance menu log on time out.

FTP access with SSL FTPACCS

The FTP Client defaults to the best possible security mode when trying to negotiate with SSL.

The automatic negotiation mode acts on port number and server features. It tries to immediately activate implicit SSL if the specified port is 990. If the specified port is any

other, it tries to negotiate with explicit SSL via AUTH SSL/TLS.

Using FTP without SSL encryption gives the FTP client reduced capabilities. This mode is only for accessing disturbance recorder data from the IED.

If normal FTP is required to read out disturbance recordings, create a specific account for this purpose with rights only to do File transfer. The password of this user will be exposed in clear text on the wire.

Generic security application AGSAL

As a logical node AGSAL is used for monitoring security violation regarding authorization, access control and inactive association including authorization failure. Therefore, all the information in AGSAL can be configured to report to 61850 client.

Activity logging ACTIVLOG

ACTIVLOG contains all settings for activity logging.

There can be 6 external log servers to send syslog events to. Each server can be configured with IP address; IP port number and protocol format. The format can be either syslog (RFC 5424) or Common Event Format (CEF) from ArcSight.

Security alarm SECALARM

The function creates and distributes security events for mapping the security events on protocols such as DNP3.

It is possible to map respective protocol to the signals of interest and configure them for monitoring with the Communication Management tool (CMT) in PCM600. No events are mapped by default.

Parameter names:

- EVENTID: Event ID of the generated security event
- SEQNUMBER: Sequence number of the generated security event

Security events

All user operations are logged as events. These events can be sent to external security log servers using SYSLOG data formats. The log servers can be configured using PCM600.

16. Station communication

IEC 61850-8-1 communication protocol

The IED supports the communication protocols IEC 61850-8-1 and DNP3 over TCP/IP. All operational information and controls are available through these protocols. However, some communication functions, for example, horizontal communication (GOOSE) between the IEDs, is only enabled by the IEC 61850-8-1 communication protocol.

The IED is equipped with optical Ethernet rear port(s) for the substation communication standard IEC 61850-8-1. IEC 61850-8-1 protocol allows intelligent electrical devices (IEDs) from different vendors to exchange information and simplifies system engineering. Peer-to-peer communication according to GOOSE is part of the standard. Disturbance files uploading is provided.

Disturbance files are accessed using the IEC 61850-8-1 protocol. Disturbance files are also available to any Ethernet based application via FTP in the standard Comtrade format. Further, the IED can send and receive binary values, double point values and measured values (for example from MMXU functions), together with their quality bit, using the IEC 61850-8-1 GOOSE profile. The IED meets the GOOSE performance requirements for tripping applications in substations, as defined by the IEC 61850 standard. The IED interoperates with other IEC 61850-compliant IEDs, and systems and simultaneously reports events to five different clients on the IEC 61850 station bus.

The Denial of Service functions DOSLAN1 and DOSFRNT are included to limit the inbound network traffic. The communication can thus never compromise the primary functionality of the IED.

The event system has a rate limiter to reduce CPU load. The event channel has a quota of 10 events/second after the initial 30 events/second. If the quota is exceeded the event channel transmission is blocked until the event changes is below the quota, no event is lost.

All communication connectors, except for the front port connector, are placed on integrated communication modules. The IED is connected to Ethernet-based communication systems via the fibre-optic multimode LC connector(s) (100BASE-FX).

The IED supports SNTP and IRIG-B time synchronization methods with a time-stamping accuracy of ±1 ms.

- Ethernet based: SNTP and DNP3
- With time synchronization wiring: IRIG-B

The IED supports IEC 60870-5-103 time synchronization methods with a time stamping accuracy of ±5 ms.

Table 1. Supported station communication interfaces and protocols

Protocol	Ethernet	Serial	
	100BASE-FX LC	Glass fibre (ST connector)	EIA-485
IEC 61850–8–1	●	-	-
DNP3	●	●	●
IEC 60870-5-103	-	●	●

● = Supported

Horizontal communication via GOOSE for interlocking

GOOSE communication can be used for exchanging information between IEDs via the IEC 61850-8-1 station communication bus. This is typically used for sending apparatus position indications for interlocking or reservation signals for 1-of-n control. GOOSE can also be used to exchange any boolean, integer, double point and analog measured values between IEDs.

DNP3 protocol

DNP3 (Distributed Network Protocol) is a set of communications protocols used to communicate data between components in process automation systems. For a detailed description of the DNP3 protocol, see the DNP3 Communication protocol manual.

IEC 60870-5-103 communication protocol

IEC 60870-5-103 is an unbalanced (master-slave) protocol for coded-bit serial communication exchanging information with a control system, and with a data transfer rate up to 19200 bit/s. In IEC terminology, a primary station is a master and a secondary station is a slave. The communication is based on a point-to-point principle. The master must have software that can interpret IEC 60870-5-103 communication messages.

IEC 60870-5-103 protocol can be configured to use either the optical serial or RS485 serial communication interface on the COM03 or the COM05 communication module. The functions Operation selection for optical serial OPTICALPROT and Operation selection for RS485 RS485PROT are used to select the communication interface.

The function IEC60870-5-103 Optical serial communication, OPTICAL103, is used to configure the communication parameters for the optical serial communication interface. The function IEC60870-5-103 serial communication for RS485, RS485103, is used to configure the communication parameters for the RS485 serial communication interface.

IEC 62439-3 Parallel Redundancy Protocol

Redundant station bus communication according to IEC 62439-3 Edition 2 is available as option in the Customized 650 Ver 1.3 series IEDs, and the selection is made at ordering. Redundant station bus communication according to IEC 62439-3 Edition 2 uses both ports LAN1A and LAN1B on the COM03 module.

Select COM03 for redundant station bus according to IEC 62439-3 Edition 2 protocol, at the time of ordering.
IEC 62439-3 Edition 2 is NOT compatible with IEC 62439-3 Edition 1.

17. Hardware description

Layout and dimensions

Mounting alternatives

- 19” rack mounting kit

See ordering for details about available mounting alternatives.

Rack mounting a single 3U IED

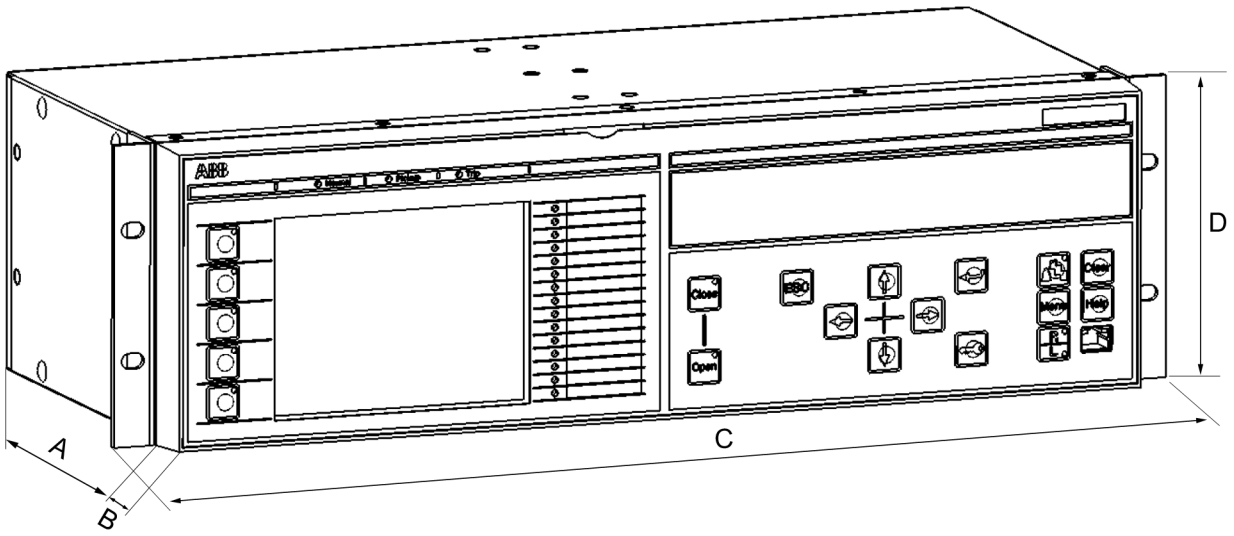


Figure 11. Rack mounted 3U IED

A 8.82 inches (224 mm) + 0.47 inches (12 mm) with ring-lug connectors

B 1 inches (22.5 mm)

C 19 inches (482 mm)

D 5.20 inches, 3U (132 mm)

18. Connection diagrams

Connection diagrams

The connection diagrams are delivered on the IED Connectivity package DVD as part of the product delivery.

The latest versions of the connection diagrams can be downloaded from http://www.abb.com/substationautomation.

Connection diagrams for Customized products

Connection diagram, 650 series 1.3 1MRK006502-AD

Connection diagrams for Configured products

Connection diagram, RET650 1.3, (2W/1CB) A01A
1MRK006502-GD

Connection diagram, RET650 1.3, (3W/1CB) A05A
1MRK006502-FD

Connection diagram, RET650 1.3, (2OLTCControl) A07A
1MRK006502-ED

19. Technical data

General

Definitions	
Reference value	The specified value of an influencing factor to which are referred the characteristics of the equipment
Nominal range	The range of values of an influencing quantity (factor) within which, under specified conditions, the equipment meets the specified requirements
Operative range	The range of values of a given energizing quantity for which the equipment, under specified conditions, is able to perform its intended functions according to the specified requirements

Presumptions for technical data
The technical data stated in this document are only valid under the following circumstances:

- CT and VT ratios in the IED are set in accordance with the associated main instrument transformers. Note that for functions which measure an analogue signal which do not have corresponding primary quantity, the 1:1 ratio shall be set for the used analogue inputs on the IED, For example, HZPDIF.
- Parameter IBase used by the tested function is set equal to the rated CT primary current.
- Parameter UBase used by the tested function is set equal to the rated primary phase-to-phase voltage.
- Parameter SBase used by the tested function is set equal to sqrt(3)* IBase* UBase for three-phase power system.

Energizing quantities, rated values and limits

Analog inputs

Table 2. TRM — Energizing quantities, rated values and limits for transformer inputs

Description	Value	
Frequency		
Rated frequency f_r	50 or 60 Hz	
Operating range	f_r ± 10%	
Current inputs		
Rated current I_r	0.1 or 0.5 A[1)]	1 or 5 A[2)]
Operating range	0 – 50 A	0 – 500 A
Thermal withstand	100 A for 1 s 20 A for 10 s 8 A for 1 min 4 A continuously	500 A for 1 s [*)] 100 A for 10 s 40 A for 1 min 20 A continuously
Dynamic withstand	250 A one half wave	1250 A one half wave
Burden	< 1 mVA at I_r = 0.1 A < 20 mVA at I_r = 0.5 A	< 10 mVA at I_r = 1 A < 200 mVA at I_r = 5 A
[*)] max. 350 A for 1 s when COMBITEST test switch is included.		
Voltage inputs[**)]		
Rated voltage V_r	100 or 220 V	
Operating range	0 – 420 V	
Thermal withstand	450 V for 10 s 420 V continuously	
Burden	< 50 mVA at 100 V < 200 mVA at 220 V	
[**)] all values for individual voltage inputs		
Note! All current and voltage data are specified as RMS values at rated frequency		

1) Residual current
2) Phase currents or residual current

Auxiliary AC and DC voltage

Table 3. Power supply

Description	600PSM01	600PSM02	600PSM03
V_n	24, 30 V DC	48, 60, 110, 125 V DC	100, 110, 120, 220, 240 V AC, 50 and 60 Hz
			110, 125, 220, 250 V DC
$V_n$variation	80...120% of V_n (24...30 V DC)	80...120% of V_n (38.4...150 V DC)	85...110% of V_n (85...264 V AC)
			80...120% of V_n (88...300 V DC)
Maximum load of auxiliary voltage supply	35 W for DC 40 VA for AC		
Ripple in the DC auxiliary voltage	Max 15% of the DC value (at frequency of 100 and 120 Hz)		
Maximum interruption time in the auxiliary DC voltage without resetting the IED	50 ms at V_n		
Resolution of the voltage measurement in PSM module	1 bit represents 0,5 V (+/- 1 VDC)	1 bit represents 1 V (+/- 1 VDC)	1 bit represents 2 V (+/- 1 VDC)

Binary inputs and outputs

Table 4. Binary inputs

Description	Value
Operating range	Maximum input voltage 300 V DC
Rated voltage	24...250 V DC
Current drain	1.6...1.8 mA
Power consumption/input	<0.38 W
Threshold voltage	15...221 V DC (parametrizable in the range in steps of 1% of the rated voltage)

Table 5. Signal output and IRF output

IRF relay change over - type signal output relay	
Description	**Value**
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A
Make and carry 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at V< 48/110/220 V DC	≤0.5 A/≤0.1 A/≤0.04 A

Table 6. Power output relays without TCM function

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at V< 48/110/220 V DC	≤1 A/≤0.3 A/≤0.1 A

Table 7. Power output relays with TCM function

Description	Value
Rated voltage	250 V DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at V< 48/110/220 V DC	≤1 A/≤0.3 A/≤0.1 A
Control voltage range	20...250 V DC
Current drain through the monitoring circuit	~1.0 mA
Minimum voltage over the TCS contact	20 V DC

Table 8. Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
100BASE-TX	-	CAT 6 S/FTP or better	100 MBits/s
100BASE-FX	TCP/IP protocol	Fibre-optic cable with LC connector	100 MBits/s

Table 9. Fibre-optic communication link

Wave length	Fibre type	Connector	Permitted path attenuation[1)]	Distance
1300 nm	MM 62.5/125 µm glass fibre core	LC	<8 dB	2 km

1) Maximum allowed attenuation caused by connectors and cable together

Table 10. X8/IRIG-B and EIA-485 interface

Type	Protocol	Cable
Tension clamp connection	IRIG-B	Shielded twisted pair cable Recommended: CAT 5, Belden RS-485 (9841- 9844) or Alpha Wire (Alpha 6222-6230)
Tension clamp connection	IEC 68070–5–103 DNP3.0	Shielded twisted pair cable Recommended: DESCAFLEX RD-H(ST)H-2x2x0.22mm^2, Belden 9729, Belden 9829

Table 11. IRIG-B

Type	Value	Accuracy
Input impedance	430 Ohm	-
Minimum input voltage HIGH	4.3 V	-
Maximum input voltage LOW	0.8 V	-

Table 12. EIA-485 interface

Type	Value	Conditions
Minimum differential driver output voltage	1.5 V	–
Maximum output current	60 mA	-
Minimum differential receiver input voltage	0.2 V	-
Supported bit rates	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	-
Maximum number of 650 IEDs supported on the same bus	32	-
Max. cable length	925 m (3000 ft)	Cable: AWG24 or better, stub lines shall be avoided

Table 13. Serial rear interface

Type	Counter connector
Serial port (X9)	Optical serial port, type ST for IEC 60870-5-103 and DNP serial

Table 14. Optical serial port (X9)

Wave length	Fibre type	Connector	Permitted path attenuation[1)]
820 nm	MM 62,5/125 µm glass fibre core	ST	6.8 dB (approx. 1700m length with 4 db / km fibre attenuation)
820 nm	MM 50/125 µm glass fibre core	ST	2.4 dB (approx. 600m length with 4 db / km fibre attenuation)

1) Maximum allowed attenuation caused by fibre

Influencing factors

Ingress protection

Table 15. Ingress protection

Description	Value
IED front	IP 54
IED rear	IP 20
IED sides	IP 40
IED top	IP 40
IED bottom	IP 20

Table 16. Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)
Short-time service temperature range	-40...+70ºC (<16h) Note: Degradation in MTBF and HMI performance outside the temperature range of -25...+55ºC
Relative humidity	<93%, non-condensing
Atmospheric pressure	12.47...15.37 psi (86...106 kPa)
Altitude	up to 6561.66 feet (2000 m)
Transport and storage temperature range	-40...+85ºC

Table 17. Environmental tests

Description		Type test value	Reference
Cold tests	operation	96 h at -25ºC 16 h at -40ºC	IEC 60068-2-1/ANSI C37.90-2005 (chapter 4)
	storage	96 h at -40ºC	
Dry heat tests	operation	16 h at +70ºC	IEC 60068-2-2/ANSI C37.90-2005 (chapter 4)
	storage	96 h at +85ºC	
Damp heat tests	steady state	240 h at +40ºC humidity 93%	IEC 60068-2-78
	cyclic	6 cycles at +25 to +55ºC humidity 93...95%	IEC 60068-2-30

Type tests according to standards

Table 18. Electromagnetic compatibility tests

Description	Type test value	Reference
100 kHz and 1 MHz burst disturbance test		IEC 61000-4-18, level 3 IEC 60255-22-1 ANSI C37.90.1-2012
• Common mode	2.5 kV	
• Differential mode	2.5 kV	
Electrostatic discharge test		IEC 61000-4-2, level 4 IEC 60255-22-2 ANSI C37.90.3-2001
• Contact discharge	8 kV	
• Air discharge	15 kV	
Radio frequency interference tests		
• Conducted, common mode	10 V (emf), f=150 kHz...80 MHz	IEC 61000-4-6 , level 3 IEC 60255-22-6
• Radiated, amplitude-modulated	20 V/m (rms), f=80...1000 MHz and f=1.4...2.7 GHz	IEC 61000-4-3, level 3 IEC 60255-22-3 ANSI C37.90.2-2004
Fast transient disturbance tests		IEC 61000-4-4 IEC 60255-22-4, class A ANSI C37.90.1-2012
• Communication ports	4 kV	
• Other ports	4 kV	
Surge immunity test		IEC 61000-4-5 IEC 60255-22-5
• Communication	1 kV line-to-ground	
• Other ports	2 kV line-to-ground, 1 kV line-to-line	
• Power supply	4 kV line-to-ground, 2 kV line-to-line	
Power frequency (50 Hz) magnetic field		IEC 61000-4-8, level 5
• 3 s	1000 A/m	
• Continuous	100 A/m	
Pulse magnetic field immunity test	1000A/m	IEC 61000–4–9, level 5
Damped oscillatory magnetic field	100A/m, 100 kHz and 1MHz	IEC 6100–4–10, level 5
Power frequency immunity test		IEC 60255-22-7, class A IEC 61000-4-16
• Common mode	300 V rms	
• Differential mode	150 V rms	
Voltage dips and short interruptionsc on DC power supply	Dips: 40%/200 ms 70%/500 ms Interruptions: 0-50 ms: No restart 0...∞ s : Correct behaviour at power down	IEC 60255-11 IEC 61000-4-11

Table 18. Electromagnetic compatibility tests, continued

Description	Type test value	Reference
Voltage dips and interruptions on AC power supply	Dips: 40% 10/12 cycles at 50/60 Hz 70% 25/30 cycles at 50/60 Hz Interruptions: 0–50 ms: No restart 0...∞ s: Correct behaviour at power down	IEC 60255–11 IEC 61000–4–11
Electromagnetic emission tests		EN 55011, class A IEC 60255-25 ANSI C63.4, FCC
• Conducted, RF-emission (mains terminal)		
0.15...0.50 MHz	< 79 dB(µV) quasi peak < 66 dB(µV) average	
0.5...30 MHz	< 73 dB(µV) quasi peak < 60 dB(µV) average	
• Radiated RF-emission, ANSI		
30 – 88 MHz	< 39,08 dB(µV/m) quasi peak, measured at 10 m distance	
88 – 216 MHz	< 43,52 dB(µV/m) quasi peak, measured at 10 m distance	
216 – 960 MHz	< 46,44 dB(µV/m) quasi peak, measured at 10 m distance	
960 – 1000 MHz	< 49,54 dB(µV/m) quasi peak, measured at 10 m distance	

Table 19. Insulation tests

Description	Type test value	Reference
Dielectric tests:		IEC 60255-5 ANSI C37.90-2005
• Test voltage	2 kV, 50 Hz, 1 min 1 kV, 50 Hz, 1 min, communication	
Impulse voltage test:		IEC 60255-5 ANSI C37.90-2005
• Test voltage	5 kV, unipolar impulses, waveform 1.2/50 µs, source energy 0.5 J 1 kV, unipolar impulses, waveform 1.2/50 µs, source energy 0.5 J, communication	
Insulation resistance measurements		IEC 60255-5 ANSI C37.90-2005
• Isolation resistance	>100 MΏ, 500 V DC	
Protective bonding resistance		IEC 60255-27
• Resistance	<0.1 Ώ (60 s)	

Table 20. Mechanical tests

Description	Reference	Requirement
Vibration response tests (sinusoidal)	IEC 60255-21-1	Class 1
Vibration endurance test	IEC60255-21-1	Class 1
Shock response test	IEC 60255-21-2	Class 1
Shock withstand test	IEC 60255-21-2	Class 1
Bump test	IEC 60255-21-2	Class 1
Seismic test	IEC 60255-21-3	Class 2

Product safety

Table 21. Product safety

Description	Reference
LV directive	2006/95/EC
Standard	EN 60255-27 (2005)

EMC compliance

Table 22. EMC compliance

Description	Reference
EMC directive	2004/108/EC
Standard	EN 50263 (2000) EN 60255-26 (2007)

Differential protection

Table 23. Transformer differential protection T2WPDIF, T3WPDIF (87T)

Function	Range or value	Accuracy
Operating characteristic	Adaptable	± 1.0% of In for I < In ± 1.0% of I for I > In
Reset ratio	>94%	-
Unrestrained differential current limit	(1.00-50.00)x*IBase* on high voltage winding	± 1.0% of set value
Base sensitivity function	(0.05 - 0.60) x *IBase*	± 1.0% of In
Minimum negative sequence current	(0.02 - 0.20) x *IBase*	± 1.0% of In
Operate angle, negative sequence	(30.0 - 90.0) degrees	± 1.0 degrees
Second harmonic blocking	(5.0-100.0)% of fundamental differential current	± 2.0% of applied harmonic magnitude
Fifth harmonic blocking	(5.0-100.0)% of fundamental differential current	± 12.0% of applied harmonic magnitude
Connection type for each of the windings	Wye or delta	-
Phase displacement between high voltage winding, W1 and each of the windings, W2 and W3. Hour notation	0–11	-
Operate time, restrained function	25 ms typically at 0 to 5 x set level	-
Reset time, restrained function	25 ms typically at 5 to 0 x set level	-
Operate time, unrestrained function	20 ms typically at 0 to 5 x set level	-
Reset time, unrestrained function	25 ms typically at 5 to 0 x set level	-

Table 24. Restricted earth-fault protection, low impedance REFPDIF (87N)

Function	Range or value	Accuracy
Operate characteristic	Adaptable	± 1% of IBase if Ibias < 1.25 IBase (i.e. base sensitivity in section 1 of the operate - restrain characteristic) ± 2% of theoretical operate value (Idiff) if Ibias >= 1.25 IBase (i.e. sections 2 and 3) (The above is valid if IBase is equal to the protected winding rated current.)
Reset ratio	0.95	-
Directional characteristic, for zero sequence directional function	ROA ± 60 to ± 90 degrees	± 1 degrees at Ibias = IBase ± 2 degrees at Ibias = 2 * IBase ± 3 degrees at Ibias = 4 * IBase (The above is valid if IBase is equal to the protected winding rated current.)
Operate time, trip function	25 ms typically at 0 to 10 x IdMin	-
Reset time, trip function	30 ms typically at 10 to 0 x IdMin	-

Table 25. 1Ph High impedance differential protection HZPDIF (87)

Function	Range or value	Accuracy
Operate voltage	(20-400) V I=V/R	± 1.0% of I_n
Reset ratio	>95%	-
Maximum continuous power	V>Pickup^2/SeriesResistor ≤200 W	-
Operate time	10 ms typically at 0 to 10 x V_d	-
Reset time	100 ms typically at 10 to 0 x V_d	-
Critical impulse time	2 ms typically at 0 to 10 x V_d	-

Impedance protection

Table 26. Power swing detection ZMRPSB (68)

Function	Range or value	Accuracy
Reactive reach	(0.10-3000.00) Ω/phase	± 2.0% static accuracy Conditions: Voltage range: (0.1-1.1) x V_n Current range: (0.5-30) x I_n Angle: at 0 degrees and 85 degrees
Resistive reach	(0.10–1000.00) Ω/phase	
Timers	(0.000-60.000) s	± 0.5% ± 10 ms
Minimum operate current	(5-30)% of IBase	± 1.0% of I_n

Table 27. Underimpedance protection for generators and transformers ZGCPDIS (21G)

Function	Range or value	Accuracy
Number of zones	3	-
Forward positive sequence impedance	(0.005-3000.000) Ω/phase	± 2.0% static accuracy Conditions: • Voltage range: (0.1-1.1) x V_n • Current range: (0.5-30) x I_n • Angle: at 85 degrees
Reverse positive sequence impedance	(0.005-3000.000) Ω/phase	-
Angle for positive sequence impedance,	(10-90) degrees	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time	25 ms typically	-
Reset ratio	105% typically	-

Table 28. Load enchroachment LEPDIS

Function	Range or value	Accuracy
Load encroachment criteria: Load resistance, forward and reverse Safety load impedance angle	(1.00–3000.00) Ω/phase (5-85) degrees	± 5.0% static accuracy ± 2.0 degrees static angular accuracy Conditions: Voltage range: (0.1-1.1) x V_n Current range: (0.5-30) x I_n
Reset ratio	105% typically	-

Current protection

Table 29. Instantaneous phase overcurrent protection, 3-phase output PHPIOC (50)

Function	Range or value	Accuracy
Operate current	(5-2500)% of IBase	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio	> 95%	-
Operate time	20 ms typically at 0 to 2 x I_{set}	-
Reset time	30 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Operate time	10 ms typically at 0 to 5 x I_{set}	-
Reset time	40 ms typically at 5 to 0 x I_{set}	-
Critical impulse time	2 ms typically at 0 to 5 x I_{set}	-
Dynamic overreach	< 5% at τ = 100 ms	-

Table 30. Four step phase overcurrent protection, 3-phase output OC4PTOC (51/67)

Function	Setting range	Accuracy
Operate current	(5-2500)% of *IBase*	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio	> 95% at (50–2500)% of *IBase*	-
Min. operating current	(5-10000)% of *IBase*	± 1.0% of I_n at $I \leq I_n$ ±1.0% of I at $I > I_n$
2nd harmonic blocking	(5–100)% of fundamental	± 2.0% of I_n
Independent time delay	(0.000-60.000) s	± 0.5% ±25 ms
Minimum operate time for inverse characteristics	(0.000-60.000) s	± 0.5% ±25 ms
Inverse characteristics, see table 69, table 70 and table 71	15 curve types	[1] ANSI/IEEE C37.112 IEC 60255–151 ±3% or ±40 ms $0.10 \leq k \leq 3.00$ $1.5 \times I_{set} \leq I \leq 20 \times I_{set}$
Operate time, nondirectional pickup function	25 ms typically at 0 to 2 x I_{set}	-
Reset time, pickup function	35 ms typically at 2 to 0 x I_{set}	-
Operate time, directional pickup function	50 ms typically at 0 to 2 x I_{set}	-
Reset time, directional pickup function	35 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Impulse margin time	15 ms typically	-

[1] **Note:** Timing accuracy only valid when 2nd harmonic blocking is turned off

Table 31. Instantaneous residual overcurrent protection EFPIOC (50N)

Function	Range or value	Accuracy
Operate current	(1-2500)% of IBase	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio	> 95%	-
Operate time	20 ms typically at 0 to 2 x I_{set}	-
Reset time	30 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Operate time	10 ms typically at 0 to 5x I_{set}	-
Reset time	40 ms typically at 5 to 0x I_{set}	-
Critical impulse time	2 ms typically at 0 to 5 x I_{set}	-
Dynamic overreach	< 5% at τ = 100 ms	-

Table 32. Four step residual overcurrent protection EF4PTOC (51N/67N)

Function	Range or value	Accuracy
Operate current	(1-2500)% of *IBase*	± 1.0% of I_n at $I < I_n$ ± 1.0% of I at $I > I_n$
Reset ratio	> 95%	-
Operate current for directional comparison, Zero sequence	(1–100)% of *IBase*	± 2.0% of I_n
Operate current for directional comparison, Negative sequence	(1–100)% of *IBase*	± 2.0% of I_n
Min. operating current	(1-10000)% of *IBase*	± 1.0% of I_n at $I < I_n$ ± 1.0% of I at $I > I_n$
Minimum operate time for inverse characteristics	(0.000-60.000) s	± 0.5% ± 25 ms
Timers	(0.000-60.000) s	± 0.5% ±25 ms
Inverse characteristics, see table 69, table 70 and table 71	15 curve types	[1] ANSI/IEEE C37.112 IEC 60255–151 ±3% or ±40 ms $0.10 \le k \le 3.00$ $1.5 \times I_{set} \le I \le 20 \times I_{set}$
Minimum polarizing voltage, Zero sequence	(1–100)% of *VBase*	± 0.5% of V_n
Minimum polarizing voltage, Negative sequence	(1–100)% of *VBase*	± 0.5% of V_n
Minimum polarizing current, Zero sequence	(2–100)% of *IBase*	±1.0% of I_n
Minimum polarizing current, Negative sequence	(2–100)% of *IBase*	±1.0% of I_n
Real part of source Z used for current polarization	(0.50-1000.00) Ω/phase	-
Imaginary part of source Z used for current polarization	(0.50–3000.00) Ω/phase	-
Operate time, non-directional pickup function	30 ms typically at 0.5 to 2 x I_{set}	-
Reset time, non-directional pickup function	30 ms typically at 2 to 0.5 x I_{set}	-
Operate time, directional pickup function	30 ms typically at 0,5 to 2 x I_N	-
Reset time, directional pickup function	30 ms typically at 2 to 0,5 x I_N	-

[1] **Note:** Timing accuracy only valid when 2nd harmonic blocking is turned off.

Table 33. Thermal overload protection, two time constants TRPTTR (49)

Function	Range or value	Accuracy
Base current 1 and 2	(30–250)% of *IBase*	± 1.0% of I_n
Operate time: $t = \tau \cdot ln\left(\frac{I^2 - I_p{}^2}{I^2 - I_{ref}{}^2}\right)$ (Equation 1) I = actual measured current Ip = load current before overload occurs Iref = reference load current	I_p = load current before overload occurs Time constant τ = (1–500) minutes	IEC 60255–8, ±5% + 200 ms
Alarm pickup 1 and 2	(50–99)% of heat content trip value	± 2.0% of heat content trip
Operate current	(50–250)% of *IBase*	± 1.0% of I_n
Reset level temperature	(10–95)% of heat content trip	± 2.0% of heat content trip

Table 34. Breaker failure protection, 3-phase activation and output CCRBRF (50BF)

Function	Range or value	Accuracy
Operate phase current	(5-200)% of *IBase*	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio, phase current	> 95%	-
Operate residual current	(2-200)% of *IBase*	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio, residual current	> 95%	-
Phase current pickup for blocking of contact function	(5-200)% of *IBase*	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Reset ratio	> 95%	-
Timers	(0.000-60.000) s	± 0.5% ±10 ms
Operate time for current detection	20 ms typically	-
Reset time for current detection	10 ms maximum	-

Table 35. Pole discrepancy protection CCRPLD (52PD)

Function	Range or value	Accuracy
Operate value, current asymmetry level	(0-100) %	± 1.0% of I_n
Reset ratio	>95%	-
Time delay	(0.000-60.000) s	± 0.5% ± 25 ms

Table 36. Directional over/underpower protection GOPPDOP, GUPPDUP (32/37)

Function	Range or value	Accuracy
Power level	(0.0–500.0)% of *SBase*	± 1.0% of S_r at S < S_r ± 1.0% of S at S > S_r
	(1.0-2.0)% of *SBase*	< ± 50% of set value
	(2.0-10)% of *SBase*	< ± 20% of set value
Characteristic angle	(-180.0–180.0) degrees	2 degrees
Timers	(0.010 - 6000.000) s	± 0.5% ± 25 ms

Table 37. Negative sequence based overcurrent function DNSPTOC (46)

Function	Range or value	Accuracy
Operate current	(2.0 - 200.0) % of *IBase*	± 1.0% of I_r at I <I_n ± 1.0% of I at I > I_n
Reset ratio	> 95 %	-
Low polarizing voltage level	(0.0 - 5.0) % of *VBase*	< ± 0.5% of V_n
Relay characteristic angle	(-180 - 180) degrees	± 2.0 degrees
Relay operate angle	(1 - 90) degrees	± 2.0 degrees
Timers	(0.00 - 6000.00) s	± 0.5% ± 25 ms
Operate time, non-directional	30 ms typically at 0 to 2 x I_{set} 20 ms typically at 0 to 10 x I_{set}	-
Reset time, non-directional	40 ms typically at 2 to 0 x I_{set}	-
Operate time, directional	30 ms typically at 0 to 2 x I_{set} 20 ms typically at 0 to 10 x I_{set}	-
Reset time, directional	40 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set} 2 ms typically at 0 to 10 x I_{set}	-
Impulse margin time	15 ms typically	-
Dynamic overreach	< 10% at t = 300 ms	-

Voltage protection

Table 38. Two step undervoltage protection UV2PTUV (27)

Function	Range or value	Accuracy
Operate voltage, low and high step	(1–100)% of *VBase*	± 0.5% of V_n
Reset ratio	<102%	-
Inverse time characteristics for low and high step, see table 73	-	See table 73
Definite time delay, step 1	(0.00 - 6000.00) s	± 0.5% ± 25 ms
Definite time delays, step 2	(0.000-60.000) s	± 0.5% ±25 ms
Minimum operate time, inverse characteristics	(0.000–60.000) s	± 0.5% ± 25 ms
Operate time, pickup function	30 ms typically at 1.2 to 0.5V_{set}	-
Reset time, pickup function	25 ms typically at 0 to 2 x V_{set}40 ms typically at 0.5 to 1.2 xV_{set}	-
Critical impulse time	10 ms typically at 1.2 to 0.8 x V_{set}	-
Impulse margin time	15 ms typically	-

Table 39. Two step overvoltage protection OV2PTOV (59)

Function	Range or value	Accuracy
Operate voltage, step 1 and 2	(1-200)% of *VBase*	± 0.5% of V_n at V < V_n ± 0.5% of V at V > V_n
Reset ratio	>98%	-
Inverse time characteristics for steps 1 and 2, see table ""	-	See table 72
Definite time delay, step 1	(0.00 - 6000.00) s	± 0.5% ± 25 ms
Definite time delays, step 2	(0.000-60.000) s	± 0.5% ± 25 ms
Minimum operate time, Inverse characteristics	(0.000-60.000) s	± 0.5% ± 25 ms
Operate time, pickup function	30 ms typically at 0 to 2 x V_{set}	-
Reset time, pickup function	40 ms typically at 2 to 0 x V_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x V_{set}	-
Impulse margin time	15 ms typically	-

Table 40. Two step residual overvoltage protection ROV2PTOV (59N)

Function	Range or value	Accuracy
Operate voltage, step 1	(1-200)% of *VBase*	± 0.5% of V_n at V < V_n ± 0.5% of V at V > V_n
Operate voltage, step 2	(1–100)% of *VBase*	± 0.5% of V_n at V < V_n ± 0.5% of V at V > V_n
Reset ratio	> 98%	-
Inverse time characteristics for low and high step, see table 74	-	See table 74
Definite time setting, step 1	(0.00–6000.00) s	± 0.5% ± 25 ms
Definite time setting, step 2	(0.000–60.000) s	± 0.5% ± 25 ms
Minimum operate time for step 1 inverse characteristic	(0.000-60.000) s	± 0.5% ± 25 ms
Operate time, pickup function	30 ms typically at 0 to 2 x V_{set}	-
Reset time, pickup function	40 ms typically at 2 to 0 x V_{set}	-
Critical impulse time	10 ms typically at 0 to 1.2 xV_{set}	-
Impulse margin time	15 ms typically	-

Table 41. Overexcitation protection OEXPVPH (24)

Function	Range or value	Accuracy
Trip value, pickup	(100–180)% of (*VBase*/f_n)	± 0.5% of V
Trip value, alarm	(50–120)% of pickup level	± 0.5% of V_n at V ≤ V_n ± 0.5% of V at V > V_n
Trip value, high level	(100–200)% of (*VBase*/f_n)	± 0.5% of V
Curve type	IEEE $IEEE: t = \frac{(0.18 \cdot TD)}{(M-1)^2}$ (Equation 2) where M = (E/f)/(Vn/fn)	± 5% + 40 ms
Minimum time delay for inverse function	(0.000–60.000) s	± 0.5% ± 25 ms
Alarm time delay	(0.00–9000.00)	± 0.5% ± 25 ms

Frequency protection

Table 42. Under frequency protection SAPTUF (81)

Function	Range or value	Accuracy
Operate value, pickup function	(35.00-75.00) Hz	± 2.0 mHz at symmetrical three-phase voltage
Operate value, restore frequency	(45 - 65) Hz	± 2.0 mHz
Reset ratio	<1.001	-
Operate time, pickup function	At 50 Hz: 200 ms typically at f_{set} +0.5 Hz to f_{set} -0.5 Hz At 60 Hz: 170 ms typically at f_{set} +0.5 Hz to f_{set} -0.5 Hz	-
Reset time, pickup function	At 50 Hz: 60 ms typically at f_{set} -0.5 Hz to f_{set} +0.5 Hz At 60 Hz: 50 ms typically at f_{set} -0.5 Hz to f_{set} +0.5 Hz	-
Operate time delay	(0.000-60.000)s	<250 ms
Restore time delay	(0.000-60.000)s	<150 ms

Table 43. Overfrequency protection SAPTOF (81)

Function	Range or value	Accuracy
Operate value, pickup function	(35.00-75.00) Hz	± 2.0 mHz at symmetrical three-phase voltage
Reset ratio	>0.999	-
Operate time, pickup function	At 50 Hz: 200 ms typically at f_{set} -0.5 Hz to f_{set} +0.5 Hz At 60 Hz: 170 ms typically at f_{set} -0.5 Hz to f_{set} +0.5 Hz	-
Reset time, pickup function	At 50 and 60 Hz: 55 ms typically at f_{set} +0.5 Hz to f_{set}-0.5 Hz	-
Timer	(0.000-60.000)s	<250 ms

Table 44. Rate-of-change frequency protection SAPFRC (81)

Function	Range or value	Accuracy
Operate value, pickup function	(-10.00-10.00) Hz/s	± 10.0 mHz/s
Operate value, restore enable frequency	(45.00 - 65.00) Hz	± 2.0 mHz
Timers	(0.000 - 60.000) s	<130 ms
Operate time, pickup function	At 50 Hz: 100 ms typically At 60 Hz: 80 ms typically	-

Secondary system supervision

Table 45. Fuse failure supervision SDDRFUF

Function	Range or value	Accuracy
Operate voltage, zero sequence	(1-100)% of VBase	± 1.0% of V_n
Operate current, zero sequence	(1–100)% of IBase	± 1.0% of I_n
Operate voltage, negative sequence	(1–100)% of VBase	± 0.5% of V_n
Operate current, negative sequence	(1–100)% of IBase	± 1.0% of I_n
Operate voltage change pickup	(1–100)% of VBase	± 5.0% of V_n
Operate current change pickup	(1–100)% of IBase	± 5.0% of I_n
Operate phase voltage	(1-100)% of VBase	± 0.5% of V_n
Operate phase current	(1-100)% of IBase	± 1.0% of I_n
Operate phase dead line voltage	(1-100)% of VBase	± 0.5% of V_n
Operate phase dead line current	(1-100)% of IBase	± 1.0% of I_n

Table 46. Breaker close/trip circuit monitoring TCSSCBR

Function	Range or value	Accuracy
Operate time delay	(0.020 - 300.000) s	± 0,5% ± 110 ms

Control

Table 47. Voltage control TR8ATCC (90), TCMYLTC (84)

Function	Range or value	Accuracy
Transformer reactance on ATCC side	(0.1–200.0)Ω, primary	-
Time delay for lower command when fast step down mode is activated	(1.0–100.0) s	-
Voltage control set voltage	(85.0–120.0)% of VB2	±0.5% of V_n
Outer voltage deadband	(0.2–9.0)% of VB2	± 5,0% of set value
Inner voltage deadband	(0.1–9.0)% of VB2	± 5,0% of set value
Upper limit of busbar voltage	(80–180)% of VB2	± 0.5% of V_n
Lower limit of busbar voltage	(70–120)% of VB2	± 0.5% of V_n
Undervoltage block level	(0–120)% of VB2	± 0.5% of V_n
Time delay (long) for automatic control commands	(3–1000) s	± 0.5% ± 110 ms
Time delay (short) for automatic control commands	(1–1000) s	± 0.5% ± 110 ms
Minimum operating time in inverse mode	(3–120) s	± 0.5% ± 110 ms
Line resistance	(0.00–150.00)Ω, primary	-
Line reactance	(-150.00–150.00)Ω, primary	-
Load voltage adjustment constants	(-20.0–20.0)% of VB2	± 5,0% of set value
Load voltage auto correction	(-20.0–20.0)% of VB2	± 5,0% of set value
Overcurrent block level	(0–250)% of IBase	± 1.0% of I_n at $I \leq I_n$ ± 1.0% of I at $I > I_n$
Level for number of counted raise/lower within one hour	(0–30) operations/hour	-
Level for number of counted raise/lower within 24 hours	(0–100) operations/day	-
Time window for hunting alarm	(1–120) minutes	-
Hunting detection alarm, max operations/window	(3–30) operations/window	-
Alarm level of active power in forward and reverse direction	(-9999.99–9999.99) MW	± 1.0% of S_n
Alarm level of reactive power in forward and reverse direction	(-9999.99–9999.99) MVAr	± 1.0% of S_n
Time delay for alarms from power supervision	(1–6000) s	± 0.5% ± 110 ms
Tap position for lowest and highest voltage	(1–63)	-
Type of code conversion	Binary, BCD, Gray, ContactPerTap	-
Time after position change before the value is accepted	(1–60) s	± 0.5% ± 110 ms
Tap changer constant time-out	(1–120) s	± 0.5% ± 110 ms
Raise/lower command output pulse duration	(0.5–10.0) s	± 0.5% ± 110 ms

Logic

Table 48. Tripping logic common 3-phase output SMPPTRC (94)

Function	Range or value	Accuracy
Trip action	3-ph	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms

Table 49. Configurable logic blocks

Logic block	Quantity with cycle time			Range or value	Accuracy
	5 ms	20 ms	100 ms		
AND	60	60	160	-	-
OR	60	60	160	-	-
XOR	10	10	20	-	-
INVERTER	30	30	80	-	-
SRMEMORY	10	10	20	-	-
RSMEMORY	10	10	20	-	-
GATE	10	10	20	-	-
PULSETIMER	10	10	20	(0.000–90000.000) s	± 0.5% ± 25 ms for 20 ms cycle time
TIMERSET	10	10	20	(0.000–90000.000) s	± 0.5% ± 25 ms for 20 ms cycle time
LOOPDELAY	10	10	20		

Table 50. Configurable logic Q/T

Logic block	Quantity with cycle time		Range or value	Accuracy
	20 ms	100 ms		
ANDQT	20	100	-	-
ORQT	20	100	-	-
XORQT	10	30	-	-
INVERTERQT	20	100	-	-
RSMEMORYQT	10	30	-	-
SRMEMORYQT	15	10	-	-
PULSETIMERQT	10	30	(0.000–90000.000) s	± 0.5% ± 25 ms for 20 ms cycle time
TIMERSETQT	10	30	(0.000–90000.000) s	± 0.5% ± 25 ms for 20 ms cycle time
INVALIDQT	6	6	-	-
INDCOMBSPQT	10	10	-	-
INDEXTSPQT	10	10	-	-

Table 51. Elapsed time integrator with limit transgression and overflow supervision TEIGGIO

Function	Cycle time (ms)	Range or value	Accuracy
Elapsed time integration	5	0 ~ 999999.9 s	±0.05% or ±0.015 s
	20	0 ~ 999999.9 s	±0.05% or ±0.04 s
	100	0 ~ 999999.9 s	±0.05% or ±0.2 s

Monitoring

Table 52. Technical data covering measurement functions: CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU

Function	Range or value	Accuracy
Voltage	(0.1-1.5) ×V_n	± 0.5% of V_n at V≤V_n ± 0.5% of V at V > V_n
Connected current	(0.2-4.0) × I_n	± 0.5% of I_n at I ≤ I_n ± 0.5% of I at I > I_n
Active power, P	0.1 x V_n< V < 1.5 x V_n 0.2 x I_n < I < 4.0 x I_n	± 1.0% of S_n at S ≤ S_n ± 1.0% of S at S > S_n
Reactive power, Q	0.1 x V_n< V < 1.5 x V_n 0.2 x I_n < I < 4.0 x I_n	± 1.0% of S_n at S ≤ S_n ± 1.0% of S at S > S_n
Apparent power, S	0.1 x V_n < V < 1.5 x V_n 0.2 x I_n< I < 4.0 x I_n	± 1.0% of S_n at S ≤ S_n ± 1.0% of S at S > S_n
Apparent power, S Three phase settings	cos phi = 1	± 0.5% of S at S > S_n ± 0.5% of S_n at S ≤ S_n
Power factor, cos (ϕ)	0.1 x V_n < V < 1.5 x V_n 0.2 x I_n< I < 4.0 x I_n	< 0.02

Table 53. Event counter CNTGGIO

Function	Range or value	Accuracy
Counter value	0-100000	-
Max. count up speed	10 pulses/s (50% duty cycle)	-

Table 54. Limit counter L4UFCNT

Function	Range or value	Accuracy
Counter value	0-65535	-
Max. count up speed	5-160 pulses/s	-

Table 55. Disturbance report DRPRDRE

Function	Range or value	Accuracy
Current recording	-	± 1,0% of I_r at I ≤ I_r ± 1,0% of I at I > Ir
Voltage recording	-	± 1,0% of V_n at V≤ V_n ± 1,0% of Vat V> V_n
Pre-fault time	(0.05–3.00) s	-
Post-fault time	(0.1–10.0) s	-
Limit time	(0.5–8.0) s	-
Maximum number of recordings	100, first in - first out	-
Time tagging resolution	1 ms	See time synchronization technical data
Maximum number of analog inputs	30 + 10 (external + internally derived)	-
Maximum number of binary inputs	96	-
Maximum number of phasors in the Trip Value recorder per recording	30	-
Maximum number of indications in a disturbance report	96	-
Maximum number of events in the Event recording per recording	150	-
Maximum number of events in the Sequence of events	1000, first in - first out	-
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)	340 seconds (100 recordings) at 50 Hz, 280 seconds (80 recordings) at 60 Hz	-
Sampling rate	1 kHz at 50 Hz 1.2 kHz at 60 Hz	-
Recording bandwidth	(5-300) Hz	-

Table 56. Event list DRPRDRE

Function		Value
Buffer capacity	Maximum number of events in the list	1000
Resolution		1 ms
Accuracy		Depending on time synchronizing

Table 57. Indications DRPRDRE

Function		Value
Buffer capacity	Maximum number of indications presented for single disturbance	96
	Maximum number of recorded disturbances	100

Table 58. Event recorder DRPRDRE

Function		Value
Buffer capacity	Maximum number of events in disturbance report	150
	Maximum number of disturbance reports	100
Resolution		1 ms
Accuracy		Depending on time synchronizing

Table 59. Trip value recorder DRPRDRE

Function		Value
Buffer capacity	Maximum number of analog inputs	30
	Maximum number of disturbance reports	100

Table 60. Disturbance recorder DRPRDRE

Function		Value
Buffer capacity	Maximum number of analog inputs	40
	Maximum number of binary inputs	96
	Maximum number of disturbance reports	100
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)		340 seconds (100 recordings) at 50 Hz 280 seconds (80 recordings) at 60 Hz

Table 61. Station battery supervision SPVNZBAT

Function	Range or value	Accuracy
Lower limit for the battery terminal voltage	(60-140) % of Vbat	± 1.0% of set battery voltage
Reset ratio, lower limit	<105 %	-
Upper limit for the battery terminal voltage	(60-140) % of Vbat	± 1.0% of set battery voltage
Reset ratio, upper limit	>95 %	-
Timers	(0.000-60.000) s	± 0.5% ± 110 ms
Battery rated voltage	20-250V	-

Table 62. Insulation gas monitoring function SSIMG (63)

Function	Range or value	Accuracy
Timers	(0.000-60.000) s	± 0.5% ± 110 ms

Table 63. Insulation liquid monitoring function SSIML(71)

Function	Range or value	Accuracy
Timers	(0.000-60.000) s	± 0.5% ± 110 ms

Table 64. Circuit breaker condition monitoring SSCBR

Function	Range or value	Accuracy
Alarm levels for open and close travel time	(0-200) ms	± 0.5% ± 25 ms
Alarm levels for number of operations	(0 - 9999)	-
Setting of alarm for spring charging time	(0.00-60.00) s	± 0.5% ± 25 ms
Time delay for gas pressure alarm	(0.00-60.00) s	± 0.5% ± 25 ms
Time delay for gas pressure lockout	(0.00-60.00) s	± 0.5% ± 25 ms

Metering

Table 65. Pulse counter PCGGIO

Function	Setting range	Accuracy
Cycle time for report of counter value	(1–3600) s	-

Table 66. Function for energy calculation and demand handling ETPMMTR

Function	Range or value	Accuracy
Energy metering	MWh Export/Import, MVArh Export/Import	Input from MMXU. No extra error at steady load

Station communication

Table 67. Communication protocol

Function	Value
Protocol TCP/IP	Ethernet
Communication speed for the IEDs	100 Mbit/s
Protocol	IEC 61850–8–1
Communication speed for the IEDs	100BASE-FX
Protocol	DNP3.0/TCP
Communication speed for the IEDs	100BASE-FX
Protocol, serial	IEC 60870–5–103
Communication speed for the IEDs	9600 or 19200 Bd
Protocol, serial	DNP3.0
Communication speed for the IEDs	300–115200 Bd

Hardware

IED

Dimensions

Table 68. Dimensions of the IED - 3U full 19" rack

Description	Value
Width	17.48 inches (444 mm)
Height	5.20 inches (132 mm), 3U
Depth	9.82 inches (249.5 mm)
Weight box	<22.04 lbs (10 kg)

Inverse time characteristics

Table 69. ANSI Inverse time characteristics

Function	Range or value	Accuracy
Operating characteristic: $t = \left(\frac{A}{\left(I^{P} - 1 \right)} + B \right) \cdot td$ $I = I_{measured}/I_{set}$	td = (0.05-999) in steps of 0.01	-
ANSI Extremely Inverse	A=28.2, B=0.1217, P=2.0	
ANSI Very inverse	A=19.61, B=0.491, P=2.0	
ANSI Normal Inverse	A=0.0086, B=0.0185, P=0.02, tr=0.46	
ANSI Moderately Inverse	A=0.0515, B=0.1140, P=0.02	
ANSI Long Time Extremely Inverse	A=64.07, B=0.250, P=2.0	
ANSI Long Time Very Inverse	A=28.55, B=0.712, P=2.0	
ANSI Long Time Inverse	A=0.086, B=0.185, P=0.02	

Table 70. IEC Inverse time characteristics

Function	Range or value	Accuracy
Operating characteristic: $t = \left(\frac{A}{\left(I^{P} - 1 \right)} \right) \cdot td$ $I = I_{measured}/I_{set}$	td = (0.05-999) in steps of 0.01	-
IEC Normal Inverse	A=0.14, P=0.02	
IEC Very inverse	A=13.5, P=1.0	
IEC Inverse	A=0.14, P=0.02	
IEC Extremely inverse	A=80.0, P=2.0	
IEC Short time inverse	A=0.05, P=0.04	
IEC Long time inverse	A=120, P=1.0	

The parameter setting *Characterist1 and 4/ Reserved* shall not be used, since this parameter setting is for future use and not implemented yet.

Table 71. RI and RD type inverse time characteristics

Function	Range or value	Accuracy
RI type inverse characteristic $t = \frac{1}{0.339 - \frac{0.236}{I}} \cdot td$ $I = I_{measured}/I_{set}$	td = (0.05-999) in steps of 0.01	
RD type logarithmic inverse characteristic $t = 5.8 - \left(1.35 \cdot ln\frac{I}{td}\right)$ $I = I_{measured}/I_{set}$	td = (0.05-999) in steps of 0.01	

Table 72. Inverse time characteristics for overvoltage protection

Function	Range or value	Accuracy
Type A curve: $t = \frac{td}{\left(\frac{V - VPickup}{VPickup}\right)}$ $V = V_{measured}$	td = (0.05-1.10) in steps of 0.01	±5% +60 ms
Type B curve: $t = \frac{td \cdot 480}{\left(32 \cdot \frac{V - VPickup}{VPickup} - 0.5\right)^{2.0} - 0.035}$	td = (0.05-1.10) in steps of 0.01	
Type C curve: $t = \frac{td \cdot 480}{\left(32 \cdot \frac{V - VPickup}{VPickup} - 0.5\right)^{3.0} - 0.035}$	td = (0.05-1.10) in steps of 0.01	

Table 73. Inverse time characteristics for undervoltage protection

Function	Range or value	Accuracy
Type A curve: $t = \frac{td}{\left(\frac{VPickup - V}{VPickup}\right)}$ V = $V_{measured}$	td = (0.05-1.10) in steps of 0.01	±5% +60 ms
Type B curve: $t = \frac{td \cdot 480}{\left(32 \cdot \frac{VPickup - V}{VPickup} - 0.5\right)^{2.0}} + 0.055$ V = $V_{measured}$	td = (0.05-1.10) in steps of 0.01	

Table 74. Inverse time characteristics for residual overvoltage protection

Function	Range or value	Accuracy
Type A curve: $t = \frac{td}{\left(\frac{V - VPickup}{VPickup}\right)}$ V = $V_{measured}$	td = (0.05-1.10) in steps of 0.01	±5% +70 ms
Type B curve: $t = \frac{td \cdot 480}{\left(32 \cdot \frac{V - VPickup}{VPickup} - 0.5\right)^{2.0}} - 0.035$	td = (0.05-1.10) in steps of 0.01	
Type C curve: $t = \frac{td \cdot 480}{\left(32 \cdot \frac{V - VPickup}{VPickup} - 0.5\right)^{3.0}} - 0.035$	td = (0.05-1.10) in steps of 0.01	

20. Ordering for Customized IED

Guidelines

Carefully read and follow the set of rules to ensure order management. Be aware that certain functions can only be ordered in combination with other functions and that some functions require specific hardware selections.

Product specification

Basic IED 650 platform and common functions housed in 3U 1/1 sized 19” casing

RET650	Quantity:	☐	1MRK 006 516-AD

Option:

Customer specific configuration		On request

Connection type for Analog modules

Rule: One connection type must be selected

Compression terminals	☐	1MRK 002 960-CA
Ring lug terminals	☐	1MRK 002 960-DA

Connection type for Power supply, Input/Output and communication modules

Rule: One connection type must be selected

Compression terminals	☐	1MRK 002 960-EA
Ring lug terminals	☐	1MRK 002 960-FA

Power supply module

Rule: One Power supply module must be specified

Power supply module	PSM01	24–30V DC, 9BO	☐	1KHL178029R0001
	PSM02	48-125V DC, 9BO	☐	1KHL178073R0001
	PSM03	110-250V DC, 100–240V AC, 9BO	☐	1KHL178082R0001

Communication and processing modules

Rule: One Communication and processing module must be selected
For redundant station communication PRP, COM03 must be selected.

Communication and processing module COM05, 12BI, IRIG-B, RS485, Ethernet LC optical, ST serial	☐	1MRK 002 346-AA
Communication and processing module COM03, IRIG-B, RS485, 3 Ethernet LC optical, ST serial, ST PPS Slave *The 3rd Ethernet port and PPS Slave is not supported in this release.*	☐	1MRK 002 346-BA

Differential protection

Rule: One and only one of Transformer differential protection can be ordered

Transformer differential protection, two winding T2WPDIF, 87T	Qty:	☐	1MRK 004 904-AB
Transformer differential protection, three winding T3WPDIF, 87T	Qty:	☐	1MRK 004 904-BB

Logic

Rule: One Tripping logic must be ordered

Tripping logic, common 3–phase output SMPPTRC, 94	Qty:	1 ☐ 2 ☐ 3 ☐	1MRK 004 922-AA

Optional functions

Differential protection

Restricted earth fault protection, low impedance REFPDIF, 87N	Qty:	1 ☐ 2 ☐ 3 ☐	1MRK 004 904-CA
1Ph High impedance differential protection HZPDIF, 87	Qty:	1 ☐ 2 ☐	1MRK 004 904-DA

Impedance protection

Power swing detection ZMRPSB, 68	Qty:	☐	1MRK 004 906-GA
Underimpedance protection for generators and transformers ZGCPDIS , 21G	Qty:	☐	1MRK 004 906–SA
Load enchroachment LEPDIS	Qty:	☐	1MRK 004 906-NA

Current protection

Instantaneous phase overcurrent protection, 3–phase output PHPIOC, 50	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-AA
Four step phase overcurrent protection, 3–phase output OC4PTOC, 51/67	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-BC
Instantaneous residual overcurrent protection EFPIOC, 50N	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-CA
Four step residual overcurrent protection, zero/negative sequence direction EF4PTOC, 51N/67N	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-FA
Thermal overload protection, two time constants TRPTTR, 49	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-KB
Breaker failure protection, 3–phase activation and output CCRBRF, 50BF	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-LA
Pole discrepancy protection CCRPLD, 52PD	Qty:	1 2 3 ☐ ☐ ☐	1MRK 004 908-NA
Directional underpower protection GUPPDUP, 37	Qty:	1 2 ☐ ☐	1MRK 004 908-RB
Directional overpower protection GOPPDOP, 32	Qty:	1 2 ☐ ☐	1MRK 004 908-SB
Negative sequence based overcurrent function DNSPTOC, 46	Qty:	1 2 ☐ ☐	1MRK 004 908-TB

Voltage protection

Two step undervoltage protection UV2PTUV, 27	Qty:	1 2 ☐ ☐	1MRK 004 910-AB
Two step overvoltage protection OV2PTOV, 59	Qty:	1 2 ☐ ☐	1MRK 004 910-BB
Two step residual overvoltage protection ROV2PTOV, 59N	Qty:	1 2 ☐ ☐	1MRK 004 910-CB
Overexcitation protection OEXPVPH, 24	Qty:	☐	1MRK 004 910-DC

Frequency protection

Underfrequency protection SAPTUF, 81	Qty:	1 2 3 4 ☐ ☐ ☐ ☐	1MRK 004 912-AA
Overfrequency protection SAPTOF, 81	Qty:	1 2 3 4 ☐ ☐ ☐ ☐	1MRK 004 912-BA
Rate-of-change frequency protection SAPFRC, 81	Qty:	1 2 3 4 ☐ ☐ ☐ ☐	1MRK 004 912-CA

Control

Rule: Only one of the Circuit breakers or APC8 can be ordered

Apparatus control for single bay, max 8 app. 1CB incl. interlocking APC8	Qty:	☐	1MRK 004 917-GA
Circuit breaker for 2 CB, CBC2	Qty:	☐	1MRK 004 918-BA
Circuit breaker for 3 CB, CBC3	Qty:	☐	1MRK 004 918-CA
Circuit breaker for 4 CB, CBC4	Qty:	☐	1MRK 004 918-DA
Automatic voltage control for tapchanger, parallel control TR8ATCC, 90	Qty:	1 ☐ 2 ☐	1MRK 004 917-EB
Tap changer control and supervision, 6 binary inputs, TCMYLTC, 84	Qty:	1 ☐ 2 ☐	1MRK 004 917-FB

Logic

Configurable logic blocks Q/T		☐	1MRK 002 917-MK

Monitoring

Station battery supervision SPVNZBAT	Qty:	☐	1MRK 004 925-HB
Insulation gas monitoring function SSIMG, 63	Qty:	1 ☐ 2 ☐	1MRK 004 925-KA
Insulation liquid monitoring function SSIML, 71	Qty:	1 ☐ 2 ☐	1MRK 004 925-LA
Circuit breaker condition monitoring SSCBR	Qty:	1 ☐ 2 ☐ 3 ☐	1MRK 004 925-MA

First local HMI user dialogue language

HMI language, English IEC		Always included

Additional local HMI user dialogue language

HMI language, English US	☐	1MRK 002 940-MA

Optional hardware

Human machine interface

Rule: One must be ordered.

Display type	Keypad symbol	Case size		
Local human machine interface LHMI01	IEC	3U 1/1 19"	☐	1KHL160055R0001
Local human machine interface LHMI01	ANSI	3U 1/1 19"	☐	1KHL160042R0001

Analog system

Rule: One Transformer input module must be ordered

Transformer module TRM01	6I 1/5A + 4U 100/220V, 50/60Hz	Qty:	☐	1KHL178083R0001
Transformer module TRM01	8I 1/5A + 2U, 100/220V, 50/60Hz	Qty:	☐	1KHL178083R0013
Transformer module TRM01	4I 1/5A + 1I 0.1/0.5A + 5U 100/220V, 50/60Hz	Qty:	☐	1KHL178083R0016
Transformer module TRM01	4I 1/5A + 6U 100/220V, 50/60Hz	Qty:	☐	1KHL178083R0003

Rule: Only one Analog input module can be ordered

Analog input module AIM01	6I 1/5A + 4U 100/220V, 50/60Hz	Qty:	☐	1KHL178083R5001
Analog input module AIM01	4I 1/5A + 1I 0.1/0.5A + 5U 100/220V, 50/60Hz	Qty:	☐	1KHL178083R5016

Binary input/output modules

Note: If analog input module AIM is ordered only 2 BIO modules can be ordered

Binary input/output module BIO01	Qty:	1 2 3 4 ☐ ☐ ☐ ☐	1KHL178074R0001

Rack mounting kit

Rack mounting kit for 3U 1/1 x 19” case	Quantity:	☐	1KHL400352R0001

21. Ordering for Configured IED

Guidelines
Carefully read and follow the set of rules to ensure order management.
Please refer to the available functions table for included application functions.

To obtain the complete ordering code, please combine code from the tables, as given in the example below.

Example code: RET650*1.3-A01AX00-X00-B1X0-D-H-SA-E-SA2B1-AAXX-F. Using the code of each position #1-11 specified as RET650*1-2 2-3-4 4-5-6-7 7-8-9 9 9-10 10 10 10-11

#	1	-	2	-	3	-	4	-	5	-	6	-	7	-	8	-	9	-	10	-	11
RET650*		-			-		-			-		-			-		-				-	

	Position	
SOFTWARE	**#1**	**Notes and Rules**
Version number		
Version no	1.3	
Selection for position #1.	1.3	

Configuration alternatives	**#2**		**Notes and Rules**
Single breaker, 2 winding	A01A		
Single breaker, 3 winding	A05 A		
Tap changer control	A07A		
ACT configuration			
ABB standard configuration		X00	
Selection for position #2.		X00	

Software options	**#3**	**Notes and Rules**
No option	X00	
Selection for postition #3	X00	

First HMI language	**#4**		**Notes and Rules**
English IEC	B1		
Selection for position #4.			
Additional HMI language		**#4**	
English US		A6	
Selection for position #4.	B1	A6	

Casing	**#5**	**Notes and Rules**
Rack casing, 3U 1/1 x 19"	D	
Selection for position #5.	D	

Mounting details	#6	Notes and Rules
No mounting kit included	X	
Rack mounting kit for 3U 1/1 x 19"	H	
Selection for position #6.		

Connection type for Power supply, Input/output and Communication modules	#7		Notes and Rules
Compression terminals	S		
Ringlug terminals	R		
Power supply			
Slot position:		pPSM	
100-240V AC, 110-250V DC, 9BO, PSM03		A	
48-125V DC, 9BO, PSM02		B	
24–30V DC, 9BO, PSM01		C	
Selection for position #7.			

Human machine interface	#8	Notes and Rules
Local human machine interface LHMI01, OL7000, ANSI 3U 1/1 x 19", Basic	D	
Selection for position #8.	D	

Connection type for Analog modules	#9			Notes and Rules
Compression terminals	S			
Ringlug terminals	R			
Analog system				
Slot position:		p2		
Transformer module TRM01, 6I 1/5A + 4U 100/220V, 50/60Hz		A1		Basic in A05A and A07A
Transformer module TRM01, 8I 1/5A + 2U 100/220V, 50/60Hz		A2		Basic in A01A
Slot position:			p4	
Analog input module AIM01, 6I 1/5A + 4U 100/220V, 50/60Hz			B1	Only in A05A
Selection for position #9.				

Binary input/output module	#10				Notes and Rules
Slot position (rear view)	p3	p4	p5	p6	p3 and p4 only for A01A and A07A
No board in slot			X	X	Only applicable for A01A and A07A
Binary input/output module BIO01, 9 BI, 3 NO Trip, 5 NO Signal, 1 CO Signal			A	A	Basic in A05A. Option in A01A and A07A
Binary input/output module BIO01, 9 BI, 3 NO Trip, 5 NO Signal, 1 CO Signal	A	A			Basic in A01A and A07A. Not available in A05A
Selection for position #10.					

Communication and processing module	#11	Notes and Rules
Slot position (rear view)	pCOM	
12BI, IRIG-B, RS485, Ethernet, LC optical, ST serial	F	
Selection for position #11.	F	

22. Ordering for Accessories

External resistor unit

High impedance resistor unit 1-ph with resistor and voltage dependent resistor for 20-100V operating voltage	Quantity:	1 ☐ 2 ☐	RK 795 101-MA
High impedance resistor unit 1-ph with resistor and voltage dependent resistor for 100-400V operating voltage	Quantity:	1 ☐ 2 ☐	RK 795 101-CB

Configuration and monitoring tools

Front connection cable between LCD-HMI and PC	Quantity:	☐	1MRK 001 665-CA
LED Label special paper A4, 1 pc	Quantity:	☐	1MRK 002 038-CA
LED Label special paper Letter, 1 pc	Quantity:	☐	1MRK 002 038-DA

Manuals

Note: One (1) IED Connect DVD containing user documentation
Operation manual
Technical manual
Installation manual
Commissioning manual
Application manual
Communication protocol manual, DNP3
Communication protocol manual, IEC61850-8-1
Communication protocol manual, IEC60870-5-103
Cyber security deployment guidelines
Type test certificate
Engineering manual
Point list manual, DNP3
Connectivity packages and LED label template is always included for each IED

Rule: Specify additional quantity of IED Connect DVD requested

User documentation	Quantity:	☐	1MRK 003 500-AA

Rule: Specify the number of printed manuals requested

Operation manual	ANSI	Quantity:	☐	1MRK 500 096-UUS
Technical manual	ANSI	Quantity:	☐	1MRK 504 135-UUS
Commissioning manual	ANSI	Quantity:	☐	1MRK 504 136-UUS
Application manual	ANSI	Quantity:	☐	1MRK 504 134-UUS
Communication protocol manual, DNP3	ANSI	Quantity:	☐	1MRK 511 280-UUS
Communication protocol manual, IEC 61850-8-1	ANSI	Quantity:	☐	1MRK 511 281-UUS
Communication protocol manual, IEC 60870-5-103	ANSI	Quantity:	☐	1MRK 511 282-UUS
Engineering manual	ANSI	Quantity:	☐	1MRK 511 284-UUS
Installation manual	ANSI	Quantity:	☐	1MRK 514 016-UUS
Point list manual, DNP3	ANSI	Quantity:	☐	1MRK 511 283-UUS
Cyber Security deployment guidelines	ANSI	Quantity:	☐	1MRK 511 285-UUS

Reference information

For our reference and statistics we would be pleased to be provided with the following application data:

Country: End user:

Station name: Voltage level: kV

Related documents

Documents related to RET650	Identity number
Application manual	1MRK 504 134-UUS
Technical manual	1MRK 504 135-UUS
Commissioning manual	1MRK 504 136-UUS
Product Guide, configured	1MRK 504 137-BUS
Type test certificate	1MRK 504 137-TUS
Application notes for Circuit Breaker Control	1MRG006806

650 series manuals	Identity number
Communication protocol manual, DNP 3.0	1MRK 511 280-UUS
Communication protocol manual, IEC 61850–8–1	1MRK 511 281-UUS
Communication protocol manual, IEC 60870-5-103	1MRK 511 282-UUS
Cyber Security deployment guidelines	1MRK 511 285-UUS
Point list manual, DNP 3.0	1MRK 511 283-UUS
Engineering manual	1MRK 511 284-UUS
Operation manual	1MRK 500 096-UUS
Installation manual	1MRK 514 016-UUS
Accessories, 650 series	1MRK 513 023-BUS
MICS	1MRG 010 656
PICS	1MRG 010 660
PIXIT	1MRG 010 658

ABB AB
Grid Automation Products
SE-721 59 Västerås, Sweden
Phone +46 (0) 21 32 50 00

www.abb.com/protection-control

Scan this QR code to visit our website

1MRK 504 137-BUS