RELION® PROTECTION AND CONTROL

630 series

Commissioning Manual

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

Safety information

Dangerous voltages can occur on the connectors, even though the auxiliary voltage has been disconnected.

Non-observance can result in death, personal injury or substantial property damage.

Only a competent electrician is allowed to carry out the electrical installation.

National and local electrical safety regulations must always be followed.

The frame of the protection relay has to be carefully earthed.

The protection relay contains components which are sensitive to electrostatic discharge. Unnecessary touching of electronic components must therefore be avoided.

Whenever changes are made in the protection relay, measures should be taken to avoid inadvertent tripping.

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Section 1 Introduction

1.1 This manual

The commissioning manual contains instructions on how to commission the protection relay. The manual can also be used by system engineers and maintenance personnel for assistance during the testing phase. The manual provides procedures for checking of external circuitry and energizing the relay, parameter setting and configuration as well as verifying settings by secondary injection. The manual describes the process of testing a relay in a substation which is not in service. The chapters are organized in the chronological order in which the relay should be commissioned.

1.2 Intended audience

This manual addresses the personnel responsible for commissioning, maintenance and taking the protection relay in and out of normal service.

The commissioning personnel must have a basic knowledge of handling electronic equipment. The commissioning and maintenance personnel must be well experienced in using protection equipment, test equipment, protection functions and the configured functional logics in the relay.

1.3 Product documentation

1.3.1 Product documentation set

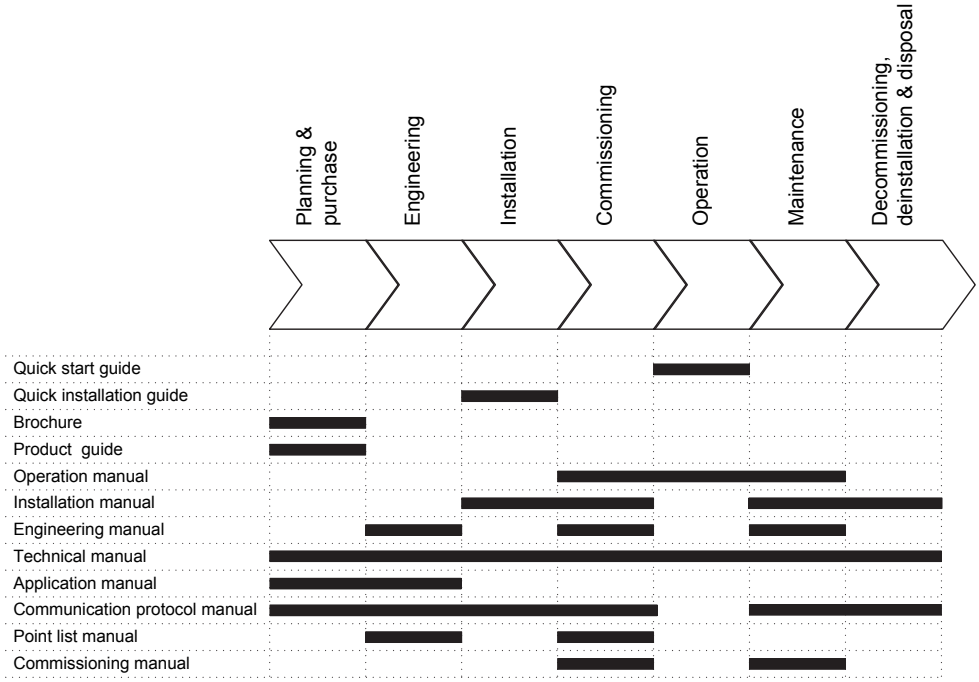

Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2009-09-15	1.0	First release
B/2011-02-23	1.1	Content updated to correspond to the product series version
C/2012-08-29	1.2	Content updated to correspond to the product series version
D/2014-11-28	1.3	Content updated to correspond to the product series version
E/2019-02-25	1.3	Content updated

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

1.3.3 Related documentation

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

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.
  To navigate between the options, use and .
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- WHMI menu names are presented in bold.
  Click **Information** in the WHMI menu structure.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile memory, select `Yes` and press .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- The ^ character in front of an input or output signal name in the function block symbol given for a function, indicates that the user can set an own signal name in PCM600.
- The * character after an input or output signal name in the function block symbol given for a function, indicates that the signal must be connected to another function block in the application configuration to achieve a valid application configuration.

1.4.3 Functions, codes and symbols

Table 1: Functions included in the IEDs

Description	IEC 61850	IEC 60617	ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	3I>	51P-1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	3I>>	51P-2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	3I>>>	50P/51P
Voltage dependent overcurrent protection	PHPVOC	I(U)>	51V
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67-2
Distance protection	DSTPDIS	Z<	21, 21P, 21N
Automatic switch-onto-fault logic	CVRSOF	SOTF	SOTF
Fault locator	SCEFRFLO	FLOC	21FL
Autoreclosing	DARREC	O -> I	79
Non-directional earth-fault protection, low stage	EFLPTOC	I0>	51N-1

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Non-directional earth-fault protection, high stage	EFHPTOC	I0>>	51N-2
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	I0>>>	50N/51N
Directional earth-fault protection, low stage	DEFLPDEF	I0> ->	67N-1
Directional earth-fault protection, high stage	DEFHPDEF	I0>> ->	67N-2
Harmonics based earth-fault protection	HAEFPTOC	Io>HA	51NHA
Transient/intermittent earth-fault protection	INTRPTEF	I0> -> IEF	67NIEF
Admittance-based earth-fault protection	EFPADM	Yo> ->	21YN
Multi-frequency admittance-based earth-fault protection	MFADPSDE	I0> ->Y	67YN
Wattmetric earth-fault protection	WPWDE	Po> ->	32N
Stabilised restricted earth-fault protection	LREFPNDF	dI0Lo>	87NL
Third harmonic based stator earth fault protection	H3EFPSEF	dUo(3H)>/ Uo(3H)<	27/59THD
High-impedance based restricted earth-fault protection	HREFPDIF	dI0Hi>	87NH
Rotor earth-fault protection	MREFPTOC	Io>R	64R
Phase discontinuity protection	PDNSPTOC	I2/I1>	46PD
Negative-sequence overcurrent protection	NSPTOC	I2>	46
Negative-sequence overcurrent protection for machines	MNSPTOC	I2>G/M	46G/46M
Phase-reversal protection	PREVPTOC	I2>>	46R
Three-phase thermal overload protection for feeder	T1PTTR	3Ith>F	49F
Three-phase thermal overload protection, two time constants	T2PTTR	3Ith>T/G	49T/G
Three-phase thermal overload protection for motors	MPTTR	3Ith>M	49M
Motor startup supervision	STTPMSU	Is2t n<	48,66,14,51LR
Motor load jam protection	JAMPTOC	Ist>	51LR
Emergency start	ESMGAPC	ESTART	ESTART
Loss of load supervision	LOFLPTUC	3I<	37
Three-phase current inrush detection	INRPHAR	3I2f>	68
Transformer differential protection for two-winding transformers	TR2PTDF	3dI>T	87T
High-impedance or flux-balance based differential protection for machines	MHZPDIF	3dIHi>G/M	87GH/87MH

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Stabilized differential protection for machines	MPDIF	3dI>G/M	87G/87M
Three-phase overvoltage protection	PHPTOV	3U>	59
Three-phase undervoltage protection	PHPTUV	3U<	27
Positive-sequence overvoltage protection	PSPTOV	U1>	47O+
Positive-sequence undervoltage protection	PSPTUV	U1<	47U+
Negative-sequence overvoltage protection	NSPTOV	U2>	47O-
Residual overvoltage protection	ROVPTOV	U0>	59G
Directional reactive power undervoltage protection	DQPTUV	Q>-->,3U<	32Q,27
Reverse power/directional overpower protection	DOPPDPR	P>	32R/32O
Underpower protection	DUPPDPR	P<	32U
Frequency gradient protection	DAPFRC	df/dt>	81R
Overfrequency protection	DAPTOF	f>	81O
Underfrequency protection	DAPTUF	f<	81U
Load shedding	LSHDPFRQ	UFLS/R	81LSH
Low voltage ride through protection function	LVRTPTUV	U<RT	27RT
Overexcitation protection	OEPVPH	U/f>	24
Voltage vector shift protection	VVSPPAM	VS	78V
Three-phase underexcitation protection	UEXPDIS	X<	40
Three-phase underimpedance protection	UZPDIS	Z< GT	21GT
Circuit breaker failure protection	CCBRBRF	3I>/I0>BF	51BF/51NBF
Tripping logic	TRPPTRC	I -> O	94
Multipurpose analog protection	MAPGAPC	MAP	MAP
Protection-related functions			
Local acceleration logic	DSTPLAL	LAL	LAL
Communication logic for residual overcurrent	RESCPSCH	CLN	85N
Scheme communication logic	DSOCPSCH	CL	85
Current reversal and WEI logic	CRWPSCH	CLCRW	85CRW
Current reversal and WEI logic for residual overcurrent	RCRWPSCH	CLCRWN	85NCRW
Control			
Bay control	QCCBAY	CBAY	CBAY
Interlocking interface	SCILO	3	3

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Circuit breaker/disconnector control	GNRLCSWI	I <-> O CB/DC	I <-> O CB/DC
Circuit breaker	DAXCBR	I <-> O CB	I <-> O CB
Disconnector	DAXSWI	I <-> O DC	I <-> O DC
Local/remote switch interface	LOCREM	R/L	R/L
Synchrocheck	SYNCRSYN	SYNC	25
Tap changer control with voltage regulator	OLATCC	COLTC	90V
Generic process I/O			
Single point control (8 signals)	SPC8GGIO	-	-
Double point indication	DPGGIO	-	-
Single point indication	SPGGIO	-	-
Generic measured value	MVGGIO	-	-
Logic Rotating Switch for function selection and LHMI presentation	SLGGIO	-	-
Selector mini switch	VSGGIO	-	-
Pulse counter for energy metering	PCGGIO	-	-
Event counter	CNTGGIO	-	-
Supervision and monitoring			
Runtime counter for machines and devices	MDSOPT	OPTS	OPTM
Circuit breaker condition monitoring	SSCBR	CBCM	CBCM
Fuse failure supervision	SEQRFUF	FUSEF	60
Current circuit supervision	CCRDIF	MCS 3I	MCS 3I
Trip-circuit supervision	TCSSCBR	TCS	TCM
Station battery supervision	SPVNZBAT	U<>	U<>
Energy monitoring	EPDMMTR	E	E
Measured value limit supervision	MVEXP	-	-
Hot-spot and insulation ageing rate monitoring for transformers	HSARSPTR	3Ihp>T	26/49HS
Tap position indication	TPOSSLTC	TPOSM	84M
Power quality			
Voltage variation	PHQVVR	PQMU	PQMV
Voltage unbalance	VSQVUB	PQMUBU	PQMUBV
Current harmonics	CMHAI	PQM3I	PQM3I
Voltage harmonics (phase-to-phase)	VPPMHAI	PQM3Upp	PQM3Vpp
Voltage harmonics (phase-to-earth)	VPHMHAI	PQM3Upe	PQM3Vpg
Measurement			
Three-phase current measurement	CMMXU	3I	3I

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Three-phase voltage measurement (phase-to-earth)	VPHMMXU	3Upe	3Upe
Three-phase voltage measurement (phase-to-phase)	VPPMMXU	3Upp	3Upp
Residual current measurement	RESCMMXU	I0	I0
Residual voltage measurement	RESVMMXU	U0	U0
Power monitoring with P, Q, S, power factor, frequency	PWRMMXU	PQf	PQf
Sequence current measurement	CSMSQI	I1, I2	I1, I2
Sequence voltage measurement	VSMSQI	U1, U2	V1, V2
Analog channels 1-10 (samples)	A1RADR	ACH1	ACH1
Analog channels 11-20 (samples)	A2RADR	ACH2	ACH2
Analog channels 21-30 (calc. val.)	A3RADR	ACH3	ACH3
Analog channels 31-40 (calc. val.)	A4RADR	ACH4	ACH4
Binary channels 1-16	B1RBDR	BCH1	BCH1
Binary channels 17 -32	B2RBDR	BCH2	BCH2
Binary channels 33 -48	B3RBDR	BCH3	BCH3
Binary channels 49 -64	B4RBDR	BCH4	BCH4
Station communication (GOOSE)			
Binary receive	GOOSEBINRCV	-	-
Double point receive	GOOSEDPRCV	-	-
Interlock receive	GOOSEINTLKRCV	-	-
Integer receive	GOOSEINTRCV	-	-
Measured value receive	GOOSEMVRCV	-	-
Single point receive	GOOSESPRCV	-	-

Section 2 Starting up

2.1 Factory and site acceptance testing

Testing the proper IED operation is carried out at different occasions.

- Acceptance testing
- Commissioning testing
- Maintenance testing

This manual describes the workflow and the steps to carry out the commissioning testing.

Factory acceptance testing (FAT) is typically done to verify that the IED and its corresponding configuration meet the requirements of the utility or industry. This test is the most complex and in depth, as it is done to familiarize the user with a new product or to verify a new configuration. The complexity of this testing depends on several factors.

- New IED type
- New configuration
- Modified configuration

Site acceptance testing (SAT or commissioning testing) is typically done to verify that the installed IED is correctly set and connected to the power system. SAT requires that the acceptance testing has been performed and that the application configuration is verified.

Maintenance testing is a periodic verification that the IED is healthy and has correct settings, depending on changes in the power system. There are also other types of maintenance testing.

2.2 Commissioning checklist

Before starting up commissioning at site, the following items should be available.

- Single line diagram
- Protection block diagram
- Circuit diagram
- Setting list and configuration
- RJ-45 Ethernet cable (CAT 5)
- Three-phase test kit or other test equipment depending on the complexity of the configuration and functions to be tested.

- PC with PCM600 installed along with the connectivity packages corresponding to the IEDs to be tested.
- Administration rights on the PC, to set up IP addresses
- Product documentation (engineering manual, installation manual, commissioning manual, operation manual, technical manual and communication protocol manual)

2.3 Checking of the power supply

Check that the auxiliary supply voltage remains within the permissible input voltage range under all operating conditions. Check that the polarity is correct before powering the protection relay.

2.4 Energizing the IED

2.4.1 Checking the IED operation

Check all connections to external circuitry to ensure correct installation, before energizing the IED and carrying out the commissioning procedures.

- Energize the power supply of the IED to start it up. This can be done in a number of ways, from energizing a whole cubicle to energizing a single IED.
- Set the IED time if no time synchronization source is configured.
- Check the self-supervision function via the LHMI path **Main menu/ Monitoring/IED status** or **Main menu/Monitoring/Internal events** to verify that the IED operates properly.

2.4.2 IED startup sequence

The following sequence is expected when the IED is energized.

- The green Ready LED starts flashing instantly and the ABB logo is shown on the LCD.
- After approximately 30 seconds, "Starting" is shown on the LCD.
- Within 90 seconds, the main menu is shown on the LCD and the green Ready LED shows a steady light, which indicates a successful startup.

The startup time depends on the size of the application configuration. Application configurations with less functionality have shorter startup times.

If the green Ready LED continues to flash after the startup, the IED has detected an internal error. Navigate via **Main menu/Monitoring/IED status** to investigate the error description.

2.5 Setting up communication between PCM600 and the IED

The communication between the IED and PCM600 is independent of the used communication protocol within the substation or to the NCC.

The communication media is always Ethernet and the used protocol is TCP/IP.

Each IED has an Ethernet interface connector on the front and on the rear side. Both Ethernet connectors can be used for communication with PCM600.

When an Ethernet-based station protocol is used, PCM600 communication can use the same Ethernet port and IP address.

For the connection of PCM600 to the IED, two basic variants have to be considered.

- Direct point-to-point link between PCM600 and the IED front port.
- Indirect link via a station LAN or from remote via a network.

The physical connection and the IP address must be configured in both cases to enable communication.

The communication procedures are the same in both cases.

1. If needed, set the IP address for the IEDs.
2. Set up the PC or workstation for a direct link (point-to-point), or
3. Connect the PC or workstation to the LAN/WAN network.
4. Configure the IED IP addresses in the PCM600 project for each IED to match the IP addresses of the physical IEDs.

Setting up IP addresses

The IP address and the corresponding mask can be set via the LHMI for each available Ethernet interface in the IED. Each Ethernet interface has a default factory IP address when the complete IED is delivered.

- The default IP address for the IED front port is 192.168.0.254 and the corresponding subnetwork mask is 255.255.255.0, which can be set via the local HMI path **Main menu/Configuration/Communication/TCP-IP configuration/Front port**.
- The default IP address for the IED rear port is 192.168.2.10 and the corresponding subnetwork mask is 255.255.255.0, which can be set via the local HMI path **Main menu/Configuration/Communication/TCP-IP configuration/LAN1**.

The front and rear port IP addresses cannot belong to the same subnet or communication will fail. It is recommended to change the IP address of the front port if the front and rear port are set to the same subnet.

Setting up the point-to-point access to IEDs front port

The IED front port is a standard Ethernet interface with DHCP server functionality. When a PC is connected to the front port, the DHCP server automatically assigns the IP address from the same subnetwork.

See the operating system manual for details on how to obtain the IP address automatically.

1. Connect the PC network adapter to the IED front port.
2. Wait until the operating system automatically acquires the network address.
3. Check that the front port connector green status LED is lit.
4. Ping the IED to verify that the connection is correctly established. The default IP address of the front port is 192.168.0.254.

Use Ethernet crossover cables only for point-to-point connections. Modern network adapters contain logic for automatic detection if they are connected directly to another network adapter using a regular Ethernet cable.

Setting up the PC to access the IED via a network

This task depends on the used LAN/WAN network. The PC and the IED must belong to the same subnetwork.

2.6 Writing an application configuration to the IED

Ensure that the IED includes the correct application configuration according to project specifications.

- Create the application configuration using PCM600 and then write it to the IED.
- Establish a connection between PCM600 and the IED when an application configuration must be written to the IED.
  After writing an application configuration to the IED, the IED makes an application restart or a complete IED restart, when necessary.

Be sure to set the correct technical key in both the IED and PCM600 to prevent writing an application configuration to a wrong IED.

See the engineering manual for information on how to create or modify an application configuration and how to write to the IED.

2.7 Checking CT circuits

Check that the wiring is in strict accordance with the supplied connection diagram.

The CTs must be connected in accordance with the terminal diagram provided with the protection relay, both with regards to phases and polarity. The following tests are recommended for every primary CT or CT core connected to the protection relay.

- Primary injection test to verify the current ratio of the CT, the correct wiring up to the protection relay and correct phase sequence connection (that is L1, L2, L3.)
- Polarity check to prove that the predicted direction of the secondary current flow is correct for a given direction of the primary current flow. This is an essential test for the proper operation of the directional function, protection or measurement in the protection relay.
- CT secondary loop resistance measurement to confirm that the current transformer secondary loop DC resistance is within specification and that there are no high resistance joints in the CT winding or wiring.
- CT excitation test to ensure that the correct core in the CT is connected to the protection relay. Normally only a few points along the excitation curve are checked to ensure that there are no wiring errors in the system, for example, due to a mistake in connecting the CT's measurement core to the protection relay.
- Earthing check of the individual CT secondary circuits to verify that each three-phase set of main CTs is properly connected to the station earth and only at one electrical point.
- Insulation resistance check.

CT and VT connectors are pre-coded, and the CT and VT connector markings are different. For more information, see the installation manual.

Both the primary and the secondary sides must be disconnected from the line and the protection relay when plotting the excitation characteristics.

2.8 Checking VT circuits

Check that the wiring is in strict accordance with the supplied connection diagram.

Correct possible errors before continuing to test the circuitry.

Test the circuitry.

- Polarity check
- VT circuit voltage measurement (primary injection test)
- Earthing check
- Phase relationship
- Insulation resistance check

The polarity check verifies the integrity of circuits and the phase relationships. The polarity must be measured as close to the protection relay as possible to ensure that most of the wiring is also checked.

The primary injection test verifies the VT ratio and the wiring all the way from the primary system to the protection relay. Injection must be performed for each phase-to-neutral circuit and each phase-to-phase pair. In each case, voltages in all phases and neutral are measured.

2.9 Checking the RTXP test switch

The RTXP test switch is designed to provide the means of safe testing of the IED. This is achieved by the electromechanical design of the test switch and test plug handle. When the test plug handle is inserted, it first blocks the trip and alarm circuits then it short circuits the CT secondary circuit and opens the VT secondary circuits making the IED available for secondary injection.

When pulled out, the test handle is mechanically stopped in half withdrawn position. In this position, the current and voltage enter the protection, but the alarm and trip circuits are still isolated. Before removing the test handle, check that no trip or alarms are present in the IED.

The trip and alarm circuits are not restored for operation until the test handle is completely removed.

By pulling in all cables, verify that the contact sockets have been crimped correctly and that they are fully inserted. Never do this with current circuits in service.

1. Check the current circuit.
   1.1. Verify that the contacts are of current circuit type.
   1.2. Verify that the short circuit jumpers are located in the correct slots.
2. Check the voltage circuit.
   2.1. Verify that the contacts are of voltage circuit type.
   2.2. Check that no short circuit jumpers are located in the slots dedicated for voltage.
3. Check the alarm and trip circuits.
   3.1. Check that the correct types of contacts are used.

2.10 Checking transducer circuits

- Verify from the manufacturer that the total circuit resistance is under specified values from the instrument (transducer) manufacturer.

2.11 Checking binary input and output circuits

2.11.1 Checking binary input circuits

- Preferably, disconnect the binary input connector from the binary input cards.
- Check all the connected signals so that both the input level and the polarity are in accordance with the protection relay specifications.

Do not use AC voltage. Binary inputs are rated for DC voltage only.

2.11.2 Checking binary output circuits

- Preferably, disconnect the binary output connector from the binary output cards.
- Check all connected signals so that both load and voltage are in accordance with the protection relay specifications.

2.12 Checking RTD inputs and mA outputs

2.12.1 RTD input circuits

RTD inputs must be connected in accordance with the terminal diagram provided with the IED and following the RTD input specifications.

Table 2: RTD input

Terminal	Value
Supported RTD sensors	PT100 TCR 0.00385 (DIN 43760) PT250 TCR 0.00385 NI100 TCR 0.00618 (DIN 43760) NI120 TCR 0.00618 CU10 TCR 0.00427
Supported analog inputs	Voltage ±10 V Current ±20 mA Resistance: 0...10 kΩ
Max lead wire resistance (three-wire-measurement)	PT and NI sensors: 25 Ω CU10 sensor: 2.5 Ω Resistance measurement: 25 Ω
Accuracy	PT and NI sensors: ±1°C for measuring range -40°C…+200°C and ±5°C for measuring range -40°C…-100ºC CU10 sensor: ±4°C for measuring range -40°C…+200°C and ±5°C for measuring range -40°C…-100ºC Resistance 0...400 Ω: ±2.5 Ω Resistance 400 Ω...10 kΩ: ±1.25% Voltage ±10 V: ±0.1% ±40 ppm/ºC Current ±20 mA: ±0.1% ±20 ppm/ºC
RTD / Resistance sensing current	Max 2.2 mA RMS
Current input impedance	100 Ω
Isolation	4 kV (inputs to outputs and inputs to protective earth)

2.12.2 mA outputs circuits

mA outputs must be connected in accordance with terminal diagram provided with the IED.

Table 3: mA outputs

Terminal	Value
Output range	±20 mA
Accuracy	±0.2 mA (ambient temperature -25ºC...+55ºC) ±1 mA (ambient temperature -40ºC...-25ºC / 55ºC...70ºC)
Max load	700 Ω (including lead wire resistance)
Isolation	4 kV (output to output, output to inputs and output to protective earth)

2.13 Checking optical connections

Check that the Tx and Rx optical connections are correct.

A relay equipped with optical connections requires a minimum depth of 180 mm for plastic fiber cables and 275 mm for glass fiber cables. Check the allowed minimum bending radius from the optical cable manufacturer.

Section 3 Establishing connection and verifying the station communication

3.1 Setting the station communication

IEC 61850 communication is always included in 630 series IEDs and it is enabled by default. IEC 61850 communication configuration is done using IET600 and PCM600.

Based on ordering and licensing either DNP3 or IEC 60870-5-103 can be included in addition to IEC 61850. Mapping data points to DNP3 protocol is done using Communication Management in PCM600, and mapping data points to IEC 60870-5-103 protocol is done using Application Configuration in PCM600.

- To enable or disable a station protocol, set the parameter *Operation* to "On" or "Off" in **Main menu/Configuration/Communication**.
- IEC 61850 GOOSE receive functions are disabled by default. Set the parameter *Operation* to "On" or "Off" in **Main menu/Configuration/Communication/1:IEC61850-8-1/GOOSE**.

3.2 Verifying the communication

The station communication status is shown in **Main menu/Monitoring/IED status**.

The IEC 60870-5-103 communication status is not available in the IED status menu.

If the station control system is not available for verifying the communication, then separate testing or diagnostics tools made for the specific protocol must be used.

For example, for IEC 61850 communication, ABB provides Integrated Testing Tool ITT600 SA Explorer. It is designed for easy on-line diagnosis and troubleshooting of IEC 61850 based substation automation systems.

Section 4 Testing IED operation

4.1 Preparing the IED to verify settings

- If a test switch is included, start preparation by making the necessary connections to the test switch. This means connecting the test equipment according to a specific and designated IED terminal diagram.
- Put the IED into the test mode to facilitate the test of individual functions and prevent unwanted operation caused by other functions. The test switch should then be connected to the IED.
- Verify that analog input signals from the analog input module are measured and recorded correctly by injecting currents and voltages required by the specific IED.
- To make testing even more effective, use PCM600. PCM600 includes the Signal monitoring tool, which is useful in reading the individual currents and voltages, their amplitudes and phase angles. In addition, PCM600 contains the Disturbance handling tool. The content of reports generated by the Disturbance handling tool can be configured which makes the work more efficient. For example, the tool may be configured to only show time tagged events and to exclude analog information and so on.
- Check the disturbance report settings to ensure that the indications are correct.
- For test functions and test and signal parameter names, see the technical manual. The correct initiation of the disturbance recorder is made on start and/or release or trip from a function. Also check that the wanted recordings of analogue (real and calculated) and binary signals are achieved.

Parameters can be entered into different setting groups. Make sure to test functions for the same parameter setting group. If needed, repeat the tests for all different setting groups used. The difference between testing the first parameter setting group and the remaining is that there is no need for testing the connections.

- During testing, observe that the right testing method, that corresponds to the actual parameters set in the activated parameter setting group, is used.
- Set and configure the functions before testing.
  Most functions are highly flexible and permit a choice of functional and tripping modes. The various modes are checked at the factory as part of the design verification. In certain cases, only modes with a high probability of coming into operation need to be checked when commissioned to verify the configuration and settings.
  Requirements for testing the function.

- Calculated settings
- Valid configuration diagram for the IED
- Valid terminal diagram for the IED
- Technical manual
- Three-phase test equipment

- The test equipment should be able to provide a three-phase supply of currents and three-phase voltage. The magnitude and angle of currents (and voltages) should be possible to vary. Check that the IED is prepared for test before starting the test session. Consider the logic diagram of the function when performing the test.

The response from a test can be viewed in different ways.

- Binary output signals
- Service values in the LHMI (logical signal or phasors)
- A PC with PCM600 (configuration software) in debug mode

Do not switch off the auxiliary power supply to the IED before the changes, for example, setting parameter or local/remote control state changes, are saved.

A mechanism for limiting the number of writings per time period is included in the IED to prevent the flash memory from wearing out due to too many writings caused by the application configuration. As a consequence, saving application function states may take up to an hour. If the auxiliary power is interrupted before the states are saved, that change is lost. Settings and configuration parameters are saved without delay.

4.2 Activating the test mode

Put the IED into the test mode before testing. The test mode blocks all protection functions and some of the control functions in the IED, and the individual functions to be tested can be unblocked to prevent unwanted operation caused by other functions. In this way, it is possible to test slower back-up measuring functions without the interference from faster measuring functions. Test mode is indicated when the yellow StartLED flashes.

1. Select **Main menu/Tests/IED test mode**
2. Set parameter *TestMode* to "On".
3. Save the changes.
   As a consequence, the yellow startLED starts flashing as a reminder and remains flashing until the test mode is switched off.

4.3 Preparing the connection to the test equipment

The IED can be equipped with a test switch of type RTXP8, RTXP18 or RTXP24. The test switch and its associated test plug handle (RTXH8, RTXH18 or RTXH24) are a part of the COMBITEST system, which provides secure and convenient testing of the IED.

- When using the COMBITEST, preparations for testing are automatically carried out in the proper sequence, that is, for example, blocking of tripping circuits, short circuiting of CT's, opening of voltage circuits, making IED terminals available for secondary injection. Terminals 1 and 8, 1 and 18 as well as 1 and 12 of the test switches RTXP8, RTXP18 and RTXP24 respectively are not disconnected as they supply DC power to the protection IED.
- The RTXH test-plug handle leads may be connected to any type of test equipment or instrument. When a number of protection IEDs of the same type are tested, the test-plug handle only needs to be moved from the test switch of one protection IED to the test switch of the other, without altering the previous connections.
- Use COMBITEST test system to prevent unwanted tripping when the handle is withdrawn, since latches on the handle secure it in the half withdrawn position. In this position, all voltages and currents are restored and any re-energizing transients are given a chance to decay before the trip circuits are restored. When the latches are released, the handle can be completely withdrawn from the test switch, restoring the trip circuits to the protection IED.
- If a test switch is not used, perform measurement according to the provided circuit diagrams.

Never disconnect the secondary connection of a current transformer circuit without first short-circuiting the transformer's secondary winding. Operating a current transformer with the secondary winding open will cause a massive potential build up that may damage the transformer and cause personal injury.

4.4 Connecting test equipment to the IED

- Connect the test equipment according to the IED specific connection diagram and the needed input and output signals for the function under test.
- Connect the current and voltage terminals. Pay attention to the current polarity. Make sure that the connection of input and output current terminals and the connection of the residual current conductor is correct. Check that the input and output logical signals in the logic diagram for the function under test are connected to the corresponding binary inputs and outputs of the IED under test.

To ensure correct results, check that the IED as well as the test equipment are properly earthed before testing.

4.5 Releasing the function to be tested

Release or unblock the function to be tested to ensure that only the function or the chain of functions to be tested are in operation and that other functions are prevented from operating. Release the tested function(s) by setting the corresponding *Blocked* parameter under Function test modes to “No” in the LHMI.

When testing a function in this blocking feature, not only the actual function but the whole sequence of interconnected functions (from measuring inputs to binary output contacts) including logic must be activated. Before starting a new test mode session, scroll through every function to ensure that only the function to be tested (and the interconnected ones) have the parameters *Blocked* and eventually *EvDisable* set to “No” and “Yes” respectively. A function is also blocked if the BLOCK input signal on the corresponding function block is active, which depends on the configuration. Ensure that the logical status of the BLOCK input signal is equal to 0 for the function to be tested. Event function blocks can also be individually blocked to ensure that no events are reported to a remote station during the test. This is done by setting the parameter *EvDisable* to “Yes”.

Any function is blocked if the corresponding setting in the LHMI under **Main menu/Tests/Function test modes** menu remains “On”, that is, the parameter *Blocked* is set to “Yes” and the parameter *TestMode* under **Main menu/Tests/IED test mode** remains active. All functions that were blocked or released in a previous test mode session, that is, the parameter *Test mode* is set to “On”, are reset when a new test mode session is started.

1. Select **Main menu/Tests/Function test modes**.
2. Browse to the function instance that needs to be released.
3. Set parameter *Blocked* for the selected function to “No”.

4.6 Verifying analog primary and secondary measurement

Verify that the connections are correct and that measuring and scaling is done correctly. This is done by injecting current and voltage to the IED.

Apply input signals as needed according to the actual hardware and the application configuration.

1. Inject a symmetrical three-phase voltage and current at rated value.
2. Compare the injected value with the measured values.
   The voltage and current phasor menu in the local HMI is located under **Main menu/Measurements**.
3. Compare the frequency reading with the set frequency and the direction of the power.
   The frequency and active power are located under **Main menu/Monitoring/I/O status/Monitoring/PWRMMXU(PQf):1**. Then navigate to the bottom of the list to find the frequency.
4. Inject an asymmetrical three-phase voltage and current, to verify that phases are correctly connected.

If some setting deviates, check the analog input settings under

Main menu/Configuration/Analog inputs

Measured values such as current (phase and residual) and voltages (phase-to-earth, phase-to-phase and residual) as well as active, reactive and apparent power, power factor phase angles as well as positive and negative sequence currents and voltages are available in the local HMI under **Main menu/Monitoring/I/O status/Monitoring**.

Navigate to the measurement function that contains the quantity to be checked.

Table 4: Measurement functions

Function	Quantity	Description
CMMXU	I_A; I_B and I_C	amplitude range and angle
RESCMMXU	I_0	amplitude range and angle
CSMSQI	I1 and I2	amplitude range and angle
VPHMMXU	U_A; U_B and U_C i.e. phase-to-neutral	amplitude range and angle
VPPMMXU	U_{AB}; U_{BC} and U_{CA} i.e. phase-to-phase	amplitude range and angle
RESVMMXU	U_0	amplitude range and angle
VSMSQI	U1 and U2	amplitude range and angle
PWRMMXU	S; P; Q; PF; Ilag; Ilead and f	amplitude range and angle

Also the Signal Monitoring tool in PCM600 can be used to read the measured values. In many cases it is more convenient to use PCM600 since, for example, reports on measured values can be exported from the Signal Monitoring tool to other tools (for example, MS Excel) for further analysis.

4.7 Testing the protection functionality

Each protection function must be tested individually by secondary injection.

1. Verify operating levels (trip) and timers.
2. Verify alarm and blocking signals.
3. Use the disturbance handling tool in PCM600 to evaluate that the protection function has received the correct data and responded correctly (signaling and timing).
4. Use the event viewer tool in PCM600 to check that only expected events have occurred.

Section 5 Troubleshooting

5.1 Fault tracing

5.1.1 Identifying hardware errors

1. Check the module with an error.
   - Check the general IED status in **Main menu/Monitoring/IED status** for a faulty hardware module.
   - Check the history of changes in internal event list in **Main menu/ Monitoring/Internal events**.
2. Inspect the IED visually.
   - Inspect the IED visually to find any physical error causes.
   - If you can find some obvious physical damage, contact ABB for repair or replacement actions.
3. Check whether the error is external or internal.
   - Check that the error is not caused by external origins.
   - Remove the wiring from the IED and test the input and output operation with an external test device.
   - If the problem remains, contact ABB for repair or replacement actions.

5.1.2 Identifying runtime errors

1. Check the error origin from IED's internal event list **Main menu/Monitoring/ Internal events**.
2. Reboot the IED and recheck the supervision events to see if the fault has cleared.
3. In case of persistent faults, contact ABB for corrective actions.

5.1.3 Identifying communication errors

Communication errors are normally communication interruptions or synchronization message errors due to communication link breakdown.

- Check the communication status in the internal event list in **Main menu/ Monitoring/IED status**.
- In case of persistent faults originating from IED's internal faults such as component breakdown, contact ABB for repair or replacement actions.

5.1.3.1 Checking the communication link operation

There are several different communication links on the product. First check that all communication ports that are used for communication are turned on.

To check that optical serial port hardware is working, check the optical fibres for light. Do not look directly into the transmitter since the direct light can be harmful for the eyes. Point the fibre or transmitter towards a surface where it is possible to observe when the light is on. To turn on the transmitter although there is no actual communication, set *revPolarity* in **Main menu/Configuration/Communication/IEC60870-5-103/General** to "On".

1. Check the front communication port RJ-45.
   1.1. Check that the uplink LED is lit with a steady green light.
   The uplink LED is located on the LHMI above the RJ-45 communication port on the left. The port is used for direct electrical communication to a PC connected via a crossed-over Ethernet cable.
   1.2. Check the communication status of the front port via the LHMI in **Main menu/Monitoring/Ethernet/Front port**.
   Check that the "LINKUP" value is 1, that is, the communication is working. When the value is 0, there is no communication link.
2. Check the communication status of the rear port X0 via the LHMI in **Main menu/Monitoring/Ethernet/LAN1**.
   The X0 communication port on the rear side of the IED is for electrical communication to a PC connected via a crossed-over Ethernet cable. This communication port is an alternative to the front communication port.
   - Check that the "LINKUP" value is 1, that is, the communication is working. When the value is 0, there is no communication link.
3. Check the communication status of the rear port X1 via the LHMI in **Main menu/Monitoring/Ethernet/LAN1**.
   The X1 communication port on the rear side of the IED is for optical Ethernet via LC connector or electrical via RJ-45 connector of the IEC 61850-8-1 station bus communication.
   - Check that the "LINKUP" value is 1, that is, the communication is working. When the value is 0, there is no communication link.

5.1.3.2 Checking the time synchronization

- Select **Main menu/Monitoring/IED status** and check the status of the time synchronization on **Time Synch**.
  The *Time synch* value is "Ready" when the synchronization is in order.

Activate the time synchronization source. Otherwise, the value is always "Ready".

5.1.4 Running the display test

To run the display test, either use the push buttons or start the test via the menu.

- Select **Main menu/Test/LED test**.
- Press or simultaneously ESC and .
  All the LEDs are tested by turning them on simultaneously. The display shows a set of patterns so that all the pixels are activated. After the test, the display returns to normal state.

5.2 Indication messages

5.2.1 Internal faults

When the Ready LED indicates an internal fault by flashing, the message associated with the fault is found in the internal event list in the LHMI menu **Main menu/Monitoring/Internal events**. The message includes the date, time, description and signal state for the fault. The internal event list is not updated dynamically. The list is updated by leaving the **Internal events** menu and then selecting it again. The current status of the internal fault signals can also be checked via the LHMI in **Main menu/Monitoring/IED status**.

The ABB logo together with the `IED FAILURE` message appear on the screen after a five minutes' communication break between the LHMI and the IED. The LHMI panel displays the message due to a communication failure or a severe functional error in the IED. The protection functionality of the device can be ensured by testing the IRF contact status.

Different actions are taken depending on the severity of the fault. If the fault is found to be permanent, the IED stays in internal fault mode. The IED continues to perform internal tests during the fault situation.

When a fault appears, the fault indication message is to be recorded and stated when requesting support or service.

Table 5: Internal fault indications

Fault indication	Additional information
Internal Fault Real Time Clock Error	Hardware error with the real time clock.
Internal Fault Runtime Exec. Error	One or more of the application threads are not working properly.
Internal Fault SW Watchdog Error	This signal will be activated when the terminal has been under too heavy load for at least 5 minutes.
Internal Fault Runtime App Error	One or more of the application threads are not in an expected state.
Internal Fault File System Error	A file system error has occurred.
Internal Fault TRM-Error	A TRM card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault COM-Error	A COM card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault PSM-Error	A PSM card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault RTD Error	An RTD card error has occurred. The instance number is displayed at the end of the fault indication.

5.2.2 Warnings

The warning message associated with the fault is found in the internal event list in the LHMI menu **Main menu/Monitoring/Internal events**. The message includes the date, time, description and signal state for the fault. The current status of the internal fault signals can also be checked via the LHMI in **Main menu/Monitoring/IED status**.

When a fault appears, record the fault indication message and state it when ordering service.

Table 6: Warning indications

Warning indication	Description
Warning IEC 61850 Error	IEC 61850 has not succeeded in some actions such as reading the configuration file or startup.
Warning DNP3 Error	Error in DNP3 communication

5.2.3 Additional indications

The additional indication messages do not activate internal fault or warning.

The messages are listed in the LHMI menu under the event list. The signal status data is found under the IED status and in the internal event list.

Table 7: Additional indications

Warning indication	Additional information
Time Synch Error	Source of the time synchronization is lost or time system has made a time reset.
BATTERY1 Error	Auxiliary power is disconnected.
Settings Changed	Settings have been changed.
Setting Groups Changed	Setting group has been changed.

5.3 Correction procedures

5.3.1 Factory settings restoration

In case of configuration data loss or error that prevents the IED from working properly, the configuration can be restored to the original factory state. All default settings and configuration files stored in the factory are restored.

For further information on restoring factory settings, contact customer support.

5.3.2 Changing and setting the password

The password can only be set with PCM600.

For more information, see the PCM600 documentation.

5.3.3 Identifying IED application problems

Navigate to the appropriate menu in the LHMI to identify possible problems.

- Check that the function is on.
- Check that the correct setting group (1 to 4) is activated.
- Check the blocking.
- Check the mode.
- Check the measurement value.
- Check the connection to trip and disturbance recorder functions.
- Check the channel settings.

5.3.3.1 Inspecting the wiring

The physical inspection of wiring connections often reveals the wrong connection for phase currents or voltages. Even when the phase current or voltage connections to IED terminals are correct, wrong polarity of one or more measurement transformers can cause problems.

- Check the current or voltage measurements and their phase information from **Main menu/Measurements**.
- Check that the phase information and phase shift between phases is correct.
- Correct the wiring if needed.
  - Change the parameter *ReversePolarity* in **Configuration/I/O modules/ AIM2** for the channel n (n= the number of the channel that has wrong polarity).
  - In PCM600, change the parameter *CTStarPointn* (n= the number on the current input) under the parameter settings for each current input.
- Check the actual state of the connected binary inputs.
  - In LHMI, select **Main menu/Monitoring/I/O status/Binary input modules**. Then navigate to the board with the actual binary input to be checked.
  - With PCM600, right-click the product and select **Signal Monitoring**. Then navigate to the actual I/O board and to the binary input in question. The activated input signal is indicated with a yellow-lit diode.
- Measure output contacts using the voltage drop method of applying at least the minimum contact load given for the output relays in the technical data, for example, 100 mA at 24 V AC/DC.

Output relays, especially power output relays, are designed for breaking high currents. Due to this, layers of high resistance may appear on the surface of the contacts. Do not determine proper functionality of connectivity or contact resistance by measuring with a regular hand-held ohm meter.

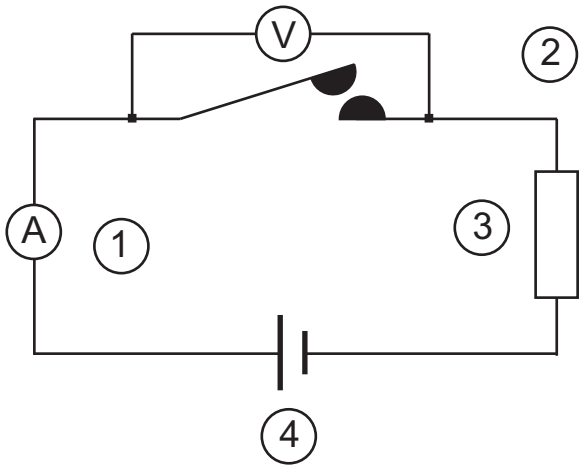

Figure 2: Testing output contacts using the voltage drop method

1 Contact current
2 Contact voltage drop
3 Load
4 Supply voltage

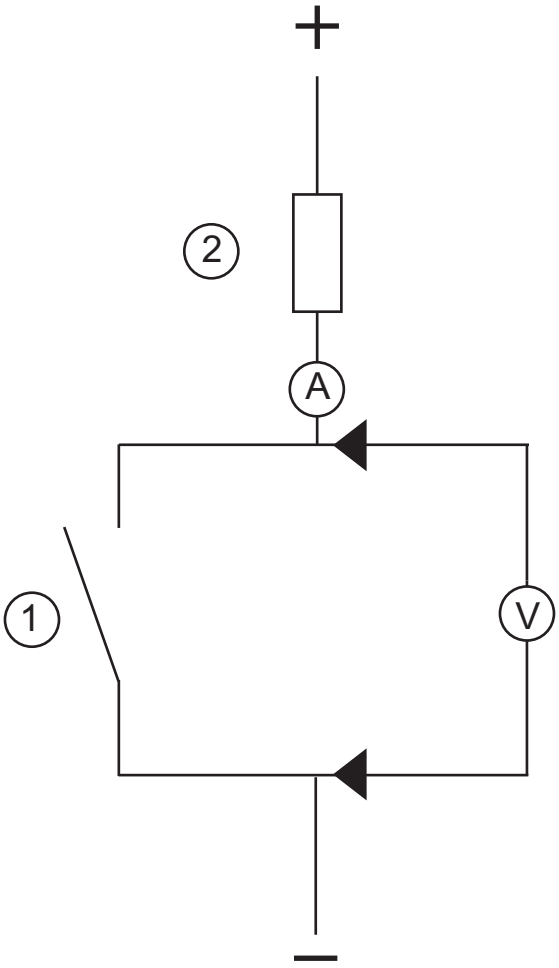

Figure 3: Testing a trip contact

1 Trip contact under test
2 Current limiting resistor

- To check the status of the output circuits driving the output relay via the LHMI, select **Main menu/Monitoring/I/O status/Binary output modules** and then navigate to the board with the actual binary output to be checked.
- Test and change the relay state manually.
  1. To set the IED to test mode, select **Main menu/Test/IED test mode/ TestMode** and set the parameter to ”On”.
  2. To operate or force the output relay to operate, select **Main menu/Test/ Forcing/Binary output values** and then navigate to the board with the actual binary output relay to be operated/forced.
  3. Select the BOn_PO to be operated or forced and press and or to operate the actual output relay.
     In PCM600, only the result of these operations can be checked by right-clicking the product and selecting Signal Monitoring and then navigating to

the actual I/O-board and the binary input in question. The activated output signal is indicated with a yellow-lit diode. Each BOn_PO is represented by two signals. The first signal in LHMI is the actual value “1” or “0” of the output, and in PCM600 a lit or dimmed diode. The second signal is the status Normal or Forced. Forced status is only achieved when the BO is set to “Forced” or operated on the LHMI.

Set the parameter *TestMode* to “Off” after completing these tests. The Start LED stops flashing when the relay is no longer in test mode.

An initially high contact resistance does not cause problems as it is reduced quickly by the electrical cleaning effect of fritting and thermal destruction of layers, bringing the contact resistance back to the mOhm range. As a result, practically the full voltage is available at the load.

5.3.3.2 Inspecting the RTD wiring

- Verify the sensor measuring mode by using a suitable resistor instead of a real sensor.
  - PT100 80...170 Ω
  - PT250 220...430 Ω
  - NI100 80...240 Ω
  - NI120 100...280 Ω
  - CU10 8...16 Ω

  Resistance measuring mode can be verified with a resistance from 0...10 KΩ.

Table 8: Examples of temperature and resistance

	PT 100	PT 250	NI 100	NI 120	CU 10
R	°C	°C	°C	°C	°C
7.5	-	-	-	-	-39.8
8.2	-	-	-	-	-21.6
9.1	-	-	-	-	1.7
10	-	-	-	-	25
11	-	-	-	-	50.9
12	-	-	-	-	76.9
13	-	-	-	-	102.8
15	-	-	-	-	154.6
82	-45.8	-	-34.2	-	-
91	-23	-	-16.5	-46.7	-
100	0	-	0	-31.5	-
110	25.7	-	18	-15.5	-

Table continues on next page

	PT 100	PT 250	NI 100	NI 120	CU 10
R	°C	°C	°C	°C	°C
120	51.6	-	35	0	-
150	130.5	-	82.6	43.3	-
160	157.2	-	97.5	56.8	-
180	-	-	125.5	84	-
200	-	-50.8	151.8	107	-
220	-	-30.6	176.3	130	-
240	-	-10.2	199.3	151.8	-
270	-	20.5	-	182.2	-
300	-	51.6	-		-
330	-	82.9	-		-
360	-	114.6	-		-
390	-	146.5	-		-
430	-	189.6	-		-

RTD connector numbering is an example of a 4U case. See the technical manual for complete terminal diagrams.

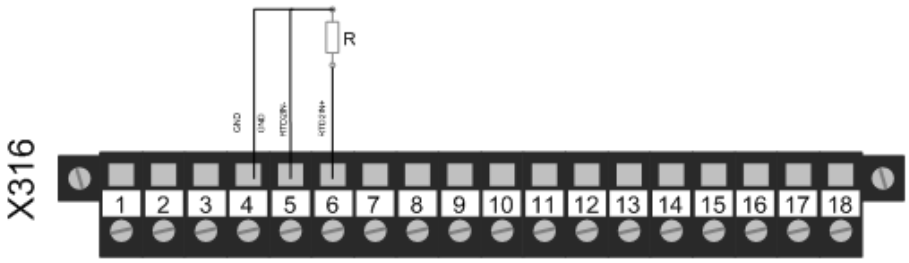

Figure 4: Testing sensor/resistance input by connecting resistor directly to connector

Voltage type measurement mode can be verified by connecting a voltage source on the input and measure input voltage at the same time by multimeter, for example, 5 VDC voltage.

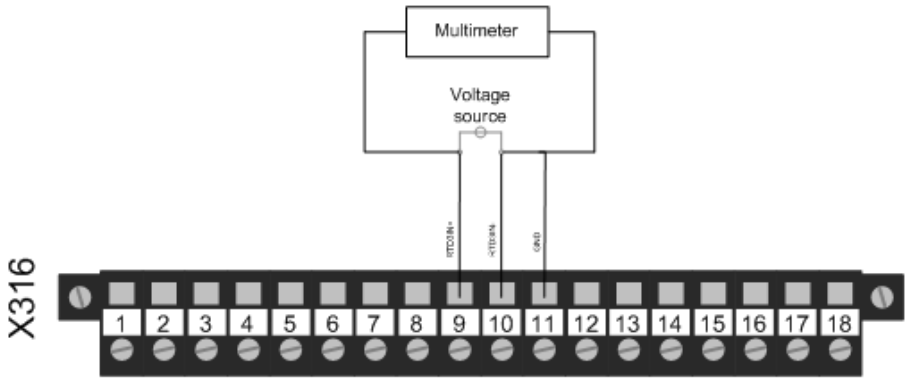

Figure 5: Testing voltage input by connecting voltage source directly to connector and measuring input voltage by multimeter

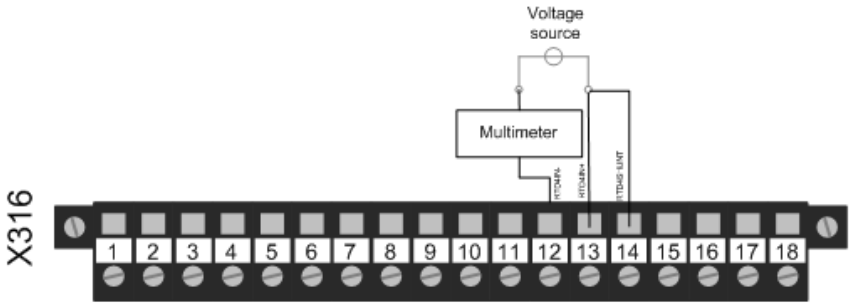

Figure 6: Testing current input by connecting voltage source directly to connector and measuring input current by multimeter

Current type measurement mode can be verified by connecting a voltage source on the input, for example, 1 V DC.

- Verify milliampere ouputs by connecting a multimeter to mA output.

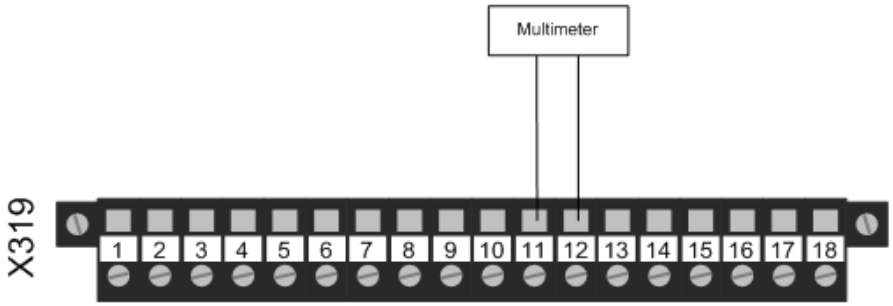

Figure 7: Testing mA output by connecting multimeter directly to connector and measuring output current by multimeter

- Check the status of the output circuits driving the mA outputs via the LHMI. Select **Main menu/Monitoring/I/O status/mA output modules/RTD3** and check the output status and value for the channel under inspection.
- Test and change the output manually.

  1. Select **Main menu/Test/IED test mode/TestMode** and set the parameter to “On”.
  2. Select **Main menu/Tests/Forcing/Analog output values/RTD3**.
  3. Select the AOn to be forced.
  4. Force the actual output using  and  or  .

  Each AOn is represented by two signals. The first signal in LHMI is the actual primary value of the output. The second signal is the status Normal or Forced. Forced status is only achieved when the AO is set to “Forced” on the LHMI.

When forcing analog output signals the scaling defined by analog output channel configuration is not used. Fixed scaling factor 1000:1 is used instead. This means that forcing value 5.000 A is seen as 5 mA when measured from output.

Do not force or send values to disconnected channels. This results in an out-of-range error.

Forcing feature can be tested only for configured output channels. When mA current values are forced to non-configured output channels, values are not passed to mA output channel HW circuitry.

Set the parameter *TestMode* to”Off” after completing the tests. The Start LED stops flashing when the relay is no longer in test mode.

Section 6 Glossary

AC	Alternating current
CAT 5	A twisted pair cable type designed for high signal integrity
Connectivity package	A collection of software and information related to a specific protection and control IED, providing system products and tools to connect and interact with the IED
CT	Current transformer
DC	1. Direct current 2. Disconnector 3. Double command
DHCP	Dynamic Host Configuration Protocol
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FAT	Factory acceptance testing
HMI	Human-machine interface
HW	Hardware
I/O	Input/output
IEC	International Electrotechnical Commission
IED	Intelligent electronic device
IET600	Integrated Engineering Toolbox
IP	Internet protocol
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRF	1. Internal fault 2. Internal relay fault
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LED	Light-emitting diode

LHMI	Local human-machine interface
NCC	Network control center
PC	1. Personal computer 2. Polycarbonate
PCM600	Protection and Control IED Manager
RJ-45	Galvanic connector type
RTD	Resistance temperature detector
Rx	Receive/Received
SAT	Site acceptance testing
TCP/IP	Transmission Control Protocol/Internet Protocol
Tx	Transmit/Transmitted
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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